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VOL. XIB-PROCEEDINGS

PROCEEDINGS

OF THE ELEVENTH

GENERAL ASSEMBLY

BERKELEY, 1961

Edited by

D. H. SADLER

(*General Secretary of the Union*)

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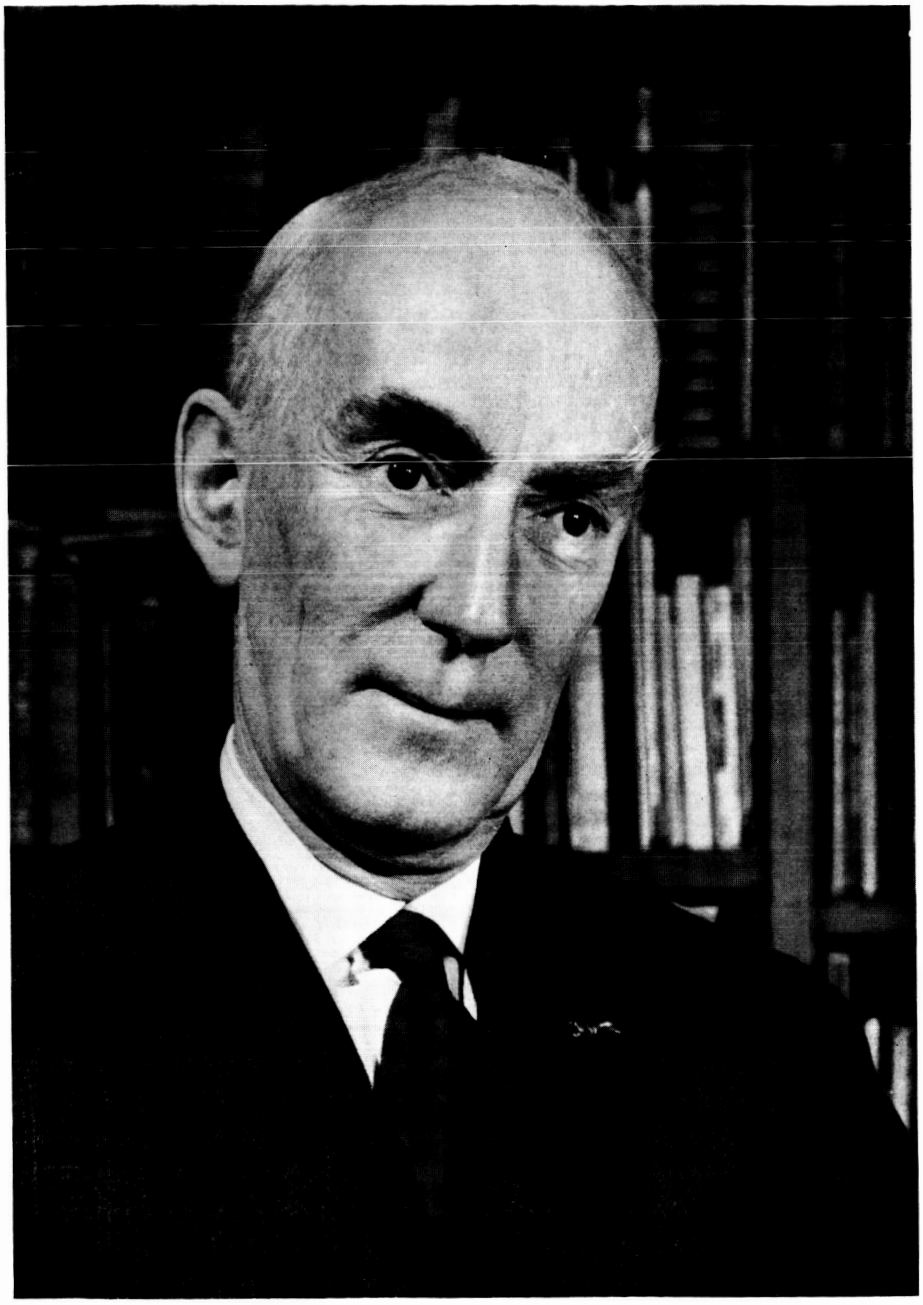

JAN HENDRIK OORT
Director of the University Observatory, Leiden
PRESIDENT 1958 - 1961

PREFACE

The increasing size of the complete volume of the *Transactions* of the Union has made it necessary to divide the present volume (the eleventh to be published) into two parts, bound and published separately. In order to preserve the relationship with the corresponding General Assembly, both parts carry the same volume number together with a distinguishing letter A or B.

The present part, volume XI B, has been given the title *Proceedings of the Eleventh General Assembly*. It contains a complete record of both the administrative and scientific proceedings of the eleventh General Assembly of the Union, held in Berkeley, California, from 15 to 24 August 1961.

Volume XI A, with the title *Reports on Astronomy*, has been published before the present volume; it contains the Draft Reports of Commissions as presented to the eleventh General Assembly, and as subsequently amended. It stands, in its own right, as an authoritative, detailed and unique record of the present state of Astronomy in all its branches. However, the Reports of Commissions 3, 5, 6 and 38, which are almost entirely of an administrative character, have been included in the present volume XI B, as appendices to the Report of the Executive Committee.

No Symposia were held during the eleventh General Assembly; but two Symposia, No. 15 (Problems of Extra-Galactic Research) and No. 17 (Visual Double Stars), were held immediately before and one, No. 16 (The Solar Corona), was held shortly after the General Assembly. The proceedings are being published as follows:

No. 15 *Problems of Extra-Galactic Research*—as a separate volume (*Symp. IAU* **15**) by The MacMillan Company.

No. 16 *The Solar Corona*—as a separate volume (*Symp. IAU* **16**) by Academic Press Inc.

No. 17 *Visual Double Stars*—in *Publications of the Astronomical Society of the Pacific;* reprints will be available for sale as *Symp. IAU* **17.**

The texts of the three Invited Discourses (in part 3), and the reports of the four Joint Discussions (in part 5), arranged during the General Assembly, are included in this volume. There is also included, in part 5, the report of the first meeting of the Inter-Union Commission on Solar and Terrestrial Relationships, which was held on the day before the General Assembly.

There is a considerable divergence of practice in the reports of the meetings of Commissions, which form part 4. For almost all Commissions there is a report, usually brief, of the "administrative" discussions concerning the internal organization of the Commission and the arrangement of programmes of observation and international co-operation. In addition, the Presidents of some Commissions arranged formal scientific meetings, which are reported at some length together with summaries of the papers that were presented; others were satisfied to report briefly the subjects of the discussion and the names of the principal speakers. This divergence merely reflects the widely varying characters of the Commissions.

There were in all well over a hundred separate formal meetings during the General Assembly; it is a considerable tribute to the diligence and efficiency of the secretaries of the Commissions that reports are included in this volume of all such meetings. To these secretaries, and to many others, I am greatly indebted.

The list of contents that follows this *Preface* has been expanded to provide a ready means of reference, not only to the principal administrative reports and decisions, but also to the reports of the major scientific meetings organized by the Commissions. There is no index.

The preparation of much of this volume, particularly parts 1, 2 and 6, would have been impossible without the devoted work of the Assistant Secretary, Miss Nel Splinter, who has combined a capacity for faithful reporting with a remarkable care and skill in ensuring that her intentions are accurately translated into print. I am deeply grateful to her. I also thank the members of the staff of H.M. Nautical Almanac Office, particularly Mr W. Nicholson and Mr H. W. P. Richards, who have given valuable assistance in proof reading.

Our new printers, Messrs. Willmer Brothers and Haram Limited, have again shown their craftsmanship and efficiency in producing a unified volume from copy that necessarily varied greatly in style and quality.

D. H. SADLER
General Secretary

Royal Greenwich Observatory
Herstmonceux Castle
Hailsham, Sussex, England

1 July 1962

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The following list of contents has been expanded to facilitate reference both to the principal administrative reports and decisions and to the reports of the major scientific discussions. Parts 1, 2 and 6 are primarily of administrative interest, while parts 3 and 5 consist entirely of scientific reports; part 4 (Reports of Commission meetings) contains material of both administrative and scientific interest. There is no index.

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INAUGURAL CEREMONY

Tuesday, 15 August 1961 at 10^h 15^m

The Inaugural Ceremony took place, in the open air, on the Plaza in front of Dwinelle Hall on the Berkeley Campus of the University of California, in the presence of a distinguished gathering of representatives of the U.S. Government, the U.S. Academy of Sciences, the University of California, the diplomatic services and many local organizations. Apart from Members of the Union and their guests, it was attended by several thousand members of the public, of whom a large proportion were students.

The Union was honoured by the presence of the Honorable the U.S. Ambassador to the United Nations Organization, Adlai E. Stevenson, representing the President of the United States of America; and by the Chancellor of the University of California, Edward W. Strong.

Professor Leo Goldberg, Chairman of the U.S. National Committee for Astronomy, acted as chairman for the ceremony. After a few words of welcome to Members and guests, he read the following telegram of welcome from President John F. Kennedy:

TELEGRAM FROM THE PRESIDENT OF THE UNITED STATES OF AMERICA

August 15, 1961

To: Dr J. H. Oort, President, International Astronomical Union

I would like to extend my greetings to all of the delegates to the Eleventh General Assembly of the International Astronomical Union. It is a privilege for the United States to be host to this distinguished meeting and to welcome the assembly once again to our shores.

Astronomy is an ancient art, and from the earliest times has known no national boundaries. Today, American astronomers work with their colleagues in observatories all over the world. I hope that tomorrow this collaboration will extend to observatories in outer space.

The breadth and freedom of scientific exchange among astronomers sets a high example for other disciplines, I know that this exchange will continue, even as man's curiosity about the structure and history of the universe continues.

My very best wishes for a successful meeting.

(Signed) JOHN F. KENNEDY

He then read the following message from the Governor of the State of California, Edmund G. Brown.

MESSAGE FROM THE GOVERNOR OF THE STATE OF CALIFORNIA

It is with extreme pleasure, as Governor of California, that I welcome the Eleventh General Assembly of the International Astronomical Union to Berkeley and to California. I also join with other Americans in welcoming those from foreign shores to our United States.

The work of your organization in uniting professional men from all over the world into an effective organization for the advancement of science is an outstanding example of what can be accomplished by friendship among men. There are many advantages to this kind of

cooperation, such as the elimination of waste in the duplication of effort. But the most important, of course, is that men who work together, whether in science or any other field, come to know each other and have respect for their fellows.

Citizens of a nation become citizens of much more when pursuing knowledge. Thus it could be among all men, regardless of the cause which unites them, if sense and reason could prevail.

We in this city, this state and this nation are honored by the convening here of the General Assembly of the International Astronomical Union.

(Signed) EDMUND G. BROWN

The Chairman then called upon Dr Donald H. Menzel to address the gathering on behalf of the National Academy of Sciences.

ADDRESS BY THE REPRESENTATIVE OF THE U.S. NATIONAL ACADEMY OF SCIENCES DR DONALD H. MENZEL

Professor Detlev Bronk, President of the National Academy of Sciences, joins me in extending the Academy's welcome to you—our friends and colleagues of many countries. We are grateful to you for having come so far to share with us your friendship and your knowledge.

Dr Bronk and I wish that we could adequately express the many special reasons why the friendly associations of international gatherings such as this give so much pleasure to American Scientists. It is in part because we Americans have so recently come from your native lands. The brothers of your fathers built our nation. Your ancestors are our ancestors too.

Another reason for a feeling of close association stems from the fact that our science has grown from seeds imported by our teachers who first studied in your lands. From the days of Franklin on, we have had a deep debt of gratitude for this friendly nurturing of our scientific education.

Every gathering such as this is a significant breach in the walls that separate people of good will. Such gatherings make statesmen aware that, through science, nations can peacefully gain those material benefits they have fruitlessly sought to acquire through war.

Scientists are uniquely fitted to persuade their fellow citizens that shared knowledge enriches the intellectual resources of all people. As you well know, the science of Copernicus and Galileo and Newton has extended the intellectual and spiritual horizons of people in every nation.

Fifty years ago, when Lord Bryce was the ambassador from Britain to this country, he expressed the international significance of science as follows: 'one of the most delightful things of science is that it knows no allegiance to nationality. Science is a republic in which there is no passport to greatness except service and genius. It is a republic of which everyone is a citizen and where everyone has equal rights in every part of the world'.

Your own National Academies and Royal Societies comprise this republic of science, wherein inquiring men continually engage in the great adventure of advancing the frontiers of human knowledge.

The U.S. National Committee of the IAU operates under our National Academy of Sciences. Many of you have received grants in support of your travel to this meeting. I should like to point out, however, that these funds came not from the Academy, but from many

sources: U.S. Government agencies, numerous industrial companies, charitable foundations, and scientific institutions. These donors join Professor Bronk and me, for the National Academy of Sciences, in a most hearty welcome and with best wishes for a successful and profitable meeting.

After thanking Dr Menzel for his address, Dr Goldberg then invited Dr D. H. McLaughlin, Regent of the University of California, to speak.

ADDRESS BY THE REPRESENTATIVE OF THE UNIVERSITY OF CALIFORNIA, DR D. H. MCLAUGHLIN

Dr Oort and Members of the International Astronomical Union:

On behalf of the President and the Regents of the University of California, I welcome you most cordially to our Berkeley campus. We are very pleased that you have elected to hold your second meeting in the United States after an interval of twenty-nine years. Your selection of this once remote site on the far western side of the North American continent is truly a gracious recognition on your part of the value of the contributions that the staff of the University of California has made to the advancement of astronomy and the sciences on which it depends to such an increasing degree.

The University of California is a relatively young institution. Less than a century ago, this plaza, in which we are gathered this morning, was an open field—a sunny spot on the long, grassy slope from the hills to the bay which was then unbroken except for scattered clusters of oaks and a few low buildings at the distant landing. Yet, in that short time, a University has been created that has won a respected place among institutions of learning in the world, and our setting has been transformed from its quiet emptiness to the extensive urban region that surrounds us.

In a century of growth such as this, when this pleasant land with its mild Mediterranean climate was being rapidly filled with energetic people who built cities, developed vast orchards, farms and ranches and created a host of industries, it might have been expected that emphasis on the practical needs of life would have completely diverted attention from scholarly or scientific interests. Fortunately, it did not, for even in its earliest days the University was generously supported not only by the people of the state through their legislature, but by individuals whose gifts made possible the prompt initiation of work in many fields that otherwise might have been cultivated much more slowly. Among them was the bequest of James Lick from which the first structures of the observatory that bears his name was built and which provided California with the first great refracting telescope that enabled the young institution to attract and hold astronomers of highest competence.

It is, I think, particularly significant that this early benefaction—in fact one of the very first the University received—was to support a science that could hardly be expected to pay its way in direct service to the needs of the growing state. Its appeal was solely intellectual and it is surely greatly to the credit of the spirit of the early pioneer days that men were stirred by such visions and that the people at large through their representative bodies provided the continued financial means necessary to carry on the work that the private donors had started.

Men tend to express their gratitude for material wealth—or perhaps their pride in it—in many different ways, some admirable, some otherwise. The Spanish conquerors and settlers, from California to Peru, were inclined to build churches and many a mining town is richly

adorned with worthy examples of the architecture of the sixteenth to eighteenth centuries that achieved some of its loveliest expressions on the Pacific side of the Americas. In Mexico, towns such as Guanajuato or Tasco, built near the bonanzas of silver—or the town of Huancavelica in Peru where great deposits of quicksilver were mined—are adorned with numerous churches with rich facades and towers that are still a joy to see. Their contruction was an expression of the desire of those who had been made affluent by the precious metals they had won from the earth to express their belief in something more enduring than mere wealth—or perhaps to record their repentance for some aspects of their behavior when they were winning their wealth.

We can be grateful for the beauty of the early churches and monuments left us by the Spaniards—and they are particularly good to have in this age when most of the fine arts are so sterile—but we can be even more appreciative of the early Americans in California who very wisely gave their support to schools, to laboratories and to the creation of instruments for observation and precise measurement. Our forebears here, who had comparable good fortune in the mines and in the early development of the country, perhaps showed less skill in architecture, but they were equally eager to find a worthy way to make an adequate return for the riches they had won in this new and growing land.

Devotion of fortunes to such causes was truly an act of faith, and that to me is far more impressive than the earlier expression of belief through the building of churches, worthy though it may have been.

It was faith in the scientific method that led to the generous support astronomy has received here and elsewhere, and particularly faith in the men who are called scientists. And today, even more, the generous support of our laboratories and observatories reveals the same deep trust in the ends of science and in the integrity of the men who are devoted to it.

The acceptance of the concepts of modern astronomy requires faith of the highest order on the part of a layman—faith in the accuracy of instruments, in the precision of measurements and in the interpretation of seemingly obscure data. The acceptance of the idea that a distant star is receding from us at some fantastic speed simply from the observation of the displacement of a line on a spectrogram must remain an act of faith on the part of most non-scientists—even on the part of those whose learning in the humanities may be profound. But the faith is widely held, and continues to be demonstrated by the persistent and growing respect and steady support given to the work of men, such as yourselves, whose devotion to the highest ideals of science is unquestioned.

The existence of this Union, however, is not only an expression of such confidence on the part of men, but is also a demonstration that devotion to the ideals of science and belief in the integrity of fellow scientists is not restricted to national boundaries. Through it, the intellectual unity of competent and thoughtful individuals of all nations and races should be made clear to the smaller minds that would create dissention. From its example, we can find hope even in times as troubled as the present, that wise co-operation for worthy ends will displace strife, that competition will be fair, generous and exciting, and that faith in the men of science will be justified.

As the high priests of this great cult—if I may use these words in a new and better sense—you are indeed welcome here and we are proud to be your hosts.

The Chairman thanked Dr McLaughlin and then invited Professor J. H. Oort, President of the Union, to address the gathering.

ADDRESS BY THE PRESIDENT OF THE INTERNATIONAL ASTRONOMICAL UNION, PROFESSOR J. H. OORT

Mr Chairman, Ambassador Stevenson, Doctor Menzel, Regent McLaughlin, Representatives of our sister Scientific Unions, Ladies and Gentlemen:

It is a pleasure to open the second General Assembly which the International Astronomical Union is holding in America. It is a special privilege to be able to do this in California, to which astronomy owes so much of its development in this century. We are deeply indebted to the Government of the United States and the National Academy of Sciences for inviting us to their country and in particular for providing the means to enable us to hold so complete a meeting at such a large distance from Europe. I thank President Kennedy and the Governor of California for their messages of welcome. That you, Ambassador Stevenson, have come to Berkeley especially for this occasion to welcome us, is a source of particular gratitude. You may be assured that we astronomers will do all we can to make our small contribution to international understanding as perfect as possible. World-wide international co-operation in astronomy dates back much further than such co-operation on political or economic levels. And I think that *we* have already arrived at the point where competition between nations has become almost entirely replaced by the strong conviction that it is only by helping each other internationally that we can really succeed in penetrating into the Universe.

An important part of the history of the American people is connected with the migration to the west. It even seems that, after having reached the western boundary of their continent they could not resign themselves to halt there, and, becoming possessed by a desire to penetrate further and further, they reached out into the skies. Thus they became pioneers of large telescopes, through which their thoughts travelled out into space. Here there was no boundary to stop them and they boldly headed for the outer limits of the physical universe.

It was near this West Coast that the first large mountain observatory was founded on Mount Hamilton. Under the auspices of the University, which has received us with such great hospitality, a large 36-inch refractor was there installed in 1888. Already early in its history the Lick Observatory has made basic contributions to our knowledge of the motions of the stars. It is continuing this today with an invaluable survey in which stellar positions are tied to the motionless background of distant galaxies. With a new 120-inch telescope it is now entering a new phase of its existence. I may use this opportunity to extend to the Lick Observatory and to the University of California the good wishes of all astronomers who are here today, and to express the impatience with which we wait for the treasures which the Lick astronomers will gather out of the depths of the Universe.

At one time there was a personal union and triple alliance between the Lick Observatory, the University of California and the Astronomical Union, when W. W. Campbell, who had been director of the Lick Observatory and later president of the University of California, became president of our Union. We are happy that this alliance of the past is now reborn in an actual coming together.

The greatest development of astronomy in the United States has been inspired and led by a man who appeared to have combined almost all of the best human qualities. It is fitting that on this first large international gathering in California tribute be paid to George Ellery Hale, without whose penetrating foresight, idealism and perseverance neither the Mount Wilson Observatory nor the giant telescope on Mount Palomar would have come into existence.

It was with the 60-inch telescope on Mount Wilson that Harlow Shapley obtained the first insight into the actual size of the Galactic System and the Sun's eccentric position in this

System. It was also with the 60-inch that he found the characteristic colour-magnitude diagrams of globular clusters which theoreticians together with astronomers on Palomar later developed into such a wonderfully penetrating picture of stellar evolution. Hale's second large instrument, the 100-inch telescope on Mount Wilson, was, at its completion in 1917, as much ahead of its time as the 60-inch had been in 1909. With this instrument Edwin Hubble and, later, Walter Baade, revealed the true character of the 'great nebulae', indicating that they were enormous star systems, like our own Galaxy. In the same period Hubble began his great attack on the universe, an attack that was to be completed with the new telescope on Palomar. This new telescope, which was named after Hale, was such a grand conception that, though it is now thirty-three years since the plans for it were started, the instrument still completely commands the field. It is in the 200-inch telescope that the courage and skill of the American people are shown at their best. It is perhaps the most exquisite blossom that has ever grown from the meeting of science and technique.

Practically all we know about stellar systems outside the Galactic System and the Clouds of Magellan, has been discovered with the giant telescopes in the Western United States. It may therefore be fitting at this occasion to dwell for a moment on some of the problems in this domain by which astronomers are now confronted.

If you look through the Hubble Atlas of Galaxies, which has just been completed by Sandage, and which you will certainly find on display, you will be particularly struck by two things: In the first place by the great variety of forms, in the second place by the fact that the majority of galaxies have structures that cannot possibly be in equilibrium. These galaxies seem to be midway between a curious kind of chaos and a stage in which they would become well-mixed and regular. They clearly bear the imprint of their birth in a past and quite different phase of the universe. One of the most fascinating problems is to penetrate into that distant past and to find out what it was that gave the galaxies the curious spiral and other shapes that we observe today. The investigation is as difficult theoretically as observationally. It requires among other things a much more advanced knowledge of the role of magnetic fields in galaxies and of plasma physics than we possess today. So far, we have hardly been able to decipher any of the hieroglyphs of these galaxies. And more riddles appear to come up all the time. We can only optimistically hope that when we have amassed enough enigmas the solution may be near. There are two other roads beside that of the structure and dynamics of galaxies that appear to lead to that most distant past. One goes through the star clusters and their ages. The oldest clusters appear to be between twenty and thirty billion years old and probably date from the time when the Galactic System was born. The third road is that of the expanding universe, which indicates that the entire Universe was born at about the same time as these oldest star clusters. Or, at least, that it evolved at that time from something different from the present universe. On this point, however, there is still some divergence of opinion. All of the three fascinating fields that I have mentioned are in a rapid state of development. The large reflectors on the American continent, headed by the 200-inch, play a leading part in the observational and most important side of this development.

Since the war a totally different kind of observing has come to our aid, namely, observations at radio frequencies. There can be no doubt that radio telescopes, when sufficiently large, permit observations penetrating much deeper into the Universe than is possible by optical means. It is clear from the outset that this possibility contains a promise for extremely interesting discoveries. Radio instruments have already helped the 200-inch to find a galaxy running away from us with half the velocity of light, and having an age of about half that of the universe directly around us. It is most likely that a search out to much larger distances, such as appears possible with the largest radio telescopes, will reveal quite novel things. In fact, there are indications that they are already doing so. These observations will be a topic of

discussion at this meeting. The radio galaxies which form these most distant signposts in the Universe are themselves most enigmatic objects. We have not yet the slightest idea what causes some galaxies, or pairs of galaxies, to become such powerful radio emitters.

Here, as in many other domains of astronomy, it is a symbiosis between different observing techniques which is making the big advance possible. It would be interesting to speculate how far radio astronomers could have developed the subject of radio sources if they had not had the help of large optical telescopes. I think that it would long have remained a hopelessly speculative field. In a sense one might say that, but for the help of large optical instruments, radio telescopes are almost blind.

The advent of the radio telescope has brought a large change in astronomy. Not only by extending its scope, but also in changing the character of our science. Our ranks have partly been filled by electronic engineers and physicists. Moreover, astronomy, which used to share with music, mathematics and painting the privilege of being something for which there was little direct practical application, and which because of that was left quietly to pursue its own ideals, has now become something of the world: the technical world, which is interested in the low-noise amplifiers as well as in other problems connected with the electronics part of radio astronomy. In addition, an entirely new situation has arisen, where astronomy has come into conflict with society. Communication services, television and broadcast transmitters are rapidly filling the ether with so much noise that it becomes impossible for the radio astronomer to hear the extremely weak signals coming from the outer limits of the Universe. This is a matter of life or death for radio astronomy as well as for scientific space research. Other grave dangers for astronomy have arisen by plans to put reflecting screens consisting of small dipoles in orbits around the Earth. The International Astronomical Union has an important duty in backing by its full authority the Inter-Union Committee which it has entrusted with the task of obtaining free channels for radio astronomy and space research, and of protecting the interests of astronomy from human inroads in the sky.

A still greater change in the character of our science has come through the development of that younger brother of radio astronomy: space research. In opening the congress of the Union in 1958 Professor Danjon expressed his admiration for what had then been accomplished in the successful launching of sputniks and other space vehicles, in connection with the International Geophysical Year. Since then, there has been a still more rapid development than could have been foreseen. I may remind you only of that wonderful first experiment made by our colleagues of the Soviet Union in which they obtained pictures of the rear side of the Moon and also of the interesting investigations on cosmic-ray particles outside the atmosphere which led to the discovery of the Van Allen belts, about which we shall hear a first-hand report during this meeting.

Particularly important for astronomy are the projects for putting telescopes of considerable size in vehicles above the atmosphere. There can be no doubt but that the realization of these plans will offer immense new possibilities for astronomical research. I would not try to predict the nature of the results. For, like in radio astronomy, the most interesting are likely to be the things of which nobody has any inkling. These purely astronomical space projects, as well as the enormous Government plans for manned journeys through the planetary system, are absorbing an increasing number of our small astronomical family, but they are at the same time adding a large fringe of distant relatives in the form of electronic engineers, space physicists and future space travellers.

The astronomical workshop is seething with life. Almost everybody appears to be hammering and building. It is a joy to watch this activity and it is making the old astronomers wish to live long enough to see the results.

But it also poses problems for our Union. Problems for which we shall have to find a solution if we wish to keep it successful. I have been in close contact with the Union throughout its life. I may, in fact, be the only astronomer who has been to all eleven General Assemblies, although in 1922 I attended only by accident and quite unofficially. At that Rome meeting there were eighty-three members and guests; it was the nicest General Assembly I have seen! Since then every meeting became larger than its predecessor, and after the war they began gradually to grow out of hand. At the same time also the administration of the Union became too much for a single general secretary, even for such exceptionally efficient secretaries as we have recently had.

Though the General Assemblies of the Union continue to fulfil a most useful purpose in bringing together representatives from all different branches of astronomy, thus helping to develop these branches in such a way that they are most useful for one another, and though they continue to be a fruitful meeting place for old and young astronomers from all nations and vocations, we must nevertheless ask seriously whether or not we should go further in this way. I must confess that I feel quite uneasy about this. We must not run the risk that by an unwieldy size of our meetings the possibility of forming close ties and friendships is lost, or that some of our best astronomers refrain from attending because of disappointment about the too large meetings. The Union should, in time, take steps to ensure that its fine tradition of international co-operation is preserved. But what should be the steps? Is the only way out to arrange for separate Assemblies for different subjects, for instance, the Planetary System, the Sun, Stars and Galaxies?

For the present we still have all subjects of astronomy united. And we must enjoy this meeting to the fullest extent.

That this gathering of astronomers will be a successful and happy one can hardly be doubted since we are meeting in California. For this state of California was named after a fabulous island described in the sixteenth century by Ordonez de Montalvo as being situated *close to Paradise*; for astronomers it *is* the paradise!

May some of this paradisian spirit pervade our meetings and also the new international ties that will be knotted during these days.

The President then repeated part of his address in the French language, as follows:

C'est un plaisir pour moi d'ouvrir la seconde Assemblée Générale que l'Union Astronomique Internationale tient en Amérique. Mais c'est pour moi un privilège tout à fait spécial d'ouvrir cette assemblée en Californie, pays qui a contribué d'une façon si éminente au développement de l'astronomie dans ce siècle.

Nous sommes infiniment reconnaissants au gouvernement des Etats-Unis et à l'Académie Nationale des Sciences de nous avoir invité dans leur pays. Nous avons été particulièrement sensibles aux facilités qu'ils nous ont accordées pour nous permettre d'organiser une assemblée générale si nombreuse dans un pays aussi éloigné de l'Europe. En particulier je souhaite la bienvenue à l'Ambassadeur Stevenson qui est venu de si loin pour ouvrir notre Assemblée.

Une grande partie de l'histoire du peuple Américain est intimement liée à la migration vers l'Ouest. Il semble même qu'ayant atteint les limites extrêmes de leur continent ces hommes n'ont pu se résoudre à s'arrêter là, et toujours possédés par le désir d'aller de plus en plus loin, ils s'échappèrent dans les cieux. Ainsi ils devinrent les pionniers de ces grands télescopes qui permirent à leurs pensées de voyager dans l'espace. Là il n'y avait plus de limites pour les arrêter et ils partirent hardiment vers la découverte des frontières de l'univers physique. C'est sur cette côte ouest que fut fondé au Mont Hamilton le premier grand

observatoire de montagne. Sous les auspices de l'université même qui nous reçoit aujourd'hui si généreusement, un grand réfracteur de 90 cm y fut installé en 1888.

Le grandiose développement de l'astronomie aux Etats-Unis a été inspiré et dirigé par un homme qui réunissait en lui toutes les plus grandes qualités humaines. Il est opportun de rappeler, à l'occasion de cette première grande réunion internationale de Californie, avec respect et reconnaissance le nom de George Ellery Hale. Sans son intuition, son idéalisme et sans sa persévérance ni l'observatoire du Mont Wilson ni le télescope géant du Mont Palomar n'auraient vu le jour.

C'est avec le télescope de 60 pouces du Mont Wilson que Harlow Shapley a pu se faire une idée des dimensions actuelles du système galactique et de la position excentrique du soleil dans ce système. C'est encore grâce à ce même télescope de 60 pouces qu'il a pu construire pour les amas globulaires les diagrammes couleur-luminosité si particuliers et dont l'interprétation récente par les théoriciens et les observateurs du Mont Wilson a fourni une image si merveilleusement nette de l'évolution des étoiles.

Le second grand instrument de Hale, le télescope de 2,50 m, lui aussi installé au Mont Wilson, était au moment de son achèvement en 1917 aussi perfectionné pour son époque que l'était en 1909 le télescope de 1,50 m. C'est avec ce nouvel instrument que Edwin Hubble et plus tard Walter Baade nous ont révélé la véritable nature des "grandes nébuleuses" en découvrant qu'il s'agissait d'énormes systèmes stellaires ressemblants au système galactique. C'est à la même époque que Hubble a commencé à s'attaquer sérieusement à l'univers lui-même; cette attaque a d'ailleurs été développée et continuée avec le télescope du Mont Palomar. Ce nouveau télescope, auquel on a donné le nom de Hale, était d'une conception si grandiose qu'actuellement encore, 33 années après le début du projet, il est toujours l'instrument par excellence dans le domaine des recherches sur les galaxies.

Pratiquement, tout ce que nous savons des systèmes stellaires situés en dehors du système galactique et des Nuages de Magellan a été découvert à l'aide des télescopes géants de l'ouest des Etats-Unis. C'est pourquoi je voudrais m'attarder un peu en examinant avec vous quelques uns des problèmes sur les galaxies que discutent actuellement les astronomes.

En regardant l'atlas des galaxies de Hubble, qui vient d'ailleurs d'être complété par Sandage et dont vous pouvez feuilleter un exemplaire exposé ici même, on est frappé surtout par deux choses: d'abord par la grande variété des formes et ensuite par le fait que la majorité des galaxies ont des formes qui, sans doute, ne peuvent pas être des formes d'équilibre. Ces galaxies semblent se trouver à mi-chemin entre un ancien état de chaos et un état dans lequel leur matière est bien mélangée. Ces galaxies portent nettement l'empreinte de leur formation pendant une phase antérieure et très différente de l'univers. Un des problèmes le plus fascinants qui se posent à nous est de pénétrer dans ce passé lointain et d'essayer de découvrir ce qui a donné aux galaxies leur forme en spirale ou ces autres aspects curieux que nous observons actuellement.

Il y a deux autres voies, en dehors de celle qui passe par la structure et la dynamique des galaxies, pour nous mener à ce passé si lointain. L'une est celle qui nous y mène par les amas stellaires et la détermination de leurs âges. L'autre est celle de l'univers en expansion qui nous apprend que l'univers dans son ensemble a pris naissance à peu près en même temps que les amas stellaires les plus vieux.

Depuis la guerre une technique d'observation tout à fait différente est venue à l'aide de notre science: l'observation dans le domaine des fréquences Hertziennes. Il n'y a pas de doute que les radiotélescopes, pourvu qu'ils soient suffisamment grands, nous permettent d'observer des régions beaucoup plus lointaines que celles que nous pouvons atteindre avec des moyens optiques.

Dès maintenant ces possibilités nous font entrevoir des découvertes du plus haut intérêt.

Ce sont les radiotélescopes qui ont aidé les télescopes du Mont Palomar à découvrir une galaxie qui s'éloigne de nous avec une vitesse égale à la moitié de celle de la lumière. Cette galaxie a un âge égal à la moitié de celui de l'univers dans notre voisinage immédiat.

Il est tout à fait certain que la poursuite de ces recherches vers de plus grandes distances, comme cela est possible avec les plus grands radiotélescopes, révèlera des choses tout à fait nouvelles. En fait, certaines indications nous montrent que nous sommes déjà sur cette voie.

Ici, comme dans beaucoup d'autres domaines de l'astronomie, c'est la symbiose entre différentes techniques d'observation qui permet les grands progrès. L'avènement du radiotélescope a produit un grand changement en astronomie, non seulement en étendant son domaine, mais encore en changeant le caractère de notre science. Des ingénieurs électroniciens et des physiciens ont rejoint nos rangs.

De plus, une situation tout à fait nouvelle s'est présentée: l'astronomie est entrée en conflit avec la société. Les services de télécommunication remplissent si rapidement l'éther avec de si nombreux bruits qu'il devient impossible aux radioastronomes d'entendre les très faibles signaux qui parviennent des limites extrêmes de l'univers. Ceci est devenu une question de vie ou de mort pour la radioastronomie aussi bien que pour les recherches scientifiques de l'espace. D'autres graves dangers guettent l'astronomie par le projet de mettre en orbite autour de la terre un écran réfléchissant constitué par des petits dipôles.

Un changement encore plus grand dans le caractère de notre science est arrivé avec le développement de la jeune soeur de la radioastronomie, la recherche spatiale.

En ouvrant le Congrès de l'Union en 1958, M. Danjon exprimait son admiration pour ce qui avait été accompli dans le lancement réussi des spoutniks et d'autres véhicules spatiaux à l'occasion de l'Année Géophysique Internationale. Depuis lors les événements se sont développés beaucoup plus rapidement qu'on aurait pu le prévoir. Je vous rappellerai seulement cette merveilleuse expérience faite par nos collègues de l'Union Soviétique lorsqu'ils ont obtenus pour la première fois des images de la partie invisible de la lune.

Je vous rappellerai aussi les très intéressantes recherches sur les rayons cosmiques en dehors de l'atmosphère qui ont conduit à la découverte des ceintures de Van Allen. Nous entendrons d'ailleurs au cours de notre Congrès un rapport de première main sur cette question.

Les projets de placer des télescopes de diamètre considérable dans des véhicules spatiaux sont particulièrement importants pour l'astronomie. Sans aucun doute la réalisation de ces projets offre d'immenses possibilités tout à fait nouvelles pour la recherche astronomique.

L'atelier astronomique regorge de vie. Presque tout le monde semble avoir pris le marteau pour construire. C'est une joie d'observer cette activité et les astronomes âgés souhaitent de vivre assez longtemps pour en voir les résultats. Mais cela pose aussi des problèmes à l'Union, problèmes que nous devons résoudre si nous voulons que l'Union continue à travailler avec succès.

A la première assemblée de notre Union qui s'est tenue à Rome en 1922, il n'y avait qu'une assistance de 83 membres et invités. C'est l'Assemblée Générale la plus agréable que j'ai vue.

Depuis, chaque Assemblée devient plus importante que la précédente et depuis la Guerre il devient presque impossible de les diriger. Or, bien que les Assemblées générales de notre Union aient continué à poursuivre un but très important en permettant la rencontre des représentants de toutes les branches de l'Astronomie, et qu'elles aident ainsi ces branches à se développer de façon harmonieuse, et bien qu'elles continuent à être un lieu de rencontre des plus utiles pour les astronomes jeunes et vieux de toutes les nations, nous devons nous

demander sérieusement si nous devons ou non continuer dans cette voie. Je dois avouer que je suis très inquiêt et très indécis à ce sujet.

Nous ne devons pas courir le risque que des assemblées trop nombreuses empêchent les astronomes de nouer des liens d'amitié, ni le risque de voir certains de nos meilleurs astronomes, déçus par ces trop nombreuses assemblées, éviter nos réunions.

L'Union doit, à temps, prendre des mesures pour assurer que cette belle tradition de coopération internationale soit préservée. Mais quelles doivent être ces mesures? Le seul remède serait-il d'organiser des réunions séparées sur différents sujets, par exemple, le système planétaire, le soleil, les étoiles et les galaxies?

Actuellement tous ces domaines de l'Astronomie sont encore réunis et nous devons nous réjouir et en profiter pleinement.

Comme cette réunion a lieu en Californie, nous ne pouvons douter, un seul instant, qu'elle sera une pleine et heureuse réussite. Cet Etat de Californie dont le nom vient de cette île fabuleuse décrite au seizième siècle par Ordonez de Montalvo comme étant située *près du Paradis*, pour les astronomes *c'est* le Paradis.

Puisse cette atmosphère de paradis régner sur nos réunions et aussi sur les nouveaux rapports internationaux qui seront renoués pendant ces journées.

Dr Goldberg thanked Professor Oort for his address and then called upon Ambassador Adlai E. Stevenson to address the assembly.

ADDRESS BY THE REPRESENTATIVE OF THE UNITED STATES OF AMERICA, AMBASSADOR ADLAI E. STEVENSON.

On behalf of the Government of the United States, and of the American people, it is my duty and my privilege to express to all of you, the distinguished members of the International Astronomical Union, a most cordial welcome to this country.

In this gathering are learned scientists from every continent and latitude, from Australia to that ancient cradle of astronomy, Egypt. We heartily welcome you all to the United States. And since Moscow was the site of your most recent Assembly three years ago, it is my particular pleasure to greet the large and distinguished delegation which has come here from the Soviet Union.

For yours is a community of the mind—ordered by reason, united in the single pursuit of truth about the universe. We who try to keep the peace among unruly nations cannot help envying and admiring your unity and purity of purpose. Would that all of us at the United Nations could follow your example, would that all of us could unite to end cold war and conflict, and concentrate on the arts of peace and the wider enjoyment of the benefits of this age of unparalleled technical progress.

I have been told that one of the reasons the astronomers of the world co-operate is the fact that there is no one nation from which the entire sphere of the sky can be seen. Perhaps there is in that fact a parable for national statesmen, whose political horizons are all too often limited by national horizons. In the United Nations we have mankind's greatest attempt so far—halting though it is—to widen all our horizons, to cause all men and all nations to accept the fact that there is but one world, without horizons other than the common horizon of illimitable space—one world not only in science, not only in the search for truth, but in the ordering of their international lives.

But science is more than a search for truth and a noble exercise of the mind. For generations the scientist and his practical cousin, the engineer, have been widening man's grasp of nature with geometrically increasing speed. They have put into the hands of the statesman and the citizen unimaginable powers. And although science itself, and the powers it bestows, are ethically neutral with the cold neutrality of outer space, the ways in which men use those powers carry the greatest consequence for good or for evil.

The same hydrogen fusion process that gives the burning light of the Sun and the stars has been in our grasp for a decade—but will we use it for construction or for cataclysm? Earth satellites may soon give us direct and instantaneous communication and television spreading simultaneously around the world—but will we use them for truth or for falsehood, for tolerance or for hatred, for peace or for conflict?

Scientifically and technically the world has already become a single community—yet in our ethical response to this fact, and in our political institutions, we, governments and citizens, are lagging dangerously far behind you, the scientists.

You have given us dangerous powers, but we have not yet learned to control them. You have given us tools to abolish poverty—but we have not yet mastered them. You have given us means to extend the span of human life, but this may prove a curse, not a blessing, unless we can assure food, survival, and then health and a good life for the bodies and minds of our exploding populations. You have made the world small and interdependent, but we have not built the new institutions to manage it—nor cast off the old institutions which scientific progress has made obsolete.

Every great change wrought by science is foreshadowed years ahead in the laboratory and on the drawing board. But it is not until the new device is fully built and functioning, and has astonished the whole world, that we begin to think of its human and political implications. We are forever running today to catch up tomorrow with what you made necessary yesterday.

This gap must be closed—this disruptive and dangerous lag between scientific discovery and political adaptation to it. I suggest that the natural scientist and the political practitioner must enter into a new communion of early and constant intercommunication, so that the world's institutions can more nearly keep up with the incessant march of science. Unless this is done, the gap will surely widen, for there is no way to slow down the pace of scientific discovery even if we wanted to do it.

Today things move more swiftly. Within ten years after man set off his first atomic explosion, the leaders of all the great powers had acknowledged that a nuclear war between any nations would be a catastrophe for *all* nations. There is now an Atomic Energy Agency which is *international.* There are strenuous negotiations for a permanent, reliable, controlled ban on nuclear weapons tests by any nation. There is a groping determination to halt the further spread of nuclear weapons to any nation. Thus, no doubt the exploration of outer space will breach them further.

We can only guess at such possibilities. But there is no guessing any more as to whether man will undertake the adventure of space exploration. Yesterday's dreams are today's facts. Scientific instruments, then animals, then men, have been hurled into space. The splendid flight and safe landing of Major Titov, just nine days ago, marks one further stride in this progression. There is no turning back; as certainly as the oceans were conquered in the century of Columbus and Magellan, new realms of space will be conquered in our century.

These questions are beyond the scope of science—but all of us, as citizens, must help to answer them. If the scientist and the engineer can create a thrust strong enough to defeat the Earth's gravitation, and can plan to send groups of men into flight far beyond the Earth—

then it is up to us in government and diplomacy to develop a comparable "orbital velocity" of our own, great enough to lift *all* mankind beyond the dread gravitation of mistrust and war.

In the years ahead, then, international diplomacy must do far more than put out the recurrent fires of conflict. It must apply itself with massive energy to three great areas of creative effort: to disarmament, to the building of institutions to keep the peace, and to international cooperation for human progress.

After fifteen years' debate all the world agrees that the arms race, especially in nuclear weapons, is anarchic, wasteful, and deadly dangerous for humanity. So all agree that we must stop the race, reverse the process and disarm.

Yet it is not done. Why? Because of deep conflicts of purpose, and an even deeper mistrust. But it can be done. It involves principles which are familiar to you as scientists—freedom of investigation, freedom of inspection, and freedom of verification. There must be, in any disarmament program, adequate inspection and verification such that each side can be quite sure, at every stage, that the other is living up to its part of the bargain.

Disarmament has been misconstrued as if it were in some way the enemy of national defense. And the idea of inspection and verification has unfortunately been misconstrued in certain quarters, as if it were in some way the enemy of disarmament. It is not. It is a necessity. The acid test of sincerity is whether one agrees to fully adequate inspection and verification. Only with them can we know that, inside the box marked "Disarmament", we will really find the reality and a peaceful world, and not something ticking away to the destruction of all of us. The same, of course, applies to the banning of nuclear weapons tests, for no permanent ban is possible without adequate inspection and verification. In nearly three years of negotiations in Geneva that has always been the key issue. And it still is.

The next question is: Who is to do the inspection and verification? What sort of policeman can police the great powers?

Here we find that we cannot take even the first practical step toward general and complete disarmament and a peaceful world unless the nations are willing to build new world institutions which stand above the individual nations and act impartially for the entire human community. What is called for is an international organization within the framework of the United Nations which will see to it that no single nation fails to comply with agreed steps toward general and complete disarmament.

And if we look still further down the road, to the day when national armed forces will be done away with and only internal police units remain, then all the more will the world need institutions of international law and order. Then the United Nations will need its own United Nations Peace Force, capable of deterring or subduing the strongest combinations which might be raised against it.

That is the long-run need—but the short run makes similar demands on us. Events in the Congo have shown how vital it is that the United Nations retain and develop further the capacity to act for peace, to deploy military forces with speed and precision, and thus to uphold the integrity of vulnerable nations in emergencies where direct intervention by a great power would risk disaster. The United Nations is the world community's greatest instrument, and the world community must act now to uphold it, pay for it, invigorate it, and support its able and courageous Secretary General.

All these things are demanded of us to save mankind from violence and war. But the community of nations, as this meeting today so eloquently attests, should be bound together by more affirmative and creative purposes. More and more we must, as a world community,

learn to practise the arts of peace cooperatively and together. And, at this fateful moment in history, when man has, so to speak, one foot already in the heavens, surely we must find ways for the powers to cooperate rather than fight in the exploration of outer space.

And surely all the world would breathe easier if the conquest of space were looked on henceforward not as a means to the power and glory of particular nations or ideologies, but as one of the great adventures of the whole human race.

"Together let us explore the stars"—so said President Kennedy at his inauguration last January, appealing especially to the Soviet Union. A few days later he renewed this appeal in these words: "I now invite all nations—including the Soviet Union—to join with us in developing a weather prediction program, in a new communications satellite program, and in preparation for probing the distant planets of Mars and Venus."

Technology will not wait long for an answer. In just a few years there will be rocket boosters, in more than one country, big enough to launch whole teams of men on journeys to the nearest planets. Shall this too be a race for military or psychological advantage at huge and wasteful expense? Or shall it be the occasion for teamwork, ignoring ideological lines? We haven't much time left in which to decide—it is a fork in the road which will soon be passed.

We have many similar choices to make closer to home. The new nations, which have recently become independent, have an almost unlimited need for education, health, industrial development, agricultural improvement, communications, and exchanges in the fields of science and culture. Shall more fortunate nations exploit those needs by offering aid only in exchange for political influence? Or shall we help because it is right to help? And shall we prefer more and more the disinterested channels of the United Nations? The path to peace must lie increasingly in the multilateral direction of the United Nations, especially with all the self-restraint and mutual tolerance which it requires.

Such are the specific challenges which face international diplomacy today and which draw still greater urgency under the accelerating pressures of science and technology. Disarmament. The building of institutions to keep the peace, both now and in a future disarmed world. International cooperation in the creative arts of peace, to abolish poverty and backwardness.

We have no choice but to meet these challenges. And, in meeting them, we shall be building together a grand design of peace—a design whose keynote is world community.

If there can be said to be a way of the future for mankind, I believe it is in that principle of community. No one nation, no empire, no imposed system can dare to speak any more for mankind. All must be willing, if sovereignty is to make any sense in the thermo-nuclear age, to deny themselves some of the extravagant jungle habits which have accompanied it in times past—and to join their sovereign wills in community institutions, in common community action, and in common obedience to the community's rules.

The rules themselves already exist. They are proclaimed in one of the greatest creative acts of history, the United Nations Charter. We can attempt to restate some of them in the light of our experience since 1945, when that Charter was framed—on the other side of San Francisco Bay.

The Charter commands every nation not to use or threaten force against the territory or independence of another. But experience requires us to go further, for there are other means of conquest. We have seen nations and peoples subjugated by political subversion and guerrilla warfare. We have seen economic aid used as bait and club to impose political influence and subservience. We could well see the raising of new territorial claims, or even, claims of possession in outer space. To all these exaggerations of sovereignty we must say: no, no

nation, any more, by any means, direct or indirect, shall seek to extend its control at the expense of another. And we can say so with rising confidence now that the Republic of the Congo, which was mortally threatened with new conquest by outside powers, has with the massive help of the United Nations regained its unity and its hopes for the future. Long may it live! And long may the world remember the triumphant achievement of the United Nations!

A second provision of the United Nations Charter calls for international cooperation for human progress—economic, social, cultural, and in the field of human rights. Much has been accomplished along those lines, but how much more could be done, both on this earth and in the spaces beyond, if all the nations would willingly pool their capacities and their efforts! The wonderful techniques of material progress should not be perverted to satisfy political or ideological ambitions. The poor and the hungry and the diseased of this world do not ask for help in the name of one "system" or another. They ask for it in the name of humanity—of the community of mankind—and it is in that name only that they should receive it.

There is a third principle of the United Nations that needs reaffirmation. It is summed up in those splendid words of the Preamble—"to practice tolerance, and live together in peace with one another as good neighbors."

Tolerance is the key to peace, for there can be no peace unless there is mutual tolerance as between differing peoples and systems and cultures. Peaceful co-existence should not and cannot involve "burial" by any one of any other.

You men of science above all others should value and preach tolerance, for you have only to recall the blight that intolerance cast on Copernicus and Galileo, a blight that held back astronomy for generations, and you know only too well how the orthodoxy of one scientific era becomes the heterodoxy of the next.

The condition of tolerance is openness and the understanding that comes from openness. How can there be tolerance or understanding if great nations continue in secretive isolation from the rest of the world, in suspicion and fear of sinister foreigners, excluding outside information, periodicals, books, and broadcasts, restricting travel, and hiding great parts of their territory? Only in openness will that mistrust that poisons the world atmosphere today be dispelled, and only through open societies can there arise that tolerance that will permit all of us to live in confidence and peace with one another.

Amid the darkness of this noontime there are rays of hope that we *will* achieve an open world. It is happening, bit by bit. Just the other day, we read that next year there will be direct air service between New York and Moscow. We see it in the growing record of tourism and cultural and technical exchanges. Indeed, we see it in such great world-wide assemblies as this of the International Astronomical Union.

Just last week I was happy to read the remark of the eminent Soviet astronomer, Professor A. A. Mikhailov, at a meeting in Pasadena on the astronomy of the space age. "Science is international," said Professor Mikhailov. "My hope is for the United States and Russia to share in space projects and in many other fields of human endeavor."

I am glad Professor Mikhailov is here this morning, because I would like to tell him how much I agree with him!

Community, tolerance, openness—those are the words which I would leave with you. And if they are to be made real, we all have one more great duty: to support the United Nations, which is the community's greatest symbol and greatest instrument. It is the world center of tolerance and openness. It is, as long as men are free to differ—which I trust will be forever!—a center of disciplined disagreement. No one power can dominate it, or use it to drive another

to the wall. It is the greatest defense of the weak against the bullying of the strong. It is the lightning rod which prevents rampant nationalism from sparking war. And if the world is to be saved from disaster, the United Nations must be built into still more—an institution which can enforce the judgments of the world community against those who threaten or break the peace.

I hope I have not detained you too long. After this exposition of our terrestrial worries, I suspect you will all be glad to get back to the remotest celestial bodies!

Indeed, I rather wish that all of us who deal in human affairs could be astronomers for a while. Sir James Jeans called astronomy "the most poetic of the sciences." Perhaps if we all practiced it we would be filled with the wonder and excitement of discovery, with a sense of elemental majesty and beauty, with our little quarrels in better perspective, and would thus be purged of our pride and prejudice, and all the base motives which complicate and endanger our lives.

At all events, I devoutly hope that all of us in and out of the United Nations will make a new beginning; that we will dare to part with habits and institutions dangerously outworn; and that we will have the courage and determination to construct, soon enough to save mankind, a new world order more nearly worthy of the scientist and the poet, and of the best that man has in him.

The Chairman expressed the thanks of the gathering to Ambassador Stevenson for his inspiring address, and formally declared open the Eleventh General Assembly of the Union.

LIST OF MEMBERS AND GUESTS

present at the XIth General Assembly of the Union in Berkeley, California, 15-24 August 1961.

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M. Jaschek
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J. A. Lopez
L. A. Milone
J. J. Nissen
R. P. Platzeck
J. Sahade
J. L. Sersic
S. J. Slaucitajs

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R. W. Tanner
M. M. Thomson
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Z. Ceplecha
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S. Laustsen
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R. A. Saakian
A. B. Severny
V. V. Sharonov
V. P. Shcheglov
A. A. Shpitalnaya

UNION OF THE SOVIET SOCIALIST REPUBLICS (*cont.*)

I. S. Stcherbina-Samoilova
N. V. Steshenko
G. F. Sultanov
K. N. Tavastsherna
B. Vorontsov-Velyaminov
S. K. Vsekhsvyatsky

VATICAN CITY STATE

F. C. Bertiau, S.J.
M. F. McCarthy, S.J.
D. J. K. O'Connell, S.J.
P. J. Treanor, S.J.

VENEZUELA

J. Abdala

YUGOSLAVIA

V. Oskanjan
L. Randić

GENERAL ASSEMBLY

AGENDA

The agenda for the General Assembly, which had been published in the *Agenda and Draft Reports* and distributed to all Members, read as follows:

1. Official opening of the General Assembly, by the President.
2. Appointment of official interpreters.
3. Report of the Executive Committee:
   (*a*) discussion of the printed Report;
   (*b*) report of decisions taken at meetings in Berkeley.
4. Report by the General Secretary.
5. Report by the President of the proposals for membership of the Executive Committee.
6. Announcements of:
   (*a*) the names of representatives of Adhering Countries, empowered to vote on their behalf;
   (*b*) the names of representatives to serve on the Nominating Committee;
   (*c*) the names of Acting Presidents of Commissions.
7. The appointment of the Finance Committee.
8. The revision of the Statutes and By-laws.
9. Statement of the revised structure of Commissions. (Details have been given in *Information Bulletin* no. 4).

   The Executive Committee will formally propose that all Sub-Commissions become committees or working parties of their main Commissions, with the exception of Sub-Commission 29*a*, which it will propose should become a Commission.
10. Resolutions submitted by Adhering Organizations or National Committees of Astronomy:

    (*a*) (i) By the Czechoslovak Academy of Sciences:

    'That the General Assembly revoke the decision, made by the Executive Committee at its meeting in September 1959, to admit Taiwan as an adhering country.'

    (ii) By the U.S.S.R. Academy of Sciences:

    'Proceeding from the facts that the decision of the Executive Committee, in September 1959, to admit Taiwan:

    '(*a*) has already brought harm to the interests and prestige of the Union and to the international co-operation of astronomers (the Academy of Sciences of the People's Republic of China, where astronomical research is being carried on rapidly and on a large scale, has notified the IAU of its resignation from membership);

    '(*b*) taking into account the fact that there is no independent scientific activity in the field of astronomy in Taiwan, the above decision of the Executive Committee runs counter to the letter and spirit of the Statutes of the Union;

'the General Assembly resolves to cancel the decision to admit Taiwan, as adopted by the Executive Committee on 8 September 1959.'

(*b*) By the National Committee for Astronomy of Australia:

That Commissions 25 and 29 consider the compilation of a small select list of stars, between declinations $+15°$ and $-15°$, on which attention could be concentrated by photo-electric observers in both hemispheres: using

(i) multi-colour photometry, *e.g.* UBV or 6-colour work;

(ii) spectral scans.

(*c*) By the Science Department of the Royal Belgian Academy:

That action be taken concerning the danger to Astronomy of a proposed system of telecommunication using resonant dipoles in the high atmosphere.

11. Resolutions submitted by Commissions or Sub-Commissions:

(*a*) By the President of Commission 19:

Considering that the polar motion and the variation in the speed of rotation of the Earth should be treated as a single problem, it is recommended that Commissions 19 and 31 be combined into a single Commission on 'The Rotation of the Earth', which should include the following Sub-Commissions (or Committees) on:

(i) 'The International Polar Motion Service', to act as an Advisory Council to the Central Bureau of the IPMS;

(ii) 'The International Time Service', to act in the same way to the Bureau International de l'Heure.

(*b*) By the President of Commission 41:

'That committees on the History of Astronomy be established in each adhering country, the Chairmen of such committees becoming members of Commission 41.'

12. Consideration of the future of the International Latitude Service, and the institution of a proposed International Polar Motion Service.
The text of a resolution, adopted by the International Union of Geodesy and Geophysics was referred to the IAU for consideration.

13. Report of the Finance Committee:

(*a*) the accounts for the previous period;

(*b*) the budget for the ensuing period.

14. Consideration of the unit of subscription for the ensuing period.
The Executive Committee will propose to the Finance Committee that the unit of subscription be increased from 500 to 600 gold francs.

15. The appointment of the Advisory Finance Committee.

16. The appointment of the Special Nominating Committee.

17. The nomination of new Members of the Union.

18. Commissions:

(*a*) Dissolution and the creation of Commissions.
(*b*) The election of Presidents and Vice-Presidents.
(*c*) The membership of Organizing Committees.

19. Resolutions submitted by Commissions, subject to the recommendation of the Resolutions Committee.

20. The place and date of the twelfth General Assembly.

21. The election of a President, six Vice-Presidents and a General Secretary.

22. The appointment of representatives to the International Council of Scientific Unions.

23. Addresses by the retiring and the newly-elected Presidents.

24. Closing ceremonies.

The items of agenda were taken, as far as practicable, in the order in which they were given; but items 3(*b*), 10(*c*) and 12 onwards were deferred until the second session. The same item numbers are used throughout this report, for both the first and second sessions of the General Assembly.

FIRST SESSION

Held on Tuesday 15 *August* 1961 *at* 14^h15^m, *in the main auditorium of Wheeler Hall on the Berkeley Campus of the University of California.*

Professor J. H. OORT, President, in the chair.

1. *Official opening.* The President spoke a few words of welcome to the Members of the Union, invited participants and their guests, and formally declared open the first session of the eleventh General Assembly of the Union.

2. *Official interpreters.* The General Secretary asked the General Assembly to approve of the appointment of the following six official interpreters:

from English to French: L. Houziaux and J.-C. Pecker

from French to English: D. S. Evans and S. D. Gossner

from Russian to English: A. G. Massevitch

from Russian to French: P. G. Kulikovsky

This was unanimously approved.

1. (*cont.*) The President then welcomed the official representatives of other scientific Unions and organizations as follows:

IUGG (Geodesy and Geophysics): M. Nicolet

IUPAP (Pure and Applied Physics): G. Herzberg

IUTAM (Theoretical and Applied Mechanics): N. J. Hoff

IUPAC (Pure and Applied Chemistry): H. C. Urey

URSI (Scientific Radio): J. F. Denisse

OEEC (Organization for European Economic Co-operation): A. H. Delsemme

He referred particularly to the fact that Dr H. P. Robertson, who was to have represented the ICSU (International Council of Scientific Unions) had been prevented from attending owing to an accident. He was to have spoken at the Inaugural Ceremony on behalf of the U.S. National Academy of Sciences, of which he was the foreign secretary.

The President reminded the General Assembly of the gracious message that had been received from the President of the United States of America, and proposed from the chair that a telegram, expressing the appreciation of the General Assembly, be sent to the President

of the United States. He also proposed that a similar telegram be sent to the Governor of the State of California for his message of good wishes. These proposals were approved by acclamation.

At the request of the Chairman, the General Secretary informed the General Assembly that during the last few months he had received information from many Members that they were prevented from attending the General Assembly; he would not give a detailed list. However, he had just received a telegram, which he read, from the Academy of the Rumanian People's Republic, regretting that they could not be represented at the General Assembly, but sending their good wishes for a successful meeting.

The General Secretary then asked Members to stand while he read the following list of Members who had died since the last meeting:

A. Ali, J. A. Anderson, W. Baade, J. Baillaud, J. Bobone, W. Brunner, Miss E. J. Bugoslavskaja, G. Contino, D. Cot, A. K. Das, B. H. Dawson, A. Dittrich, A. D. Dubyago, I. A. Dyukov, C. S. Gum, J. Jackson, F. A. Jenkins, H. Spencer Jones, A. Kopff, E. Lange, P. Lejay, F. C. Leonard, A. McKellar, C. E. Kenneth Mees, P. W. Merrill, M. Milankovitch, S. A. Mitchell, S. V. Orlov, A. Pannekoek, P. P. Parenago, A. Patry, I. Polit, F. E. Ross, R. F. Sanford, O. Seydl, C. K. Seyfert, A. V. Soloviev, F. J. M. Stratton, G. Thiessen, G. A. Tikhov, P. J. van Rhijn, R. Vernić, Miss J. M. Vinter Hansen, H. von Zeipel, V. P. Vyazanitsyn, H. P. Wilkins, R. E. Wilson, W. H. Wright.

3.(*a*) *Report of the Executive Committee.* The General Secretary said that the Report of the Executive Committee, as printed in the *Agenda and Draft Reports*, was now open for discussion; and that he would be happy to answer any questions that might be asked. There were no questions, and the report was approved.

4. *Report by the General Secretary.* The General Secretary stated that he did not wish to add anything to the published report of the Executive Committee, but took the opportunity of making one or two announcements concerning the arrangements for the General Assembly. He referred particularly to the publication of the *IAU News Bulletins*, which were being published by the editors of *Sky and Telescope* and from which all participants would obtain day-to-day information about meetings of Commissions and other arrangements.

5. *Proposals for membership of the Executive Committee.* In accord with the provisions of the Statutes and By-laws, the President submitted for consideration to the General Assembly the names of those proposed, by the present Executive Committee, for membership of the Executive Committee for the period 1961–64. He reminded Members that there was an agreed procedure by which a Special Nominating Committee, largely appointed by the Nominating Committee and approved by the General Assembly at its previous meeting, makes proposals to the Executive Committee. On this occasion the proposals by the Special Nominating Committee, to fill the positions of President and two Vice-Presidents, had been unanimously adopted by the Executive Committee and were those now before the General Assembly. The President accordingly submitted the name of Academician V. A. Ambartsumian for the office of President, and the names of Professor Y. Hagihara and Professor G. Haro for the offices of Vice-President. The membership of the new Executive Committee would then be as follows:

PRESIDENT: V. A. Ambartsumian.

VICE-PRESIDENTS: L. Goldberg, Y. Hagihara, G. Haro, R. M. Petrie, B. Sternberk, R. H. Stoy.

GENERAL SECRETARY: D. H. Sadler.

In accord with the By-laws the formal election would take place at the final session of the General Assembly.

6. *Announcements.* At the request of the Chairman, the General Secretary announced:

(*a*) the names of representatives of Adhering Countries, empowered to vote on their behalf;

(*b*) the names of representatives of Adhering Countries to serve on the Nominating Committee.

Country	(*a*) *Official Representative*	(*b*) *Representative on Nominating Committee*
Argentina	C. O. R. Jaschek	J. Sahade
Australia	J. L. Pawsey	J. L. Pawsey
Austria	no representative	no representative
Belgium	H. L. Vanderlinden	H. L. Vanderlinden
Bulgaria	no representative	no representative
Canada	C. S. Beals	J. F. Heard
Chile	A. Gutierrez-Moreno	A. Gutierrez-Moreno
Czechoslovakia	E. Buchar	E. Buchar
Denmark	E. Hertzsprung	E. Hertzsprung
Egypt	A. H. Samaha	M. R. Madwar
Eire	M. A. Ellison	M. A. Ellison
Finland	G. Järnefelt	G. Järnefelt
France	A. Danjon	J. Rösch
Germany	H. Haffner	H. Strassl
Great Britain	R. O. Redman	W. H. McCrea
Greece	J. Xanthakis	J. Xanthakis
Hungary	L. Detre	L. Detre
India	M. K. Vainu Bappu	M. K. Vainu Bappu
Israel	N. Robinson	N. Robinson
Italy	M. Cimino	F. Zagar
Japan	M. Miyadi	M. Miyadi
Lebanon	no representative	no representative
Mexico	P. Pishmish de Recillas	P. Pishmish de Recillas
Netherlands	A. Blaauw	M. G. J. Minnaert
Norway	E. Jensen	E. Jensen
Poland	E. Rybka	J. Witkowski
Portugal	A. Botelheiro	A. Botelheiro
Rumania	no representative	no representative
South Africa	W. S. Finsen	W. S. Finsen
Spain	P. J. Cardus	J. M. Torroja
Sweden	B. Lindblad	C. Schalén
Switzerland	M. Schürer	M. Waldmeier
Taiwan	M. Tsao	M. Tsao
U.S.A.	L. Goldberg	F. K. Edmondson
U.S.S.R.	V. A. Ambartsumian	A. G. Massevitch
Vatican City State	D. J. K. O'Connell	D. J. K. O'Connell
Venezuela	no representative	J. Abdala
Yugoslavia	L. Randic	L. Randic

(*c*) *Acting Presidents.* The General Secretary announced that several Presidents of Commissions had been unable to attend the General Assembly, and that the Executive Committee had invited the following Members to serve as Acting Presidents during the General Assembly:

Commission 3: D. Barbier
Commission 21: F. E. Roach
Commission 22: L. Krésak
Commission 23: P. Sémirot

7. *Finance Committee.* In accord with the Statutes the following Finance Committee, consisting of one representative of each Adhering Country, was appointed by the General Assembly:

Argentina	J. Landi Dessy	Italy	G. Righini
Australia	B. J. Bok	Japan	M. Miyadi
Austria	no representative	Lebanon	no representative
Belgium	P. Bourgeois	Mexico	A. Poveda
Bulgaria	no representative	Netherlands	G. B. van Albada
Canada	M. M. Thomson	Norway	T. Ringnes
Chile	A. Gutierrez-Moreno	Poland	S. Piotrowski
Czechoslovakia	E. Buchar	Portugal	A. Botelheiro
Denmark	K. Gyldenkerne	Rumania	no representative
Egypt	M. K. M. Aly	South Africa	W. H. van den Bos
Eire	M. A. Ellison	Spain	M. Loron
Finland	G. Järnefelt	Sweden	E. Holmberg
France	Ch. Fehrenbach	Switzerland	M. Schürer
Germany	H. Siedentopf	Taiwan	M. Tsao
Great Britain	C. W. Allen	U.S.A.	N. U. Mayall
Greece	J. Xanthakis	U.S.S.R.	E. K. Kharadze
Hungary	L. Detre	Vatican City State	P. J. Treanor
India	M. K. Vainu Bappu	Venezuela	no representative
Israel	N. Robinson	Yugoslavia	L. Randic

Professor Ch. Fehrenbach was appointed chairman of the Finance Committee.

8. *Statutes and By-laws.* The General Secretary formally proposed that the revised Statutes and By-laws, for which the proposed texts in French and English were printed in the *Agenda and Draft Reports* should be adopted. He referred Members to the section of the Report of the Executive Committee dealing with the Statutes and By-laws (page 51) and explained that, apart from the specific points mentioned, all amendments are concerned with minor matters of wording and clarification. He mentioned a few minor typographical errors in the printed copies and requested that he should be given permission to make such minor corrections. He gave it as his view that, in other respects, the Statutes and By-laws should be accepted or rejected *in toto*; since otherwise it would not be possible to submit amendments to Adhering Countries with appropriate notice.

The Chairman formally put the question to the vote and the revised Statutes and By-laws were unanimously adopted.

[The Statutes and By-laws, as revised, are printed on pages 476–483].

It was then announced that the proceedings of the Union (in particular in regard to the organization and membership of Commissions) would be ruled by the revised Statutes and By-laws as from that moment.

9. *Revised Structure of Commissions.* The Chairman requested the General Secretary to make a statement on the revised structure of the Commissions, of which full details had already been given to Members in *Information Bulletin* No. 4 of August 1960. The General Secretary explained that some small changes in procedure, mainly of simplification, had been introduced in the By-laws as compared with the revised structure given in the *Information Bulletin.* These changes were not substantial. He answered one or two questions on matters of detail.

He then announced that the Executive Committee wished formally to propose that all Sub-Commissions become Committees or Working Parties of their main Commissions, with the

exception of Sub-Commission 29*a*, which it proposed should become Commission 36. If this were approved the existing Sub-Commissions would remain in being until the end of the present General Assembly.

This proposal was then approved.

10. *Resolutions by Adhering Countries.*

(*a*) *Admission of Taiwan.* The General Secretary stated that the official representatives of Czechoslovakia and the U.S.S.R. had requested him to combine the two resolutions (i) and (ii) (given in the *Agenda*) into one resolution, and to present the combined resolution to the General Assembly as objectively as possible. He then proceeded to give a brief history of the events that had given rise to these resolutions. He pointed out that it was quite possible to adopt different view points on this matter and that some of these are incorporated in the resolution as proposed by the U.S.S.R. Academy of Sciences. However, the majority of the Executive Committee had taken a rather different view, which would be presented to the General Assembly in a statement by the President. He then formally put the motion to the meeting by reading the resolution in item 10 (*a*) (ii), as printed in the *Agenda and Draft Reports*. The representatives of Czechoslovakia and U.S.S.R. stated that they did not wish to add anything to the presentation of the motion as made by the General Secretary.

The President then read the following statement which had been prepared by the Executive Committee:

"On behalf of the Executive Committee, I formally move the rejection of the motion and ask representatives of adhering countries to vote against the motion.

"In the opinion of the majority of the Executive Committee, the application for adherence to the Union from Taiwan was in proper form, and it was neither possible nor desirable for the Executive Committee to decline the application. There can be no question that Taiwan qualifies for adherence to the Union under the terms of the Statutes of the Union. Taiwan already adhered to the International Council of Scientific Unions, in which the IAU is federated. At present, astronomical activity is on a very small scale, but it must surely be the policy of the Union to encourage the development of astronomy in such countries. In recent years the Union has been glad to welcome the adherence of other countries in which astronomical activity is on no higher level. There is no evidence that this astronomical activity is not independent; it is directed by a properly-constituted National Committee of Astronomy.

"The Executive Committee much regrets the resignation of China from adherence to the Union as a consequence of the decision to admit Taiwan, but it must be made absolutely clear that the decision to withdraw was made by China alone, for reasons which have nothing whatsoever to do either with the Union or with Astronomy. The Executive Committee was, however, informed that China might withdraw if Taiwan were admitted, and for that reason approved a resolution which it was hoped would enable China to maintain its adherence to the Union. This resolution reads:

"*Whereas* there is the possibility of confusion in the descriptions variously accorded to the two Republics of China, both of which adhere to the Union, and

in order to indicate unambiguously the two geographical areas in which independent astronomical activity has been developed,

it is resolved that short names, as indicated below, shall be used for all purposes of the Union, with the exception of formal correspondence and descriptions in which the use of the official titles of the two countries is desirable.

1. Official title of country:	The People's Republic of China
Site of Government:	Peking, China
Adhering Organization:	National Committee of Astronomy (Nanking)
Date of Adherence:	1935
Geographical area in which astronomers are represented:	The mainland of China
Short name:	*China* (in French: *Chine*)
2. Official title of country:	The Republic of China
Site of Government:	Taipei, Taiwan
Adhering Organization:	The Astronomical Society of the Republic of China (Taipei), recognized as a National Committee of Astronomy by the Academia Sinica (Taipei), through which organization the Republic of China adheres to the International Council of Scientific Unions.
Date of Adherence:	1959
Geographical area in which astronomers are represented:	Taiwan (Formosa)
Short name:	*Taiwan* (in French: Taiwan)

"The Executive Committee can only express the hope that circumstances will soon change in such a way as to enable China to resume its adherence to the Union, and so to play its full part, formally, in international co-operation in Astronomy. We have noted the great strides that are being made in Astronomy in China, and have learned with pleasure from Chinese astronomers that international co-operation will continue informally even though China no longer adheres to the Union."

He then announced that the matter was open for discussion.

Dr Kukarkin, a Vice-President of the Union, said that the only comment he wished to make at this stage was to dissociate himself from the statement that had been made on behalf of the Executive Committee.

There being no further discussion, the motion was put to the ballot. The General Secretary explained that this was an administrative question, not involving a question of finance, to be voted upon by countries, each country having one vote. He asked the General Assembly to approve the appointment of two of the interpreters (Mrs Gossner and Dr Pecker) to act as scrutineers of the ballot.

As a result of the ballot there were:

5 countries for acceptance of the motion and 24 against; 3 countries abstained from voting; and the representative of one country was prevented by illness from being present at the General Assembly.

The President accordingly declared that the motion was lost.

He then asked the General Assembly to approve that a message be sent to the astronomers of the People's Republic of China, regretting their absence from the General Assembly and sending every good wish for astronomical research in China. This proposal was received with acclamation, and the General Secretary was instructed to send an appropriate message.

Professor Blaauw, the official representative of the Netherlands, requested permission to make a statement. The statement, made on behalf of the Dutch delegation, concerned the usage of official and unofficial names of countries in the proceedings of the Union, and arose from the resolution of the Executive Committee, contained in the statement read by the President.

The President stated that this matter was not formally on the agenda for the General Assembly, and could only be discussed with the approval of the General Assembly. He asked the General Secretary to make a statement.

The General Secretary reported that the Executive Committee had received a letter from the Academia Sinica in Taipei, Taiwan, formally requesting that the question of the name used for their country in the proceedings of the Union be submitted to the General Assembly, as they do not approve of the resolution adopted by the Executive Committee. As this request was received too late for it to be placed on the circulated Agenda, in accord with the Statutes of the Union it could only be discussed provided a proposal to that effect was approved by one half of the votes of the countries represented at the General Assembly. The Executive Committee had, however, considered the matter and it recommended to the General Assembly that the matter be not discussed.

The Chairman then asked whether the representative of any country present wished to propose that this question be discussed; there being no demand for discussion, the meeting proceeded to the next business.

10. (*b*) On the recommendation of the Executive Committee the General Assembly agreed to refer the motion by the National Committee for Astronomy of Australia to Commissions 25 and 29.

11. *Resolutions by Commissions.* Again on the recommendation of the Executive Committee, the General Assembly agreed to refer the resolution by the President of Commission 19 to Commission 19, and the one by the President of Commission 41 to Commission 41.

The General Secretary then announced that all other items of agenda would be deferred until the next session, pending reports from the various Commissions and Committees.

The Chairman thanked the interpreters and the scrutineers of the ballot and formally adjourned the meeting at 16^h15^m.

FINAL SESSION

Held on Thursday 24 August 1961 at 9^h15^m, in the main auditorium of Wheeler Hall on the Berkeley Campus of the University of California.

Professor J. H. OORT, President, in the chair.

3. (*b*) *Report of decisions taken by the Executive Committee.* In opening the second, and final, session of the General Assembly the President said that this was a convenient opportunity to inform the General Assembly of various decisions taken by the Executive Committee during its meetings in Berkeley. These decisions do not require the formal approval of the General Assembly.

He announced that the Executive Committee had accepted the applications for membership from the following countries, with the adhering organizations as stated:

BRAZIL: Conselho Nacional de Pesquisas, Rio de Janeiro.
NORTH KOREA: Academy of Sciences of the Popular Democratic Republic of Korea, Pyongyang.
TURKEY: Turkish Astronomical Society, Istanbul.

The President said that he was very happy to welcome these three countries to membership of the Union, and he noted with pleasure that representatives of two of the countries were present at the General Assembly.

The President then informed the meeting that the Executive Committee, on the recommendation of Commission 5, had decided to terminate publication of the *Astronomical News Letters* as from 1 January 1962. The last number to be published would be 109. He called attention to the great services to Astronomy rendered by Professor V. Kourganoff, who had edited the *Astronomical News Letters* so efficiently since 1953, and the General Assembly agreed that a suitable message of thanks should be sent to Professor Kourganoff.

The President further announced that the Inter-Union Commission on Solar and Terrestrial Relationships (IUCSTR) was now formally constituted, with Professor C. W. Allen as President and Dr D. K. Bailey as Secretary. [A report of the inaugural meeting of this Inter-Union Commission is given on pages 469–474].

He finally informed the meeting that the present Executive Committee had discussed to some extent the question of possible changes in the structure of the Union, which might be necessary in the near future. It is proposing to the new Executive Committee that a Committee be formed to study the future organization of the Union, and to report on it to the Executive Committee and to the next General Assembly.

10. *Resolutions by Adhering Countries.*

(*b*) The General Secretary announced that the resolution by the National Committee for Astronomy of Australia had been withdrawn from the agenda for the General Assembly. Commissions 25 and 29 had already taken all necessary action.

(*c*) *Contamination of space; project West Ford.* The General Secretary announced that the Executive Committee had given long and careful consideration to the danger to Astronomy of a proposed system of tele-communication using resonant dipoles outside the atmosphere. It accordingly submitted, to the General Assembly, two resolutions that had been drawn up on the basis of drafts proposed at meetings of various Commissions and by a special committee appointed within the Executive Committee. He then proceeded to read the texts of the resolutions, which had been made available to Members in *IAU News Bulletin* No. 8 and of which the amended texts are given on pages 82–85.

Resolution No. 1 was accepted by the General Assembly without discussion.

In connection with Resolution No. 2 Professor G. Lemaître raised the question that whereas Resolution No. 1 was addressed to all governments, Resolution No. 2 was not so addressed; he thought that it should have a wider appeal. Professor P. Swings called attention to the danger that interference, at a level which is not detectable with instruments to-day, might in the future cause serious interference with astronomical observations by instruments of improved performance. He accordingly proposed that the words "or not" be added in the third paragraph of Resolution No. 2. He also agreed with Professor Lemaître's remark, and regretted that the texts of the Resolutions were made available so shortly before the meeting.

The President explained that it had not been possible to circulate the texts of these resolutions earlier, but they had been given very detailed consideration, and that it was not in general practicable to enter into discussion of wording. He assured Professor Lemaître that his point would be met by a wider circulation of Resolution No. 2 and agreed, on behalf of the Executive Committee, to accept the amendment proposed by Professor Swings.

Resolution No. 2 was then formally adopted by the General Assembly *nemine contradicente.*

11. *Resolutions by Commissions.*

The General Secretary informed the meeting that both resolutions (*a*) and (*b*) had been withdrawn from the agenda for the General Assembly. Commissions 19 and 31 will reconsider resolution (*a*) before the next General Assembly. The substance of resolution (*b*) has been

adopted by Commission 41, and the Executive Committee has agreed to assist in its implementation.

12. *The future of the International Latitude Service.* The General Secretary formally proposed, on behalf of the Executive Committee, that the resolution submitted to the Union by the International Union of Geodesy and Geophysics (see pages 86 and 87) be adopted. This was agreed.

He then reported that, on the basis of recommendations made to it by the working group (see paragraph 4 of the resolution), the Executive Committee had accepted the offer from the Science Council of Japan to set up the Central Bureau of the ILS (later to become the International Polar Motion Service—IPMS) at Mizusawa under the directorship of Dr T. Hattori. He went on to say that Dr Hattori will take over from Professor G. Cecchini of the Osservatorio Astronomico di Torino, to whom the Union owes much gratitude for having directed the ILS since 1 January 1949, about the end of 1961.

13. *Report of the Finance Committee.* At the first session of the General Assembly a Finance Committee had been appointed to examine the accounts of the preceding three years and the budget for the coming three years, as submitted to it by the Executive Committee. The Chairman now called upon the President of the Finance Committee to present his report to the General Assembly, which was adopted as follows:

"Le Comité des Finances a élu un sous-comité composé par B. J. Bok, E. Buchar, Ch. Fehrenbach, E. K. Kharadze, et N. U. Mayall.

"1. Ce sous comité a examiné les comptes de l'UAI pour la période allant du 1er novembre 1957 au 31 décembre 1960. Les comptes correspondant à des avoirs en Dollars U.S., Livres Sterling, Florins néerlandais, et Francs français ont été tous vérifiés par des experts comptables agréés et certifiés-exacts. Le sous-comité a examiné ces documents et a demandé au comité de les approuver. Le comité les a approuvés à l'unanimité.

"2. Pour rendre ces comptes, très complexes, facilement compréhensibles, le Secrétaire Général a fait préparer les comptes sommaires figurant aux pages xxvi et xxvii du *Agenda and Draft Reports.* (pages 58 et 59). Le sous-comité a constaté que ce document reproduit bien les dépenses qui figurent dans les comptes vérifiés par les experts comptables. Il a exprimé le désir de voir figurer aussi dans ces comptes les sommes allouées pour des buts spéciaux et seulement administrées par l'UAI. Le comité a accepté ce point de vue et le Secrétaire Général a fait modifier en conséquence les pages xxvi et xxvii. [Voir pages 58 et 59]. Les sommes figurant à la fois en recettes et en dépenses s'élèvent ainsi à 228 022 $U.S.

"3. Le comité a constaté à cette occasion l'importance du travail de comptabilité de l'Union, il a été heureux de constater avec quel soin ce travail a été fait par Mlle Splinter sous la direction du Secrétaire Général. Le Comité des Finances leur exprime sa vive reconnaissance. Le Comité des Finances signale au Comité Exécutif la grande aide que représenterait pour le Secrétariat Général l'engagement d'un comptable.

"4. Le comité a examiné la demande du Comité Exécutif d'augmenter la contribution unitaire de 500 à 600 Francs Or. Le Comité a examiné avec attention cette demande, elle lui a paru très justifiée par

(*a*) l'augmentation du coût de la vie,
(*b*) l'augmentation du nombre de membres de l'Union,
(*c*) l'augmentation considérable de son activité par la réunion de nombreux symposiums, et de la publication de leurs procès verbaux,
(*d*) l'augmentation considérable des échanges d'astronomes entre les divers pays adhérents.

Le comité a voté cette augmentation par 25 voix pour et une voix contre.

"5. Le budget pour la période des trois années a ensuite été examiné. Après discussion ce budget est proposé en équilibre à 132 000 $U.S.

"Le comité propose de réduire toutes les dépenses au minimum indispensable de façon à garder disponible les sommes les plus élevées pour l'échange des astronomes, les réunions de symposiums, et la publication de leurs travaux.

Le président du Comité des Finances,

(*Signed*) CH. FEHRENBACH"

(*a*) *Accounts for* 1957–60. The necessary amendments to the accounts, as published in the Report of the Executive Committee on pages 59–59, will be added in a footnote.

(*b*) *Budget of expenditure for* 1962–64. The budget of expenditure for the period 1962–64, as submitted to the Finance Committee by the Executive Committee and as approved by the Finance Committee, was adopted by the General Assembly in the following form:

BUDGET OF EXPENDITURE, 1 JANUARY 1962—31 DECEMBER 1964

(The details of the budget are given on the facing page, page 39.)

This budget is based on an estimated total income of the equivalent of 132 000 U.S. dollars. Part of this income cannot be reliably estimated in advance, but certain headings of expenditure, notably 5, 7, 8, 9, and 12, are within the control and discretion of the Executive Committee.

Accordingly, the General Assembly, in approving this budget, specifically authorizes the Executive Committee to vary the expenditure under headings 5, 7, 8, 9, and 12, indicated by an asterisk(*). This variation may be achieved by increasing or decreasing the activities, or in other ways, to accord with any variations in the estimated income of the Union.

The General Assembly is conscious that it will have the opportunity, if it should prove necessary, of approving a supplementary budget for the period 1 January 1964 to 31 December 1964, at the General Assembly in 1964.

The General Secretary informed the General Assembly that neither the Executive Committee nor the Finance Committee had been able to make provision in the budget for two grants requested by Commissions 5 and 40.

The Chairman then expressed the thanks of the Union to Professor Fehrenbach, the Finance Committee and the General Secretary for their valuable work.

14. *Unit of Contribution.* In adopting the Report of the Finance Committee, the General Assembly formally agreed to accept the proposal of the Executive Committee, as advised by the Finance Committee, to increase the unit of contribution from 500 to 600 gold francs.

15. *Advisory Finance Committee.* The General Secretary announced that the Executive Committee had agreed to recommend that the Advisory Finance Committee be discontinued. The reason for this was that a new form of budget had been adopted, in which provision was made for the expenditure of the total income of the Union during the next three years. The main purpose of the Advisory Finance Committee, which was to advise on the expenditure of the ICSU subvention, was therefore at an end; and its remaining functions could in future be adequately carried out by the Executive Committee itself.

It was agreed not to re-appoint an Advisory Finance Committee.

The General Secretary expressed his appreciation of the work done in the last three years by the Advisory Finance Committee, and asked that he might thank the members on behalf of the General Assembly.

Heading	Purpose			U.S. dollars
1	Expenses of the Administrative Office 1962: $5 000; 1963: $5 000; 1964: $6 000			16 000
2	Subscription to the ICSU			1 200
3	Expenses of Commissions			2 000
4	Specific projects			44 676
	Comm. No.	*Project*	*Sum*	
	5	*Bibliography of Astronomy*, 1881–1898	$5 000	
	6	IAU Telegram Bureau ($666.66 annually)	2 000	
	10	*Cartes héliographiques de la Photosphère* ($326.66 annually)	980	
	10	*Cartes synoptiques de la Chromosphère solaire* ($882 annually)	2 646	
	20	Minor Planet Center, at Cincinnati ($750 annually)	2 250	
	23	*Carte du Ciel*	8 900	
	27	English version of remarks to the supplement of the second edition of GCVS	400	
	38	Exchange of astronomers ($7 500 annually)	22 500	
*5	Expenses of the General Assembly, 1964			15 000
6	Printing of *Transactions*, Vol. XI and Draft Reports 1964			12 000
*7	Meetings of the Executive Committee			5 000
*8	Expenses of Symposia			18 000
*9	Publication of the Proceedings of Symposia			8 000
10	Meetings of Inter-Union Committees			5 000
11	Representation			1 000
*12	Projects authorized by the Executive Committee			4 000
				131 876

16. *Special Nominating Committee.* The President reminded the General Assembly of the agreed procedure by which a Special Nominating Committee—to consist of the President of the Union, the immediate past President, one retiring member of the Executive Committee (to be appointed by the Executive Committee) and four other Members (to be appointed by the Nominating Committee)—is appointed within one year following each General Assembly to advise the Executive Committee on nominations for the new Executive Committee.

On this occasion there would be five members of the new Executive Committee who might retire in 1964, and the Nominating Committee, only appointed for the duration of the General Assembly, had therefore to consider five alternative appointments of the four Members.

The President then announced that the Nominating Committee proposed the following alternative committees, the final composition being dependent on which of the retiring members of the new Executive Committee (L. Goldberg, R. M. Petrie, D. H. Sadler, B. Sternberk or R. H. Stoy) would be selected by the new Executive Committee:

1. L. Goldberg—V. A. Ambartsumian, J. H. Oort; Ch. Fehrenbach, W. H. McCrea, M. Miyadi, J. Sahade.

2. R. M. Petrie—V. A. Ambartsumian, J. H. Oort; Ch. Fehrenbach, M. Miyadi, J. Sahade, A. E. Whitford.

3. D. H. Sadler—V. A. Ambartsumian, J. H. Oort; Ch. Fehrenbach, M. Miyadi, J. Sahade, A. E. Whitford.

4. B. Sternberk—V. A. Ambartsumian, J. H. Oort; Ch. Fehrenbach, W. H. McCrea, M. Miyadi, J. Sahade.

5. R. H. Stoy—V. A. Ambartsumian, J. H. Oort; Ch. Fehrenbach, M. Miyadi, J. Sahade, A. E. Whitford.

17. *New Members of the Union.* The General Secretary announced that, according to the Statutes, the Union is composed of Members approved, on the proposals of the Adhering Organizations or National Committees, by the Executive Committee on the basis of their achievement in some branch of Astronomy; and that, according to the By-laws, proposed changes in the list of Members are submitted by the Executive Committee to the Nominating Committee. He went on to say that the Executive Committee had acted according to these procedures and, on the advice of the Nominating Committee, had approved of the addition of 238 new Members and the deletion of 16 Members. He further announced that, as a result of proposals from Commissions, the Executive Committee had agreed to the co-option of two scientists from countries that do not adhere to the Union. The General Secretary then proceeded to read the names of the new Members and of the deleted Members, and informed the General Assembly that these names would be published in the next *Information Bulletin* and would be incorporated in the list of Members to be printed in the *Transactions.*

18. *Commissions.*

(*a*) The President announced that, sometimes as a result of proposals by the Commissions themselves, the Executive Committee formally proposed to the General Assembly that the following changes be made in the Commissions of the Union:

(i) Commission 3 (Notations) be dissolved;
(ii) Commission 14 be renamed "Commission on Fundamental Spectroscopic Data";
(iii) Commission 28 be renamed "Commission on Galaxies";
(iv) Sub-Commission 29*a* become Commission 36 on "The Theory of Stellar Atmospheres".

The General Secretary stated that the Executive Committee had given careful consideration to the proposal that Sub-Commission 29*c* on Stellar Classification should become a separate Commission, but had been unable to recommend this change to the General Assembly.

With this explanation the proposals above were adopted by the General Assembly.

(*b*) The General Secretary, on behalf of the Executive Committee, submitted the following list of Presidents and Vice-Presidents of Commissions for election by the General Assembly, subject to their willingness to serve:

No.	*President*	*Vice-President*	*No.*	*President*	*Vice-President*
4	W. Fricke	G. M. Clemence	15	K. Wurm	F. L. Whipple
5	J. Kleczek	J. B. Sykes	16	A. Dollfus	M. G. J. Minnaert
6	A. R. Hogg	F. L. Whipple	17	K. Koziel	Th. Weimer
7	Y. Hagihara	W. J. Eckert	19	B. Guinot	P. Melchior
8	F. P. Scott	R. H. Stoy	20	P. Herget	N. S. Yakhontova
9	I. S. Bowen	O. A. Melnikov	21	D. Barbier	P. Swings*
10	A. B. Severny	M. A. Ellison	22	V. V. Fedynsky	P. M. Millman
12	R. Michard	M. N. Gnevyshev	23	P. Sémirot	G. J. Järnefelt
14	Ch. Moore-Sitterly	G. Herzberg	24	A. N. Deutsch	W. J. Luyten

No.	*President*	*Vice-President*	*No.*	*President*	*Vice-President*
25	V. B. Nikonov	A. W. J. Cousins	35	M. Schwarzschild	P. Ledoux
26	P. van de Kamp	R. v.d. R. Woolley	36	C. de Jager	K. H. Böhm
27	P. Th. Oosterhoff	G. H. Herbig	37	H. Haffner	M. F. Walker
28	B. Lindblad	R. L. Minkowski	38	M. G. J. Minnaert	P. Swings
29	L. H. Aller	A. B. Underhill	40	J. F. Denisse	R. Hanbury Brown
30	Ch. Fehrenbach	R. M. Petrie	41	P. G. Kulikovsky	J. Ashbrook
31	A. A. Mikhailov	M. Miyadi	42	J. E. Merrill	V. P. Tsesevich
33	B. J. Bok	L. Perek	43	H. Alfvén	L. Spitzer
34	B. Strömgren	S. B. Pikelner	44	L. Goldberg	A. G. Massevitch

This list was agreed by the General Assembly.

[*Subsequent to the General Assembly, at the request of Professor Swings, the Executive Committee appointed F. E. Roach as Vice-President of Commission 21].

(*c*) The General Secretary explained that, according to the revised By-laws, the members of the Organizing Committees of the Commissions are appointed by the Commissions themselves, subject to the approval of the Executive Committee and the General Assembly. He accordingly submitted for general approval the list of Organizing Committees, which had been approved by the Executive Committee on the advice of the Nominating Committee. The Organizing Committees as approved by the General Assembly are given in the list of Commissions on pages 486–495.

Before proceeding with the next item of agenda the General Secretary mentioned briefly the fact that, according to the new By-laws, the membership of Commissions was no longer a concern of the General Assembly. He said that the composition of the membership of Commissions had been carried out in accord with the revised Statutes and By-Laws and, as far as practicable, with the procedure described in detail in section 3 of *Information Bulletin* No. 4. [A list of Commissions and their membership is given on pages 486–495].

19. *Resolutions submitted by Commissions.* The General Secretary reminded the General Assembly that the Executive Committee had appointed a Resolutions Committee, consisting of A. A. Mikhailov, O. Struve and himself (see page 51), to advise the Executive Committee in respect of resolutions submitted by Commissions, with a view to recommending to the General Assembly which resolutions should be formally submitted for consideration by the General Assembly. Of the twenty-three resolutions submitted by the due date: ten, concerned with finance, were submitted to the Finance Committee for consideration and are incorporated in the budget of expenditure for 1962–64; five were included in decisions of the Executive Committee, or in the resolutions proposed by the Executive Committee; seven were considered by the Resolutions Commission as not requiring the full weight and authority of the General Assembly; and only one was recommended for separate consideration by the General Assembly. The Executive Committee accordingly recommended that only this one resolution, proposed by Commission 14, be formally submitted to the General Assembly.

This was agreed.

The General Secretary then formally proposed the adoption of the resolution by Commission 14 of which the full text is given on pages 88 and 89. This was adopted unanimously.

The General Secretary continued to say that, in order to give greater authority to those resolutions adopted by Commissions but not submitted to the General Assembly, the Executive Committee proposes the following resolution:

"*Considering* the impracticability of giving individual attention to every resolution adopted

by each of its fifty-eight Commissions and Sub-Commissions, and having full confidence in its Commissions, this General Assembly

wishes to give its endorsement to the resolutions adopted by its individual Commissions, and

recommends that astronomers give effect to these resolutions in so far as they are able."

This was unanimously adopted.

[*Note:* the texts of resolutions adopted by Commissions are given in part 2.]

20. *The place and date of the twelfth General Assembly.* The Chairman called upon Professor O. Heckmann to address the Assembly. Professor Heckmann spoke as follows:

"Ladies and Gentlemen:

As early as 1955 the government of one of the smallest German countries, der Senat der Freien und Hansestadt Hamburg, the Senate of the Free and Hanseatic City of Hamburg, invited the International Astronomical Union to have one of its meetings in Hamburg. The invitation was repeated in 1958 and confirmed in 1961. The Foreign Office of the Federal Republic of Germany assured the Union that all participants qualified to attend the General Assembly under the Statutes will be welcomed as individuals to our country.

"Hamburg is a large city well suited to accommodate assemblies of considerable size. It has a university whose facilities will help to organize a scientific congress without too much difficulty. It has a state observatory which, with the whole city, suffers from a rainy climate. But late in August or early September the probability of meeting with friendly and even warm days is appreciably larger than zero. So it could happen, if the International Astronomical Union decides to gather in Hamburg in 1964, that you would find the city colourful and gay. But in this respect I cannot give any promise. What I can say, however, is, that all of my German colleagues will feel honoured and that the meeting would be prepared with great care if you choose Hamburg as the place of your next General Assembly. After the unique success of the Berkeley Meeting we can only promise that we would do our best.

"I therefore have the pleasure of formally inviting the International Astronomical Union to have its next meeting in Hamburg.

"Par conséquent j'ai le grand plaisir d'inviter officiellement l'Union Astronomique Internationale de tenir sa prochaine assemblée à Hambourg."

On the proposal of the President the General Assembly unanimously agreed to accept this gracious invitation to meet in the City of Hamburg in 1964, the precise dates being left for later decision by the Executive Committee. The President expressed the thanks of the Union to Professor Heckmann.

21. *Election of new Executive Committee.* The Chairman formally proposed that Academician V. A. Ambartsumian be elected the new President of the Union. This was approved by acclamation.

The Chairman reminded the Assembly of the names submitted for consideration at the first session, and formally proposed that Professor Y. Hagihara and Professor G. Haro be elected Vice-Presidents in place of Professor O. Heckmann and Professor B. V. Kukarkin who were due to retire. This was unanimously approved.

He pointed out that Professor L. Goldberg, Dr R. M. Petrie, Professor B. Sternberk and Dr R. H. Stoy, as Vice-Presidents, and Mr D. H. Sadler, as General Secretary, would continue to serve for a further term of three years.

The President then announced, on behalf of the Executive Committee, that it had been agreed to appoint an Assistant General Secretary, and that Dr J.-C. Pecker had very kindly consented

to take on the duties of this post. The General Assembly expressed its approval of this appointment.

The Chairman then invited Professor Ambartsumian and Professor Hagihara to take seats on the platform. [Professor Haro was not present at the General Assembly.]

22. *Representatives to the ICSU.* In accord with the By-laws, the General Assembly appointed the President and the General Secretary as the Union's representatives to the International Council of Scientific Unions.

23. *Addresses by the retiring and the newly-elected Presidents.* The retiring President, Professor J. H. Oort, addressed the meeting as follows:

"Before inviting the new President to take the chair, I should still like to say a few words to all of you.

"I have greatly appreciated the honour and confidence of electing me as President in Moscow. I have done my best to fulfil the duties of a President, but I am deeply conscious of the fact that I have given far too little time and energy to it.

"If I have not felt the presidency as a burden but as a pleasure, this is due to generous co-operation and the great good-will that I have met with in so many of you, and in particular in the Executive Committee. This has been so even in the few cases where in the Executive Committee we held different views and had to agree to disagree. I want to thank you for this.

"*Far above all* you as well as I are indebted to the General Secretary. Neither the Union as a whole, nor this meeting, nor all the symposia and the many valuable publications that have been connected with them could have had anything like the success they have had, but for the untiring devotion of Mr Sadler. Many have been in contact with him in writing. But none of you can have had an adequate idea with how many others he was *at the same time* keeping up a sometimes extensive and difficult correspondence. I am the only one besides Miss Splinter who has seen all the correspondence he has carried on and I have had some trouble in keeping my head above it. He has systematically taken all difficult tasks upon himself and has made mine as light as possible.

"In a normal Government Department such work as carried out by the Bureau of our Union would probably have required about the tenfold of the staff of two that *we* have, and I am sure it would not have worked so efficiently. If you think that beside all this Mr Sadler had his many responsible duties at the Nautical Almanac Office, you may well marvel about how he did it.

"And he has done still more. He has at several occasions given extensive thought to the deeper problem of how our Union should be reformed to keep it a workable and successful proposition.

"At the close of my three-year term as President I should like to propose a special vote of thanks to our wonderfully-efficient General Secretary and wish to include in this vote the Assistant Secretary Miss Splinter."

Professor Ambartsumian then took the chair and addressed the Assembly as follows:

"Professor Oort, Ladies and Gentlemen, Members of the International Astronomical Union, and guests:

"The International Astronomical Union is one of the oldest and most successful scientific organizations. Therefore the confidence shown by the Union to an astronomer, in electing him President, is a great honour to him. I am very grateful to you for the election and for this

confidence. It is very honourable; but at the same time it is a serious responsibility. Such outstanding astronomers as Spencer Jones, Lindblad, Struve, Danjon and Oort have acted as Presidents, and have set standards that are difficult to emulate; our Union is much indebted to them for its present authority and success.

"I should like particularly to call attention to the great capacity for work, ability and magnificent talent of Professor Jan Oort, which have characterized his presidency. The great success of our present General Assembly in Berkeley is the best evidence of this. I am glad that the Union, through its Executive Committee, may hope to have Professor Oort's further active assistance.

"Under the present difficult conditions, when relations between many countries have become very complicated, the activity of the IAU may serve as a good example of successful co-operation and good will. And we see how this co-operation brings forth fruitful results, being a powerful instrument for the progress of astronomy.

"We should further increase the regular exchange of scientific experience and new scientific ideas among astronomers of different countries, and further strengthen collaboration directed to the solution of great international problems and to the co-ordination of the activities of observatories in different countries.

"Proceeding on these lines we must pay particular attention to:

(*a*) The extension of IAU activity to the new problems and branches of modern astronomy.

(*b*) The strengthening of scientific exchanges between the countries of the West and the East. We (astronomers) have good achievements in this direction, and I hope that the different aspects of scientific co-operation, including the exchange of astronomers, will continue to grow in the future.

(*c*) The development of astronomy in the new States which have entered the path of independent development. Each of you understand the role of astronomy in the progress of mankind, and it is quite natural to require that young nations should have the privilege of intensive participation in the development of the science, which is the most international of all.

(*d*) The requirement that all countries, in which astronomical activity exists, should have the possibility of participating in the work of the Union. If we can create conditions that will allow the admission of China into the Union, this will be a great contribution to our Union becoming a real international organization.

"The expanding fields of research in astronomy all over the world, and the increasing number of adhering countries, lead to a considerable increase in the number of Members of our Union. I consider this to be inescapable, because it is connected with the development of the progress of astronomy. But such an increase implies the necessity for the consideration of possible changes in the structure and organization of the Union. Undoubtedly some aspects of the organization of the Union have become out of date. We must examine very carefully possible changes in the character of our General Assemblies. Considering this question the Executive Committee must take into account the opinions of both individual Members and of National Committees. My personal opinion is that the number of symposia should be increased and that their organization should be more perfect.

"We are all very glad to meet here in a country where the astronomical traditions are old and where the large modern astronomical reflectors appeared for the first time. We are most impressed by the hospitality of our hosts—astronomers of the U.S.A. With all my heart I wish them further successes in their work.

"I have had to fly over nearly a half of the Globe to come from Soviet Armenia to California. We started from Moscow nearly at the moment when Major Titov started his flight aboard his cosmic ship; the time interval was only about 5 minutes. And nearly at the moment when our plane landed in Los Angeles, Titov's space ship was landing in U.S.S.R.; and again the time interval was only some minutes. But there was one more difference: the space ship 'Vostok 2' made 16½ revolutions more than we did! Of course all of us are impressed with the increasing role of astronomical and cosmical investigations in developments for the benefit of the whole of mankind.

"Let the IAU do its utmost so that our science, to which we all are so devoted, can contribute to the progress of, and peace between, all nations.

"We shall return soon to our own observatories in order to put into operation the plans of scientific research adopted here. I do not doubt that all of you will come to the next General Assembly with new achievements and new knowledge about the Universe. But every new-solved problem, every revealed secret, gives rise in its turn to a great number of new problems; and this makes our science so attractive. With every new success new problems, which did not exist before, appear.

"I should like very much to know the new results and achievements which will be discussed in 99 years' time at the 44th General Assembly of the Union. By the way, if the number of Members continues to increase in the same proportion as at present, more than 1½ million Members and invited participants (without taking into account wives and other members of families) will participate in the 44th General Assembly. I am equally eager to know what *new problems* will be raised at that General Assembly. With these thoughts I should like to wish you new successes in your work, and to express my confidence that our Union will prosper further."

24. *Closing ceremonies.*

In the course of her comprehensive vote of thanks, Mrs A. G. Massevitch spoke the following words of thanks to the hosts:

"It is a unique privilege for me to have the responsibility of expressing the thanks of so many astronomers to so many persons, who have individually and collectively contributed so much to the success of this General Assembly and to our enjoyment of it. I think that we each have found some special provision or special service of which we each would like special mention to be made; I know that I have. But all I can do on your behalf is to thank all those I know have contributed to the General Assembly and to apologize both to you and to them for any accidental omissions that I may make.

"First of all I am sure that you would wish me to express our thanks to the Government of the United States of America, particularly to the President for his gracious message and to Mr Adlai Stevenson for having made a special journey to California to welcome us on behalf of the President; and for his address at the Inaugural Ceremony. Our host organization is, however, the National Academy of Sciences which has been ultimately responsible for the invitation to meet in this country and for all the arrangements that others have so brilliantly carried out; there are many of us who owe a particular gratitude to the officers and the staff of the Academy for their efficient administration of the travel grants from U.S. funds.

"We owe special thanks to the University of California and, in particular the Chancellor, Dr Strong, for providing this wonderful setting for our meetings, and for making available for our use these fine buildings—the well-equipped lecture rooms and auditoria, and the friendly Residence Halls.

"To the U.S. National Committee for Astronomy, particularly its chairman Dr Leo Goldberg, has fallen most of the general planning for this General Assembly. Its Financial Committee,

under its energetic chairman Dr D. H. Menzel, has been impressively successful in raising from public and private sources so much money to form the Special U.S. Fund to assist the travel expenses of Members to attend this Assembly; I do not know—and I think it is quite impossible to assess—the number of participants who, without grants from this U.S. Fund, would otherwise have been unable to attend. But the General Secretary tells me that, in all, grants were made to over 300 non-American astronomers. On your behalf I thank all those who contributed to this Fund and those, particularly Dr Goldberg and Dr Menzel, who inspired and administered it.

"Most of you have already expressed your gratitude to Dr and Mrs C. D. Shane and through them to the Local Organizing Committee. No words of mine can convey adequate thanks to them for their arduous efforts over many months; the success of those efforts is clear from the perfection of the organization, and our appreciation is unlimited. Their aim was to provide us with every facility; I hope that their knowledge that they have succeeded brilliantly and that we are all abundantly satisfied will be a source of great pleasure to them. But we must not forget all the many others who have given their services: I can mention by name only Dr J. G. Phillips, who organized such an impressive exhibition, and Dr H. F. Weaver who has contributed so much in ideas.

"There are so many whose names are unknown to us who have contrived to make our meetings successful and our stay in Berkeley so enjoyable: the staff of the Residence Halls have made us both welcome and comfortable, and have fed us well; the staff of the University have guided our footsteps and have provided us with all the facilities our meetings required, often at short notice; the many voluntary and other helpers at the registration offices, on the excursions, and in countless other ways have earned our gratitude; the performers at the delightful concerts and other entertainments. To all of them I say 'thank you' on your behalf.

"This General Assembly would, however, not have been possible without the careful planning and detailed preparation by the General Secretary Mr D. H. Sadler and the Assistant Secretary Miss Nel Splinter. They have worked extremely hard during the last fortnight, and I should like them to know that we all recognize and appreciate their efforts.

'It is my pleasure to ask you to express your thanks to all those I have named, and the many who I have by accident omitted."

On behalf of the ladies, Mrs Oort addressed the meeting as follows:

"It is a great pleasure for me to express the gratitude of all the ladies attending this meeting to the ladies of the receiving committee, who all made the stay in Berkeley for *everyone* such an immense joy and happiness.

"Everybody knows how much work there was behind all this and that the ladies-committee did a very fine job and worked day and night to show us the nicest places and the loveliest sites in this neighbourhood.

"We tried to express these feelings already yesterday when we had a gathering of all the ladies and presented something that may add colour to the astronomers' gardens in Berkeley and on Mount Hamilton, hoping that all of you who received us so hospitably will often be reminded of the friends you made all over the world!

"I also want to give our special thanks to the Berkeley ladies who showed us their homes and gave us such happy times at coffee parties, and who guided us around the Bay area, showing the lovely California coast and the impressive sequoias. The sunset supper at Mount Hamilton will always remain as a treasure in our memory, and when drinking a glass of wine we will always think of the party in the garden of Napa Valley.

"I could go on and on mentioning the enjoyable events during the past ten days.

"Being housewives we realize to the full extent the great effort which must have lain behind the remarkably smooth running of information desk and meal services and the innumerable small things that were necessary for the care of this huge family gathering.

"I wish I had words enough to convey our warm thanks to all those who contributed; especially because it was done with so much kindness. If there were time enough I would like to thank each of you personally.

"There cannot be any doubt however that it was Mrs. Shane who contributed most to the organization of this meeting. It was *she* who gave not only for a whole year all her *time*; but she put her *heart* into it and this must have been the reason that we all liked *so* well the splendid excursions offered to us with such care and taste! We have admired the skill and perfection in which it was all made ready for us.

"If I may say a few personal words now, I want to tell you a recollection of the first time I came in touch with you, Mrs Shane: One year, very long ago, we received a Christmas card from Lick Observatory which showed a photograph of a front-door standing ajar, with the wish that all your friends might enter the door of your house and that we were welcome in your home on the mountain!

"During this meeting I often wondered if the number of friends which entered your home this summer was not a bit *too* large for *one* front-door and I sincerely hope that after the end of the meeting you will be able to close all doors behind you and that it will be given to you and your husband to find time to enjoy your family and your personal life.

"Don't forget, wherever you come, that you will find *many* doors open all over the world of the homes and houses of astronomers' wives who remember the beauties you showed them in such a charming way of your beloved *California.*"

The Chairman then gave the General Secretary the opportunity to thank all those who had contributed so much to the organization of the General Assembly, and closed the meeting around noon.

EXECUTIVE COMMITTEE

AUGUST 1958 — AUGUST 1961

PRESIDENT

Prof. J. H. OORT, Director of the University Observatory, Leiden, the Netherlands.

VICE-PRESIDENTS

Prof. L. GOLDBERG, Harvard College Observatory, Cambridge 38, Massachusetts, U.S.A.

Prof. O. HECKMANN, Direktor der Hamburger Sternwarte, Hamburg-Bergedorf, Germany.

Prof. B. V. KUKARKIN, Sternberg Astronomical Institute, Moscow, U.S.S.R.

Dr R. M. PETRIE, Dominion Astrophysicist, Dominion Astrophysical Observatory, Victoria, B.C., Canada.

Prof. B. STERNBERK, Director, Astronomical Institute, Czechoslovak Academy of Sciences, Budečska 6, Prague 2 – Vinohrady, Czechoslovakia.

Dr R. H. STOY, H.M. Astronomer, Royal Observatory, Observatory, C.P., South Africa.

GENERAL SECRETARY

Mr D. H. SADLER, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

REPORT OF THE EXECUTIVE COMMITTEE 1957-1960

NARRATIVE REPORT

Introduction

The Report of the Executive Committee must necessarily contain, for the purpose of permanent record, many formal matters and lists. Moreover, much of the content of greatest interest to Members has already been published in the *Information Bulletins*, which are circulated to Adhering Organizations, to institutions on the Distribution List, and to all Members. However, the Executive Committee does give a great deal of thought to the broad policies of the Union, both scientifically and administratively, and it is hoped that at least an indication of these can be communicated to Members in this report. As far as practicable details of formal and routine matters are relegated to appendices.

At the request of the International Council of Scientific Unions (the ICSU), the end of the financial year of the Union was changed in 1958 from 31 October to 31 December. This report therefore relates to the period of 38 months from 1 November 1957 to 31 December 1960. In many ways this period, terminating eight months before the General Assembly, is anomalous: it relates to rather less than one year's tenure of office by the former Executive Committee and a little more than two years by the present Committee; moreover it is governed by the decisions at two meetings of the General Assembly, particularly in respect of finance. There seems no entirely satisfactory way of avoiding this difficulty, which is of course common to Presidents of Commissions in the preparation of their reports. The best solution in regard to finance is for the General Assembly to approve, if necessary, a supplementary budget for the current year.

However, many of the decisions of the former Executive Committee either related to the tenth General Assembly or were reported in Volume X of the *Transactions*; and these are not necessarily repeated in this Report.

The reports of Commissions 3, 5, 6 and 38 follow immediately after this Report, on page 68.

Meetings of the Executive Committee

The former Executive Committee met during the tenth General Assembly in Moscow in August 1958, under the presidency of Professor A. Danjon; research reveals that this meeting could properly be numbered the 18th since the foundation of the Union in 1919. The 19th meeting, the first of the present Executive Committee, was held at the Royal Greenwich Observatory, Herstmonceux, England on 7 to 9 September 1959, under the presidency of Professor J. H. Oort, when all members were present with the exception of R. M. Petrie (Vice-President); both A. Danjon (former President) and P. Th. Oosterhoff (former General Secretary) were unable to attend in their advisory capacity. The present Executive Committee also met, for the 20th meeting, at the Academy of Sciences in Prague, Czechoslovakia on 6 to 9 July 1960; all members and both advisers were present.

Full reports of these meetings have been placed in the Union's archives, and the principal decisions made have been included in the *Information Bulletins*; accordingly no report of the proceedings at these meetings is given here.

Between meetings the Executive Committee directs the affairs of the Union by correspondence; fourteen Circular Letters have been sent to the present Executive Committee, since the Moscow meeting.

Membership

Since the last General Assembly (Moscow, 1958) Taiwan (The Republic of China) has adhered to the Union, and China (The People's Republic of China) has withdrawn from the Union. There are thus 38 countries at present adhering to the Union; a list of these countries, and of the adhering organizations, together with the approximate number of individual Members in each country, is given in Appendix I.

Owing to delays in receiving notices of deaths and of changes of address, it is not possible to state the precise number of individual Members or to allocate them uniquely to particular countries. The figures in the following table are therefore approximate:

Number of Members in November 1957	901
Elected at the tenth General Assembly (Moscow)	+248
Co-opted (not nationals of adhering countries)	+ 2
Resigned	− 25
Notified, since November 1957, as deceased	− 45
Number of Members as at 31 December 1960	1081

A list of those Members whose deaths have been notified since November 1957 is given in Appendix II. Among so many distinguished astronomers, who have each in their way contributed greatly to Astronomy, it is invidious to select a few for special mention. But it is impossible not to pay separate tribute to the memory of those who have also contributed greatly to the administration of the Union:

to F. J. M. Stratton, General Secretary from 1925 to 1938, the only person who has attended every General Assembly of the Union, the great advocate of international co-operation and the trusted friend of astronomers everywhere;

to Harold Spencer Jones, President during the difficult years from 1944 to 1948, a veritable statesman of Astronomy, a wise counsellor and a steadfast friend of the Union.

Both believed passionately in international co-operation and held, with distinction, the most important post in the administration of international science, that of Secretary General of the International Council of Scientific Unions; the Union is grateful to them for many acts of kindness.

Commissions and their Membership

A full report of the decisions of the Executive Committee on this important aspect of the work of the Union is given in *Information Bulletin* No. 4 of August 1960. The proposals of the Executive Committee will be formally submitted to the General Assembly for approval, and the consequential changes will be introduced into the revised Statutes and By-laws.

One new Commission (No. 44 on 'Astronomical Observations from outside the Terrestrial Atmosphere') was formed, with Professor P. Swings as its first President; one new Sub-Commission (No. 29*c* on 'Stellar Classification') was also formed, with Dr W. P. Bidelman as President. Details of membership are given in the *Information Bulletins*, and in the list of Commissions in Part V of Volume X of the *Transactions*; reports from these Commissions will be included in the *Draft Reports*.

The Executive Committee also appointed Dr L. H. Aller as President of Commission 29 (Stellar Spectra) and Dr P. M. Millman as President of Sub-Commission 22*b* (Standardisation of Terminology and Notations concerning Meteors).

As announced in *Information Bulletin* No. 2, the Executive Committee set up a temporary working group of Sub-Commission 9*b* to consider the question of Site Testing. It is hoped

that the report of this working group will be generally available before the General Assembly. The future organization of the working group will be the subject of discussion in Berkeley.

In view of the rules regarding membership of the Union and the policy regarding membership of Commissions, in force at the General Assembly in 1958, the Executive Committee decided to restrict co-options to Commissions between General Assemblies to cases of oversight or error, to exceptional cases for which full information was not available to the Nominating Committee, and to astronomers in countries not adhering to the Union. In accordance with this policy, there have been few co-options; a full list is given in Appendix III.

Statutes and By-laws

In the course of the years, during which many amendments have been made to the original Statutes and By-laws, many minor inconsistencies and ambiguities have been introduced particularly in respect to the precise correspondence and meaning of the French and English texts. The Executive Committee agreed, at its meeting in September 1959, to a revision designed to remove such anomalies. Later it became evident that more substantial changes would be required to implement the proposed changes in the structure and membership of Commissions. A comprehensive revision of the Statutes and By-laws has therefore been undertaken and will formally be submitted, in accord with the provisions of the existing Statutes, to the General Assembly for adoption. The opportunity has been taken to clarify the constitutional position of the Executive Committee and to simplify the procedure for the co-option to membership of nationals of countries that do not adhere to the Union.

Organization of General Assemblies

The rapidly extending fields of interest of Astronomy, the increase of membership of the Union, and the much larger increase in the numbers of those wishing to participate in the meetings of the Union, will undoubtedly lead to increased organizational difficulties at the General Assemblies. The Executive Committee has given much consideration to the problems thus arising, without being able to propose any solution that is completely satisfactory; probably no such solution exists, which preserves the character of the earlier meetings of the General Assembly at which most Members knew personally most other Members. Certain changes have been introduced, notably the clear distinction being made between the Symposia and the General Assembly itself, which it is hoped will help to counteract the increased numbers and complexity of the meetings during the General Assembly.

One positive step (see *Information Bulletin* Nos 4 and 5) has been the decision to set up a Resolutions Committee to consider resolutions submitted by Commissions, with a view to recommending to the General Assembly which resolutions should be formally submitted for consideration. The Executive Committee requests the co-operation of Presidents of Commissions and others in restricting resolutions, formally submitted to the General Assembly, to those for which the full weight and authority of the Union will serve some useful purpose.

Symposia

During the period under review the following symposia were held:

No.	Subject	Place	Date
9	Radio Astronomy	Paris	August, 1958
10	The Hertzsprung-Russell Diagram	Moscow	August, 1958
11	The Rotation of the Earth and Atomic Time Standards	Moscow	August, 1958
12	Aerodynamical Phenomena in Stellar Atmospheres	Varenna	August, 1960
13	The Future of the International Latitude Service	Helsinki	July, 1960
14	The Moon	Leningrad	December, 1960

No. 9 was held shortly before, and Nos. 10 and 11 during, the tenth General Assembly. Through a variety of circumstances, no symposia were organized during 1959.

No. 9 was held in co-operation with the International Union for Scientific Radio (URSI); No. 12 was held in co-operation with the International Union of Theoretical and Applied Mechanics (IUTAM); No. 13 was held in co-operation with the International Association of Geodesy, during the General Assembly of the International Union of Geodesy and Geophysics (IUGG).

Full details of the arrangements for these symposia, with the names of the organizing committees, were given in the *Circulars* and the *Information Bulletins* which succeeded them. Particulars concerning the publication of the proceedings are given under the heading 'Publications'.

Representation and Representatives

The International Council of Scientific Unions (the ICSU). The President (J. H. Oort) and General Secretary (D. H. Sadler) represented the Union at the eighth General Assembly and tenth Meeting of the Executive Board of the ICSU in Washington, D.C., U.S.A. in October 1958, at the eleventh Meeting of the Executive Board in The Hague, The Netherlands in October 1959, and at the twelfth Meeting of the Executive Board in Lisbon, Portugal in October 1960.

The Union was represented: at the third Congress of the World Meteorological Organization at Geneva in April 1959 by P. B. Bouvier; at the International Symposium on Magneto-Fluid Dynamics in Washington, D.C. in January 1960 by L. Spitzer; at the Tercentenary Celebrations of the Royal Society of London in July 1960 by J. H. Oort; at the twelfth General Assembly of the International Union of Geodesy and Geophysics in Helsinki in July 1960 by A. Danjon; at the General Assembly of the International Union of Pure and Applied Physics in Ottawa, in September 1960 by G. Herzberg, and at the thirteenth General Assembly of the International Scientific Radio Union in London in September 1960 by J. H. Oort.

The Union was represented, jointly with URSI and COSPAR, at the Administrative Radio Conference of the International Telecommunication Union in Geneva from August to December 1959.

The Union is represented on:

(*a*) Federation of Astronomical and Geophysical Services (FAGS):
by A. Danjon and M. Waldmeier. Meetings were held in May 1958, May 1959, and in May 1960.

(*b*) Ad Hoc Committee on Contamination by Extra-Terrestrial Exploration (CETEX):
by J. Rösch. Meetings were held in May 1958 (The Hague) and in March 1959 (The Hague).

(*c*) The International World Days Service (IWDS);
by J. F. Denisse. This service has taken over, as from 1 January 1958, the work on World Days from the Special Committee on the International Geophysical Year.

A single Advisory Committee for the Steering Committee of the International World Days Service and for the Central Committee on Ursigrams of U.R.S.I. has been set up. The Union has appointed the following astronomers to serve on this committee in respect of the scientific fields indicated:

Sunspots: M. WALDMEIER

Flares: M. A. ELLISON

Corona: W. O. ROBERTS

Other solar optical phenomena: E. R. MUSTEL

Solar radio phenomena on metre wave-lengths: A. D. FOKKER

Solar radio phenomena on short waves: A. E. COVINGTON

Localization of solar radio sources: P. SIMON

Spectra: J. P. WILD

Polarization: T. HATANAKA.

(*d*) The Board of the International Foundation of the Pic-du-Midi;
by A. Danjon.

(*e*) Comité Consultatif pour la Définition de la Seconde, du Bureau International des Poids et Mesures:
by W. Markowitz and N. Stoyko.

(*f*) Comité Consultatif pour la Définition de la Mètre, du Bureau International des Poids et Mesures: by G. Herzberg.

Inter-Union Committees

The Union participates in the work of a number of Special Committees, Committees, or Inter-Union Committees, set up under the auspices of the ICSU, in co-operation with other international scientific unions. Where relevant to the Union, details of the constitution and membership of these committees have been given in the *Information Bulletins*. The following list is concerned only with the current representation from the Union.

(*a*) Committee on Space Research (COSPAR), established by the ICSU:
by H. C. van de Hulst, who was elected President of the Committee at its first meeting. Meetings were held in London in November 1958, in the Hague in March 1959, in Nice in January 1960.

(*b*) Comité International de Géophysique (CIG);

by M. G. J. Minnaert (as a member of the Bureau), and by M. A. Ellison (as representing the scientific discipline of 'Solar Activity').
This Committee is in continuation of the Special Committee for the International Geophysical Year, on which committee the Union was represented by A. Danjon and Y. Öhman.

(*c*) Inter-Union Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF):
by J. F. Denisse (chairman), J. H. Oort, A. Unsöld and V. V. Vitkevitch.

(*d*) Inter-Union Committee 'Triple Commission for Spectroscopy':
by G. Herzberg and Mrs Ch. Moore-Sitterly as members, and J. G. Phillips and J. Racah as corresponding members.

(*e*) Inter-Union Committee on the Ionosphere:
the membership of this Committee has not yet been finally decided.

(*f*) Inter-Union Commission on Solar and Terrestrial Relationships:
the IAU has nominated the following representatives: C. W. Allen, J. F. Denisse, R. Giovanelli and E. N. Parker.

Administrative Commissions

In order to separate the mainly administrative reports, to be published in Volume B of the *Transactions*, from the purely scientific reports, to be published in Volume A, the *Draft Reports* of Commissions 3, 5, 6 and 38 are appended to the Report of the Executive Com-

mittee. But the responsibility for these *Draft Reports* continues to be solely that of the Presidents of the respective Commissions.

PUBLICATIONS

As a recognition of the important part that publication takes in the affairs of the Union, a separate section of the Report is being devoted to this subject. A detailed list of publications issued during the period under review is given in Appendix IV.

General Policy

The general policy of the Executive Committee is to achieve rapid publication, with an acceptable but not unnecessarily high standard of presentation, in a form which provides wide dissemination among individual astronomers at a reasonable price. The prices of many commercial scientific publications are often so high as to inhibit purchase by individual research workers for their own use, even at the reduced prices often obtainable by Members of the Union.

For the principal publication, the *Transactions of the International Astronomical Union*, the Union must pay the full cost of production; the free distribution to all Members and to all institutions on the Distribution List, as laid down in the By-laws, reduces its potential sale to a point at which commercial publication is impracticable.

On the other hand the proceedings of some of the symposia, which are only distributed free to actual participants and to institutions on the Distribution List, are often of such general interest as to become commercial propositions to be published at no cost to the Union. This does not apply to all symposia, some of the smaller of which are unsuitable for publication in separate, expensively-bound volumes. It was with considerable reluctance that the Executive Committee discontinued, partly for this reason, the series of uniformly-bound symposium volumes (for example, nos. 1, 3 to 7) published for the Union by the Cambridge University Press; for these volumes the Union paid the full cost of production, and eventually received the net returns from sales. For the smaller, and usually more specialised, symposia the preferred policy is now to enter into an agreement with a suitable astronomical journal for publication of the proceedings in the journal; at the cost of some variation in format, style and presentation, there are gained rapid publication, and wide dissemination, at no or little extra cost to themselves, among those most particularly interested in the subject. Reprints from the journal provide separate numbered volumes in the series of IAU Symposium Volumes. The total cost to the Union may in some cases actually be higher than if published separately by a commercial publisher or by the Union itself; but the increased availability is ample justification for the increased cost. It is hoped that such arrangements may also be advantageous to the journals themselves.

For the larger symposia inclusion in current numbers of scientific journals is not possible, and for nos. 9 and 14 satisfactory offers for commercial publication, at no cost to the Union, have been accepted. However, the Union enters into an agreement to purchase some 350-400 copies for free distribution, and, in return, retains the right of consultation regarding the published price. In every case an agreement is also made by which Members may purchase copies at a reduced price.

Transactions and Draft Reports

Volume X of the *Transactions* was published in May 1960, several months later than scheduled because of the printing strike in Great Britain. It is the last volume to be printed and published by the Cambridge University Press under a contract dated in 1928; the Union owes much to the extremely high standard set by the Press in all aspects of printing, which has made the

Transactions one of the finest series of publications from all International Unions. A new printing contract has now been concluded with the firm of Willmer Brothers & Haram Ltd. of Birkenhead in England; it may confidently be expected that publication will be rather more rapid, without any significant diminution in standard. In this connection it must be emphasized that it is *impossible* to achieve the uniformity and consistency that might reasonably be expected in a publication by a single author, when some 60 Presidents of Commissions and Sub-Commissions present independent reports in widely different styles.

The increasing size of the volumes has led the Executive Committee to decide to issue Volume XI in two separate volumes, as follows:

A. Reports on the State of Astronomy
B. Proceedings of the General Assembly.

In broad outline, volume A will contain the scientific portions of the *Draft Reports*, while volume B will contain the purely administrative portions, including the Reports of the Executive Committee and of the administrative Commissions 3, 5, 6 and 38.

A separate agreement for the publication and sale of these volumes has been entered into with Academic Press (Inc.) London Ltd. Members will continue to receive both volumes free.

No satisfactory solution has yet been devised to avoid the expense of duplicate distribution to all members of the *Draft Reports* and the printed *Transactions*. It may be that in future it will be possible to print the Reports in final form, as volume A of the *Transactions*, for distribution before the General Assembly; but this would involve a rigid time-table for the receipt of typescripts, and for the reading of proofs, and inevitably many Reports would have to be omitted.

Symposia

A full list of the volumes already published is given in Appendix IV. The arrangements for publication of the proceedings of the symposia held in 1960 are as follows:

No.	Subject	Arrangements for publication
12	Aerodynamical Phenomena in Stellar Atmospheres	To be included in a supplement to *Il Nuovo Cimento*
13	The Future of the International Latitude Service	To be included in *Bulletin Géodésique*
14	The Moon	To be published commercially by Academic Press (Inc.) London Ltd.

As with Symposium Volume No. 11 (The Rotation of the Earth and Atomic Time Standards), the Union is glad to extend its approval of the proposal of the U.S.S.R. Academy of Sciences to publish a separate Russian-language edition of Symposium Volume No. 14.

Other publications

Apart from the *Transactions* and the Symposium Volumes, there are many publications which are subsidized wholly or partly by the Union, generally by resolution of the General Assembly. The Executive Committee has tried to standardize procedure for such publications, without in any way limiting the freedom (laid down in the By-laws) of Commissions to issue their publications independently. The Executive Committee is concerned to ensure three simple requirements:

(*a*) that acknowledgment is made to the Union and, if applicable, to UNESCO for the subsidy towards the cost of publication;

(*b*) that there is adequate publicity for the publication, and that it is readily available for purchase;

(*c*) that, where agreed by the Executive Committee, copies are made available for distribution to the institutes on the Distribution List.

The Executive Committee has been concerned with the many publications, published by or for the Union, or sponsored by the Union, which are now almost unobtainable, because there is no named publisher and no readily available source from which they can be obtained. To remedy this a *Provisional List of IAU Publications* was prepared and circulated with *Information Bulletin No.* 2; it was hoped that this would result in the receipt of information, from those directly concerned with the publications, which would enable the list to be completed in respect of publications mentioned by name only or omitted entirely. The response has so far been disappointing; but it is not too late, and all Members are asked to communicate information that will add to the completeness of the list.

THE FINANCIAL SITUATION

Introduction

It is essential to consider a three-year period as a financial unit, since expenditure in any year varies according as to whether a General Assembly is held or not. Moreover, the Union has accounts in four currencies: U.S. dollars; British pounds: French francs (now New Francs); and Dutch guilders. Payments are made to and from each of these accounts according to convenience, and it is often difficult to ascertain from the individual accounts the total cost of any particular activity. The Executive Committee, acting on the advice of the Advisory Finance Committee, has accordingly decided to present to Members a single, much simplified statement, covering the whole three-year period in one single currency. The currency chosen is U.S. dollars, and amounts in other currencies have been converted to U.S. dollars at the following adopted conversion rates, treated as exact:

£1 sterling = $2·80; $1 = 3·80 Dutch guilders

Balance at 1 November 1957,	1$ = 350 French francs
1 November 1957—31 December 1958,	1$ = 420 French francs
1 January 1959—31 December 1960,	1$ = 4.90 French New Francs

The devaluation of the French franc has naturally resulted in a loss expressed in terms of U.S. dollars; moreover the simplification of using a constant conversion factor for the whole of 1958 has slightly falsified some entries in the accounts. The effect of the change of rates cannot be calculated precisely from the balances of the French accounts as different rates were used at different times; the net loss thus arising is accounted for in an equalisation account. The conversion of each receipt or payment at the conversion rate then applicable would neither be practicable nor realistic.

The relationship of the U.S. dollars to the gold franc, in which the unit of subscription to the Union is expressed, is:

1 gold franc = 0·29032 25 gramme of fine gold = 0·3266 U.S. dollar
1 U.S. dollar = 3·06185 gold francs

However, for simplicity all amounts have been rounded off to the nearest dollar; *exact* agreement of the amounts with those in the individual accounts is thus not possible, apart from discrepancies introduced by variations in the rates of exchange. The twelve individual accounts have all been audited, and certified as correct, by the Union's professional accountants; these accounts, omitted from this Report for the first time, will be available for examination by the Finance Committee at the eleventh General Assembly in Berkeley in August 1961.

The Executive Committee, acting on the advice of the Advisory Finance Committee, and on the decisions of the tenth General Assembly, prepared, for its own guidance, a budget for the three years from 1 January 1959 to 31 December 1961, taking into account the heavy expenditure likely to be associated with a General Assembly on the west coast of America. The present three-year account is thus not a complete entity, and the financial result is not necessarily representative. Accordingly, no attempt has been made to do other than to present a practical statement of actual income and expenditure in the period 1 November 1957 to 31 December 1960. No account is taken of subscriptions due but not yet paid, nor of the balances of payments made after 31 December 1960 in respect of activities in 1960 or earlier years.

The fact that the period is slightly longer than three years has little effect on the accounts since the only substantial item directly dependent on the length of time is the salary of the Assistant Secretary.

The Union is very fortunate in having a reserve of about $100 000, somewhat less than its total income for a three-year period; a great tribute is due to the wise counsel and economical administration in the past. This reserve provides the Union with a considerable measure of flexibility in the planning of meetings and symposia, for which precise estimates of cost cannot be made in advance. However, the existence of the reserve in no way diminishes the need for the efficient and economical use of the Union's income; in this connection it may be remarked that less than 15% of the Union's income is used for administration, including the cost of meetings of the Executive Committee.

Statement of balances

On 1 November 1957 the total of balances in the savings accounts and in the four bank accounts was 103 245·88 U.S. dollars, of which 39 993·47 U.S. dollars was in savings accounts. On 31 December 1960, the corresponding figures were 112 349·97 and 55 378·65, increases of 9104·09 and 15 385·18 respectively. During this period a further sum of $10 500 was transferred to the savings accounts; the remainder of the increased balance represents interest. In these figures no account is taken of the small balances (of cash and stamps) in the Administrative Office, or in the hands of those to whom annual grants are made.

Statement of Income and Expenditure, 1957–60

The statement on pages 58 and 59 presents a much simplified picture of the income and expenditure of the Union from 1 November 1957 to 31 December 1960. For clarity, all entries are expressed in U.S. dollars under only a few main headings, generally for all three years combined. For the reasons explained above, this statement does not constitute an *exact* account; the twelve separate accounts, from which this statement is prepared, have been audited professionally and certified as correct.

The following explanatory notes provide more detailed information in relation to each item of the accounts, where this is applicable.

A. Income

1. *Balance.* The balance on 1 November 1957 is stated on page 44 of Volume X of the *Transactions*, in the report of the Executive Committee presented to the tenth General Assembly of the Union.

2. *Subscriptions.* The unit of subscription is fixed by the General Assembly and was 500 gold francs, equivalent to 163·30 U.S. dollars, during each of the three years 1958, 1959 and 1960. Account is taken only of the actual payments received; in some cases there is a small difference

STATEMENT OF INCOME AND EXPENDITURE, 1957–1960

Income, 1957–1960

				U.S. dollars	U.S. dollars
1.	Balance, 1 November 1957				103 246
	(*a*) in four bank accounts			63 252·41	
	(*b*) in savings accounts:			39 993·47	
2.	Subscriptions from 38 adhering countries				62 322
	Year	*No. of units due*	*received*		
	1957	—		equivalent, after conversion, to the	
	1958	122	142	following actual receipts	23 255
	1959	122	138		22 566
	1960	115	101		16 501
3.	Sales of Publications				10 102
	(*a*) Transactions and Symposia (including reprints)			8 017	
	(*b*) Astronomical News Letters			2 085	
4.	Interest on Savings Accounts:			4 885·18	4 885
5.	Subventions from UNESCO, through ICSU				43 000

year	meetings	symposia	publications	Com. 38	grants allocated for:
1958	5 500	5 000	6 000		16 500
1959		4 000	8 500		12 500
1960		3 000	8 000	3 000	14 000

223 555

Note added October 1961

As requested by the Finance Committee (see page 37) details are given of two self-balancing items of income and expenditure that were omitted from the statements above:

(*a*) Subvention from the ICSU for the expenses of the meetings in Moscow of the two Joint Commissions (of ICSU)
(i) Joint Commission on Spectroscopy
(ii) Joint Commission on Solar and Terrestrial Relationships } $2 467

(*b*) Contribution from URSI towards the travel expenses and publication costs for IAU Symposium No. 9 (URSI Symposium No. 1) $2 000

STATEMENT OF INCOME AND EXPENDITURE, 1957 – 1960

Expenditure, 1957–1960

	U.S. dollars	U.S. dollars
1. Administrative Office (Bureau de l'Union)		11 638
2. Projects approved by the General Assembly (details are given in the notes)		40 639
3. General Assembly, Moscow, August 1958		10 181
(*a*) travel grants for Executive Committee and Presidents of Commissions	4 246	
(*b*) travel grants for Young Astronomers	5 025	
(*c*) incidental expenses	910	
4. *Draft Reports and Transactions* of the IAU		16 631
(*a*) *Draft Reports* 1958, and *Trans. IAU* 10	14 376	
(*b*) balance for *Trans. IAU* 9	2 255	
5. Meetings of Executive Committee		4 216
(*a*) Herstmonceux, September 1959	1 391	
(*b*) Prague, July 1960	2 825	
6. Symposia—travel and organizational expenses		6 130
No. 9 Radio Astronomy, Paris, August 1958	1 412	
No. 10 H. R. Diagram, Moscow, August 1958	1 410	
No. 11 Rotation of the Earth, Moscow, August 1958	530	
No. 12 Stellar Atmospheres, Varenna, August 1960	1 470	
No. 13 Variation of Latitude, Helsinki, July 1960	100	
No. 14 The Moon, Leningrad, December 1960	1 208	
7. Publication of Proceedings of Symposia		17 209
No. 4 reprints	689	
No. 5 72 pages, bound, full cost paid by IAU	1 546	
No. 6 545 pages, bound, full cost paid by IAU	8 919	
No. 7 93 pages, bound, full cost paid by IAU	1 125	
No. 8 204 pages, bound, reprinted from *Rev. Mod. Phys.*	—	
No. 9 612 pages, bound, published by Stanford Univ. Press	3 060	
No. 10 129 pages, bound, reprinted from *Ann. Astrophys.*	1 020	
No. 11 43 pages, unbound, reprinted from *A.J.*	850	
8. Subscriptions to the ICSU		1 273
9. Representation		824
10. Expenditure, authorized by the Executive Committee (details are given in the notes)		1 455
11. Equalisation account		1 009
12. Balance, 31 December 1960		112 350
(*a*) in four bank accounts	56 971·32	
(*b*) in savings accounts	55 378·65	
		223 555

Note added October 1961

(*a*) Payments made for travel expenses for the meetings in Moscow of the two Joint Commissions (of ICSU) on Spectroscopy and on Solar and Terrestrial Relationships .. $2 467

(*b*) Payments (excluded from items 6 and 7 above) made on behalf of URSI in connection with IAU Symposium No. 9 (URSI Symposium No. 1): .. $2 000

in exchange rates. On 31 December 1960, six countries were in arrear with their subscriptions to the extent of a total of 13 units of subscription.

3. *Sales of Publications.* Owing to the complexity of the accounts from the printers and publishers, the professional accountants have not always made a clear distinction between charges for: (*a*) printing, binding and paper; (*b*) distribution; (*c*) provision of reprints, for which the Union receives repayment; (*d*) sales. It has been judged to be impracticable, and unnecessary, to recapture the precise figures under these headings; accordingly, both the income from sales and the expenditure on publications are increased by the same small (unknown) sum in respect of reprints.

The sales of publications show an appreciable increase over the previous period of three years, due mainly to the sale of the Symposium volumes. The future trend of this item of income will depend on the policy adopted for the publication and sale of the Transactions and the Symposium volumes.

4. *Interest.* The interest on the money in the savings accounts has been allowed to accumulate and has been added to the balances of those accounts.

5. *Subvention from UNESCO.* This is administered through the International Council of Scientific Unions, which exercises financial control; full accounts (not given here) of the expenditure of the subvention are returned each year to the ICSU and to UNESCO. Although the subvention is made up of grants allocated for specific purposes, it is possible, without formality, to transfer such grants from one purpose to another, provided it is within the permitted UNESCO category. In 1960, for the first time, a specified grant was allocated to Commission 38 for the exchange of astronomers; and this has been continued for 1961.

Expenditure

1. *Administrative Office.* Prior to the tenth General Assembly the 'Bureau de l'Union' accounted financially for the expenditure, not only of the amounts voted for administration by the General Assembly but also for those approved by the Executive Committee for expenditure from the UNESCO subvention. At the tenth General Assembly, the annual sum allocated to the Administrative Office was reduced to the actual sum required for administration. All specific items of expenditure, such as for the publication of the proceedings of symposia, have been accounted for under the appropriate headings, even though for the year 1958 the money was allocated to the Bureau.

The expenses of the Administrative Office include the printing and distribution of the Information Bulletins, travelling expenses of the General and Assistant Secretaries (except for meetings of the Executive Committee), and miscellaneous small payments for services for some Commissions, as well as salaries, social security and pension payments, and all normal office expenses.

For part of the period, the Office was in Leiden but was moved to Herstmonceux in January, 1959. The Union is grateful to the authorities of the University Observatory, Leiden, and of the Royal Greenwich Observatory, Herstmonceux, for free accommodation and many facilities.

2. *Projects approved by the General Assembly.* The expenditure of the Union's proper income, excluding the UNESCO subvention, is governed by the decisions of the General Assembly, as advised by the Finance Committee. Full details of the allocations approved by the General Assembly are given in the resolutions printed in the *Transactions* (*Trans. IAU* **9,** 66, 1957 for the year 1958 and **10,** 71, 1960 for the years 1959 and 1960).

The details of the actual expenditure on these projects follow; some allocations have not

yet been taken up, a few have been increased by the Executive Committee (for example the allocation to the Telegram Bureau), and some projects have lapsed.

Payments made, in U.S. dollars, 1 November 1957 to 31 December 1960

	U.S. dollars
Commission 5 (*Astronomical News Letters*)	5 460
Commission 5 (*Bibliographie mensuelle*)	163
Commission 6 (Telegram Bureau)	1 588
Commission 10 (*Cartes héliographiques de la Photosphère*)	981
Commission 10 (*Cartes synoptiques de la Chromosphère solaire*)	2 646
Commission 20 (Minor Planet Center, at Cincinnati)	750
Commission 23 (*Carte du Ciel*)	8 247
Commission 24 (*Catalogue of proper motions*)	1 000
Commission 26 (*Catalogue of double stars, J*)	2 000
Commission 27 (English version of remarks to the second edition of GCVS)	615
Commission 29 (*Vatican Atlas of Molecular Spectra*)	382
Commission 38 (Exchange of astronomers)	16 157
Commission 42 (Eclipsing binary Centre, Cracow)	650

The following subventions, approved by the General Assembly, are still outstanding, and must be regarded as commitments for future years. If not paid by the next General Assembly it would be desirable to include them in the budget for the following period.

	U.S. dollars
Commission 12 (Solar spectrum tables)	3 960
Commission 20 (Comet catalogue)	1 400

The annual grant of $750 for 1960 has not yet been paid to the Minor Planet Centre at Cincinnati; no grant was paid for 1957–8 as it was not needed, so that only one payment has been made in the three years. Further, there are balances in favour of the *Carte du Ciel* of about $8850 and of Commission 38 of about $1525; in both cases, all payments are made by the Administrative Office on instructions from the Presidents of the respective Commissions.

3. *General Assembly.* The three main items of expenditure in connection with a General Assembly are those listed separately. Generally the Executive Committee, advised as necessary by the Advisory Finance Committee, agrees beforehand on fixed total sums for the first two items; and those are apportioned among those requiring travel grants in the best way possible. Allocations have usually to be fixed at considerably less than the actual fares. In the past the sum allocated for travel grants for young Astronomers has been supplemented by a grant from the funds at the disposal of Commission 38; this was also done in 1958, and the figure under heading 2 for Commission 38 includes 1000 dollars for this purpose.

Through the generosity of the host countries, the incidental expenses, associated with the organization of the meetings, are usually small and bear little relation to the total cost of the organization. The items under (*c*) mainly consist of the travelling expenses of the General Secretary to Moscow in April 1958, and of the Assistant General Secretary and Assistant Secretary to the General Assembly.

4. *Draft Reports and the Transactions.* The printing and distribution of the *Draft Reports* and the *Transactions* of the IAU forms the largest single item of expenditure. The cost is enhanced by the practice of circulating half the complete volume, containing the *Draft Reports*, twice to all Members; and there is no simple answer to this problem. In the three years covered by the accounts, most of the cost of Volume X has been paid for, including both the *Draft Reports*

and the final volume; but the account for the distribution of Volume X has not been presented, while the similar account for Volume IX (together with some other items including reprints) has been paid. As explained under 'Sales of publications' the total cost has been slightly enhanced by the inclusion of the cost of some reprints, for which payment has been, or will be, recovered.

5. *Meetings of the Executive Committee.* The amounts given include all incidental expenses as well as the cost of travel and subsistence; that they are so small is a measure of the success attained by members of the Executive Committee in combining the meetings with other business. Much also is owed to the generosity of the host countries and of the organizations at whose invitations the meetings were held. The expenses of the meeting in Moscow, in August 1958, are included in those of the General Assembly.

6. *Symposia.* The main cost of the symposia lies in the contribution made by the Union towards the travelling expenses of the participants; this is supplemented sometimes by a grant towards organizational and secretarial expenses, but, as with other activities, considerable expense is always borne by the host organization. In the case of a joint symposium with another Union, the expenses are shared between the Unions. Generally, a grant of a fixed sum is made to the organizing committee by the Executive Committee on the advice of the Advisory Finance Committee; it is not always possible to allocate the whole sum, as individual grants are often returned when it is too late for them to be re-allocated. A greater measure of flexibility will be allowed in future.

Some payments in respect of Symposium No. 14 are still to be made in 1961.

No symposia were organized in the calendar year 1959, and two in 1958 were held during the General Assembly; this is unusual and supplies another factor in the rather unrepresentative picture provided by the statement of income and expenditure.

7. *Publication of the proceedings of symposia.* Reference is made elsewhere in this report to the change in policy regarding the publication of the proceedings of symposia; separate arrangements are now made for each symposium, depending on the public appeal of the subject, the length of the proceedings, and its suitability for publication in a particular scientific journal. The details of each arrangement vary, and it is not practicable to give them in full. Generally, the Union will continue to receive the proceeds of the sale of Symposium Volumes 1, 3 to 7, published for the Union by the Cambridge University Press; it may receive royalties on future sales of Volume 9, for which the payment represents the cost of purchasing and distributing copies to participants in the symposium and institutions on the Distribution List; it will receive no income from Volumes Nos. 8, 10, and 11, for which special arrangements were made with the scientific journals in which they were published. Where applicable, *i.e.* for Volumes 6 and 9, editorial costs are included in the cost of publications.

No payments are outstanding on any of the symposia listed. Some small residual payments in respect of reprints from Symposium No 4 are, however, included. The cost of the publication of the proceedings of symposia Nos. 12, 13 and 14 will enter in 1961, and that for Nos. 15, 16 and 17 will probably enter in 1962.

8. *Subscription to the ICSU.* The Union makes a contribution towards the administrative expenses of the ICSU to the extent of 2% of the income from subscriptions for the previous year; the figure therefore relates to the income for the years 1957, 1958 and 1959.

9. *Representation.* The general policy in respect of formal representation of the Union at General Assemblies of other Unions, and similar meetings, is for the Executive Committee to appoint representatives who will be attending in other capacities, and so may represent the Union without expense to the Union. However, it is sometimes necessary to reimburse the

travelling and other expenses of representatives to technical meetings, as well as of representatives on Inter-Union Committees. In 1960 the Union shared, with URSI and COSPAR, the expense of maintaining a representative at the Ordinary Administrative Radio Conference of the International Telecommunication Union in Geneva, the Union's share of the expenses was 824 U.S. dollars. Similar expenses in future years will be borne by the Inter-Union Committee on Frequency Allocations for Radio Astronomy and Space Science, to the expenses of which the Union will contribute.

There were no other payments under this heading, but it will nevertheless be desirable to provide a small sum in future budgets for this purpose.

10. *Expenditure authorised by the Executive Committee.* At the General Assembly in 1958 no allocation was made, nor could it properly be made, in respect of the UNESCO subvention; but an Advisory Finance Committee (*Trans. IAU* **10,** 27, 1960) was appointed to advise the General Secretary and the Executive Committee on how best to use these funds. This expenditure, not governed by the decisions of the General Assembly, is made under headings 3-10. Headings 3-9 represent definite items of expenditure foreseen by the Finance Committee but not specifically provided for in the budget, which was based only on the Union's proper income. Some of the items, such as those under headings 5, 8 and 9, do not wholly come within the categories to which the UNESCO subvention can be allocated, but, on the other hand, the UNESCO subvention can be, and is, properly used in respect of many of the publications under heading 2. The division of the UNESCO subvention between the headings, and between individual items under each heading, is quite arbitrary.

However, between General Assemblies there arise demands from Commissions, similar to those under heading 2, which it would be undesirable to defer to the next General Assembly; the Executive Committee, with the advice of the Advisory Finance Committee, should have discretion to make appropriate grants in the same way as it does with the much larger amounts for symposia and publications. Some small amounts have actually been included in the expenditure of the Administrative Office, but the following items were specifically approved by the Executive Committee:

	U.S. dollars
Commission 19 (grant to Dr P. Melchior in respect of the declination of stars for the International Latitude Service)	400
Commission 23 (reprinting Part II, vol. 2 of the Catania section of the *Astrographic Catalogue*)	300
Commission 27 (translation and printing of the introduction to supplements of the GCVS)	400
Sub-Commission 29*a* (informal colloquium, Meudon, September, 1960)	255
Annual contribution to the Fondation Internationale du Pic-du-Midi	100

Moreover, promises have been made in respect of the following, although no payments have yet been made:

	U.S. dollars
Commission 5 (grant-in-aid of the publication of the *Bibliography of Astronomy* 1881–98)	5 000
Commission 33 (Publication of tables for the conversion of equatorial to galactic co-ordinates)	2 000
Sub-Commission 33*b* (Reprints of report)	200

11. *Equalisation account.* The statement of income and expenditure, abstracted from accounts in four different currencies, can only be made to give an exact balance by excessively complicated adjustments; this is particularly so when the rates of exchange have been varying. The

sum under this heading is the total of the adjustments necessary; its main constituent is the small loss due to the devaluation of the French franc. The balance of the French account on 1 November 1957 was unusually large, namely 1 937 540 (old) francs; the immediate loss on revaluation was thus 923 U.S. dollars.

Preparation of a budget

It is the duty of the Executive Committee, imposed by the Statutes of the Union, to prepare a budget for the approval of the General Assembly, on the recommendation of the Finance Committee. A budget, such as has been drawn up in the past, which ignores one of the Union's principal sources of income and the major sources of its expenditure, cannot be realistic; the Finance Committee at the next General Assembly will accordingly be asked to approve a comprehensive budget for the following three-year period, including all items of income and expenditure. This is only possible because of the flexibility provided by the Union's reserve, and by the freedom to vary the expenditure under several headings (particularly for symposia) according to the amount of the UNESCO subvention. It is essential that this budget should contain provision for expenditure on projects arising between General Assemblies, subject to the approval of the Executive Committee as advised by the Advisory Finance Committee.

APPENDIX I. LIST OF COUNTRIES ADHERING TO THE UNION

In the following list are given the 38 countries that adhere to the Union in December 1960, together with the year of adherence, the approximate number of Members, and the adhering organizations.

Country	Year	No.	Adhering Organization
Argentina	1927	8	Comité Nacional de Astronomia, La Plata.
Australia	1939	25	Australian Academy of Science, Canberra.
Austria	1955	10	Österreichische Akademie der Wissenschaften, Wien.
Belgium	1920	34	Académie Royal de Belgique, Bruxelles.
Bulgaria	1957	1	Bulgarische Akademie der Wissenschaften, Sofia.
Canada	1920	28	Department of Mines and Technical Surveys, Ottawa.
Chile	1947	3	Observatorio Astronomico Nacional, Universidad de Chile, Santiago de Chile.
Czechoslovakia	1922	23	Academy of Sciences, Prague.
Denmark	1922	10	Det Kongelige Danske Videnskabernes Selskab, København.
Eire	1947	2	Dublin Institute for Advanced Studies.
Finland	1948	8	Académie des Sciences et Lettres, Helsinki.
France	1920	97	Académie des Sciences, Paris.
Germany	1951	86	Astronomische Gesellschaft, Hamburg-Bergedorf Sternwarte.
Great Britain	1920	106	Royal Society, London.
Greece	1920	9	Academy of Athens, Athens.
Hungary	1947	2	Hungarian Academy of Sciences, Budapest.
India	1946	12	Government of India, Ministry of Scientific Research and Cultural Affairs, New Delhi.
Israel	1954	1	Research Council of Israel, Jerusalem.
Italy	1921	31	Consiglio Nazionale delle Ricerche, Roma.
Japan	1920	18	Science Council of Japan, Tokyo.
Lebanese Republic	1954	2	National Lebanese Committee for Astronomy, Ksara.
Mexico	1921	8	Universidad Nacional, Mexico, D.F.
Netherlands	1922	30	Koninklijke Nederlandse Akademie van Wetenschappen, Amsterdam.
Norway	1922	10	Det Norske Videnskaps-Akademi, Oslo.
Poland	1922	24	Polska Akademia Nauk, Warszawa.
Portugal	1924	4	Government, Lisbon.
Roumania	1928	7	Comitetul National Astronomic, Bucarest.
South Africa	1938	8	South African Council for Scientific and Industrial Research, Pretoria.
Spain	1922	12	Academia de Ciencias Exactas, Madrid.
Sweden	1925	24	Kungl. Vetenskapsakademien, Stockholm.
Switzerland	1923	11	Schweizerische Naturforschende Gesellschaft, Zürich.
Taiwan (The Republic of China)	1959	—	Astronomical Society of the Republic of China, Taipei.
United Arab Republic (Egypt)	1925	8	Astronomical Center at Helwan, Egyptian Region.
United States	1920	276	National Research Council, Washington.
U.S.S.R.	1935	129	Academy of Sciences of the U.S.S.R., Moscow.
Vatican City State	1932	3	Pontificia Accademia delle Scienze i Nuovi Lincei, Rome.
Venezuela	1953	—	Academia de Ciencias Fisicas Matematicas y Naturales, Caracas.
Yugoslavia	1935	9	Conseil Fédéral de la Recherche Scientifique, Belgrade.

APPENDIX II. LIST OF DECEASED MEMBERS

The Executive Committee regrets to record the loss by death of the following 45 Members of the Union:

A. Ali	7 February 1960	M. Milankovitch	12 December 1958
J. A. Anderson	2 December 1959	S. A. Mitchell	22 February 1960
G. Armellini	16 July 1958	S. V. Orlov	11 January 1958
W. Baade	25 June 1960	A. Pannekoek	28 April 1960
J. Baillaud	28 November 1960	P. P. Parenago	5 January 1960
J. Bobone	21 October 1958	A. Patry	20 June 1960
W. Brunner	1 December 1958	I. Polit	19 October 1958
Miss E. J. Bugoslavskaja	30 May 1960	W. Rabe	1 April 1958
K. Burns	30 April 1958	F. E. Ross	21 September 1960
B. H. Dawson	18 June 1960	R. F. Sanford	7 April 1958
A. Dittrich	15 December 1959	O. Seydl	15 February 1959
A. D. Dubyago	29 October 1959	C. K. Seyfert	13 June 1960
C. S. Gum	29 April 1960	A. V. Soloviev	23 August 1959
J. Jackson	9 December 1958	F. J. M. Stratton	2 September 1960
F. A. Jenkins	Summer 1960	G. A. Tikhov	25 January 1960
Sir Harold Spencer Jones	3 November 1960	P. J. van Rhijn	9 May 1960
A. Kopff	25 April 1960	R. Vernic	20 October 1958
P. Lejay	11 October 1958	Miss J. M. Vinter Hansen	27 July 1960
F. C. Leonard	Autumn 1960	H. von Zeipel	8 June 1959
K. Lundmark	23 April 1958	V. P. Vyazanitsyn	14 October 1960
A. McKellar	6 May 1960	H. P. Wilkins	23 January 1960
C. E. Kenneth Mees		R. E. Wilson	
		W. H. Wright	16 May 1959

APPENDIX III. CO-OPTIONS TO COMMISSIONS

Subsequent to the tenth General Assembly in 1958 (Moscow) the following were co-opted by the various Commissions under the provisions of By-law IV, 15:

F. M. Bateson (27), L. I. Gama (31), L. Goldberg (44), L. G. Henyey (35), F. Hoyle (35), H. L. Johnson (37), E. F. McClain (40), L. Mestel (35), Miss E. Roemer (20*a*), S. Rosseland (35), E. E. Salpeter (35), E. Schatzman (35), H. Schneller (42), H. Zirin (10).

APPENDIX IV. LIST OF PUBLICATIONS

Transactions of the IAU, Volume X,	Published by the Cambridge University Press.
IAU Symposia Volumes	
No. 5 *Comparison of the Large-Scale Structure of the Galactic System with that of other Stellar Systems*	Editor: N. G. Roman Published by the Cambridge University Press.
No. 6 *Electromagnetic Phenomena in Cosmical Physics*	Editor: B. Lehnert Published by the Cambridge University Press.
No. 7 *Second Conference on Co-ordination of Galactic Research*	Editors: A. Blaauw G. Larsson-Leander N. G. Roman A. Sandage A. D. Thackeray H. F. Weaver Published by the Cambridge University Press.

LIST OF PUBLICATIONS (*continued*)

No. 8 *Proceedings of the Third Symposium on Cosmical Gas Dynamics*	Editors: J. M. Burgers R. N. Thomas Published in *Reviews of Modern Physics.*
No. 9 *Paris Symposium on Radio Astronomy*	Editor: R. N. Bracewell Published by the Stanford University Press.
No. 10 *The Hertzsprung-Russell Diagram*	Editor: J. L. Greenstein Reprinted from *Annales d'Astrophysique.*
No. 11 *The Rotation of the Earth and Atomic Time Standards*	Editor: D. Brouwer Reprinted from the *Astronomical Journal.*
Commission 5:	
Astronomical News Letters Nos. 88–101	Editor: V. Kourganoff. Published and distributed by Laboratoire d'Astronomie de Lille.
Les Observatoires Astronomiques et Les Astronomes (second edition)	Prepared by F. Rigaux Issued and distributed by l'Observatoire Royal de Belgique.
Commission 6:	
IAU Circulars	Issued by the 'Bureau Central des Télégrammes Astronomiques'.
Commission 10:	
Heliographic Charts of the Photosphere Volume XI, nos. 2, 3 and 4	Published by the Eidgen. Sternwarte in Zürich, under the direction of M. Waldmeier.
Commission 10 (formerly 11):	
Cartes Synoptiques de la Chromosphère Solaire Volume II, fascicule 2 and 3	Prepared by the Section d'Astrophysique de l'Observatoire de Paris at Meudon, under the direction of L. d'Azambuja.
Commission 20:	
Minor Planet Circulars	Mimeographed Circulars issued by the Minor Planet Center in Cincinnati.
Commission 23:	
Astrographic Catalogues Melbourne Section Volume VI, Zones $-75°$, $-76°$, and $-77°$ Volume VII, Zones $-78°$, $-79°$, $-80°$ and $-81°$	Prepared by J. Baillaud.
Commission 26:	
Circulaires d'Information	Prepared by P. Muller.
Commission 27:	
English version of Introduction and Remarks from the seventh and eighth Supplements to the General Catalogue of Variable Stars.	Prepared by P. Th. Oosterhoff.
English Version of the Remarks to the second Edition of 'The General Catalogue of Variable Stars'.	Prepared by the President of Commission 27.
Circulars, 1958, Nos. 1 - 4; and *Information Bulletins* Nos. 1 - 4	Prepared by the General Secretary of the IAU.

3. COMMISSION DES NOTATIONS, DES UNITES ET DE L'ECONOMIE DES PUBLICATIONS

PRÉSIDENT: Professor Dr M. F. Subbotin, Director of the Institute of Theoretical Astronomy, Leningrad-V. 164, U.S.S.R.

MEMBRES: Barbier, Chandrasekhar, Martin, Martynov, Mikhailov, Mlle Northcott, R. W. Shaw, Zagar.

Depuis sa fondation en 1922 la Commission 3 a fait beaucoup des efforts pour établir une notation uniforme dans l'astronomie. On a commencé par l'établissement d'une liste des notations récommandées dans le domaine de l'astronomie sphérique et partiellement dans ceux de la mécanique céleste et de l'astronomie stellaire (*Trans. IAU* **1**, 20, 1922, et **2**, 177, 1925). Le développement progressif de ce travail a donné la liste bien connue des notations astronomiques (*Trans. IAU* **6**, 345–55, 1938). Quelques compléments à cette liste ont été faits à la IXème Assemblée Générale (*Trans. IAU* **9**, 66, 1955).

Une autre liste des notations à peu près de la même étendue a été préparée tout récemment par la Commission terminologique du Conseil Astronomique de l'Académie des Sciences de l'U.R.S.S. (**1**). Pour la plupart, notamment dans les cas où l'unification des notations serait particulièrement désirable, ces deux listes coïncident. Les différences entre ces deux listes montrent, à ce qu'il semble, les limites entre lesquelles l'unification peut pratiquement être atteinte à présent.

D. Barbier croit 'que la situation actuelle en ce qui concerne les notations et abréviations n'est pas trop mauvaise' et il ajoute: 'Sans doute, l'uniformité absolue n'est-elle pas la règle, mais je ne me rappelle pas que la lecture de publications astronomiques ait, pour moi, présenté des difficultés tenant aux notations employées.'

Je partage entièrement cet avis et je crois que faire d'autres efforts pour l'unification des notations serait, à présent, de dépasser le but de la Commission 3. Maintenant, c'est la tâche des Commissions spéciales de l'Union Astronomique Internationale de proposer, s'il y a lieu, des notations nouvelles et des changements dans la liste publiée. Les fonctions de la Commission 3 pourraient être réduites à l'enregistrement des notations dûment adoptées par les Commissions et à la publication, de temps en temps, de la liste générale des notations recommandées.

D. Ya. Martynov pense qu'il serait utile de prendre pour base la liste des notations publiée (en russe) par le Conseil Astronomique de l'Académie des Sciences de l'U.R.S.S. Il a transmis à la Commission la proposition, faite par J. Kleczek en ces termes:

'*Astronomical Glossary*. All knowledge of astronomy is conserved and communicated by language. The substantial part of astronomer's language is terminology. A glossary containing the terms of all branches of astronomy would be useful.

'The proposed glossary should explain by definitions, description or figures the terms and symbols used in astronomy. Some work has already been done or is being done (*e.g.* in meteor astronomy by Commission 22*b*) and many recommendations are scattered in various publications. It would be useful to expand this work to all Commissions and to publish the glossary as a separate publication of the IAU. The glossary should contain not only terms fixed by current usage, but also recommendations for indiscriminate cases.

'Commission 5 could take care of the organisation and of the editing of the glossary.'

D. Ya. Martynov fait savoir que les membres de la Commission 5 trouvent cette proposition utile, mais pensent qu'elle soit plutôt du ressort de la Commission 3. D. Barbier pense que 'Le dictionnaire proposé par le Professor Kleczek pourrait être utile. Mais il faudrait, semble-t-il, qu'il soit préparé en plusieurs langues. L'entreprise parait difficile à mener à bien mais il vaudrait peut-être la peine d'en discuter à la prochaine réunion de la Commission 3.'

Telles sont les propositions qui doivent être discutées à l'Assemblée Générale.

M. F. SUBBOTIN
Président de la Commission

RÉFÉRENCE

1. 'Notations fondamentales de l'Astronomie', Académie des Sciences de l'U.R.S.S., Moscou 1959.

5. COMMISSION DES ANALYSES DE TRAVAUX ET DE BIBLIOGRAPHIE

PRÉSIDENT: Professor Dr D. Ya. Martynov, Director of Sternberg Astronomical Institute, Moscow University, Leninskije Gory, Moscow-V. 234, U.S.S.R.

MEMBRES: Baldet, Belorizky, Bourgeois, Bouska, Brasch, Dermul, Fricke, Guyot, Heinemann, Kourganoff, Ogorodnikov, Sconzo, Slouka, Witkowski, Zinner.

L'achèvement de la bibliographie astronomique pour les années 1881–98 a toujours rencontré de grandes difficultés. M. Dermul qui s'en occupe sous les auspices du Comité National Belge d'Astronomie n'a pas encore reçu les nombreuses annotations bibliographiques préparées en Allemagne et en Tchécoslovaquie; il évalue en pessimiste la plénitude du dépouillement des articles anglais et français. Le Comité exécutif de l'UAI a approuvé l'intention du Comité National Belge d'Astronomie de commencer l'impression de la bibliographie par la méthode de photo-lithographie; il assigne à ce but un subside de $5000.

Le *Referativny Journal, Astronomie et Geodésie* russe a paru régulièrement douze fois par an. Les exposés des articles y paraissent généralement un an après la publication de ces derniers. A partir de 1960 les fascicules d'Astronomie et de Geodésie sont publiés séparément. L' *Astronomischer Jahresbericht* a continué à paraître régulièrement. Les tomes **57** et **58** sont parus à temps, la parution du tome **59** (littérature de 1959) est attendue vers mai 1961.

Le Professeur Kourganoff a continué de publier régulièrement les *Astronomical News Letters* (*ANL*) contenant des exposés de la littérature russe. En 1959 il a publié les numéros 92–97 et en 1960 les numeros 98–102. Beaucoup de spécialistes-astronomes s'occupent avec le Professeur Kourganoff de cette revue bibliographique; citons entre autres les Professeurs Minnaert et Vyssotsky, et le Dr Belorizky. Conformément à la décision adoptée par la X-ème Assemblée Générale le conseil de rédaction du journal de références russe 'Astronomie' a régulièrement envoyé au Professeur Kourganoff les épreuves des exposés d'articles russes, dont les textes originaux ont été publiés sans sommaires anglais ou français. Ces envois ont contribué à la rapidité de la traduction des sommaires et de leur publication dans *ANL*. Cependant le Professeur Kourganoff, qui dirige l'édition des *ANL* depuis 1953, exprime des doutes sur leur utilité en temps actuel, puisque des sommaires détaillés en langue française et anglaise sont maintenant publiés pour tous les articles de l'*Astr. Zhourn.* et des *Izvestia de Crimée*; de plus, l'*Astr. Zhourn.* est complètement traduit en anglais. Le Professeur Kourganoff se démet des devoirs de Rédacteur en chef des *ANL* à partir du 15 Octobre 1961.

Le *Bulletin signalétique de Chronométrie Générale* a cessé de paraître à la fin de 1958 et ses matériaux font maintenant partie du *Bulletin signalétique du CNRS*. Des extraits très utiles de ce journal ont été publiés régulièrement et à temps chaque mois et distribués gratis à 157 institutions astronomiques. Mais, comme l'écrit le Dr Baldet, pour pouvoir continuer la publication et la distribution gratuite des *Extraits* il est nécessaire de rétablir pour les années 1961–3 le subside de $900, interrompu depuis 1958.

Entre les bibliographies spéciales on doit marquer la continuation du 'Catalogue of star clusters and associations' (en fiches), préparé par MM. Alter, Ruprecht et Vanýsek, qui viennent d'achever le 3-me complément. Ce catalogue contiendra à présent près de 1000 objets. Le Dr Schneller a entrepris la publication du tome V de la 2-ème édition de *Geschichte und Literatur des Lichtwechsels der veränderlichen Sterne* (Band V, enthaltend die zwischen 1938 und 1958 benannten Sterne). En 1960 il a publié le Heft 1, *Andromeda-Crux*.

Korytnikov, Lavrov et Martynov ont continué leur travail commun de bibliographie des étoiles doubles spectrales. Ils en sont actuellement au stade de la composition du texte dactylographié du manuscrit.

Mme Lavrova a publié en 1959 (1) un grand 'Essai sur l'histoire de la bibliographie astronomique', une espèce de vade-mecum parmi les nombreuses éditions bibliographiques en astronomie. Une 'Bibliographie de travaux en astronomie, exécutés en U.R.S.S. depuis 1917 à 1957' a été préparée sous sa direction et publiée en 1960 (2). Cette bibliographie contient tous les travaux d'astronomes russes publiés dans l'intervalle de temps indiqué, à l'exception de ceux qui ne contiennent que des résultats d'observations (en tout 9500 titres de livres et d'articles de 1800 auteurs).

La décision de la X-ème Assemblée de l'UAI, concernant la désignation aux Comités Nationaux de spécialistes en transcription phonétique de noms d'auteurs et de titres de livres et d'articles, n'a pas été réalisée. Le Comité National d'astronomie de Grande Bretagne (British National Committee for Astronomy) a désapprouvé cette proposition; il a offert de son côté de se servir du British Standards 2979: 1958 ou *Transliteration of Cyrillic and Greek Characters* pour la transcription des noms d'auteurs accompagnant leur transcription en langue natale.

L'*Astronomischer Jahresbericht* établit cependant ses propres règles de translitération; *Physics Abstracts* et *Mathematical Reviews* en ont établi aussi chacun à sa guise. Cela mène à des quiproquos, non seulement dans la bibliographie, mais aussi dans les relations personnelles entre les savants. Ainsi, par exemple, la prononciation correcte du nom 'Protheroe', est impossible pour un russe sans l'accompagnement d'une translitération phonétique. De même, le nom 'Alter' sera prononcé différemment par un anglais, un français et un allemand.

Nous constatons avec regret que la pratique de publication par les journaux occidentaux de sommaires en langue russe se fait de plus en plus rare. *Monthly Notices* a cessé de les publier. Il est regrettable que la recommandation de la X-ème Assemblée Générale, concernant l'établissement de contacts entre les grands journaux astronomiques au sujet de la traduction des sommaires, n'a pas été réalisée.

Le répertoire *Les observatoires astronomiques et les astronomes* de F. Rigaux, publié en 1959 sous les auspices de l'UAI par l'Observatoire Royal de Belgique, était déjà suranné sous beaucoup de rapports au temps de sa parution et contenait des inexactitudes et des lacunes. Aussi la publication des compléments et des corrections de cet ouvrage recommandée par la X-ème Assemblée de l'UAI doit être effectuée le plus tôt possible.

La Commission 5 devra décider à Berkeley ne serait-t-il pas mieux d'apprêter une nouvelle édition du répertoire d'après un principe nouveau; par example, comme le propose le Secrétaire Général de l'UAI, D. H. Sadler, on pourrait se borner à une énumération autoritaire des observatoires en ajoutant pour chacun d'eux l'adresse, les noms des dirigeants et une description sommaire. On devra penser aussi à la composition d'une commission autoritaire qui serait en état de contrôler l'exactitude de ce répertoire à l'intérieur de chaque pays.

Le Dr Kleczek a proposé d'élaborer un dictionnaire astronomique polyglotte de termes courants. Rigoureusement parlant, cette question se rapporte à la compétence de la Commission 3; cependant beaucoup de membres de la Commission 5 se sont déclarés en faveur de cette proposition.

La composition d'un dictionnaire de cette sorte exigera une coopération d'astronomes de beaucoup de pays; beaucoup d'autres Commissions de l'UAI devront y participer. Cette

question devrait être débattue avec les autres commissions pendant la XI-ème Assemblée.

D. J. MARTYNOV
Président de la Commission

RÉFÉRENCES

1. 'Recherches historico-astronomiques', fasc. 5, Moscou, 1959.
2. Dans le recueil 'Astronomie en U.R.S.S. au cours de quarante années (1917–57)'. Moscou, 1960, p. 371–723.

6. COMMISSION DES TELEGRAMMES ASTRONOMIQUES

PRÉSIDENT: Professor Dr E. Buchar, Astronomical Institute, Technical University, Karlovo nám. 13, Prague 2, Czechoslovakia.

DIRECTRICE DU BUREAU: Mlle J. M. Vinter Hansen†.

DIRECTEUR INTERIMAIRE: M. K. A. Thernöe.

MEMBRES: Bobone†, Cunningham, Finsen, Hogg, Whipple.

In the course of the last period the Commission suffered the loss of two members. Dr J. Bobone of the National Observatory in Cordoba died on 21 October 1958, and Miss Julie M. Vinter Hansen, Director of the Central Bureau for Astronomical Telegrams, died on 27 July 1960. The latter conducted for many years the work of the Bureau and was largely responsible for the efficient working of this institution. Thanks to arrangements by Dr A. Reiz, Director of the University Observatory in Copenhagen, no interruption in the activity of the Bureau occurred, as Mr K. A. Thernöe assumed the duties of the late Miss Vinter Hansen

With regard to a suggestion that the Telex System be introduced in the Bureau, most members of the Commission expressed the opinion that the present system of distribution of astronomical telegrams has proved satisfactory so far. No other suggestions have been made.

The Report of the Bureau has been prepared by Mr K. A. Thernöe.

E. BUCHAR
President of the Commission

REPORT OF THE CENTRAL BUREAU FOR ASTRONOMICAL TELEGRAMS

The Central Bureau suffered a sad loss through the death, on 27 July 1960, of its director Miss Julie Vinter Hansen who since 1947 had conducted its work very efficiently and with never failing interest. In order to maintain the activities of the Bureau until a permanent arrangement could be made, the supervision was temporarily entrusted to the writer who for several years has participated in its work. In this capacity I have prepared the following report, covering the period from 20 October 1957 to 31 December 1960.

The work of the Bureau since 1957 has proceeded along the usual lines. The number of subscribers to telegrams and circulars, and to circulars only, has continued to rise, namely from 68 to 73 and from 117 to 158 respectively. Pleasing as is this rise, it calls, however, for a correspondingly greater amount of clerical work at the Bureau, and it would not have been possible to keep the subscription fees fairly low if we were not the recipients of subsidies from the International Astronomical Union and the Danish Rask-Orsted Foundation. These subsidies have so far paid for all the clerical work, but are definitely unable to do so any longer, owing to the considerably greater number of subscribers and the general rise in payments. Therefore, the Bureau has been impelled to ask for a somewhat larger subsidy from the Union.

The Bureau tries its best to satisfy the various wishes of the subscribers. In order to achieve this, the Bureau would be greatly helped if subscribers as far as possible would deal with the Bureau directly, and not through local agencies, as such arrangements may often cause unnecessary clerical work for the Bureau.

As to the more scientific work involved in the activities of the Bureau we have been greatly helped by astronomers not attached to the Copenhagen Observatory, primarily the British

Astronomical Association computers, but also by many others, for example in Czechoslovakia, U.S.A., and the U.S.S.R.

Below are given the number of telegrams received and transmitted to the subscribers together with the number of circulars issued, all in the period since the report in *Trans. IAU*, **10**, *i.e.* from 20 October 1957 to 31 December 1960.

	Telegrams		
	Received	Sent	Circulars
1957 (from 20 Oct.)	12	76	12 (1623–1634)
1958	11	240	28 (1635–1662)
1959	36	522	43 (1663–1705)
1960 (to 31 Dec.)	29	602	42 (1706–1747)
	88	1440	125

On the suggestion of the General Secretary, the full lists of the names and addresses of the 73 and 158 subscribers to telegrams and circulars, and to circulars alone, have been omitted from this report.

K. A. THERNÖE

38. COMMISSION POUR L'ECHANGE DES ASTRONOMES

PRÉSIDENT: Professor F. J. M. Stratton†, Gonville and Caius College, Cambridge, England.

PRÉSIDENT INTERIMAIRE: Professor M. G. J. Minnaert, Director of the Observatory 'Sonnenborgh', Zonnenburg 2, Utrecht, the Netherlands.

MEMBRES: Abetti, Bok, Bowen, Danjon, Dawson†, Minnaert, Mohr, Nassau, Pawsey, Rosseland, Swings, Witkowski.

In the course of 1960, Commission 38 suffered a severe loss by the sudden death of Professor F. J. M. Stratton, who has been its President ever since it was instituted in 1946. From reading his successive reports and from personal experience we all know how effectively he carried out his duties, avoiding any unnecessary formalities, but treating each individual case with great human kindness. At the invitation of the Executive Committee the undersigned took over the Presidency until the next General Assembly.

The number of grants is regularly increasing, as may be seen from the following data:

1952–54	14 astronomers (34 – 47)
1955–57	22 astronomers (48 – 69)
1957–60	30 astronomers (70 – 99)

In this last period, the following grants were made:

70. A Czechoslovak astronomer to Manchester.
71. A Czechoslovak astronomer to Marseille and Haute Provence.
72. A French astronomer to Asiago.
73. A Spanish astronomer to Cambridge.
74. A British astronomer to Madrid and Tenerife.
75. A Czechoslovak astronomer to Mt Palomar and Tonantzintla.
76. An Italian astronomer to Berkeley.
77. A Greek astronomer to Arcetri.
78. A British astronomer to Victoria.
79. A French astronomer to London.
80. A Finnish astronomer to Greenwich.
81. An Italian astronomer to Manchester.
82. An Indian astronomer to Edinburgh.
83. A French astronomer to the Cape.
84. A British astronomer to Liège.
85. A British astronomer to Paris.
86. An Ecuadorean astronomer to Strasbourg.
87. A French astronomer to Padova and Asiago.
88. An Indian astronomer to the McMath-Hulbert Observatory.
89. An Italian astronomer to Leiden and Dwingeloo.
90. A Japanese astronomer to Victoria.
91. An Indian astronomer to Yale.
92. A Japanese astronomer to Utrecht.
93. A Japanese astronomer to Utrecht.
94. An American astronomer to London.
95. An Indian astronomer to Stockholm.
96. A Belgian astronomer to Torino.

97. An Indian astronomer to Bloomington.
98. An Indian astronomer to Middletown.
99. A Japanese astronomer to Manchester.

The following grants have been promised for 1961:

100. An Australian astronomer to London and Paris.
101. A Japanese astronomer to Utrecht.

In many cases applicants wanted to make observations with powerful instruments, not available in their country. One of the applications was made for studies of the Southern sky. Much observational material, obtained with great effort and not sufficiently exploited, has been put to good use with the co-operation of visiting astronomers. Astronomers acquiring a new telescope wished to ask for advice from an observatory where a large instrument is already in operation; even for the establishment of a new observatory foreign experts were sometimes consulted. Theorists wished to do research in close contact with a specialized group. In one case, two astronomers wanted to write a book together and had to discuss the text in close co-operation. Sometimes an assistantship was available at an astronomical institute abroad, but the Commission was asked to furnish travelling expenses. Often such visits were combined with lectures, held at colloquia or congresses. Some countries, in which astronomy is insufficiently developed, wanted to have an excellent young scientist trained at one of the big centres. A subsidy of $1000 was granted to assist young astronomers wishing to attend the Moscow General Assembly of the Union in 1958; apart of this, only one small grant has been made especially for participation in a symposium.

The way in which the Commission operates is well known. Applicants should give full details of their qualifications and experience, details of the proposed research and study, and the reasons why this research cannot be carried out in their own country. Applications must be approved by the Director of the home Observatory and by the Director of the Observatory at which the proposed research is to be carried out. Usually the grants are restricted to the payment of travelling expenses, but when funds permit a small additional grant is occasionally made to assist with living expenses.

In this list, some types of research are still insufficiently represented: observations in the southern hemisphere; radio-astronomical investigations; rocket and satellite problems. The Union wishes to encourage also the study of very specialized instruments and computing machines, for which a stay abroad is often necessary. In general every effort should be made to promote East-West exchanges. On a modest scale, young astronomers invited to attend international astronomical symposia will be assisted, when other funds are not available.

In agreement with a decision, taken at the Moscow meeting in 1958, Professor Stratton communicated with members of the Commission and 15 other astronomers in order to compile a list of assistantships and fellowships, available for foreign astronomers at many observatories. This very valuable list is an up-to-date version of the publication in *Trans. IAU* **7**, 414, 1950. It was duplicated and sent to all institutions on the IAU distribution list in August 1959 and is now reproduced as an addendum to this report, corrected and completed in minor details.

During the three years 1958–60 the grants totalled $15 517·36. The balance at hand on 31 December 1960 is $1 525·13. The annual allocations of the Union amounted to $4 000 + $6 000 + $6 000 = $16 000. It is clear that the increase from $4 000 to $6 000, decided at the Moscow meeting of 1958, has been most useful; and it would be appropriate if a sum of at least $6 000 would be again available for each of the next three years.

M. G. J. MINNAERT
Acting President of the Commission

ADDENDUM. FACILITIES FOR VISITING ASTRONOMERS

In general the directors of observatories are very willing to receive visiting astronomers and to offer them observational facilities, but often there is no scholarship or fellowship attached to the observatory. The following list includes only those institutes where some assistance for visitors may be available locally. For all observatories not in the list below the procedure for a young astronomer would be to apply directly to the Director of the Observatory, indicating the nature of the research that he wishes to carry out.

For general information on facilities for study or research in other countries, the book *Study Abroad*, published by UNESCO, will be found very helpful.

Argentina

The Argentine National Research Council has important funds for travelling and local expenses for a senior astronomer. Inquiries should be addressed to Dr C. R. Jaschek, Secretary of the Argentine National Committee for Astronomy, Observatorio Astronómico, La Plata.

Córdoba. Two fellowships each year for a period of two or three months of observational work at Bosque Alegre with the 60-inch reflector.

La Plata. Similar arrangements.

Australia

Canberra. The Mount Stromlo Observatory is the Department of Astronomy of the Australian National University in Canberra. The University offers two scholarships for post-graduate study in Astronomy with preference for students from overseas. The annual scholarship award is of the order of £1000 (Australian) and the scholarships are generally tenable for a period of three years. All inquiries should be addressed to the Director of Mount Stromlo Observatory, Canberra, A.C.T.

Sydney. The Division of Physics of the Commonwealth Scientific and Industrial Research Organization is prepared to consider applications for fellowships for theoretical or observational research in solar physics: structure of the photosphere and chromosphere; studies of disturbances involving these layers (sunspots, flares, prominences, plages); the development of new types of observational equipment. The fellowships may be at senior or junior level in the approximate range of £1500 or £3500 (Australian) annually. All inquiries should be addressed to The Chief, Division of Physics, C.S.I.R.O., University Grounds, Sydney, New South Wales.

The Division of Radiophysics offers from time to time fellowships for work in radio astronomy. The conditions for remuneration are the same as for solar physics. All inquiries should be addressed to The Chief, Division of Radiophysics, C.S.I.R.O., University Grounds, Sydney, New South Wales.

Belgium

Liège. Occasional temporary assistantships. Apply to the Director, Institut d'Astrophysique, Cointe-Sclessin.

American astronomers may get help under the Belgian-American Educational Foundation Inc., Graybar Building, 420 Lexington Avenue, New York.

Canada

Post-doctorate fellowships, National Research Council. Fellowships of $3700 a year for single fellows and $4500 a year for male fellows who are married. Tenure: one year, but

renewable. Travel grant allowed. Applicants must be not more than 35 years of age and should possess a Ph.D. degree (or equivalent) from a recognized University. Apply to the Awards Office, National Research Council of Canada, Ottawa or to the Chief Scientific Liaison Officer, National Research Council of Canada, Africa House, Kingsway, London, W.C.2, England. These Fellowships are tenable at:

Ottawa, Dominion Observatory. Fellowships tenable for Geomagnetism, Gravity, Positional Astronomy, Stellar Physics and Seismology.

Victoria, British Columbia, Dominion Astrophysical Observatory. Fellowships tenable for Stellar Atmospheres, Galactic Structure, Photo-electric Photometry, Spectroscopic Binaries, Interstellar Matter.

Toronto, David Dunlap Observatory of the University. Postgraduate fellowships.

Eire

Dunsink. One Scholarship every two years at the Dublin Institute for Advanced Studies in the School of Cosmic Physics. Qualification: an honours degree in mathematics, physics or astronomy, with evidence of capacity for original research. Apply to the Registrar, Dublin Institute for Advanced Studies, 64 Merrion Square, Dublin.

Germany

For fellowships tenable at astronomical observatories and institutions apply, after securing the approval of the chosen institution, to: the Deutsche Forschungsgemeinschaft, Frankengraben 40, Godesberg, or to the Deutscher Akademischer Austauschdienst, Nassestrasse, Bonn a.Rh.

Tautenburg. Applications should be sent to the Director.

India

Kodaikanal. For young Indian students with a M.Sc. or equivalent degree. Four Research Scholarships of Rs. 2400 a year. Apply to the Director, Astrophysical Observatory, Kodaikanal.

Naini Tal. Two Fellowships for one year, with a possibility of renewal, for photometric work. Apply to the Director, U.P. State Observatory, Naini Tal.

Italy

After securing the approval of the Director of the Observatory where the student wishes to work, apply for a fellowship to the Consiglio Nazionale delle Ricerche, Piazzale delle Scienze 7, Rome.

Netherlands

Leiden. Occasional vacancy for a young astronomer on the staff for a period between six months and a year.

Utrecht. Occasional exchanges of astronomers for a period of three to six months.

In each observatory there may be a room available free of charge in the Observatory. Apply in each case to the Director.

South Africa

Radcliffe Observatory, Pretoria. See Oxford.

Switzerland

Zürich. Foreign astronomers may be able to obtain an assistantship to work in solar research

for a period ranging between several semesters and several years. Apply to the Director, Swiss Federal Observatory, Zürich.

United Arab Republic (Egyptian region)

Helwan. Assistantship for two years. Visiting professorship for limited time in 1962–63.

United Kingdom

Cambridge. The Isaac Newton Studentship of £400 a year for two years, open to graduates of any University, under 25 years of age on January 1 of the year of election. Apply to the Registrar, University Registry, Cambridge, by 25 March each year with evidence of age, evidence of qualifications, testimonials and a statement of proposed course of study or research.

Oxford. Radcliffe Travelling Fellowship to be held partly at Oxford University Observatory and partly at the Radcliffe Observatory, Pretoria. Vacancies are advertised from time to time as they occur. Apply to the Director, Oxford University Observatory.

Skynner Senior Studentship for students working for a research degree. Apply to the Master, Balliol College, Oxford.

Scotland. Robert Cormack Fellowships in Astronomy £300 to £600 a year for three years. Tenable at the Observatory of *Edinburgh*, *Glasgow* or *St. Andrew's* in the case of graduates of Universities outside Scotland. Apply to the Convener, Robert Cormack Bequest Committee, Royal Society of Edinburgh, 22 George Street, Edinburgh 2.

U.S.A.

Berkeley. One Lick Fellowship of $1820 a year for a graduate student, usually for theoretical astrophysics. Apply to the Head of Berkeley Astronomical Department, Leuschner Observatory, Berkeley 4, California.

California Institute of Technology. Graduate fellowships for study for the doctor's degree. Apply to The Dean of Graduate Studies, California Institute of Technology, Pasadena, California.

Flower and Cook. Assistantships and fellowships; Pawling Fellowship ($1800 a year). Apply to the Director of the Flower and Cook Observatory, University of Pennsylvania, Philadelphia 4, Pa.

Harvard. Agassiz and other fellowships and assistantships. Apply to The Director, Harvard College Observatory, Cambridge, Mass.

Kirkwood. Assistantships and fellowships. Apply to the Director, Kirkwood Observatory, Indiana.

Lick. Two Lick Observatory Fellowships of $1820 a year. Apply to The Director, Lick Observatory, Mount Hamilton, California.

Los Angeles. Occasional assistantships, especially in the field of celestial mechanics. Apply to the Chairman of the Department of Astronomy, University of California, Los Angeles 4, California.

Michigan. Part time assistantships for graduate students, for Post-doctoral research in Solar Physics and Radio Astronomy. Apply to The Director, University of Michigan Observatory, Ann Arbor, Michigan.

Mount Wilson and Palomar. Carnegie Fellowships for men who have recently received

doctor's degree. Apply to The Director, Mount Wilson and Palomar Observatories, 813 Santa Barbara Street, Pasadena 4, California.

Perkins. Fellowships of the Ohio State University. Apply to The Director, Perkins Observatory, Delaware, Ohio.

Van Vleck. Assistantships in the fields of positional astronomy and astrophysics. Apply to the Director, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut.

Warner and Swasey. Research fellowships. Apply to The Secretary, Case Institute of Technology, East Cleveland, Ohio.

Yerkes and MacDonald. Post-graduate research fellowships and assistantships. Apply to The Director, Yerkes Observatory, Williams Bay, Wisconsin.

American Astronomical Society. Each year the Society awards four Foreign Visiting Professorships to distinguished astronomers from overseas. No one can apply for these positions; candidates are nominated by the university or observatory where they will serve for a period of about four months and are paid salary and travel expenses from funds provided by the National Science Foundation. Further information is available from Prof. Thornton Page, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut.

U.S.S.R.

The largest astronomical institutions of the Academy of Sciences and the Ministry of Higher Education have facilities for visiting astronomers from other countries in an exchange programme. The Academy and the Ministry decide on any application, which has to be made through diplomatic channels.

It would be appreciated if directors of observatories in the above list would send corrections or additional details to the President of Commission 38.

Directors of observatories not included in the above list who have fellowships or occasional assistantships available for visiting astronomers are also asked to send details.

PART 2

RESOLUTIONS ADOPTEE

A. PAR L'ASSEMBLEE GENERALE

B. PAR LES COMMISSIONS

RESOLUTIONS ADOPTED

A. BY THE GENERAL ASSEMBLY

B. BY COMMISSIONS

RESOLUTIONS ADOPTEES

A. PAR L'ASSEMBLEE GENERALE

SOMMAIRE DES DÉCISIONS CONTENUES DANS LE RAPPORT DE L'ASSEMBLÉE GÉNÉRALE

1. *Statuts et Règlements.* Le texte révisé des Statuts et Règlements, tel qu'il a été adopté, se trouve page 476, 6ème Partie.

2. *Structure des Commissions.* Une révision de la structure des Commissions a été adoptée.

3. *Admission de nouveaux Pays.* La décision prise par le Comité Exécutif d'admettre Taiwan comme pays adhérent a été confirmée. Il a été annoncé que le Comité Exécutif avait également décidé d'admettre le Brésil, la Corée du Nord, et la Turquie.

4. *Le Service International des Latitudes.* La résolution soumise par l'Union Géodésique et Géophysique Internationale a été adoptée. Il a été noté que le Comité Exécutif avait accepté l'offre faite par le Conseil Scientifique du Japon d'installer le Bureau Central à Mizusawa sous la direction de M. T. Hattori.

5. *Unité de Cotisation.* Il a été décidé de porter l'unité de cotisation pour les années 1962, 1963 et 1964 de 500 à 600 francs-or.

6. *Budget des Dépenses.* En acceptant le Budget, tel qu'il a été proposé par le Comité des Finances (voir page 39), l'Assemblée Générale a approuvé celles des résolutions financières issues des Commissions, pour lesquelles un financement est prévu. Ces résolutions ne sont pas reproduites ici.

7. *Comité Financier Consultatif.* Il a été décidé de mettre fin à l'existence de ce Comité.

8. *Commissions et Sous-Commissions.* Les décisions suivantes ont été prises:

(*a*) la Commission 3 (Notations) est dissoute;

(*b*) la Commission 14 prend le nouveau nom de "Commission sur les Données spectroscopiques fondamentales";

(*c*) la Commission 28 prend le nouveau nom de "Commission des Galaxies";

(*d*) la Sous-Commission 29*a* devient la Commission 36 sur "La Théorie des Atmosphères stellaires";

(*e*) toutes les autres Sous-Commissions deviennent des Comités ou des Groupes de Travail de leur Commission principale.

RÉSOLUTION NO. 1

Proposée par le Comité Exécutif

Considérant avec une grande inquiétude certains projets de recherches spatiales qui pourraient compromettre sérieusement les observations astronomiques aussi bien optiques que radioélectriques,

RESOLUTIONS ADOPTED

A. BY THE GENERAL ASSEMBLY

SUMMARY OF DECISIONS CONTAINED IN THE REPORT OF THE GENERAL ASSEMBLY

1. *Statutes and By-laws.* The revised Statutes and By-laws, as adopted, are printed on pages 477 in Part 6.

2. *Structure of Commissions.* A revised structure was adopted for Commissions.

3. *Admission of Countries.* The action of the Executive Committee in admitting Taiwan as an Adhering Country was confirmed. It was announced that the Executive Committee had also admitted: Brazil, North Korea, and Turkey.

4. *The International Latitude Service.* The resolution submitted by the International Union of Geodesy and Geophysics was adopted. It was noted that the Executive Committee had accepted the offer from the Science Council of Japan to set up the Central Bureau at Mizusawa under the directorship of Dr. T. Hattori.

5. *The Unit of Contribution.* It was agreed to increase the unit of contribution for the years 1962, 1963 and 1964 from 500 to 600 gold francs.

6. *Budget of Expenditure.* In accepting the Budget, as proposed by the Finance Committee (see page 39), the General Assembly approved those financial resolutions from Commissions for which provision is made. These resolutions are not repeated here.

7. *Advisory Finance Committee.* It was agreed to discontinue this committee.

8. *Commissions and Sub-Commissions.* It was agreed that:

(*a*) Commission 3 (Notations) be dissolved;

(*b*) Commission 14 be renamed "Commission on Fundamental Spectroscopic Data";

(*c*) Commission 28 be renamed "Commission on Galaxies";

(*d*) Sub-Commission 29 *a* become Commission 36 on "The Theory of Stellar Atmospheres";

(*e*) All other Sub-Commissions become Committees or Working Parties of their main Commissions.

RESOLUTION NO. I

Proposed by the Executive Committee

Viewing with great concern the grave danger that some future space projects might seriously interfere with astronomical observations in the optical as well as in the radio domain,

persuadée qu'un degré de pollution de l'espace, à peine décelable actuellement, pourrait, s'il était durable, se révéler un jour désastreux pour les observations utilisant des techniques perfectionnées,

affirmant qu'aucune collectivité n'a le droit de modifier sensiblement l'espace au voisinage de la Terre, sans un accord international fondé sur une enquête approfondie,

l'Union Astronomique Internationale *insiste* tout particulièrement pour que soient pris en considération les progrès futurs de l'astronomie, qu'il y aurait de graves inconvénients moraux et matériels à perdre de vue,

et *demande* instamment à tous les gouvernements engagés dans les expériences spatiales qui pourraient affecter la recherche astronomique, de prendre l'avis de l'Union Astronomique Internationale avant d'entreprendre de telles expériences et de ne procéder à aucun lancement sans qu'il soit établi d'une manière irréfutable qu'aucun dommage ne peut en résulter pour la recherche astronomique.

RÉSOLUTION NO. 2

Proposée par le Comité Exécutif

L'Union Astronomique Internationale constate avec satisfaction que les plans du projet West Ford ont été annoncés publiquement bien avant l'époque du lancement projeté et que, selon les intentions officielles* du Gouvernement des Etats-Unis, au sujet des expériences suivantes, de tels projets ne seront pas entrepris sans que des assurances suffisantes aient été obtenues qu'elles ne compromettront pas gravement les observations astronomiques.

Cependant, l'Union Astronomique Internationale considère avec la plus grande inquiétude le cas où la ceinture de dipôles qui fait l'objet du projet West Ford serait de longue durée et reste résolument opposée à cette expérience jusqu'à ce que le problème de la permanence ait été clairement exposé dans des publications scientifiques, un délai suffisant étant laissé pour son étude. L'Union Astronomique Internationale reste opposée aux expériences qui pourraient empêtrer les développements futurs dans l'astronomie.

S'il peut être prouvé que les dipôles auront une vie courte et que l'expérience ne présente aucun inconvénient, et si l'expérience West Ford est entreprise, l'Union Astronomique Internationale considère comme essentiel que les observations et les expériences les plus complètes sur les propriétés et le comportement de la ceinture de dipôles soient entreprises par tous les moyens possibles. Ces observations et ces expériences devront être exécutées et analysées au niveau scientifique le plus élevé et avec le meilleur équipement disponible, en considérant que des signaux à peine, ou non, décelables aujourd'hui pourraient compromettre gravement les recherches entreprises dans la suite avec des moyens de sensibilité accrue.

Il est probable que ces observations et ces expériences seront difficiles à exécuter, et seront à maints égards identiques à celles que les autorités responsables du projet entreprendront à l'occasion de l'opération West Ford. En outre, beaucoup de données, telles que des éphémérides précises et tenues à jour, seront nécessaires. L'Union Astronomique Internationale s'efforcera d'organiser une coopération rapide et efficace entre les observateurs et les calculateurs, et d'assurer la diffusion mondiale de leurs résultats conformément à l'usage en matière de recherche scientifique.

L'Union Astronomique Internationale apprend avec satisfaction que les décisions* du Gouvernement des Etats-Unis, relatives aux expériences ultérieures du type West Ford, seront

* Lettre du 11 août 1961, du Dr. J. B. Wiesner au Dr. L. V. Berkner

and *believing* that a degree of contamination of space which at the present time would be hardly detectable, might, if long-lived, well be disastrous to future observations with improved techniques,

and *maintaining* that no group has the right to change the Earth's environment in any significant way without full international study and agreement;

the International Astronomical Union *gives* clear warning of the grave moral and material consequences which could stem from a disregard of the future of astronomical progress,

and *appeals* to all Governments concerned with launching space experiments which could possibly affect astronomical research to consult with the International Astronomical Union before undertaking such experiments and to refrain from launching until it is established beyond doubt that no damage will be done to astronomical research.

RESOLUTION NO. 2

Proposed by the Executive Committee

The International Astronomical Union expresses its appreciation that the plans for Project West Ford have been publicly announced well ahead of proposed launching and of the United States Government's official policy* that further launchings will be guided by the principle that such projects shall not be undertaken unless sufficient safeguards have been obtained against harmful interference with astronomical observations.

Nevertheless the International Astronomical Union views with the utmost concern the possibility that the band of dipoles proposed in Project West Ford might be long-lived, and it is completely opposed to the experiment until the question of permanence is clearly settled in published scientific papers with adequate time being allowed for their study. The International Astronomical Union is opposed to any experiment which might hamper future developments in astronomy.

If a short lifetime for the dipoles and the harmless nature of the experiment can be assured, and if Project West Ford is carried out, the International Astronomical Union regards it as essential that the fullest observations of, and experiments on, the properties and behaviour of the band of dipoles be carried out by all possible means. The observations and experiments should be performed and analysed according to the highest scientific standards and with the best equipment available, bearing in mind that signals which are barely, or not, detectable today will probably cause serious interference with future scientific research because of the development of more sensitive equipment.

The observations and experiments to be made on West Ford are likely to be difficult to perform, and will, in many ways, be similar to those carried out by the authorities responsible for operating West Ford. Moreover, much specific information such as precise and up-to-date ephemerides will be required. The International Astronomical Union will attempt to arrange for rapid and full co-operation among astronomers making observations and calculations, and to provide for world-wide dissemination of their results conforming to accepted standards of scientific research.

The International Astronomical Union welcomes the position* taken by the Government of the United States that any decision on later experiments of the West Ford type will be taken in

* Letter of August 11, 1961, from Dr. J. B. Wiesner to Dr. L. V. Berkner

prises à la lumière des résultats de l'expérience actuellement en projet. Pour lui permettre de réunir les données nécessaires, l'Union Astronomique Internationale prie le Gouvernement des Etats-Unis de donner tous pouvoirs à un groupe d'astronomes agréé à la fois par le Gouvernement et par l'Union, pour coopérer avec les autorités West Ford en vue de déterminer par des expériences quantitatives les propriétés de la ceinture de dipôles, ses variations dans le temps et l'espace, et ses répercussions sur les recherches astronomiques présentes et futures.

RÉSOLUTION NO. 3

Soumise par l'UIGG et proposée par la Commission 19

L'Union Géodésique et Géophysique Internationale

Recommande

(1) qu'un accroissement des ressources financières du Bureau Central du Service International des Latitudes (SIL) soit fait,

(2) que les Stations du Service des Latitudes de l'hémisphère Nord continuent leur activité avec les instruments actuels et en apportant quelques améliorations à leur équipement, parce que la nécessité de coordonnées précises du pôle, à la fois pour les buts astronomiques et géodésiques, est plus grande que jamais,

(3) que le SIL soit réorganisé en un Service International du Mouvement du Pôle, qui utilisera à la fois les observations d'heure et de latitudes faites aussi bien dans les stations indépendantes que dans celles du SIL,

(4) qu'un groupe de travail restreint soit créé initialement pour établir un plan définitif pour l'organisation de la coopération internationale dans l'étude du mouvement du pôle et ensuite pour diriger le travail dans l'avenir. Le groupe devra soumettre à l'UAI des recommandations concernant l'emplacement futur du Bureau Central du SIL (à devenir SIMP),

(5) que l'on publie les coordonnées du pôle sous la forme

$$x = x_0 + x_1,\ y = y_0 + y_1$$

où x et y sont les coordonnées du pôle calculées à partir de latitudes moyennes initiales fixes, et x_1 et y_1 sont les coordonnées calculées à partir de la latitude moyenne de l'époque. Les coordonnées du pôle moyen de l'époque sont x_0 et y_0.

(6) que les résultats obtenus avec les instruments du SIL et avec les instruments indépendants soient publiés en détail aussitôt que possible,

(7) que les problèmes suivants soient pris en considération:

(*a*) réduction à un système uniforme et analyse soigneuse des données du SIL;

(*b*) élaboration de critères pour définir la précision des observations de latitude, et comparaison, sur la base de ces critères, des observations faites avec les différents instruments,

(8) que le champ de densité de l'atmosphère en altitude soit étudié au-dessus de chaque station, pour fixer l'ordre de grandeur des réfractions accidentelles, et qu'au moins une telle étude soit faite lors du choix d'un emplacement nouveau,

(9) que par des mesures appropriées l'équilibre de température entre l'instrument et l'air de l'abri soit assuré, et que les propriétés intrinsèques de l'instrument, pour en dépister les défauts optiques ou mécaniques, soient étudiées,

the light of the results obtained from the presently proposed experiment. To enable the International Astronomical Union to obtain the necessary data, it requests the Government of the United States to grant full privileges to a group of astronomers, acceptable both to the Government and to the Union, to co-operate with West Ford authorities in performing quantitative experiments to determine the properties of the proposed belt of dipoles, its changes with time and location, and its impact upon present and future astronomical research.

RESOLUTION NO. 3

Submitted by IUGG and proposed by Commission 19

The International Union of Geodesy and Geophysics:

Recommends

(1) that an increase be made in the financial resources of the Central Bureau of the International Latitude Service (ILS),

(2) that the northern ILS stations should continue in operation with the present instruments, and with some improvement in their equipment, due to the fact that the need for accurate polar co-ordinates for both astronomical and geophysical purposes is greater than ever before,

(3) that the ILS be reorganized into an International Polar Motion Service utilizing both time and latitude observations made at both independent and ILS stations,

(4) that a small working group be created initially to establish a definite plan for the organization of international co-operation in the study of polar motion and then to direct the work in the future. The group should submit to the IAU recommendations concerning the future location of the Central Bureau of the ILS (to become IPMS),

(5) that the co-ordinates of the pole shall be given in the following forms:

$$x = x_0 + x_1,\ y = y_0 + y_1,$$

where x and y are computed using fixed initial latitudes and x_1 and y_1 are computed using the mean latitude of epoch. The co-ordinates of the mean pole of epoch are x_0 and y_0.

(6) that results obtained with the ILS and independent instruments should be published in detail as soon as practicable,

(7) that the following problems should be investigated further:

(*a*) reduction to a uniform system, and careful analysis of the data of the ILS,

(*b*) elaboration of criteria for the precision of latitude observations and comparison, by means of these criteria, of observations made with different instruments,

(8) that the density field in altitude of the atmosphere above each station should be studied in order to fix the order of magnitude of accidental refraction, and that as a minimum one such study be made when choosing a new location,

(9) that the necessary measures be taken to assure equilibrium in temperature between an instrument and the air of the shelter, and that the intrinsic properties of the instrument should be studied to avoid optical and mechanical faults,

(10) que l'on procède à une étude de détail du champ de pesanteur local, pour en déceler les anomalies éventuelles, chaque fois qu'on aura quelque raison de suspecter des variations anormales de la verticale. Une telle prospection serait utile lorsqu'on se propose de créer une station nouvelle,

(11) qu'un astrolabe soit installé à Mizusawa,

(12) que l'Observatoire de Quito mette en service l'astrolabe qui y a été envoyé et que l'Observatoire entreprenne la détermination de l'heure et de la latitude et l'observation d'étoiles fondamentales,

(13) que deux autres astrolabes soient installés dans l'hémisphère Sud, pour l'étude du mouvement du pôle, de préférence dans des observatoires déjà équipés d'instruments d'astronomie de position, et encourage le projet de l'Observatoire National du Chili d'installer un de ces appareils à Santiago,

(14) que l'Observatoire de La Plata installe un PZT sur la même latitude que celle de Mount Stromlo,

note

avec satisfaction l'assurance donnée par le Professeur Cassinis que l'activité de la station de latitude de Carloforte continuera, et souligne l'importance de cette station,

et *recommande*

que l'Union Astronomique Internationale considère l'adoption de cette résolution.

RÉSOLUTION NO. 4

Proposée par la Commission 14

Considérant que l'angström est égal à 10^{-10} mètre avec une précision aussi grande que celle avec laquelle il a été réalisé par la raie rouge du cadmium, et que, d'autre part, le mètre est maintenant défini avec une plus grande précision par la radiation $2p_{10}$-$5d_5$ du krypton 86

l'Assemblée générale *décide*, pour autant que les autres Unions représentées dans la Commission Triple de Spectroscopie soient d'accord, que

(1) l'angström est défini comme étant égal à 10^{-10} mètre,

(2) la définition de l'angström en vigueur depuis 1907, fondée sur la raie rouge du cadmium, est abrogée.

RÉSOLUTION NO. 5

Proposée par le Comité Exécutif

Considérant qu'il est impossible d'accorder un examen particulier à chaque résolution adoptée par chacune des 58 Commissions et Sous-Commissions, et ayant pleine confiance dans ses Commissions,

cette Assemblée générale désire donner *son accord* aux résolutions adoptées par ses Commissions individuelles,

et *recommande* que les astronomes les rendent effectives dans toute la mesure de leurs possibilités.

(10) that a detailed study of the local gravity field should be made to reveal the anomalies whenever there are reasons to suspect abnormal variations of the vertical. Such a study would be useful when a new station is created.

(11) that an astrolabe be installed at Mizusawa,

(12) that the Observatory of Quito should place in service the astrolabe that has been sent there, and that the Observatory should undertake the determination of time and latitude and the observations of fundamental stars,

(13) that two other astrolobes should be installed in the southern hemisphere for the study of polar motion, preferably in observatories already equipped with position-measuring instruments, and heartily endorses the plan of the National Chilean Observatory to install an astrolabe in Santiago,

(14) that the La Plata Observatory establish a PZT at the same latitude as that of Mount Stromlo,

notes

with satisfaction the assurance given by Professor Cassinis that the activity of Carloforte latitude station will be continued, and stresses the importance of this station,

and *recommends*

that the International Astronomical Union consider the adoption of this Resolution.

RESOLUTION NO. 4

Proposed by Commission 14

Considering that the angstrom is equal to 10^{-10} meter with an accuracy as great as that with which it has been realized in terms of the red line of cadmium and that, on the other hand, the meter now is defined with a great accuracy in terms of the $2p_{10}$-$5d_5$ radiation of krypton 86

the General Assembly *decides*, subject to agreement by the other Unions represented in the Triple Commission for Spectroscopy, that

(1) the angstrom is defined as being equal to 10^{-10} meter,

(2) the definition of the angstrom in force since 1907 based on the red line of cadmium is revoked.

RESOLUTION NO. 5

Proposed by the Executive Committee

Considering the impracticability of giving individual attention to every resolution adopted by each of its 58 Commissions and Sub-Commissions, and having full confidence in its Commissions,

this General Assembly wishes to give its *endorsement* to the resolutions adopted by its individual Commissions,

and *recommends* that astronomers give effect to these resolutions in so far as they are able.

B. PAR LES COMMISSIONS ET SOUS-COMMISSIONS

Parmi les résolutions et recommandations adoptées par les Commissions et Sous-Commissions, seules sont reproduites ici celles qui présentent un vaste intérêt et s'adressent à une large audience; les autres peuvent être trouvées dans les Comptes-Rendus de réunions, auxquels nous renvoyons. Là où ils sont donnés, les numéros des résolutions sont ceux utilisés dans les Comptes-Rendus.

Commission 4—voir page 167. (Voir aussi Commission 31.)

2. La valeur provisoire du temps des éphémérides, obtenue en comparant la longitude moyenne de la Lune résultant d'observations rapportées à l'équinoxe du FK 4, avec les positions données par l'*Improved Lunar Ephemeris* est appelée T.E.O. La différence T.E.O.—T.U.2 est appelée ΔT_0.

Commission 5—voir page 168.

Au sujet de la réédition du répertoire *Les Observatoires astronomiques et les Astronomes*, la Commission 5 propose de former un groupe de travail composé du Président de la Commission 5 et de MM. Bourgeois et Dimitroff pour coordonner aussi efficacement que possible les efforts de tous ceux qui travaillent dans ce domaine. La Commission 5 prie le Secrétaire Général de l'Union d'adresser aux représentants des divers pays la demande de bien vouloir se charger de rassembler et de vérifier les données nécessaires.

La Commission 5 rappelle à tous les observatoires et toutes les institutions qui publient des travaux astronomiques qu'ils sont priés d'envoyer régulièrement deux exemplaires de leurs travaux à la direction du *Referativny Journal* (Moscou), de l'*Astronomischer Jahresbericht* (Heidelberg), et du *Bulletin signalétique du CNRS* (Paris), afin de faciliter les travaux de ces revues bibliographiques et de leur permettre une analyse exhaustive des publications existantes.

Commission 7—voir page 173.

La Commission 7 recommande l'emploi d'une notation unifiée pour le champ de gravitation terrestre (les détails ne sont pas donnés ici).

Commission 8—voir page 178.

Commission 10—voir page 189.

La Commission 10, considérant le vœu exprimé par le Comité International de Géophysique et par d'autres organisations, d'une coopération mondiale en géophysique, demande avec insistance à tous les observateurs actifs dans la surveillance du Soleil de signaler rapidement au Centre d'Alerte Régional le plus proche (par télégramme ou par tout autre procédé rapide) toutes les éruptions d'importance 1+ (et plus importantes) pendant les prochaines périodes d'activité solaire en diminution, et spécialement pendant l'Année Internationale du Soleil Calme (AISC).

Sous-Commission 10 *a*—voir page 191.

La Sous-Commission note avec satisfaction l'efficacité de la coopération dans la surveillance du Soleil, réalisée sous l'égide de l'AGI et du CIG-1959, et la collaboration continue de nombreuses stations d'observation pour une étude cinématographique exhaustive des éruptions et pour une centralisation des données. La Sous-Commission note aussi la demande accrue de

B. BY COMMISSIONS AND SUB-COMMISSIONS

Of the Resolutions and Recommendations adopted by Commissions and Sub-Commissions only those of wide interest and appeal are repeated here; the others may be found in the Reports of Meetings to which reference is made. The numbers of the Resolutions, where given, are those used in the Reports.

Commission 4—see page 167. (See also Commission 31.)

2. The provisional value of ephemeris time that is obtained by comparing the Moon's mean longitude, given by observations, referred to the equinox of FK 4, with the positions tabulated in the *Improved Lunar Ephemeris* is denoted by E.T.O. The difference E.T.O.—U.T.2 is denoted by ΔT_0.

Commission 5—see page 168.

Concerning the proposed new edition of *Les Observatoires astronomiques et les Astronomes*, Commission 5 intends to form a Working Group, consisting of the President of the Commission, Professor P. Bourgeois and Dr G. Z. Dimitroff, to co-ordinate as efficaciously as possible the efforts of all working in this field. It calls on the General Secretary of the Union to request representatives from different countries to make themselves responsible for the assembly and verification of the necessary data.

Commission 5 reminds all observatories and institutions which publish astronomical works that they have been requested to send regularly two copies of each publication to the editors of the *Referativny Journal* (Moscow), of the *Astronomischer Jahresbericht* (Heidelberg), and of the *Bulletin signalétique du CNRS* (Paris), in order to facilitate the preparation of these bibliographical periodicals and to ensure an exhaustive analysis of existing publications.

Commission 7—see page 173.

Commission 7 recommends a unified notation for the Earth's gravitational field; details are not repeated here.

Commission 8—see page 178.

Commission 10—see page 189.

Commission 10, considering the wish expressed by the Comité International de Géophysique and other organizations for world-wide co-operation in geophysics, urges all observers active in the solar patrol to report promptly to the nearest Regional Warning Centre, by telegram or other available fast channel, all flare events of importance 1+ and greater, during the coming years of declining solar activity and especially during the International Year of the Quiet Sun (IQSY).

Sub-Commission 10 *a*—see page 191.

The Sub-Commission notes with satisfaction the effectiveness of the co-operative solar flare patrols of the IGY and the IGC-1959, and the continued co-operation of many observing stations in voluntary cinematographic flare coverage and data centralization; the Sub-Com-

données précises relatives aux éruptions solaires, et d'une surveillance des autres phénomènes à début brusque observables en Hα, pendant la période de l'AISC et durant le minimum de l'activité solaire; la Sous-Commission recommande par suite la poursuite des efforts en vue d'une étude complète des éruptions et du disque, par une coopération internationale. La Sous-Commission note en particulier l'importance qu'il y a à combler les principaux temps morts grâce au renforcement de la surveillance continue exercée de Chine, d'U.R.S.S., d'Inde, d'Amérique Latine et des régions orientales de l'Amérique du Nord; elle recommande de plus la préparation par les Centres Mondiaux de Données d'un catalogue complet des films disponibles aux différentes stations.

La Sous-Commission recommande la préparation par les Centres Mondiaux de Données d'un catalogue, établi d'une façon coopérative, pour les enregistrements issus des radio-télescopes solaires à balayage de fréquence, couvrant tous les domaines de longitudes, et insiste sur la grande importance, pour la physique solaire, la physique spatiale et les recherches sur les relations Soleil-Terre, de la coopération internationale la plus large possible afin d'assurer le caractère exhaustif de l'ensemble des observations.

Commission 15—voir page 228.

Commission 16—voir page 234.

La Commission 16 recommande l'adoption de conventions dans l'établissement de nouvelles cartes lunaires et de règles pour la nomenclature des différents détails lunaires (les détails ne sont pas reproduits ici).

3. Le comité de la Commission 16, "Coopération Internationale pour l'Observation des Planètes", désire faciliter cette coopération par l'établissement éventuel d'au moins deux centres de documentation, l'un aux Etats-Unis, l'autre en Europe; dans ce but il demande aux observatoires disposant de grandes collections de photographies planétaires de les rendre disponibles pour de telles études, vu la nécessité d'une répartition complète en longitude.

Commission 17—voir page 254.

Commission 20—voir page 262.

Commission 21—voir page 264.

La Commission 21 insiste pour que des chambres susceptibles d'étudier l'ensemble de la voûte céleste soient montées, sans fonctionner, dans toutes les stations d'étude du ciel nocturne même à des latitudes géomagnétiques aussi basses que 30°. Elles devraient être mises en fonctionnement dans les rares occasions où des aurores sont visibles.

Commission 22—voir page 271.

Commission 23—voir page 274.

Commission 24—voir page 278.

La Commission 24 exprime le vœu que le catalogue complet de mouvements propres trouvé dans l'étude générale de mouvements propres de Bruce (Bruce Proper Motion Survey) soit publié in extenso et distribué à tous les observatoires. Jusqu'à présent, ce catalogue n'a été publié que sous une forme miméographée et seulement en tirage limité.

mission also notes the increasing demand for accurate solar flare data and for patrol of other abrupt solar Hα phenomena during the IQSY period, and through the solar activity minimum; the Sub-Commission therefore commends continued efforts towards complete flare and disk coverage on a co-operative international basis; the Sub-Commission notes in particular the importance of filling the major time gaps by further patrol coverage from China, the U.S.S.R., India, Latin America and Eastern North America; it further urges preparation by the World Data Centers of a full catalog of films available at co-operating stations.

The Sub-Commission recommends the preparation by the World Data Centers of a co-operative catalog of records of swept-frequency solar radio noise telescopes, covering all longitudes, and emphasizes the great importance to solar physics, space physics, and solar-terrestrial research of the widest possible international co-operation to assure full observational coverages.

Commission 15—see page 228.

Commission 16—see page 234.

Commission 16 recommends conventions for use in compiling new maps of the Moon, and rules for the nomenclature of lunar features; details are not repeated here.

3. The committee appointed by Commission 16 on "International Collaboration for Planetary Observations" desires to facilitate international collaboration on planetary studies by the eventual establishment of at least two data centers, one in the United States and one in Europe; and meanwhile requests observatories having large collections of planetary photographs to make these available for such studies as require a full coverage in longitude.

Commission 17—see page 254.

Commission 20—see page 262.

Commission 21—see page 264.

Commission 21 urges that inactive all-sky cameras be set up at night-sky stations even in geomagnetic latitudes as low as 30 degrees. They should be put into operation on rare occasions when auroras are visible.

Commission 22—see page 271.

Commission 23—see page 274.

Commission 24—see page 278.

Commission 24 expresses the wish that the complete catalog of proper motions found in the Bruce Proper Motion Survey be fully published and distributed to all observatories. The catalog has up to this time been published in mimeographed form and only in a limited edition.

Commission 26—voir page 286.

Dans le Compte-Rendu de la Commission 26, sont reproduites les résolutions adoptées au Symposium No. 17 de l'UAI (Etoiles doubles visuelles).

Commission 27—voir page 289.

Commission 28—voir page 303.

Sous-Commission 29 *c*—voir page 321.

Commission 31—voir page 329. (Voir aussi Commission 4.)

1. La valeur provisoire du temps des éphémérides, obtenue en comparant la longitude moyenne de la Lune résultant d'observations rapportées à l'équinoxe du FK 4, avec les positions données par l'*Improved Lunar Ephemeris* est appelée T.E.O. La différence T.E.O. — T.U.2 est appelée ΔT_0.

3. On recommande le lancement de satellites artificiels de haute altitude qui puissent être utilisés pour les expériences sur le caractère fondamental du temps.

Commission 37—voir page 340.

Commission 40—voir page 354.

4. *Considérant* que l'attribution exclusive de canaux de fréquences pour la radioastronomie est essentielle au développement et au succès de cette branche de l'astronomie; que, pour être efficace, un tel canal, d'une largeur d'au moins 1%, devrait être utilisable dans chaque octave, d'une façon cohérente avec les discussions antérieures se référant à des fréquences particulières; qu'à l'heure actuelle l'attribution à l'échelle mondiale d'un seul canal a été l'objet d'un accord;

la Commission 40 *propose* que toutes les démarches possibles soient entreprises pour inclure la radioastronomie dans l'ordre du jour de la conférence radio extraordinaire de caractère administratif projetée par l'I.T.U. en 1963, et que des dispositions soient prises pour faire à la radioastronomie des attributions de fréquence, approximativement dans chaque octave du spectre, et ce à l'échelle mondiale.

Commission 41—voir page 356.

1. La Commission 41 exprime le vœu de voir les Comités Nationaux d'Astronomie des pays adhérant à l'Union organiser, partout où cela sera possible, des commissions sur l'Histoire de l'Astronomie, afin de coordonner les efforts des chercheurs dans des domaines voisins.

Commission 44—voir page 389.

1. La Commission 44 recommande qu'en sus des projets d'expériences astronomiques spatiales de grand intérêt scientifique qui ont déjà été prévues, attention soit portée au lancement d'une fusée-sonde au voisinage immédiat d'une comète.

Commission 26—see page 286.

In the report of the meeting of Commission 26 are given the resolutions adopted at IAU Symposium No. 17 (Visual Double Stars).

Commission 27—see page 289.

Commission 28—see page 303.

Sub-Commission 29*c*—see page 321.

Commission 31—see page 328. (See also Commission 4.)

1. The provisional value of ephemeris time that is obtained by comparing the Moon's mean longitude, given by observations, referred to the equinox of FK 4, with the positions tabulated in the *Improved Lunar Ephemeris* is denoted by E.T.O. The difference E.T.O.—U.T.2 is denoted by ΔT_0.

3. It is recommended that high-altitude satellites be launched which can be used for experiments concerning the fundamental nature of time.

Commission 37—see page 340.

Commission 40—see page 354.

4. *Considering* that the exclusive allocation of channels for radio astronomy is essential for the successful pursuance of this branch of astronomy; that in order to be effective one such channel, having a width of at least 1%, should be available in every octave consistent with earlier discussion relating to specific frequencies; that at present only one world-wide allocation of a channel has been agreed upon;

proposes that all possible steps be taken to include radio astronomy in the agenda of the proposed extraordinary administrative radio conference of ITU in 1963; and that steps be taken to make allocations for radio astronomy approximately in each octave of the spectrum on a world-wide basis.

Commission 41—see page 356.

1. Commission 41 expresses its desire that the National Committees of Astronomy in countries adhering to the Union should organize, wherever possible, commissions on the History of Astronomy in order to co-ordinate the efforts of scientists in allied fields.

Commission 44—see page 389.

1. Commission 44 recommends that, in addition to the plans for astronomical space experiments of high scientific interest which have been already planned, consideration be given to the launching of a space probe into the close vicinity of a comet.

PART 3

INVITED DISCOURSES

A. BY PROFESSOR J. A. VAN ALLEN

B. BY PROFESSOR M. SCHWARZSCHILD

C. BY ACADEMICIAN V. A. AMBARTSUMIAN

INVITED DISCOURSE A

given to participants in the General Assembly at 16^h15^m on Wednesday 16 August 1961 in the Auditorium of Wheeler Hall on the Berkeley Campus of the University of California by

Professor James A. Van Allen
(*State University of Iowa, Iowa City, Iowa*)

on

DYNAMICS, COMPOSITION AND ORIGIN OF THE GEOMAGNETICALLY-TRAPPED CORPUSCULAR RADIATION

INTRODUCTION

Before presenting his Invited Discourse, Professor Van Allen spoke as follows.

President Oort, Members of the International Astronomical Union, and Guests:

It is a great honor and privilege to participate in your meeting here in Berkeley and to speak on a topic which has a close kinship with solar, planetary and interplanetary astronomy, though it had its beginnings in a terrestrial setting.

Since sending the title of my paper to the General Secretary, I have decided to proceed in exactly the reverse manner to that indicated therein, and thus to discuss first the dynamics, second the composition, and third the origin of the corpuscular radiation, which is found to be temporarily trapped in the geomagnetic field. In this way, I proceed from the better understood to the less-well understood aspects of the subject.

1.1 THE TRAPPING OF ELECTRICALLY CHARGED PARTICLES IN THE FIELD OF A MAGNETIC DIPOLE

In 1896, Birkeland (1908, 1913) undertook the experimental study of the motion of cathode rays under the influence of the magnetic field of a relatively isolated magnetic pole, and then of a magnetic dipole. The proper interpretation of the results obtained in the former case was given by Poincaré (1896) by integrating the equation of motion of a charged particle in the field of a magnetic unipole. The laboratory phenomena produced by Birkeland in the latter case were of a much more complex character. They were suggestive of the large-scale geophysical phenomena of the polar aurorae and inspired Störmer to undertake the detailed theoretical study of the motion of electrically charged particles in the field of a magnetic dipole. This undertaking occupied much of Störmer's professional career (Störmer, 1955).

The equation of motion of an isolated charged particle in a static magnetic field **B** is:

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathbf{p}c}{Ze}\right) = \mathbf{v} \times \mathbf{B}, \tag{1.1}$$

wherein **p** and **v** are the vector momentum and velocity respectively of the particle, Ze is its electrical charge in e.s.u. and may be either positive or negative, and c is the speed of light. The scalar quantity pc/Ze is the magnetic rigidity R of the particle measured in units of electrical potential (ergs per unit charge if B is in gauss and c.g.s. units are used elsewhere; the

value of the magnetic rigidity in volts is found by multiplying its value in c.g.s. units by 300). The scalar magnitudes of $\mathbf{p}$, R and $\mathbf{v}$ are seen to be constants of the motion.

Thus, the differential equation of the spatial trajectory of the particle is

$$\left(\frac{R}{B}\right)\frac{d\mathbf{v}_1}{ds} = \mathbf{v}_1 \times \mathbf{B}_1. \tag{1.2}$$

In equation 1.2 $\mathbf{v}_1$ and $\mathbf{B}_1$ are unit vectors parallel to $\mathbf{v}$ and $\mathbf{B}$ respectively and s is the arc length measured along the trajectory. All particles having the same magnetic rigidity R and a given $\mathbf{v}_1$ at a specified point in a specified magnetic field have identical spatial trajectories. The time rate of traversal of the trajectory is proportional to v. The general relationship among magnetic rigidity, momentum, velocity and kinetic energy E is:

$$R \equiv \frac{pc}{Ze} = \frac{m_0c^2}{Ze}\frac{\beta}{(1-\beta^2)^{\frac{1}{2}}} = \frac{(E^2 + 2Em_0c^2)^{\frac{1}{2}}}{Ze}, \tag{1.3}$$

m_0 being the rest mass, m_0c^2 being the rest energy, and β being equal to v/c.

The field of a magnetic dipole M,

$$\mathbf{B} = -\operatorname{grad}\Omega = +\operatorname{grad}\left(\frac{M\sin\lambda}{r^2}\right), \tag{1.4}$$

where $\mathbf{M}$ is in the direction of the negative polar axis of a system of spherical coordinates, r, λ, ω.

For the motion of a charged particle in such a field, Störmer obtained a first integral of equation (1.2) which may be written

$$\sin A = \frac{\cos\lambda}{(r/b)^2} + \frac{2(\gamma/b)}{(r/b)\cos\lambda}, \tag{1.5}$$

In (1.5) A is the angle between the velocity vector of the particle and its projection on the meridian plane through the particle, $b \equiv (ZeM/pc)^{\frac{1}{2}}$ and γ is an arbitrary constant of integration.

Equation (1.5) may be rewritten as follows:

$$\frac{r}{b} = \frac{\cos^2\lambda}{-(\gamma/b) \pm \{(\gamma/b)^2 + \sin A\cos^3\lambda\}^{\frac{1}{2}}} \tag{1.6}$$

It is found that bounded motion is dynamically possible if and only if (neglecting special cases of little practical importance)

$$-\infty < (\gamma/b) < -1.$$

Subject to this condition there are two unconnected regions of possible motion (i.e., r is positive real):

Region I: $r_1 \leqslant r \leqslant r_2$ (Bounded Motion)

Region II: $r \geqslant r_3$ (Unbounded Motion)

Region I, hereafter referred to as the "trapping region", is bounded by two surfaces of revolution about the axis of the magnetic dipole, viz.:

$$\frac{r_1}{b} = \frac{\cos^2\lambda}{-(\gamma/b) + \{(\gamma/b)^2 + \cos^3\lambda\}^{\frac{1}{2}}}, \tag{1.7a}$$

$$\frac{r_2}{b} = \frac{\cos^2\lambda}{-(\gamma/b) + \{(\gamma/b)^2 - \cos^3\lambda\}^{\frac{1}{2}}}, \tag{1.7b}$$

The inner boundary of Region II is the surface of revolution:

$$\frac{r_3}{b} = \frac{\cos^2\lambda}{-(\gamma/b) - \{(\gamma/b)^2 - \cos^3\lambda\}^{\frac{1}{2}}}, \tag{1.7c}$$

The detailed trajectory of a particle can be found only by numerical integration. None-theless equations (1.7*a*, *b*, *c*) provide essential information of a general nature.

Störmer was primarily interested in trajectories from infinity and devoted only brief attention to those lying in Region I. He has published a numerically-calculated case of a bounded trajectory (Störmer, 1907) which will be utilized herein as an example of the general theory. The meridian projection of this trajectory is reproduced in Figure 1.1. It is, of course, understood that there is an accompanying motion in ω which is not discussed here.

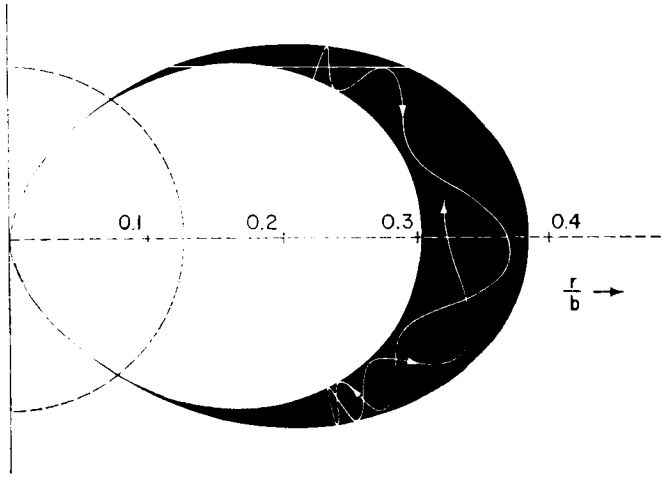


Fig. 1.1. A diagram after Störmer (1907), illustrating the meridian projection of the spatial trajectory of an electrically charged particle in the field of a magnetic dipole and the boundaries of the rigorous trapping region.

In present notation, the case of Figure 1.1 is characterized by the following, using the subscript zero to denote the values of parameters at injection:

$$(\gamma/b) = -1{\cdot}50 \qquad \lambda_0 = 26^\circ\,29'{\cdot}5 \qquad \sin A_0 = +1{\cdot}0000$$
$$(r_0/b) = 0{\cdot}24857 \qquad \cos\lambda_0 = 0{\cdot}89500$$

Hence:

$$\frac{r_1}{b} = \frac{\cos^2\gamma}{1{\cdot}50 + (2{\cdot}25 + \cos^3\lambda)^{\frac{1}{2}}}$$

$$\frac{r_2}{b} = \frac{\cos^2\lambda}{1{\cdot}50 + (2{\cdot}25 - \cos^3\lambda)^{\frac{1}{2}}}$$

$$\frac{r_3}{b} = \frac{\cos^2\lambda}{1{\cdot}50 - (2{\cdot}25 - \cos^3\lambda)^{\frac{1}{2}}}$$

At $\cos\lambda = 0{\cdot}89500$, $(r_1/b) = 0{\cdot}24857$, $(r_2/b) = 0{\cdot}29254$ and $(r_3/b) = 3{\cdot}0597$. Hence the injection conditions satisfy the condition $r_1 \leqslant r \leqslant r_2$ and the particle is assuredly trapped forever thereafter. At the equator ($\lambda = 0°$), $(r_1/b) = 0{\cdot}30277$, $(r_2/b) = 0{\cdot}38197$ and $(r_3/b) = 2{\cdot}6180$. (See Figure 1.1 wherein the linear scale of the diagram is given by $(r/b) = 0{\cdot}1$, etc., on the horizontal axis).

A sample set of physical parameters corresponding to the above case of Störmer is the following:

$$pc = 1{\cdot}548 \times 10^{-3} \text{ erg (966 Mev)}$$

$$Ze = 4{\cdot}80 \times 10^{-10} \text{ e.s.u.} \qquad M = 8{\cdot}06 \times 10^{25} \text{ gauss cm}^3$$

$$b \equiv (ZeM/pc)^{\frac{1}{2}} = 5{\cdot}0 \times 10^9 \text{ cm}$$

$$r_0 = 1{\cdot}243 \times 10^9 \text{ cm} = 1{\cdot}95 \text{ Earth radii}$$

$$A_0 = +90° \qquad \lambda_0 = 26° 29'{\cdot}5$$

$$r_1 \text{ (at } \lambda = 0°) = 1{\cdot}514 \times 10^9 \text{ cm} = 2{\cdot}38 \text{ Earth radii}$$

$$r_2 \text{ (at } \lambda = 0°) = 1{\cdot}910 \times 10^9 \text{ cm} = 3{\cdot}00 \text{ Earth radii}$$

The largest value of r_2 always occurs at the equator $\lambda = 0°$ (for a given A and for $(\gamma/b) < -1$). And when $(\gamma/b) = -1$, r_2 has a larger value than for any more negative value of (γ/b). Hence the extreme outer radial limit of the trapping region is given by

$$r_{2\,\max}/b = 1$$

The corresponding inner limit of r_1 at $\lambda = 0°$ is

$$\frac{r_1}{b} = \frac{1}{1+\sqrt{2}} \frac{r_{2\,\max}}{b} = 0{\cdot}414 \left(\frac{r_{2\,\max}}{b}\right)$$

A convenient form of the first of the immediately preceding two equations as applied to the geomagnetic field is

$$(r_{2\,\max})^2 = \frac{59{\cdot}5\,Z}{pc} \tag{1.8}$$

where $r_{2\,\max}$ in Earth radii (6371 km) is the extreme outer radial limit of the trapping region in the plane $\lambda = 0°$ for a particle of momentum p measured in units of 10^9 ev/c carrying Z electronic charges.

Table 1.1 gives a number of examples found by means of equation (1.8):

Table 1.1

$r_{2\,\max}$ Earth radii	Corresponding r_1 at $\lambda = 0$ Earth radii	$\frac{pc}{Z}$ Mev	E proton Mev	E electron Mev
1·00	0·41	$59{\cdot}5 \times 10^3$	$58{\cdot}6 \times 10^3$	$59{\cdot}5 \times 10^3$
2·00	0·83	14·9	14·0	14·9
4·00	1·66	3·72	2·90	3·72
6·00	2·49	1·65	0·96	1·65
10·0	4·14	0·60	0·173	0·60
15·0	6·21	0·264	0·036	0·264

For the case of isolated non-interacting charged particles moving in the field of a static magnetic dipole in a vacuum, the Störmer theory of trapping has a certain measure of completeness. Given an adequate computational effort the motion of a particle can be found to any degree of detail desired.

Yet if one encloses the dipole by an impenetrable sphere centered on the dipole in an effort to apply the theory to the real geophysical case, one is immediately confronted by an essential question to which (to the author's knowledge) no satisfactory theoretical answer has been given. The question is:

'As a given trapped particle performs latitudinal and longitudinal excursions within the trapping region, is there a minimum radial distance of approach to the dipole r_{min} which can be written in terms of the parameters of the problem?'

A rigorous answer to this question is of course desirable. Even if such does not exist, a quantitative, practical assessment of the matter would be very helpful.

The many published trajectories of Störmer and of others entitle one to the impression, and the hope, that it should be possible to provide an assessment of at least a statistical nature—in the form, for example, that a specified particle has a probability of 0·01 of approaching the dipole to a radial distance less than r_{min} in 10^7 latitudinal excursions. There are four evident modes of attack on the matter:

(*a*) further study of the dynamical problem in the spirit of the work of Störmer and of Lemaitre and Vallarta (Vallarta, 1938) on trajectories of particles coming from infinity, but with attention to the specific problem of trapped particles,

(*b*) a statistical mechanical study (Dresden, 1961),

(*c*) An extensive program of numerical computation using modern techniques,

(*d*) an experimental study.

The early magnetized terella experiments of Birkeland and the more recent ones of Bruche (1932), of Malmfors (1945), of Block (1955), and of Bennett (1959) have provided beautiful experimental exhibitions of trajectories leading from and leading to infinity and of apparently bounded trajectories. Yet due to gas scattering and other technical limitations no definitive quantitative answer to the central question at hand has been provided. Among recent experimental techniques in this field perhaps the one which holds the greatest promise is that of Gibson, Jordan and Lauer (1960). These workers have succeeded in confining positrons from the decay of Ne^{19} within a cylindrical 'magnetic mirror' machine in the laboratory for times of the order of 10 seconds; and since this trapping time was satisfactorily attributed to multiple scattering on the residual gas, it appears that the trapping time in a perfect vacuum must be at least an order of magnitude greater than 10 seconds and might be infinite. Relevant parameters of the experimental arrangement are as follows (derived and estimated from the published account):

Diameter of vacuum chamber:	50 cm
Length of vacuum chamber:	150 cm
Magnetic field in center of chamber:	1300 gauss
Magnetic field at ends:	2340 gauss
Typical Positron Energy:	1 Mev
Typical Positron Magnetic Rigidity:	4740 gauss cm
Diameter of Typical Larmor Circle:	~ 5 cm
Larmor frequency:	$\sim 2 \times 10^9$ sec^{-1}
Mean trapped lifetime:	$\geqslant 10$ sec
Mean number of Larmor periods	$> 2 \times 10^{10}$
Mean number of encounters with mirror:	$> 10^8$ (approx.)
Value of $\rho \lvert \text{grad } B/B \rvert$ in vicinity of mirrors	$\sim 0{\cdot}02$

The quantitative implications of these results will be discussed in Section 1.2.

1.2 THE ALFVÉN APPROXIMATION

The tedium of the straightforward application of the Störmer trapping theory has been greatly reduced in many cases of practical importance by an approximate theory due to Alfvén. The Alfvén approximation provides a notably lucid and simple foundation for visualizing the motion of magnetically trapped particles and for discussing many detailed theoretical matters. Moreover it provides an answer, under certain conditions, to the question posed in the latter part of Section 1.1.

The basis of this theory is paraphrased from Alfvén (1950) as follows. In the case when the path of a charged particle makes many loops in the region of a magnetic field which is of interest, the linear dimensions of one loop are small compared to the dimensions of the region; and during a single turn (in many practical cases) the particle is moving in an approximately homogeneous field. The detailed plotting of the trajectory by numerical methods is often beyond practicality. Moveover such detail may be of little or no interest. Alfvén, therefore, proposes first to calculate the motion in a homogeneous field, then treat the inhomogeneity as a perturbation.

In an homogeneous field the motion of a charged particle is a helical one, composed of a uniform motion parallel to the field **B** and a circular motion in a plane perpendicular to **B**. The center of the instantaneous circle is called the guiding center of the particle's trajectory. Thus the motion of the particle in an homogeneous field may be represented as equivalent to the uniform linear motion of its guiding center parallel to **B**. In the Alfvén approximation, the spiraling particle is regarded as an elementary magnetic dipole (Amperian current loop). The motion of the guiding center is then the motion of this dipole. The scalar value μ of the dipole moment is the product of the area of the particle's loop projected perpendicular to **B** multiplied by the equivalent current flowing in the loop, viz:

$$\mu = (\pi\rho^2)\,(Ze\nu/c)$$

with ρ being the radius of the loop and ν the Larmor frequency. By equation (1.1) the magnetic moment is found to be

$$\mu = \frac{p_\perp^2(1-\beta^2)^{\frac{1}{2}}}{2\,m\,B} \tag{1.9}$$

In (1.9), $p_\perp = p \sin\alpha$, the component of **p** perpendicular to the magnetic field with α the angle between **p** and **B**; $\beta = v/c$ is a constant of the motion; and m is the rest mass of the particle.

In a uniform, time-stationary magnetic field μ is obviously a constant of the motion. Moreover, Alfvén has shown that even in a non-uniform, time-varying magnetic field μ is an adiabatic invariant of the motion provided

$$\rho|\text{grad } B/B| << 1 \tag{1.10}$$

and

$$\frac{1}{B\nu}\left|\frac{\partial B}{\partial t}\right| << 1. \tag{1.11}$$

The precise nature of the conservation of μ is important to its application to the discussion of geomagnetic trapping. This subject is under theoretical study, particularly by those engaged in the study of magnetic confinement in proposed controlled-thermonuclear devices. A crucial question is whether departures from constancy are of such a nature as to lead to loss of particles from a trapped condition within a finite time which may be specified in terms of the parameters of the physical situation. The question is similar to the one posed in the latter portion of Section 1.1. This may be seen as follows:

If indeed μ is constant, then it follows from equation (1.9) that

$$\sin^2\alpha/B = \text{constant} \tag{1.12}$$

On a given line of force (along which the guiding center of a particle moves) B has its minimum value B_0 in the equatorial plane ($\lambda = 0°$). Hence α also has its minimum value α_0 there. The mirror point (or turning point) of the trajectory of the guiding center occurs at such a value of B that $\alpha = \frac{1}{2}\pi$ or

$$B_M = B_0/\sin^2\alpha_0 \tag{1.13}$$

Hence the motion of the guiding center is seen to be one of an oscillatory nature between two conjugate mirror points in opposite hemispheres, the scalar magnitude of B at the two being identical and given by equation (1.13), a result which is independent of the magnitude of the mass, charge or energy of the particle provided that conditions (1.10) and 1.11) are met. The guiding center of the particle also undergoes a monotonic, though non-uniform, drift in longitude which is discussed in a later section.

The rigorous theory of Störmer assures that a particle, once injected into a region in space defined in Section 1.1, will forever execute bounded motion (in the absence of physical perturbation). This condition, of course, continues to apply to the motion as discussed under the Alfvén approximation; that is to say, the motion of the particle is bounded between two known surfaces of revolution. Moreover if μ is strictly conserved the two loci of conjugate mirror points are small circles formed by the intersection of cones, of half angle $\frac{1}{2}\pi \pm \lambda_M$ and having axes parallel to the dipole, with the central curved surface of the Störmer trapping region. To the extent that μ is *not* conserved, the following questions arise:

(*a*) Does the mirror latitude $\pm\lambda_M$ merely oscillate in a regular or in an irregular manner over a bounded finite range λ'_M to λ''_M about a mean value which is obtained from equation (1.13)? If so can the limits of the range λ'_M and λ''_M be specified in terms of the parameters of the physical problem?

(*b*) Or does the mirror latitude move progressively or diffuse away from some initial value λ_{M0} such that after a sufficient number of latitudinal cycles it may have any value between $\frac{1}{2}\pi$ and 0? If so, can there be found a function $P(n, \lambda_M, \lambda_{M0})$ which gives the probability that a mirror latitude λ_M will have been reached after n cycles?

As mentioned earlier, the experiments of Gibson *et al* (1960) and the independent ones of Rodionov (1960) appear to provide the best available quantitative answers at present.

Further discussion of this matter is deferred to a later section. Meanwhile it is supposed that μ is conserved.

1.3 CHARACTERISTIC TIMES IN GEOMAGNETIC TRAPPING

The dynamical motion of geomagnetically trapped particles may be regarded as the composite of three forms of cyclic motion. The first of these, characterized by the Larmor period τ_1, is the circular motion of the particle around its guiding center. The second, with period τ_2, is the cyclic motion of the guiding center between mirror points. The third is the longitudinal drift of the guiding center around the Earth with period τ_3.

Visualization of the motion and of the foundations for discussing departures from a simple quiescent state depend in an essential way on a knowledge of the magnitudes of the respective cyclic periods:

$$\tau_1 = \frac{2\pi mc}{ZeB(1-\beta^2)^{\frac{1}{2}}} \tag{1.14}$$

irrespective of the pitch angle α. At radius r_0 in the plane of the geomagnetic equator, for example,

$$\tau_1 = 1{\cdot}146 \times 10^{-6} \frac{m r_0^3}{Z(1-\beta^2)^{\frac{1}{2}}} \text{ seconds}, \tag{1.15}$$

where m is the rest mass of the particle measured in electron masses and r_0 is measured in Earth radii. For the present purpose it is sufficient to note that the Larmor periods of trapped electrons are in the general range 1 to 1000 micro-seconds and of trapped protons in the general range 2 to 1000 milli-seconds.

$$\tau_2 = 4 \int_0^{\lambda_M} \frac{ds}{v_\parallel} \tag{1.16}$$

with ds the arc length along the line of force followed by the guiding center and $v_\parallel$ the component of velocity of the particle parallel to **B**. As a consequence of equation (1.12),

$$v_\parallel = v(1 - B/B_M)^{\frac{1}{2}}.$$

Hence

$$\tau_2 = \frac{4}{v} \int_0^{\lambda_M} \frac{ds}{(1 - B/B_M)^{\frac{1}{2}}}.$$

Hamlin, Karplus, Vik and Watson (1961) have reduced (1.17) to the form

$$\tau_2 = \frac{4r_0}{v} T(\alpha_0).$$

The dimensionless function $T(\alpha_0)$ increases monotonically from a value of 0·74 at $\alpha_0 = \frac{1}{2}\pi$ to 1·38 at $\alpha_0 = 0$ and is approximated by $T(\alpha_0) \approx 1{\cdot}30 - 0{\cdot}56 \sin \alpha_0$. For the geomagnetic field

$$\tau_2 = 0{\cdot}085 (r_0/\beta) T(\alpha_0) \text{ seconds},$$

with r_0 (in Earth radii) being the equatorial radius of the line of force along which the guiding center oscillates.

Some representative values of τ_2 are given in Table 1.2.

Table 1.2. Period of Latitudinal Oscillation, τ_2 for $r_0 = 2{\cdot}0$ Earth radii and $\alpha_0 = \frac{1}{2}\pi$

Particle	Kinetic Energy	β	τ_2
Electron	10 kev	0·195	0·64 seconds
	100 kev	0·548	0·23
	1 Mev	0·941	0·13
Proton	10 kev	$4{\cdot}61 \times 10^{-3}$	27·3
	100 kev	$1{\cdot}46 \times 10^{-2}$	8·6
	1 Mev	$4{\cdot}61 \times 10^{-2}$	2.7
	10 Mev	0·146	0·86
	100 Mev	0·428	0·29
	1 Bev	0·875	0·14

In addition to the oscillatory motion of the guiding center from one hemisphere to the other, there is a drift in longitude of the guiding center due to the inhomogeneity of the field and to the centrifugal force on the guiding center as it moves along the curved lines of force. The drift rate is a fluctuating function of time but is always in the same sense. The sense is opposite for particles of opposite sign. In the Earth's field, electrons drift toward the east, protons toward the west.

The drift velocity has been obtained by Alfvén and has been discussed further by Spitzer (1956), by Welch and Whitaker (1959), by Northrup and Teller (1960), by Hamlin, Karplus, Vik and Watson (1961) and by Lew (1961). The latter author has put the results into particularly convenient form. The time τ_3 required for one complete drift around the Earth is given by Lew as:

$$\tau_3 = 172{\cdot}4 \frac{1 + \epsilon}{\epsilon(2 + \epsilon)} \frac{1}{mr_0} \frac{G}{F} \text{minutes.} \tag{1.17}$$

In (1.17) $\epsilon = (1 - \beta^2)^{-\frac{1}{2}} - 1$ is the ratio of kinetic energy of the particle to its rest energy, m is the rest mass of the particle in units of the rest mass of the electron, r_0 is the equatorial radius of the line of force along which the guiding center is moving in units of the Earth's radius and G/F is the ratio of the drift period of particles mirroring at λ_M to that for particles mirroring at $\lambda_M = 0$. G/F is of the order of unity and is a function of λ_M only. It is tabulated in Table 1·3 and plotted in Figure 1.2.

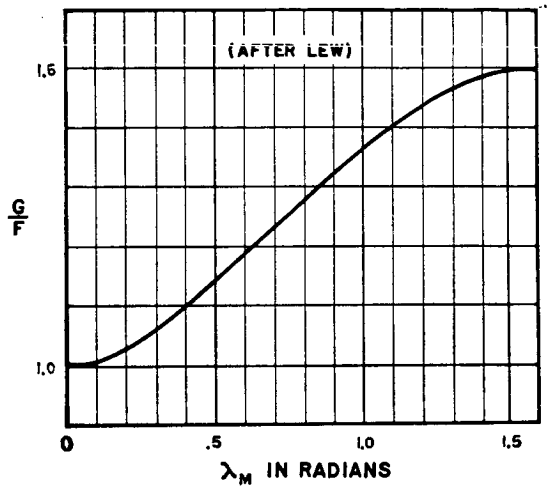


Fig. 1.2. The function G/F (after Lew) vs. mirror latitude used with Figure 1.3 in finding the longitudinal drift function.

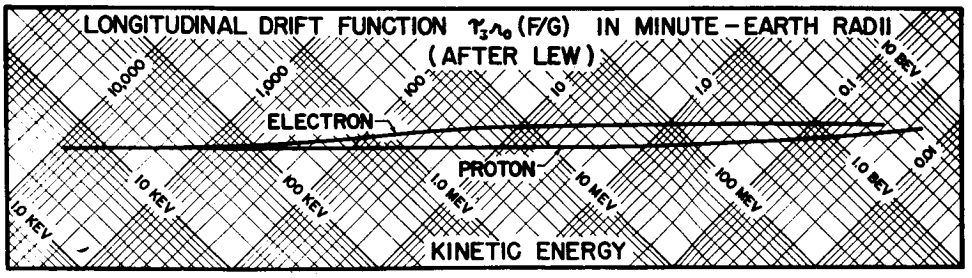


Fig. 1.3 A diagram for finding the longitudinal drift period τ_3 for electrons and protons of various energies on magnetic shells cutting the equator at radial distance r_0.

Figure 1.3 shows the 'longitudinal drift function' $r_0\tau_3 F/G$ as a function of kinetic energy for electrons and protons. As remarked by Lew, the longitudinal drift period for an electron is

always greater than that for a proton of the same kinetic energy but never more than by a factor of two.

Table 1.3. (after J. S. Lew)

λ_M	G/F	λ_M	G/F
radians		radians	
0·0	1·000	1·0	1·366
0·1	1·007	1·1	1·406
0·2	1·028	1·2	1·440
0·3	1·060	1·3	1·467
0·4	1·098	1·4	1·487
0·5	1·141	1·5	1·498
0·6	1·186	$\frac{1}{2}\pi$	1·500
0·7	1·232		
0·8	1·278		
0·9	1·323		

1.4 LARMOR RADII OF TRAPPED PARTICLES

It is often convenient in considering perturbations of trapped particles to have ready reference to the magnitudes of Larmor radii of protons and electrons of various energies in the Earth's field. Hence a brief summary is included in this section. It follows from equation (1.1) that

$$\rho = \frac{p_\perp c}{eB} = \frac{pc \sin \alpha}{eB}, \tag{1.18}$$

with e in electrostatic units, pc in ergs, ρ in centimeters and B in gauss. For a given momentum particle, ρ is proportional to sin α.

For the purposes of obtaining representative numerical values, equation (1.18) is specialized to the geomagnetic equator and to $\alpha = \frac{1}{2}\pi$:

$$\rho = 107{\cdot}0\, r_0^3\, pc \quad \text{meters} \tag{1.19}$$

In (1.19) r_0 is measured in Earth radii and pc in Mev. Sample values are given in Table 1.4.

Table 1.4. Radii of Curvature in Earth's Field

($\lambda = 0$, $\alpha = \frac{1}{2}\pi$, $r_0 = 2{\cdot}0$)

Particle	Kinetic Energy	pc	ρ
Electron	10 kev	0·102 Mev	87 meters
	100 kev	0·335 Mev	287 meters
	1 Mev	1·422 Mev	1·22 km
Proton	10 kev	4·33 Mev	3·71 km
	100 kev	13·70 Mev	11·7 km
	1 Mev	43·3 Mev	37·1 km
	10 Mev	137·4 Mev	118 km
	100 Mev	444·5 Mev	381 km
	1 Bev	1695 Mev	1451 km

2.1 THE ROLE OF ADIABATIC INVARIANTS IN GEOMAGNETIC TRAPPING

There are three adiabatic invariants of trapped particle motion associated respectively with the three classes of cyclic motion discussed above.

The first is the Alfvén magnetic moment μ. A special consequence of the conservation of μ is that the locus of the mirror points of a particle's motion lies on a surface of constant scalar $B\,(=B_{\mathrm{M}})$.

The second is often called the longitudinal integral invariant. It is the action integral of the oscillating motion of the guiding center between mirror points, viz:

$$\mathcal{J} = \int_{\mathrm{M}}^{\mathrm{M}^*} p_{\parallel}\,\mathrm{d}s, \tag{2.1}$$

the line integral being taken along the magnetic line of force between the mirror point M and its conjugate M*. The conservation of $\mathcal{J}$ was first recognized by Rosenbluth (Northrup and Teller, 1960). It is convenient to rewrite (2.1) as

$$\mathcal{J} = p\int_{\mathrm{M}}^{\mathrm{M}^*} (1 - B/B_{\mathrm{M}})^{\frac{1}{2}}\,\mathrm{d}s$$

and to let

$$I = \frac{\mathcal{J}}{p} = \int_{\mathrm{M}}^{\mathrm{M}^*} (1 - B/B_{\mathrm{M}})^{\frac{1}{2}}\,\mathrm{d}s. \tag{2.2}$$

The quantity I has the dimensions of length, is a property of the magnetic field alone and may be attributed to the mirror point M (or M*). The Rosenbluth principle for the conservation of I makes possible the identification of a unique sequence of segments of magnetic lines of force that constitute a single valued, three dimensional surface (a 'magnetic shell') on which the guiding center of a trapped particle will forever lie—to the extent that the conditions for the conservation of μ and I are met—as it moves about in the irregular geomagnetic field.

The conservation of I is essential to the understanding of trapping in the real, irregular geomagnetic field, which does not possess axial symmetry and for which the Störmer first integral does not exist. The argument is illustrated in Figure 2.1. Let the surface B = constant shown there contain the locus of mirror points for a given particle. Let the motion of the particle's guiding center at a chosen time be along the line of force shown in the right-hand side of the figure with the integral I having the value I_0. The question then is: 'Along which of the infinite number of segments of lines of force having values of $I - I_0, I_1, I_2$, etc. (sketched in the left-hand side of Figure 2.1)—and having mirror points on the specified surface of constant B, will the guiding center of the particle be moving at some later time after a drift in longitude has occurred?' The Rosenbluth principle assures that it will be the segment characterized by I_0.

It is presumed that I ceases to be conserved when there are perturbations in the guiding magnetic field on a time-scale comparable to the period τ_2. Typical, pertinent values of τ_2 are of the order of a fraction of a second. As in the case of the conservation of μ there is no satisfactory quantitative foundation for calculating the rate of change of I under specified circumstances.

The third, and weakest, of the adiabatic invariants is the flux invariant Φ. (Northrup and Teller, 1960). Φ is the total flux of **B** through a surface bounded by a magnetic shell as defined by I = constant. (The computation is made by considering flux in one sense only through the surface). Northrup and Teller show that $\mathrm{d}\Phi/\mathrm{d}t = 0$ if the magnetic field within the region in question does not change significantly during τ_3. It is seen from Figure 1.3 that τ_3 varies over a wide range for electrons and protons of typical energies—say from several

minutes to several days. Hence under actual geophysical circumstances it will not be surprising if Φ is not conserved even though both I and μ may be. Moreover, it appears that the non-conservation of Φ is strongly dependent on particle energy.

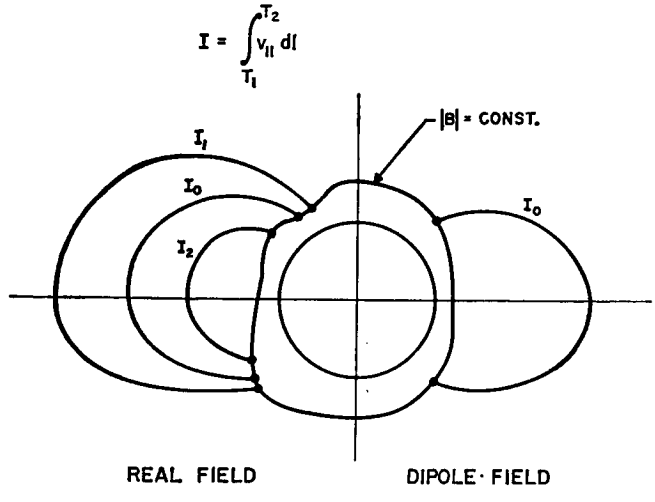


Fig. 2.1. Illustrating the principles of the conservation of the adiabatic invariants μ and I in the geomagnetic field.

The magnitude of τ_3 also gives one a measure of the extent to which a lack of axial symmetry may be expected under time-varying conditions. (Welch and Whitaker, (1959)). For example, if a quantity of electrons having various energies of the order of 100 kev be injected into the field at $r_0 = 3$ Earth radii, $\tau_3 \approx 3$ hours and a time of the order of one day will be required for the establishment of axial symmetry.

In general summary it is clear that the theory associated with the three adiabatic invariants μ, I and Φ and the three corresponding cyclic periods τ_1, τ_2 and τ_3 is essential to understanding not only

(*a*) the time-stationary trapping situation, but also

(*b*) any proposed time-dependent or spatially-dependent perturbation in the real geophysical situation.

2.2 THE NATURAL SYSTEM OF CO-ORDINATES FOR GEOMAGNETICALLY-TRAPPED PARTICLES

One of the problems in the study of the energetic particles which are trapped temporarily in the Earth's magnetic field is to identify the types of particles present, to measure the absolute energy spectrum of each type, and to make such determinations as a function of positional co-ordinates, of direction and of time.

The problem may be formulated succinctly with the help of the following symbols:

j_i —the uni-directional intensity of particles of type i having energies in dE at E.

r, ϕ, θ —the geographic polar co-ordinates of an arbitrary point in the vicinity of the Earth.

l, m, n —the direction cosines of the direction in space being considered.

E —particle kinetic energy.

t —time.

Thus, the problem may be said to be the determination of the functions

$$j_i, (r, \phi, \theta, l, m, n. E, t)$$

where i denotes successively electrons, protons, alpha particles, etc.

The observational task which corresponds directly to this naive formulation of the problem is far beyond human capability. Fortunately, in a time-stationary state the application of the foregoing trapping theory simplifies the observational enterprise immensely, viz:

(*a*) At any point the physical situation possesses cylindrical symmetry about the magnetic field vector **B** and mirror symmetry with respect to the plane perpendicular to **B**. Thus all directions which make an angle α (or $180° - \alpha$) with the magnetic field vector **B** at a specified point are equivalent.

(*b*) Within a given geomagnetic shell as defined by the integral adiabatic invariant I and as labeled by a single parameter L (see later section), the complete positional and angular dependence of j_i is contained within the dependence of j_i on the angle α_0 to the **B** vector at the position within the shell at which **B** has its minimum value (loosely speaking, on the magnetic equator).

Hence the complete observational problem for the time-stationary state is reduced to that of determining

$$j_i (L, \alpha_0, E)$$

Within the physical limitations of their applicability, the two adiabatic invariants μ and I provide a 'natural' system of geomagnetic co-ordinates which is suitable for the collation and comparison of observational data from a wide variety of geographic positions. This system of co-ordinates makes feasible the comprehensive study of large masses of data obtained under quiescent conditions; and, by the same token, it provides the proper foundation for studying time fluctuations.

In a quiescent, unperturbed case of magnetic trapping all particles which mirror on a given surface B = constant will always continue to do so; also the uni-directional intensity within a given magnetic shell $j_i (B, \alpha_0)$ is independent of the magnitude and direction of grad B. Moreover their orbits drift around the Earth on such a sequence of lines of force as to conserve I. As mentioned above this latter principle defines a unique sequence of lines of force comprising a magnetic shell. The B, I co-ordinate system is relatively trivial for an idealized dipole. Nonetheless it is instructive to see the form of the surfaces B = constant and I = constant for a dipole. Several cases are illustrated in Figure 2.2. The B = constant and I = constant surfaces intersect in a system of small circles of various radii with their centers on the dipole axis. Each pair of such surfaces intersects in two such small circles, located respectively in opposite hemispheres.

For a dipole field it is readily shown that

$$I_M = L_M g(\lambda_M), \tag{2.3}$$

where the subscript M refers to quantities pertaining to a given mirror point; λ_M is the latitude of that mirror point; L_M is the radial distance at which the line of force through the mirror point crosses the equator; I_M is the value of the integral adiabatic invariant corresponding to the mirror point; and g is a function which is known explicitly (numerically but not in closed analytical form).

Also

$$\frac{(B_M)}{(B_M)_0} = \frac{(4 - 3\cos^2 \lambda_M)^{\frac{1}{2}}}{\cos^6 \lambda_M}, \tag{2.4}$$

wherein $(B_M)_0$ is the equatorial value of B on the line of force through the mirror point designated by M.

Following McIlwain (1960), it is found from (2.3) and (2.4) that

$$L_M^3 B_M = f(I_M^3 B_M) \tag{2.5}$$

In (2.5) f is a function which has been calculated numerically.

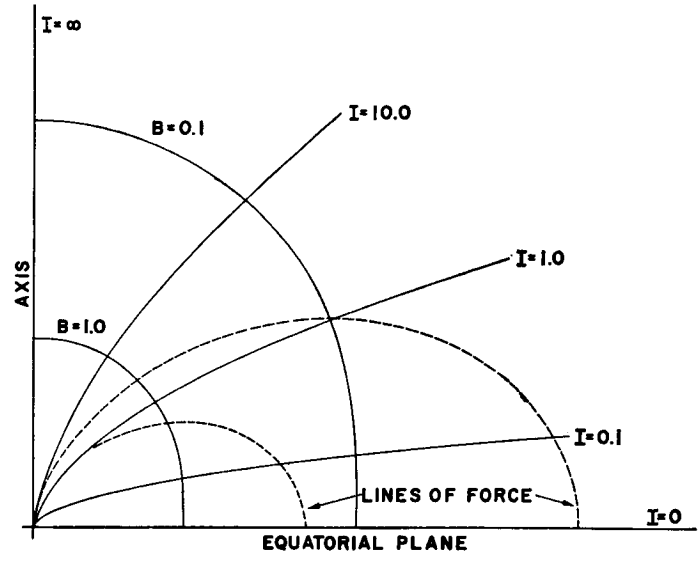


Fig. 2.2. The 'natural co-ordinate system' for trapped particles in an idealized dipole field showing contours of L = constant, B = constant and I = constant.

For the real geomagnetic field, Jensen, Murray and Welch (1960), Vestine (1960) and Vestine and Sibley (1960) have calculated extensive numerical tables of B and I as a function of geographic co-ordinates around the Earth; they have also calculated a large number of lines of force in space. McIlwain (1960) and Ray (1960) have fitted functions of geographic co-ordinates to these numerical tables in forms which are convenient for machine-computer use in labeling the observations obtained with rocket, satellite and space probe equipment.

McIlwain has made a further important advance in the treatment of observational data by utilizing the dipole relation (2.5) to define a single parameter L to characterize a specific magnetic shell in its entirety. He has shown by numerical calculation on the real geomagnetic field that the 'shell parameter' L as so defined (using real field quantities in (2.5)) not only has the same simple (though approximate) physical meaning as for the dipole case but is indeed very nearly a constant along a given line of force over a large range of B_M and for all longitudes.

Hence there has now been adopted the co-ordinate system defined by surfaces of constant B and constant L in dealing with the huge body of observations on the geomagnetically trapped radiation. This co-ordinate system has a sound theoretical foundation and, in the hands of McIlwain, Pennington, Vestine, Forbush, Venkatesan, Ray, Welch, Lin, Pizzella, Van Allen and others, is proving of very great power in the study of trapped radiation in both quiescent and disturbed states. It makes possible the ready comparison of diverse observations at diverse points in space and it provides the foundation for the study of time fluctuations and for the discussion of a variety of theoretical aspects such as the lifetime of trapped particles, the consequences of local acceleration processes and the like.

2.3 APPLICATION OF LIOUVILLE'S THEOREM TO THE INTENSITY OF RADIATION TRAPPED IN THE GEOMAGNETIC FIELD

In an unpublished memorandum (1959) Ray has discussed the application of Liouville's theorem on the conservation of density of representative points in phase space to geomagnetically trapped particles. The following two theorems are representative examples of such application:

Theorem 1. If at any point on a particular line of force the directional intensity is isotropic, then along that line of force, in the direction of increasing magnetic field strength, at each point the radiation is isotropic and the omni-directional intensity is independent of position.

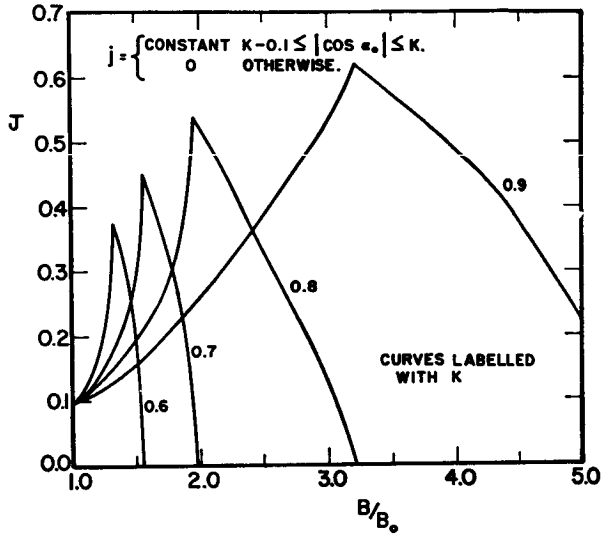


Fig. 2.3. Example of the relationship of angular distribution of uni-directional intensity j at the equator ($B = B_0$) to the omni-directional intensity as a function of B/B_0 for a given magnetic shell. (After E. C. Ray).

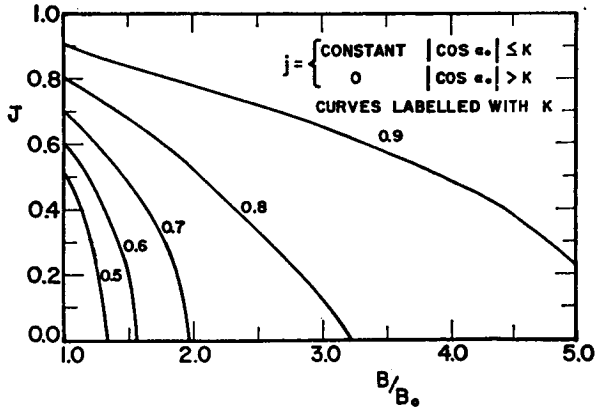


Fig. 2.4 Another example (after E. C. Ray).

Theorem 2. If, in a magnetic field in which the field strength increases as one goes along a line of force in the direction of decreasing radius r, the intensity has cylindrical symmetry about the line of force, and if the directional intensity at one point on a particular line of force increases (decreases) monotonically as the angle to the line of force decreases, the omni-directional intensity increases (decreases) monotonically as one goes to lesser radii along the same line of force.

Ray (1960a) has also solved the following problem in an explicit form which has general applicability to the interpretation of experimental results:

Given: A complete knowledge of the omni-directional intensity $\mathcal{J}_0$ of a given type particle as a function of position (or equivalently as a function of B/B_0) along a given line of force (L = constant).

To find: The angular distribution of the uni-directional intensity j as a function of pitch angle α_0 at the equator, $B/B_0 = 1$.

Assuming the conservation of μ, Ray finds:

$$j(h) = \frac{1}{2\pi^2}\frac{\mathrm{d}}{\mathrm{d}h}\int_0^h m^{\frac{1}{2}}(h-m)^{-\frac{1}{2}}\,\mathcal{J}_0(m)\,\mathrm{d}(m) \tag{2.6}$$

where h is written for $\sin^2\alpha_0$ and m for B_0/B.

2.4 GENERAL REMARKS

It is now abundantly clear that the use of the system of 'natural co-ordinates' described above for the real geomagnetic field provides an immense simplification in interpreting experimental observations. In effect, the data for each magnetic shell (as specified by the parameter L) are dealt with separately. And in fact, since the time-stationary situation has axial symmetry in B, L co-ordinates, the physical situation along a single line of force of given L is taken to be representative of the entire shell to which it belongs. Within that shell α_0 (or if more convenient B, or B/B_0 or λ_N = arc sec $(L/r_N)^{\frac{1}{2}}$) is the only other parameter necessary for a complete specification of the positional and directional characteristics of the radiation.

In addition to aiding the interpretation of the quiescent state, the 'natural co-ordinates' B and L provide the proper basis for the clear recognition of temporal variations and for study of the detailed features of such variations. The SUI laboratory now routinely converts the geographic ephemerides of its various satellites to B, L co-ordinates before attempting analysis.

3.1 DISCOVERY OF THE GEOMAGNETICALLY-TRAPPED RADIATION

The previous sections have given a sketch of the dynamics of geomagnetically-trapped particles. Discusion is now directed to observational knowledge of the actual phenomena.

With the wisdom of retrospection it may well be said that since 1905, or there-abouts, it has been clear that it is physically possible for electrically charged particles to be temporarily trapped in the geomagnetic field. Moreover, the well-known phenomena of the aurorae and geomagnetic storms have led various workers, over the years, to conjecture on the existence of trapped particles. The ring-current hypothesis by Chapman and Ferraro (see Chapman and Bartels, 1940) was of this general nature as were the auroral theories of Alfvén (1950) and Martyn (1951). Large fluxes of electrons having energies in the range of tens of kev were directly observed by the author and his associates in 1952, 1953, 1954 and 1955 by rocket experiments in the Arctic (Van Allen, 1957) at altitudes of 60 to 110 kilometers and in 1957 by further rocket experiments in the Arctic and Antarctic. A similar but much smaller effect

of the same sort was observed by a Geiger tube in Sputnik II in early November 1957 (Vernov, Grigorov, Logachev, and Chudakov, 1958). It was later suggested by these workers that the effect was due to low-energy corpuscles arriving in bursts, presumably from the Sun. Meanwhile Singer (1957) had considered the motion of very low energy trapped electrons ($E \sim 10$ ev) and protons ($E \sim 20$ kev) according to the Alfvén theory and had suggested that the longitudinal drifts of these particles provided the microscopic foundation for the Chapman ring current. During late 1957 and early 1958 Christofilos called attention to the fact that the geomagnetic field would act as a temporary trap for the charged decay products of cosmic-ray-produced neutrons emerging from the atmosphere and he proposed a series of high-altitude atomic bomb bursts for the injection of energetic electrons into the geomagnetic field as an experimental test of this idea. He also gave a detailed theory of the rate of loss of trapped electrons into the atmosphere by multiple scattering. Unhappily all of this work of Christofilos was contained in classified documents and discussion of it was confined to a small segment of the scientific profession. Portions of it were released for publication considerably later (Christofilos, 1959), after successful conduct of the proposed experiments.

The first conclusive evidence for the existence of significant intensities of geomagnetically trapped particles was obtained by the author and his students by means of Geiger tubes flown in the U.S. satellites, Explorers I and III, in early 1958 (Van Allen, 1958), (Van Allen, Ludwig Ray and McIlwain, 1958). The data from these two satellites showed that in the latitude range $\pm 30°$:

(*a*) The intensity of radiation up to some 600 km altitude was in good accord with that to be expected for cosmic rays only, when proper account was taken of the increasing opening angles of geomagnetically allowed cones with increasing altitude and of the concurrent shrinking of the solid angle subtended at the observing point by the solid Earth (Kasper, 1960).

(*b*) Above some 800 km (this transition altitude being longitude and latitude dependent) the intensity of radiation increased very rapidly with increasing altitude in a way totally inconsistent with cosmic ray expectations.

(*c*) At the higher altitudes (~2000 km) the true counting rate of a Geiger tube with a geometric factor of 17·4 cm^2 and with total shielding of about 1·5 g/cm^2 of stainless steel (extrapolated range for electron of energy 3 Mev or range for protons of 30 Mev or 1/e transmission for 75 kev X-rays) exceeded 25 000 counts per second. Hence the omni-directional intensity exceeded 1700 (cm^{2}sec)$^{-1}$ if the radiation consisted wholly of penetrating particles; or it exceeded some 10^8 (cm^{2}sec)$^{-1}$ if the radiation consisted wholly of electrons whose range was less than 1·5 g/cm^2 but whose bremsstrahlung was sufficiently energetic to penetrate the absorber with little attenuation.

These observations were interpreted by the author (Van Allen, 1958) as conclusive evidence for the existence of large intensities of geomagnetically-trapped, electrically-charged particles, on the following grounds:

(*a*) The amount of atmosphere surmounted in the altitude range say 600 to 1200 km was less by many orders of magnitude than the wall thickness of the counter. Hence the great increase in intensity with increasing altitude could not have been due to the progressive decrease of atmospheric absorption but must have been due to mechanical constraint of the radiation—specifically by the geomagnetic field. Hence the primary radiation being detected must have consisted of electrically-charged particles.

(*b*) The charged particles in question could not have been coming from a source remote from the Earth by direct Störmer trajectories. For it would have required an inconceivably well-adjusted particle momentum to have produced this altitude dependence even at a

single latitude; and even if this had been so at, say, the equator, the particles arriving at slightly higher latitudes would have reached down to much lower altitudes—contrary to the observations.

(*c*) It was also regarded as quantitatively inconceivable that the radiation being detected was arriving directly from a distant source (e.g., the Sun) and was penetrating so deeply into the geomagnetic field near the equator in the form of neutral, ionized gas; and even if it were that it would be doing so at a rate which was independent of time.

3.2 THE SCOPE OF OBSERVATIONAL STUDY OF THE GEOMAGNETICALLY-TRAPPED RADIATION

The general nature of the observed results of the Iowa group was soon confirmed by two types of apparatus in Sputnik III, which was launched on 15 May 1958. One piece of apparatus was a shielded, cylindrical Na I scintillation crystal (40 by 39 mm in size) mounted on a photo-multiplier tube. The counting rate of pulses corresponding to energy loss greater than 35 kev was telemetered, as was also the quasi-d.c. current to the anode and to the 7th dynode of the photo-multiplier tube (Vernov, Vakulov, Gorchakov, Logachev and Chudakov, 1958). The second set of apparatus comprised two thin ZnS (Ag actuated) (thickness 2 mg/cm^2) fluorescent screens covered with aluminum foils of thickness 0·8 and 0·4 mg/cm^2 respectively and also mounted on photo-multiplier tubes. (Krassovsky, Shklovsky, Galperin and Svetlitskiy, 1959). The inclination of the orbit of Sputnik III was 65° and the initial altitudes of perigee and apogee were 217 and 1878 km, respectively. The high intensity of radiation in the equatorial region was confirmed, a stripe of radiation in excess of the cosmic ray level was traversed in sub-auroral latitudes, and absolute intensities of a tentative nature were presented. The first American satellite to carry a system of radiation detectors designed with prior knowledge of the existence and approximate intensity and nature of the trapped radiation was Explorer IV, launched on 26 July 1958 into a 51° inclination orbit with initial perigee and apogee altitudes of 262 and 2210 kilometers. The apparatus designed and built by the Iowa group comprised two small Geiger tubes having different shielding, a small disk of plastic scintillator on a photo-multiplier tube for pulse counting and a small Cs I detector, covered by a 1 mg/cm^2 foil and also mounted on a photo-multiplier tube for energy flux measurement. This apparatus operated for about eight weeks and yielded an enormous amount of data as recorded on over 4000 passes by a world-wide network of receiving stations. Much of the data is still under study though several major papers have been published. (Van Allen, McIlwain and Ludwig 1959, 1959a), (McIlwain and Rothwell, 1959), (Ray, 1960), (Rothwell and McIlwain, 1959), Rothwell and McIlwain, 1960), (McIlwain, 1961). Subsequent U.S. satellites and space probes which have been devoted in part at least to study of the geomagnetically trapped radiation are the following, with launching data in parentheses: Explorer VI (7 August 1959); Explorer VII (13 October 1959); Injun (29 June 1961); Pioneer I (11 October 1958); Pioneer II (8 November 1958); Pioneer III (6 December 1958); Pioneer IV (3 March 1959); Pioneer V (11 March 1960); and a variety of smaller rockets and auxiliary scientific packages carried by military test rockets. Packages of emulsions on some of the flights in the latter category have been recovered. The longest term series of observation is that by Explorer VII; some 1 500 000 workable data points have been obtained over a sixteen month period. U.S.S.R. investigators have flown radiation measuring equipment on two deep space probes: Cosmic Rocket I (2 January 1959) and Cosmic Rocket II (2 September 1959), but have not reported any further satellite measurements in this field since Sputnik III (15 May 1958).

Thus, there is now a large body of observational knowledge concerning energetic corpuscular radiation around the Earth, obtained with a diversity of techniques. The following sections give a brief summary of what is known about various aspects.

3.3 GEOMETRIC STRUCTURE

For the present purpose the term 'geometric structure' or simply 'structure' is taken to mean the spatial distribution of the omni-directional intensity of a specified component of the trapped radiation. Inasmuch as the radiation is a mixture of protons and electrons (and perhaps other particles) having separate energy spectra which are quite different from each other and which are a function of L, of α_0 and of t, it is necessary to investigate the structure with a variety of detectors of different properties. *A priori*, it might be thought that the structures for different components might be very much different. But in fact there are certain powerful factors of a general nature which greatly reduce the conceivable variety of structures. The factors are as follows:

(*a*) The dominance of the geomagnetic field in controlling the general form of the structure.

(*b*) The dominance of atmospheric scattering and absorption in determining the form of the inner boundary of the intensity structure, near the Earth.

(*c*) The nature of the process of injection of solar gas into the outer portion of the geomagnetic field and the nature of the subsequent 'local acceleration' processes.

(*d*) The geometric character of the injection of particles from 'internal' sources.

In fact a single diagram is found to serve for the purpose of a general account of the subject of structure. Such a diagram was constructed by Van Allen and Frank (1959) on the basis of the extensive low-altitude satellite observations with the variety of detectors in Explorer IV and with the two traversals through the trapping region by Pioneer III. It is shown in Figure 3.1. On the basis of more recent data of Explorers VI and VII to be given later, it appears

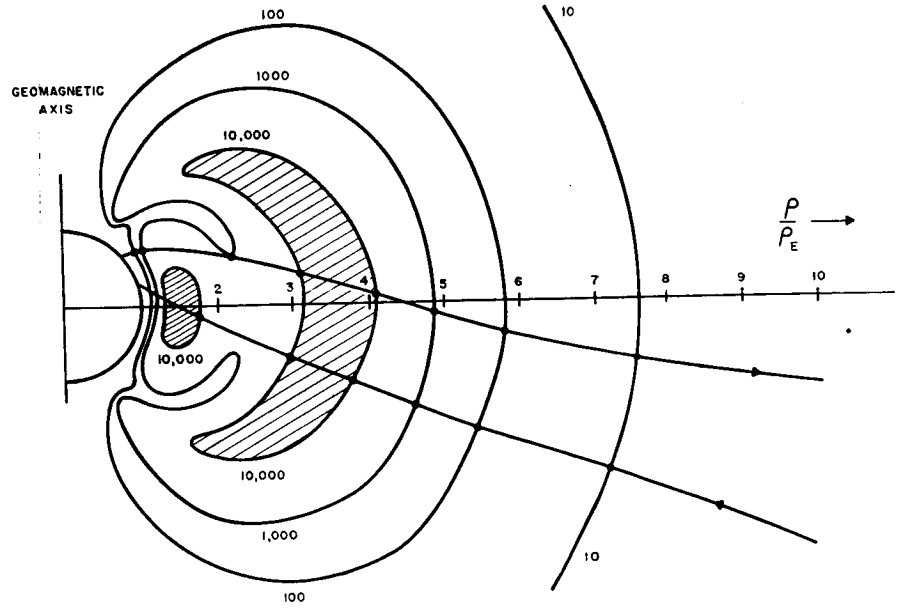


Fig. 3.1. Original diagram of the intensity structure of the trapped radiation around the Earth. The diagram is a section in a geomagnetic meridian plane of a three-dimensional figure of revolution around the geomagnetic axis. Contours of intensity are labeled with numbers, 10, 100, 1000, 10 000. These numbers are the true counting rates of an Anton 302 Geiger tube carried by Explorer IV and Pioneer III. The linear scale of the diagram is relative to the radius of the Earth—6371 km. The outbound and inbound legs of the trajectory of Pioneer III are shown by the slanting, undulating lines (after Van Allen and Frank).

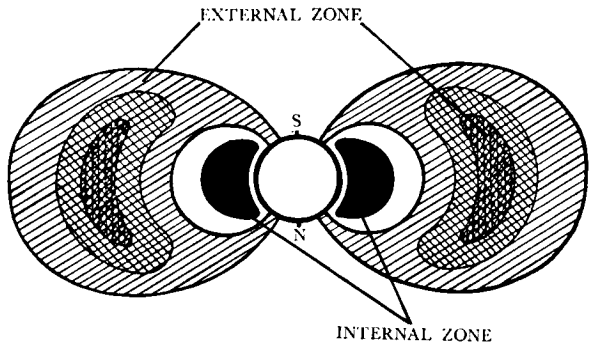


Fig. 3.2 A diagram of the same nature as Figure 3.1 (after Vernov and Chudakov).

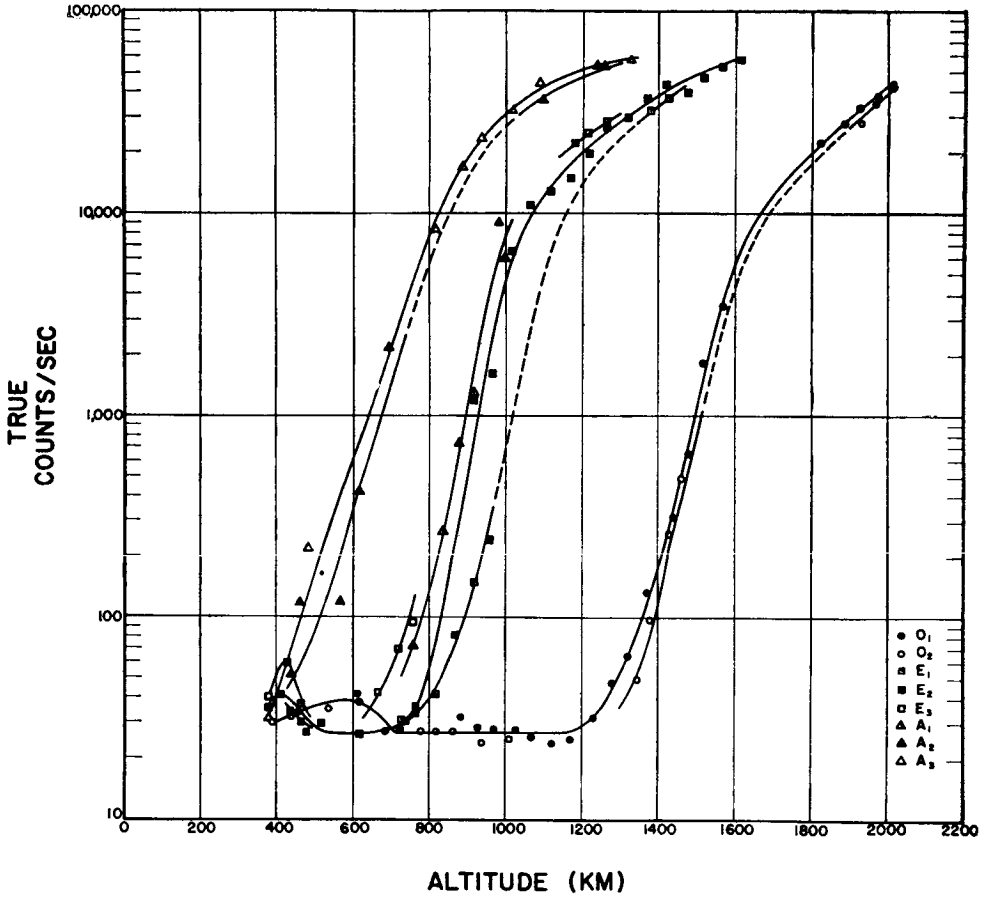


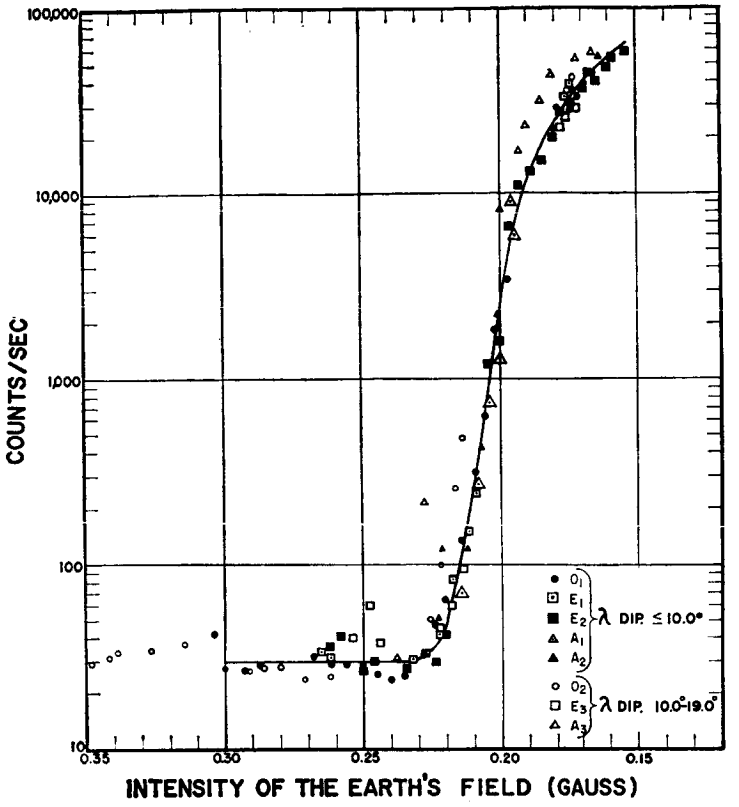
Fig. 3.3. True counting rate of the Geiger tube in Explorer I as a function of altitude above sea level for a number of geographic positions, all near the equator but at widely different longitudes. Note the precipitous rise in intensity beginning at an altitude ranging from 400 km. over the Central Atlantic (curve on the left) to 1300 km over Singapore (curve on the right). The effective eccentricity of the magnetic center of the Earth is obtained directly from the diagram. (After Yoshida, Ludwig and Van Allen).

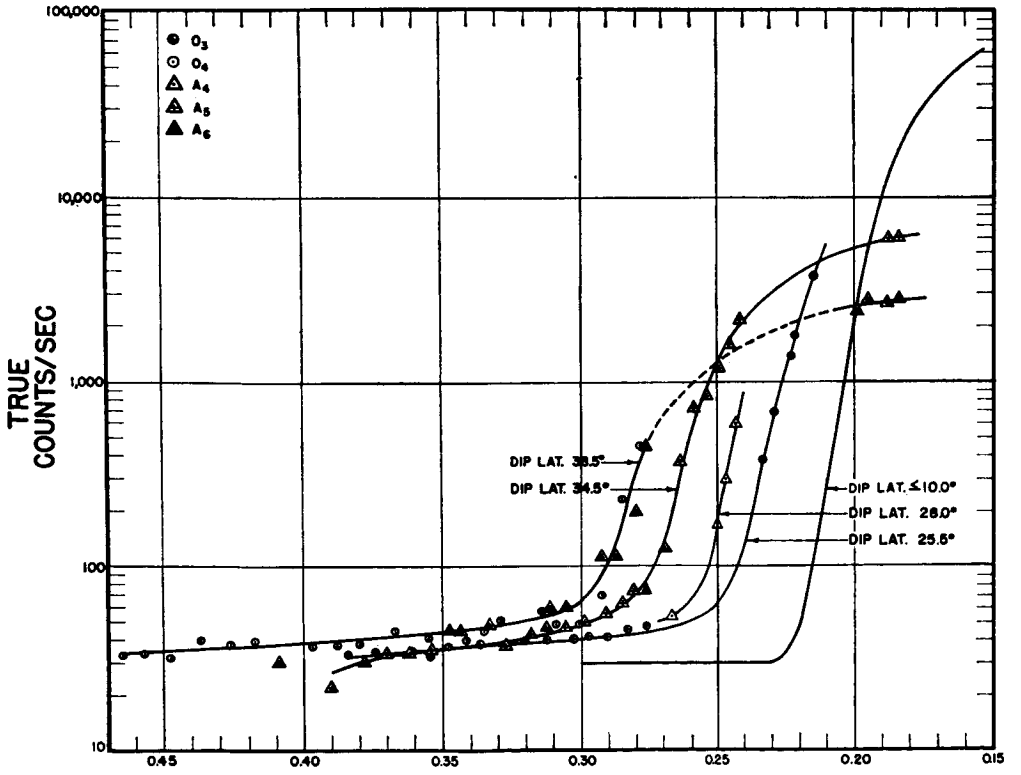
Figures 3.4 and 3.5 are printed on the opposite page, 119; the legends are:

Fig. 3.4. The counting rate data of Figure 3.3 replotted as a function of scalar B. This diagram illustrates that the omni-directional intensity $\mathcal{J}_0$ is a function only of B for $I \approx$ zero. (After Yoshida, Ludwig, and Van Allen).

Fig. 3.5. Data similar to those in Figure 3.4 but for a variety of dip latitudes or magnetic shells. (After Yoshida, Ludwig, and Van Allen).

Figs. 3·4 and 3·5





that the form of the outer zone is more nearly like that of a dipole field than shown in Figure 3.1. The radiation region appears to be fundamentally divided into two distinct zones—an inner zone whose particle population is probably due to internal sources, located in the strong

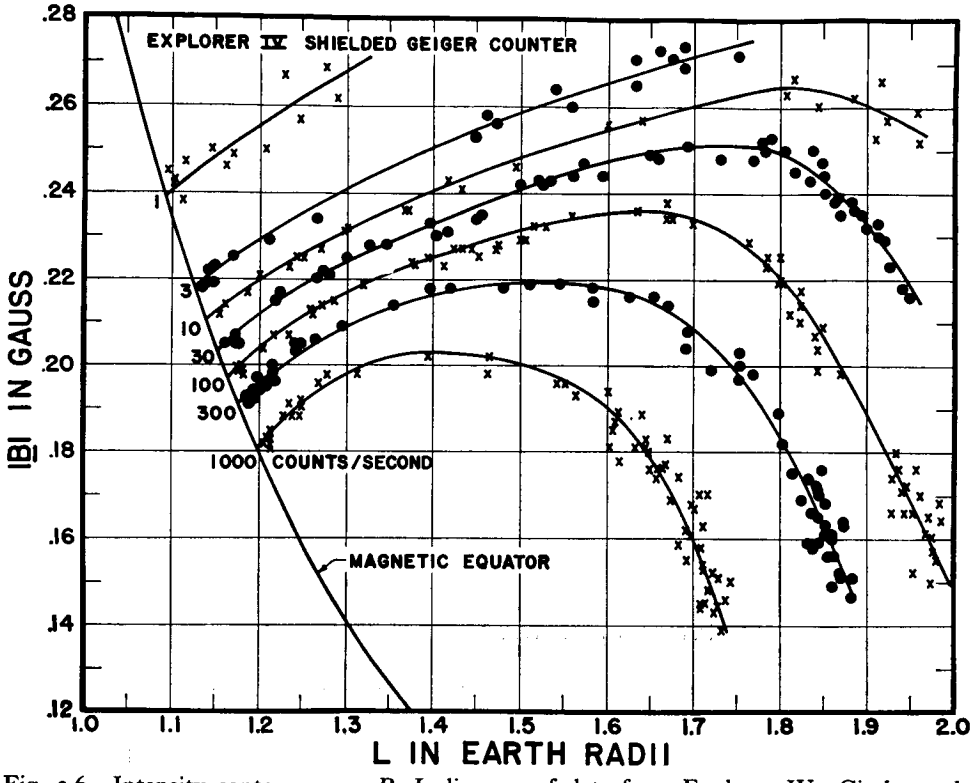


Fig. 3.6. Intensity contours on a B, L diagram of data from Explorer IV. Circles and crosses are used alternately to distinguish successive contours. (After McIlwain).

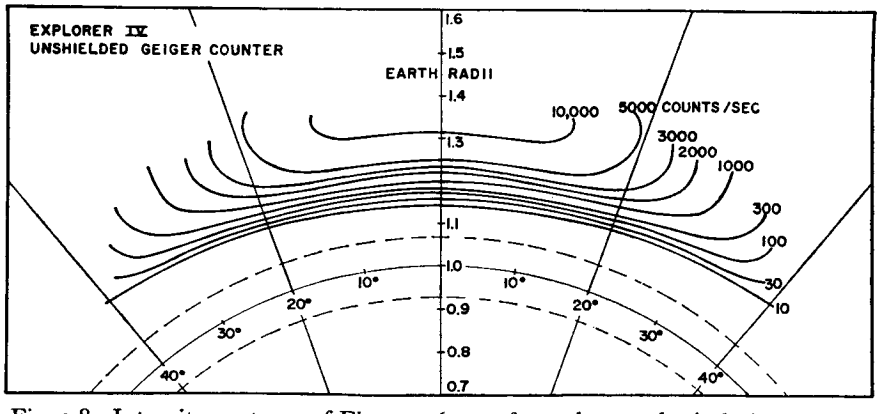


Fig. 3.8. Intensity contours of Figure 3.6 transformed to a spherical plot by using the co-ordinates r_N and λ_N defined from the natural co-ordinate system of B and L. The dashed arcs of circles represent the limits between which the surface of the solid Earth falls at various longitudes. (After McIlwain).

region of the geomagnetic field and relatively stable in time; and an outer zone, whose particle population is almost certainly due to external sources, located in the outer reaches of the geomagnetic field and having a detailed form and particle content which are strongly dependent on solar and geomagnetic activity as measured by other means. The region between the two zones has been termed the 'slot'.

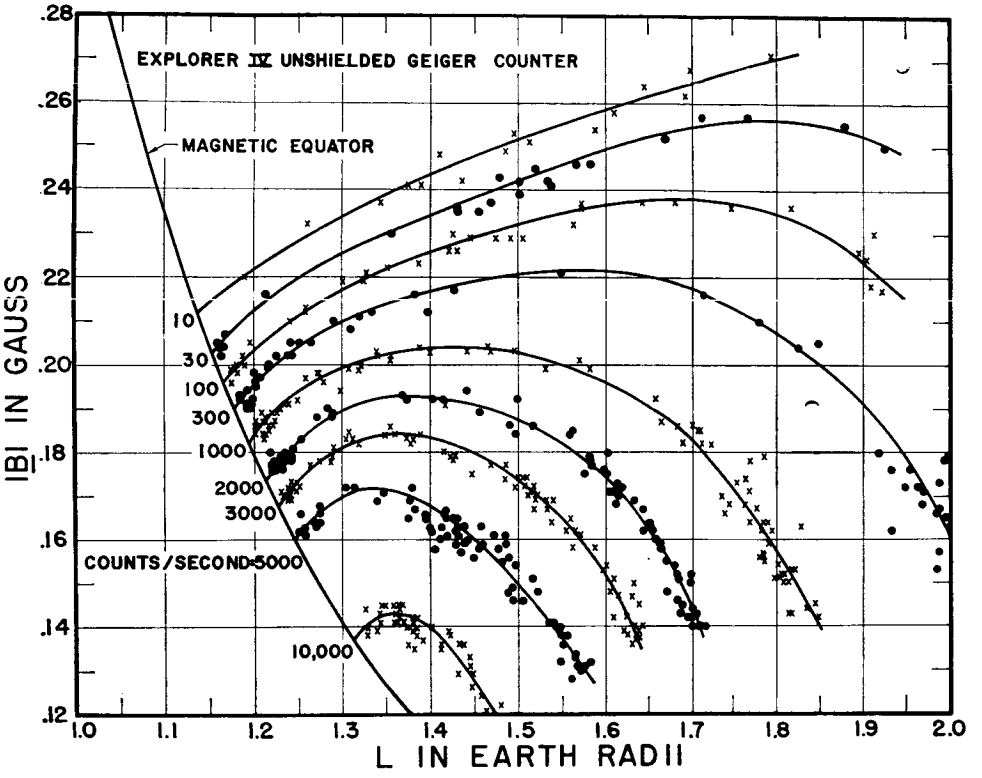


Fig. 3.7. Similar to Figure 3.6.

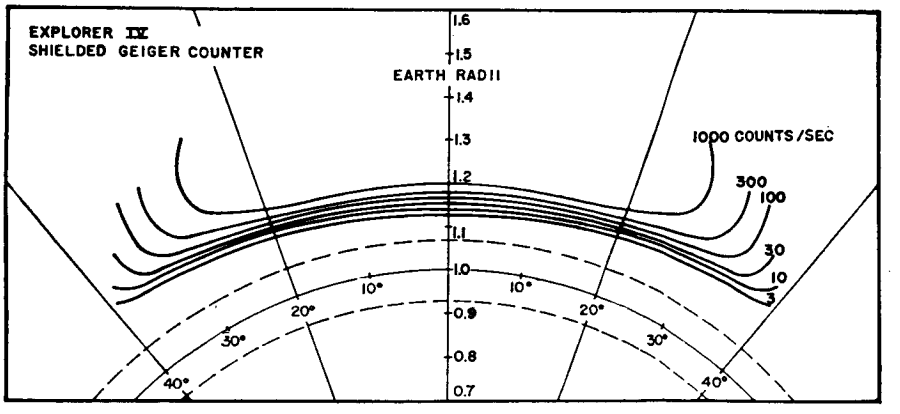


Fig. 3.9. Similar to Figure 3.8, showing the transformation of the contours of Figure 3.7.

A later version of the same sort of diagram by Vernov and Chudakov is shown in Figure 3.2.

The lower fringe of the inner zone was well determined by a single Geiger tube in Explorer I (Yoshida, Ludwig, and Van Allen, 1960). Figures 3.3, 3.4 and 3.5 summarize the main features of this work. The fact that the intensity data from all longitudes near the equator, for example, fall on a single curve when plotted against scalar B was one of the early successes of the B, L co-ordinate system described in detail in an earlier section.

The extensive undertaking of replotting in natural co-ordinates the inner zone data from the two Geiger tubes in Explorer IV has recently been completed by McIlwain (1961). Figures 3.6, 3.7, 3.8 and 3.9 show the principal results of this work. In the latter two figures, the radial and angular co-ordinates (r_N, λ_N) are defined from the B, L system by the following two relations:

$$\lambda_N = \text{arc sec}(L/r_N)^{\frac{1}{2}} \tag{3.1}$$

$$B = \frac{M}{r_N^3}\left(4 - \frac{3r_N}{L}\right)^{\frac{1}{2}} \tag{3.2}$$

(The unit of length is the radius of the Earth). The subscript N refers to the natural co-ordinate system and is intended to avoid confusion with any actual geometric co-ordinates.

The omni-directional intensity of protons in particles/cm²sec, trustworthy to a factor of two (during the period of the observations 26 July–21 September 1958), can be obtained as follows:

(*a*) Divide the counting rate number given in the figures for the unshielded counter by 0·54 to obtain the omni-directional intensity of protons having energies exceeding 31 Mev:

(*b*) Divide the counting rate number given in the figures for the shielded counter by 0·62 to obtain the omni-directional intensity of protons having energies exceeding 43 Mev.

A similar analysis is in progress on the observations with the other two detectors in Explorer IV: (*a*) the directional intensity of electrons of energy greater than 580 kev and (*b*) the directional energy flux into a thin Cs I crystal covered with a 1 mg/cm² absorber. It is already apparent that the structure of the lower half of the inner zone for energetic electrons is similar to that for protons, though it spreads out to somewhat higher latitudes. The uni-directional intensity of electrons of energy greater than 580 kev in the direction perpendicular to B in the heart of the inner zone is 1×10^7/cm² sec steradian with an uncertainty of a factor of 2 ($r_N \sim 1{\cdot}4$ Earth radii).

The altitude dependence of proton intensity in the lower portion of the inner zone is, generally speaking, as well understood as knowledge of the density and composition of the atmosphere permits. The approximate argument is as follows. In the lower portion of the inner zone the dominant mechanisms for loss of particles are energy loss and scattering in the high levels of the atmosphere. Hence the intensity at a given value of B_M in a magnetic shell of given L is essentially inversely proportional to the line integral of atmospheric path length (in g/cm²) along the trajectory of the particle between B_M and B_{M^*}, provided that the source function of particles is more or less the same over the region in question. This sort of analysis yields a substantially satisfactory understanding of the altitude dependence of intensity in the lower portion of the inner zone (Ray, 1960).

The fall-off of *both* electron and proton intensity with increasing radius (and the concomitant fall-off with increasing latitude) is not well understood. There is some contribution to the fall-off simply by the geometric dependence of the source function of albedo neutron decay products. But the observed fall-off is considerably more rapid than this.

Singer (1959, 1960) and Vernov (1960) have advocated the 'breakdown' of the Alfvén adiabatic invariant as a possible explanation and Singer has calculated what value of the Alfvén positional discriminant $\rho|\text{grad}\, B/B|$ would be required to harmonize this line of thought with the observed data of the Iowa and Chicago groups. He finds a value of 0·08 to 0·06 as calculated in the equatorial plane.

The physical process which must be envisioned in the so-called breakdown of the adiabatic invariant is that the mirror point of a particle becomes progressively or randomly lower than that given by equation (1.13):

$$B_M = B_0/\sin^2 \alpha_0,$$

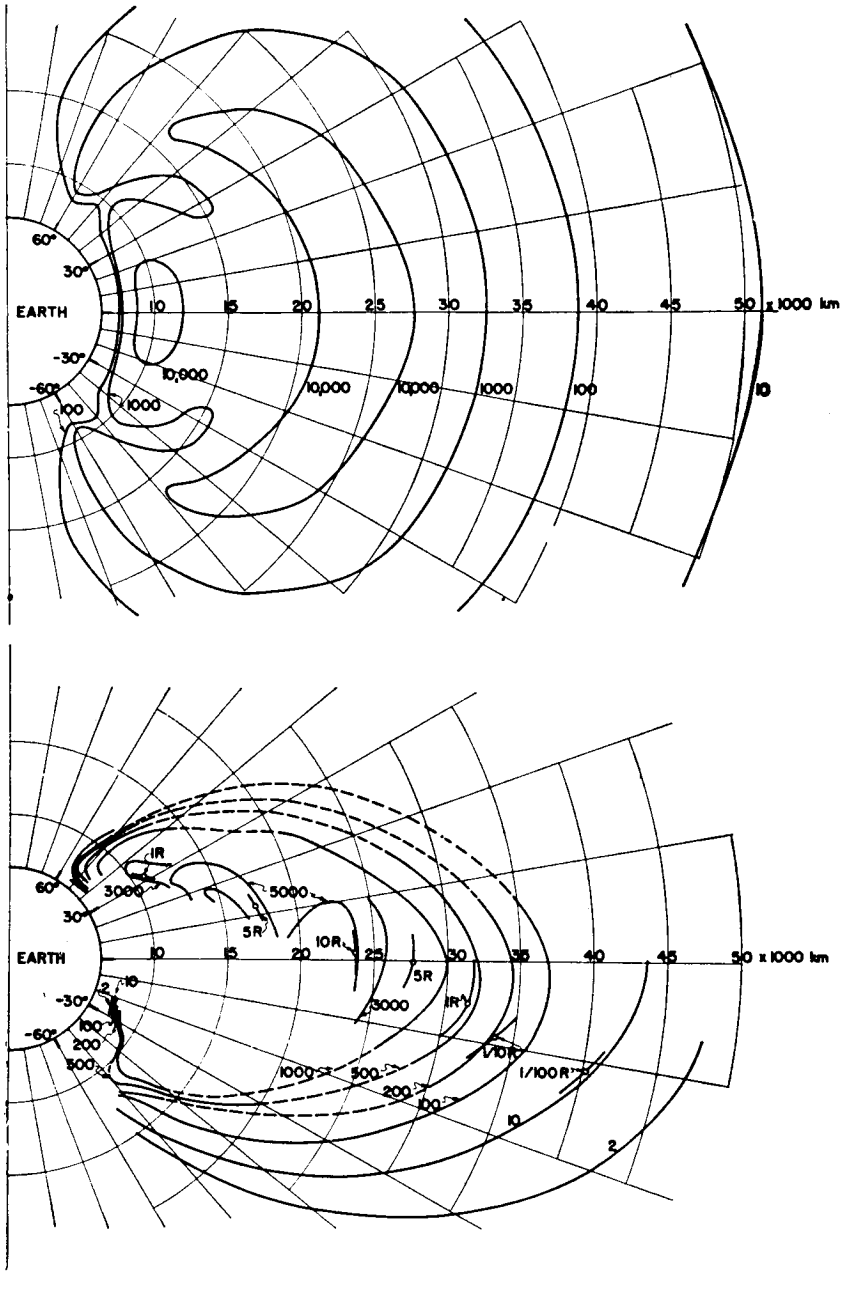
or that $p_\parallel$ at the equator progressively or randomly increases at the expense of $p_\perp$ so that α_0 diminishes. (See sections 1.2 and 1.3). In the experiments of Gibson *et al* previously cited, it was found that the quiescent loss of trapped particles due to breakdown of the adiabatic invariant was unobservably small for over 10^8 encounters with a magnetic mirror where $\rho|\text{grad}\, B/B| \sim 0.02$. The number of possible encounters may be very much greater. It is also of interest to note that for the Störmer case which has been used as an illustration in section 1.1 (Figure 1.1), $pc = 966$ Mev, $E = 400$ Mev for a proton, $(r_1 + r_2)/2 = 2{\cdot}69$ Earth radii and $\rho|\text{grad}\, B/B| \sim 0.17$ in the vicinity of the mirror point and 0·35 in the equatorial plane.

There is little doubt of the qualitative soundness of the Singer-Vernov suggestion but it is far from clear that the loss of trapped protons from the outer edge of the inner zone is actually dominated by the quiescent loss process proposed. Additional doubt is cast on the proposal by the fact that the inner zone structure for electrons whose energy exceeds 580 kev is quite similar to that for protons whose energy exceeds 30 Mev, being extended in the equatorial plane by only about 0·3 of an Earth's radius. For example, the Alfvén discriminant for an electron of 1 Mev kinetic energy at a radial distance of 2·4 Earth radii in the equatorial plane is only 4×10^{-4}.

The present author is inclined to the view that the radial limitation of the inner zone is caused in a dominant way by transient variations both in time and space of the geomagnetic field. The observational evidence for this view is that the low altitude portion of the inner zone in the equatorial region is quite stable but that temporal variations increase as one goes to higher latitudes; and in the slot variations of over an order of magnitude are observed, often with sharp spatial and temporal structure.

Specific models of hydromagnetic wave perturbations in the inner zone have been proposed by Welch and Whitaker (1959), Dragt and Dessler (Dragt, 1960) and by Wentzel (1961). The latter two authors have developed the theory of the perturbations by hydromagnetic waves in quantitative detail and have demonstrated the plausibility of the observed radial extent of the inner zone for protons. Wentzel has also discussed the question of electrons and has concluded that during strong geomagnetic storms electron orbits may also be significantly perturbed. It is important to keep in mind the fact that the presumed source function for the inner zone is a very weak one and that particle life-times of the order of 10^8 seconds are required in order to permit the development of the observed intensities in the heart of the inner zone.

The structure of the outer zone as sampled by lightly shielded Geiger tubes has been shown in Figure 3.1. A considerably modified structure (Van Allen and Frank 1959a) was observed by an identical detector in Pioneer IV, thus providing a striking example of the great time variability of the structure. This variability had been found in the earlier low-altitude observations with Explorer IV (Rothwell and McIlwain, 1960).



Comparison of the counting rate contours in the radiation zone as given by Van Allen (upper) and as given by analysis of Explorer VI (lower) shown on a polar plot. It is apparent that the radiation zones during the time of Explorer VI have shrunken considerably and changed form since those inferred from the Explorer IV and Pioneer III and IV data.

Fig. 3.10. Intensity structure of radiation region (Upper diagram after Van Allen and Frank; lower diagram after Arnoldy, Hoffman and Winckler).

Much extended studies of the outer-zone variations have been made recently using low-altitude data of Explorer VII (Forbush, Venkatesan and McIlwain, 1961) and using the high-altitude data of the very eccentric orbit of Explorer VI (Arnoldy, Hoffman and Winckler,

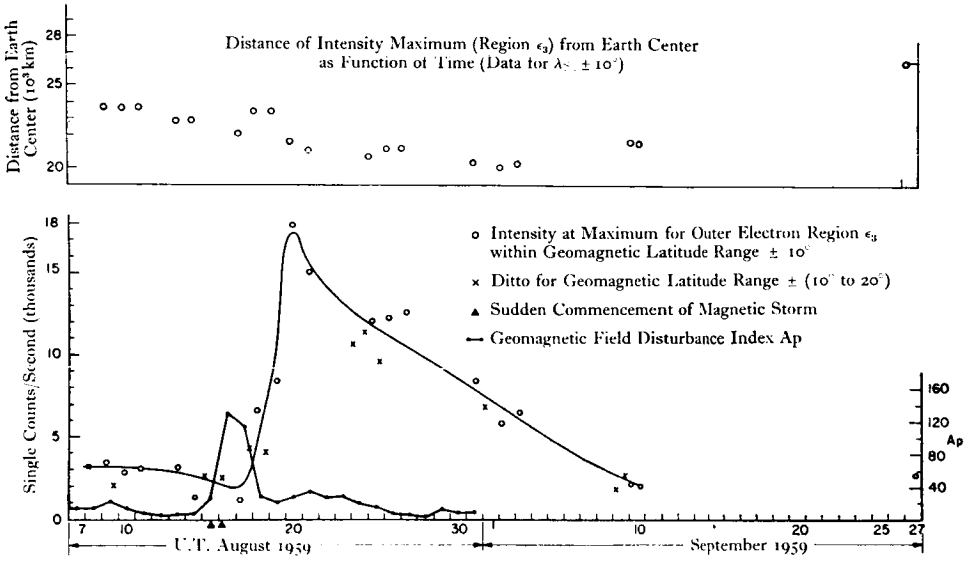


Fig. 3.11. A representation of time variations of intensity in the outer zone near the equatorial plane and relationship to magnetic activity (after Fan, Meyer, and Simpson).

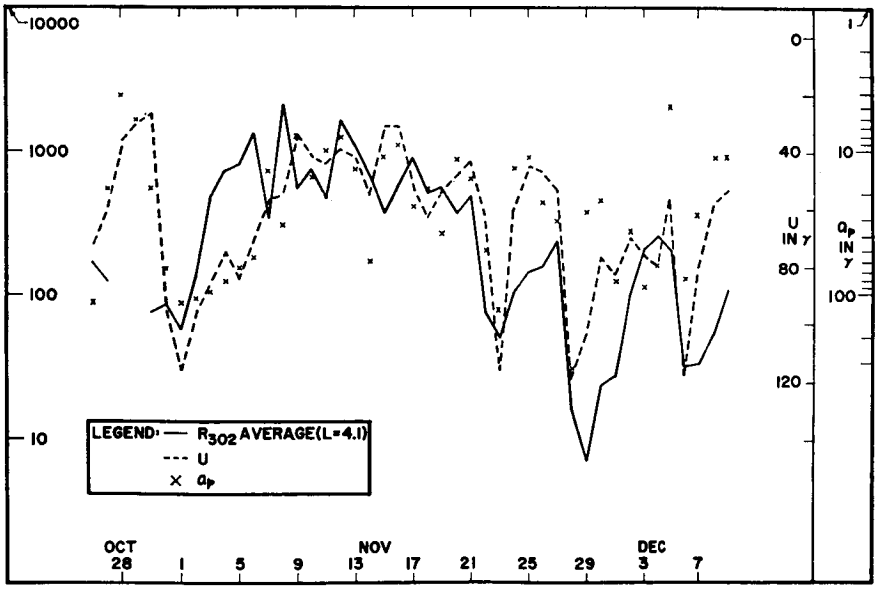


Fig. 3.12. Average counting rate, R_{302} at $L = 4{\cdot}1$ from passes for each 'day', equatorial ring current measure U, and magnetic activity a_p, 1959 October 26—December 9. A representation of time variations of intensity at about 1000 km altitude in the outer zone and relationship to magnetic activity. (After Forbush, Venkatesan, and McIlwain).

1960) (Fan, Meyer and Simpson, 1960), (Rosen and Farley, 1961). Figure 3.10 shows the structure of the outer zone during August-September 1959 as reported by Winckler *et al.* Figures 3.11 and 3.12 show examples of the time variation as measured in different ways. Forbush *et al* have found the geomagnetic ring current parameter of Kertz (1958) to be a valuable one in establishing a general connection between outer zone fluctuation and other geomagnetic effects. Fan *et al* have emphasized the bifurcation of the outer zone, as observed by Explorer VI to exist to varying degrees during August-September 1959, and as previously seen in Pioneer III data of December 1958 and have conjectured that this bifurcation is a characteristic feature of the outer zone. The low-altitude data of the Iowa group with Explorer VII show a strongly time-varying structure of the outer zone including many examples of double and multiple peaks. Hence, more extended observations of the outer zone structure as found at large radial distances will be required to find whether the August-September situation is characteristic or whether it merely represented a temporary one of a large variety of time-variable structural features.

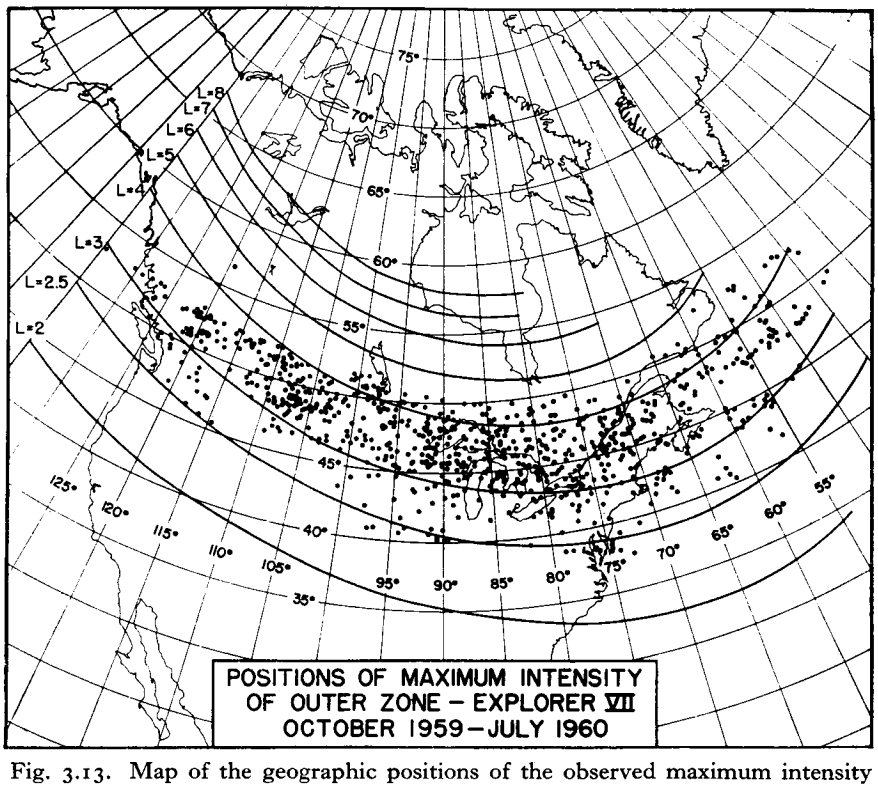


Fig. 3.13. Map of the geographic positions of the observed maximum intensity of the outer zone as projected along lines of force on to a sphere of radius 100 km greater than that of the Earth and corresponding loci of magnetic shells L = constant (after Lin and Van Allen).

Figure 3.13 shows a large collection of data (Lin and Van Allen, 1960) on the observed postion of the peak intensity of the outer zone as found at ~1000 kilometer altitude with Explorer VII. Also shown are the contours of L = constant. All of the data including the contours are with reference to a sphere of radius 100 km greater than that of the Earth. The mean position of the peak of the outer zone lies at an L of about 3·5 which is in remarkably close agreement with its location as found with Pioneer III near the equatorial plane.

Perhaps one of the most striking examples of the validity of present knowledge of the dynamics of geomagnetic trapping was provided by the Explorer IV observations of the artificially produced shells of energetic electrons from the Argus tests in August and Sept-

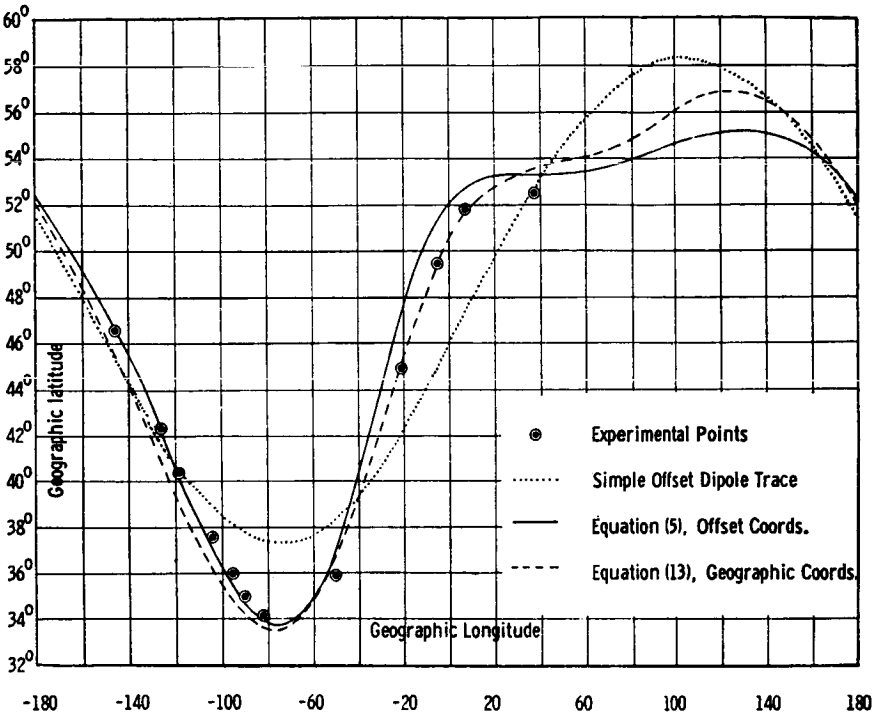


Fig. 3.14. Earth trace of Argus III shell. Various fits to the Argus III data of Explorer IV showing efficacy of the natural co-ordinate system (after Pennington).

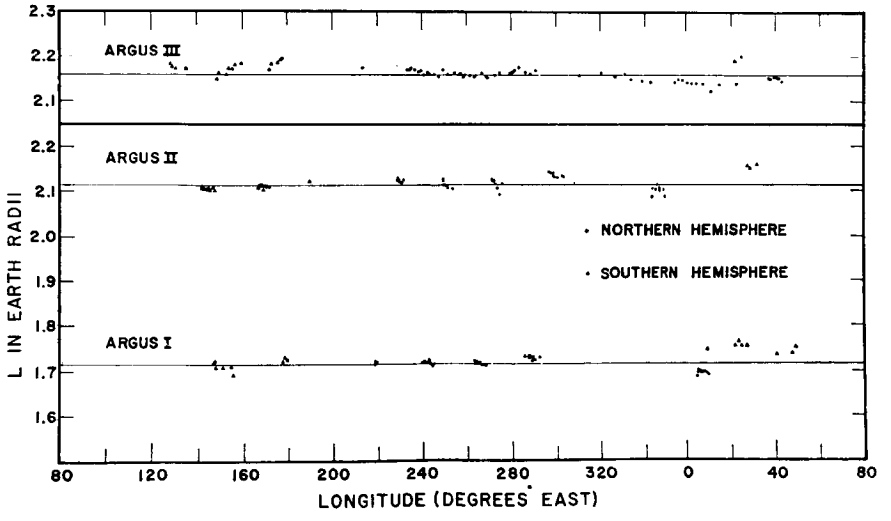


Fig. 3.15. The geomagnetic shell co-ordinate L of the three Argus shells as observed with Explorer IV as a function of geographic longitude (after McIlwain).

ember 1958. (Van Allen, McIlwain and Ludwig, 1959a), (Pennington, 1961), (McIlwain, 1961). Figures 3.14 and 3.15 show the remarkable agreement of the form of the three separate Argus shells with magnetic shells defined by L = constant.

4.1 SOURCES OF TRAPPED PARTICLES IN THE INNER ZONE

In consideration of the gross intensity structure of the Earth's radiation region (See Figure 3.1) and of the quite different level of time variability in the inner and outer zones it seems reasonable to believe that the two zones originate in different ways.

It is now regarded as likely that the principal source of the particles which are trapped in the inner zone is the neutron component of the cosmic ray albedo arising from nuclear disintegrations produced in the atmosphere by the ordinary cosmic radiation.

The charged particle albedo of the atmosphere has long been recognized as a problem in the determination of the primary cosmic ray intensity by measurements with rocket equipment above the atmosphere (H. Kulenkampf, 1933), (Van Allen and Tatel, 1948), (Gangnes, Jenkins, and Van Allen, 1949), (Van Allen and Singer, 1950) and the neutron component has been discussed by Rossi (1948) as representing one of the losses from the atmosphere in assessing the energy integral of cosmic rays by summing all observable secondary processes.

The possible significance of the albedo neutrons for injecting their charged decay products into trapped orbits within the Earth's field was apparently first recognized by Christofilos (1958) whose attention was directed primarily to their decay electrons (beta ray spectrum with upper limit of 782 kev for a neutron at rest). Later more quantitative studies of this hypothesis were published by Singer (1958), by Vernov and Lebidinsky (1958) and by Kellogg (1959) after the experimental discovery of the trapped radiation. Singer's treatment of the problem concentrated on the proton decay products and Kellogg's on the electron decay products.

Later comprehensive treatments of the neutron albedo theory have come from the work of Hess and others. (Hess, 1959), (Hess and Starnes, 1960), (Hess, Canfield, and Lingenfelter, 1961), (Hess, Patterson, Wallace, and Chupp, 1959).

The data of Explorer IV and of Pioneer IV made it appear likely that the penetrating component in the inner zone was composed of protons (Van Allen, 1959). The first conclusive identification of this component was by way of recovered nuclear emulsions which had been flown through the lower edge of the inner zone by Freden and White (1959). Subsequent work by similar techniques by the same authors (Freden and White, 1960), by Yagoda (1960), by Armstrong, Harrison and Rosen (1959, 1960) and by Naugle and Kniffen (1961) have provided a good preliminary knowledge of the energy spectrum of protons in the lower portion of the inner zone. The differential number-energy spectrum is given by Freden and White (1959) as

$$j(E)\,dE = \kappa\, E^{-1.8}\,dE \tag{4.1}$$

for

$$75 < E < 700 \text{ Mev.}$$

The absolute source function for the injection of neutron decay products into the geomagnetic field (including angular distribution, spatial distribution and energy distribution of the decay products) is now rather well known, particularly by virtue of the work of Hess and his co-workers.

Also the theory of the loss of trapped protons from the range of detectability by energy loss and scattering in the tenuous upper atmosphere is as well known as are the properties of the exosphere (Ray, 1960). Hence it is possible to calculate the absolute intensities of trapped protons and their energy spectrum without reference to the experimental data. When this is done, there is a quite plausible measure of agreement with the observed quantities.

The corresponding situation with respect to the electrons in the inner zone is far less satisfactory (Kellogg, 1960). There are disagreements of orders of magnitude between the observed absolute intensities of electrons and the predicted values. Moreover the observed spectrum (Holly and Johnson, 1960) is relatively much richer in low-energy electrons than is the predicted spectrum. And, as remarked earlier, only the lower altitude (and low-latitude) portion of the structure of the inner zone is properly accounted for by the neutron albedo theory. Any proper understanding of the outer boundary of the inner zone must rest on other considerations.

It was found by Naugle and Kniffen (1961) that the proton spectrum at the northern edge of the inner zone in the energy range 10 to 50 Mev was very much steeper than that at a position some 1600 km south of this point, being of the form:

$$j(E)\mathrm{d}E = \kappa' E^{-4.5}\,\mathrm{d}E \tag{4.2}$$

It is perhaps significant that the rocket flight on which these results were obtained was on 19 September 1960, only about two weeks after the prolonged solar cosmic ray event of 3 to 10 September 1960. For some time the present author has entertained the thought that solar cosmic rays may make a significant contribution to the trapped proton content of the inner zone by way of neutron albedo secondaries produced in the polar caps. An effect suggestive of this possibility was reported by Armstrong *et al* (1961). Recently an important new development has occurred. Pizzella (1961) has found a marked increase in intensity in the inner zone following the early April 1960 solar cosmic ray events (Van Allen and Lin, 1961). The effect was much more pronounced at high values of L, being negligible at $L = 1{\cdot}2$ and a factor of ten at $L = 1{\cdot}8$. Moreover the effect was greater for a given L at larger values of B/B_0 (i.e., for lower mirror points). Both of these effects are in qualitative agreement with the basic geometry of particle injection by neutron albedo originating in the polar caps. It is fortunate that there were also good satellite observations of the absolute solar cosmic ray intensity during the event as well as its latitude dependence (Lin, 1961). Work is now in progress to find whether or not quantitative agreement exists.

4.2 SOURCES OF TRAPPED PARTICLES AND/OR KINETIC ENERGY IN THE OUTER ZONE

The outer zone is characterized by an almost complete absence of high-energy protons. An upper limit of $1 \times 10^2/\mathrm{cm}^2$ sec of protons of energy greater than 60 Mev was placed by Pioneer IV (Van Allen and Frank, 1959). The more recent Explorer VI measurements with a lead-shielded coincidence telescope by Fan, Meyer, and Simpson (1960) has driven the upper limit of the intensity of protons of $E > 75$ Mev down to $0{\cdot}1/\mathrm{cm}^2\mathrm{sec}$. There is no information of significance on the intensities of protons of energy less than 30 Mev.

The outer boundary of the outer zone has been observed by means of substantially the same instrument (a single Geiger tube shielded by about 1 $\mathrm{g/cm}^2$) to fluctuate over the radial range 95 000 km (15 Earth radii) to about 40 000 km (6·3 Earth radii) in the equatorial plane. There is usually a major peak of intensity at a radial distance of about 22 000 km (3·5 Earth radii), though the position of the peak varies somewhat, and during some periods of time the peak has been observed to be bifurcated into two or more comparable peaks. Among the various measurements over the past three years, the magnitude of the intensity in the vicinity of 3·5 Earth radii has been observed to vary by nearly two orders of magnitude. Generally speaking the fluctuations are closely associated with solar and geomagnetic activity, though the association is not of a simple nature. (See Forbush, Venkatesan, and McIlwain, 1961). The following general pattern has begun to emerge, though it should not be regarded as universal:

(*a*) Within a time of the order of a few hours to a day after the onset of a geomagnetic storm, the content of the outer zone (as measured with a thinly shielded Geiger tube which has an electron-bremsstrahlung threshold of about 20 kev) is markedly depleted. The depletion may be by as much as an order of magnitude or more. On several occasions of large events there have been notable sub-auroral zone aurorae and red arcs lying along a locus of $L \sim 3{\cdot}5$ Earth radii (O'Brien, Van Allen, Roach and Gartlein, 1960), (O'Brien and Ludwig, 1960), (Arnoldy, Hoffman and Winckler, 1960). Also during this 'dumping' phase the ring current parameter of Kertz *increases*, apparently signifying an *increase* in the quantity of low energy protons and electrons (not directly observed with techniques used thus far) in trapped or quasi-trapped orbits after the manner of Chapman and Ferraro and of Alfvén.

(*b*) Then with a time constant again of the order of one day the observable intensity of electrons undergoes a strong increase and reaches a level equal to or perhaps an order of magnitude greater than its pre-storm value. During this period the ring current declines toward its quiescent value.

(*c*) Finally the intensity of observable electrons in the outer zone relaxes back toward its quiescent level with a time constant of the order of a week or more.

One of the best observed and most interesting case histories of an occasion such as described above occurred during early April 1960. During this period Explorer VII was making a regular patrol of the outer zone at an altitude of ~1000 kilometers and Pioneer V was measuring the particle intensity and the interplanetary magnetic field at a distance of ~0·03 A.U., (i.e., at a position well outside of the geomagnetic field but in the near-astronomical vicinity of the Earth.) (Van Allen and Lin, 1960), (Arnoldy, Hoffman and Winckler, 1960), (Coleman, Sonett, Judge and Smith, 1960).

Figure 4.1 shows on a common time scale the peak counting rate of the thinly shielded counter in the outer zone (Explorer VII), the magnetic measurements in Pioneer V, and the ground station record of the geomagnetic field intensity at Iowa City. Also of essential significance are the simultaneous observations of Winckler *et al* (also in Pioneer V) of the particle intensity measured with a Geiger tube nearly identical with the one in Explorer VII; in sharp contrast with the Geiger tube rates shown in Figure 4.1 Winckler observed an increase above cosmic ray rate of at most one count per second during the magnetic peak of Coleman *et al.*

The following interpretation of this combination of observations is proposed.

(*a*) The magnetometer in Pioneer V recorded the passage of a major burst of ionized, magnetized solar plasma.

(*b*) This plasma contained a negligible intensity of electrons with energies exceeding 20 kev.

(*c*) The arrival of the plasma at the Earth (with trivial time-lag on the scale shown) produced a major magnetic storm, perturbed the orbits of previously existing trapped electrons of energies in the range of tens of kilo-electron volts thus causing the dumping of a large fraction of the energy of the outer zone into the atmosphere to produce the widespread, brilliant, low-latitude aurora which was observed during this period.

(*d*) During this process a portion of the low-energy plasma was entrapped by the geomagnetic field.

(*e*) The low-energy particles which thus became a part of the outer zone were subsequently accelerated to a level of observability by magnetic and hydromagnetic processes of unknown detailed character.

(*f*) Finally by virtue of energy loss and other perturbations of more usual character and magnitude the outer zone intensity relaxed back to the quiescent level which is presumably maintained by a quiescent solar wind.

On the basis of this type of evidence, the present author feels that there is overwhelming evidence that the outer zone owes its existence to solar plasma and to local accelerating processes of a magnetic nature in the Earth's field. Whether or not the particles being detected are the very same ones which arrived in the solar plasma or whether they are ones belonging

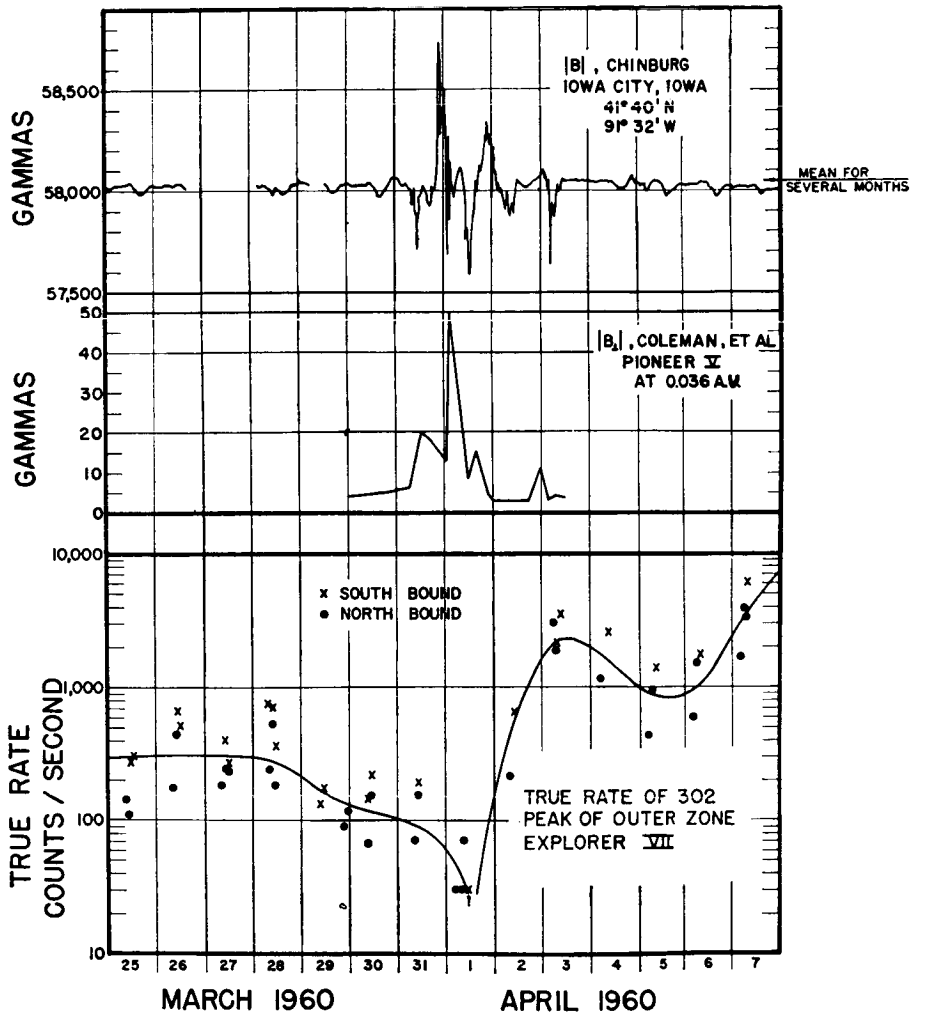


Fig. 4.1. The time relationship of (*a*) the maximum intensity in the low altitude portion of the outer zone (*b*) the interplanetary magnetic field at 0·03 A.U. and the ground station record of B (after Van Allen).

to the Earth's system prior to the arrival of the solar plasma is irrelevant. The essential aspect of the belief is that the energy for producing and maintaining the outer zone is from the Sun. Furthermore there is no significant suggestion that the necessary energy can be delivered to the outer zone in any other form than as kinetic energy of solar plasma.

There remains a wide variety of fascinating problems associated with the origin and dynamics of the outer zone and with the relationship of the outer zone to aurorae, airglow, geomagnetic

activity and atmospheric heating. No attempt to treat these problems has been made in the present paper.

Moreover even direct observational knowledge of the absolute intensities and energy spectra of electrons and protons in the outer zone is in a quite preliminary state. On the basis of the single assumption that the intensity of electrons of energies exceeding 2·2 Mev does not exceed 10^{-6} of those of lesser energy, the author has given the experimentally-based estimate of 10^{11} $(cm^2\ sec)^{-1}$ as the omni-directional intensity of electrons of energy exceeding 40 kev in the heart of the outer zone on 3 March 1959 (a date of exceptionally high intensity); and in spite of considerable later evidence some of a confirmatory and some of a conflicting nature (See for example collection of papers in *Space Research*, edited by H. K. Kallman-Bijl, 1960), he still finds it very difficult to accept a figure less than about 10^{10} $(cm^2 sec)^{-1}$ as typifying the intensity of electrons in the tens to hundreds of kilo-electronvolt energy range in the heart of the outer zone.

There remains a pressing need for more decisive experiments in the area. Such experiments are currently under way.

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INVITED DISCOURSE B

given to participants in the General Assembly at 20^h00^m on Friday 18 August 1961 in the Auditorium of Wheeler Hall on the Berkeley Campus of the University of California by

Professor M. Schwarzschild
(*Princeton University Observatory, Princeton, New Jersey*)

on

STELLAR EVOLUTION

I. RATES OF STELLAR EVOLUTION

It is perhaps one of the most important characteristics of the past decade in astronomy that the evolution of some major classes of astronomical objects has become accessible to detailed research. The theory of the evolution of individual stars has developed into a substantial body of quantitative investigations. The evolution of galaxies, particularly of our own, has clearly become a subject for serious research. Even the history of the solar system, this close-by intriguing puzzle, may soon make the transition from being a subject of speculation to being a subject of detailed study in view of the fast flow of new data obtained with new techniques, including space-craft.

In the theory of the stellar interior it has long been clear that the majority of stars, in spite of their apparent permanence, must be evolving. Simply the fact that the radiant luminosity of a star represents a persistent, enormous energy loss, makes it clear that most stars cannot remain indefinitely in their present state. Only for one type of star does this radiative loss seem to be irrelevant, namely the white dwarfs. The luminosity of the white dwarfs, we believe, is fed from the residual thermal energy still contained in the interior. However, this thermal energy in a typical white dwarf is so small compared with the gravitational energy that its eventual loss will not change the structure of the whole star to any appreciable degree. Accordingly we can consider the white dwarfs, in spite of their slowly declining brightness, essentially in a state in which they can remain indefinitely. The same does not appear to be true for any other type of stars.

In spite of the early recognition that most stars must be evolving, it was only in the last decade or two that it became possible to determine the various processes which govern the evolution of different types of stars. Three classes of such processes are now recognized: nuclear processes, thermal processes, and dynamical processes.

A star will have its slowest rate of evolution—always excluding its final white dwarf state—whenever it is in thermal and dynamical equilibrium, that is when the nuclear transmutations through their continuous alteration of the chemical composition are the only cause for any change. The rate of such a nuclear evolution is governed by the fact that a hydrogen-rich star contains approximately 10^{19} ergs/g in nuclear energy. If this energy is expended by a star of one solar mass at the rate of one solar luminosity, one finds the nuclear lifetime to be of the order of 10^{11} years.

A faster rate of evolution is encountered in a star when it is in dynamical equilibrium but not in thermal equilibrium. The thermal rate of re-adjustment can be determined from the thermal energy content of the star, which amounts to approximately 10^{15} ergs/g for a temperature of ten million degrees. If this thermal energy—or rather the equivalent gravitational energy set free during a contraction—is expended again by a star of one solar mass at the rate of one solar luminosity, a thermal adjustment time of about 10^7 years is found.

The fastest rate of stellar evolution occurs when a star is not even in dynamical equilibrium. The characteristic time for this class of evolution can be estimated by dividing the diameter of a star by the average sound velocity within it, which for the Sun gives a time interval of a couple of hours. Clearly dynamical evolution tends to be catastrophic. We will mention later, however, cases in which the individual dynamical phenomena occur at the fast rate here indicated but for which the net changes resulting for the star as a whole accrue at a substantially slower rate.

I should like now to discuss in somewhat more detail these three classes of stellar evolution phases, in order of increasing rate—which is also in order of decreasing knowledge.

2. EVOLUTION AT NUCLEAR RATE

The most outstanding example of stellar evolution at the slow nuclear rate is the main sequence phase. This phase starts after the initial contraction of a star when the central temperature has reached a value sufficient for substantial hydrogen burning. It terminates when the hydrogen is exhausted at the star's center. For the most luminous stars, of about 100 solar masses, the main sequence phase lasts about three million years, for stars of one solar mass it will last about fifteen billion years, and for the faintest main sequence stars it may well last several trillion years. The details of the main sequence evolution phases have been computed through with fair care for a variety of stellar masses and initial compositions. I think we would feel quite content with the accuracy thus far achieved if it were not for an important application which clearly requires further main sequence evolution computations with substantially increased care and accuracy.

This application consists of the determination of the ages of stars by comparing their observed positions in the Hertzsprung-Russell Diagram with the theoretically computed evolution curves. I should like to quote two such recent age determinations, both referring to relatively old stars. The color-magnitude diagram for the galactic cluster NGC 188, derived by Sandage, appears to agree quite well with the lower envelope of the near-by subgiants determined by O. C. Wilson and Oke. Hence, these two observational materials seem to give us two independent samples of disk population stars, which you may also consider as the oldest type of Population I stars. Sandage has recently carried out a comparison of the corresponding observed curve in the Hertzsprung-Russell Diagram with the theoretical evolution curves by Hoyle and Hazelgrove, which are at present the best evolution computations in the relevant mass and composition ranges. The result is an age for the disk population of approximately fifteen billion years. A similar comparison of the observed diagrams for globular clusters with theoretical curves, in this case, for metal-poor stars, gives an age for the extreme Population II of about twenty-five billion years. Both these numbers are preceded by a lengthy and painful history beset with errors. Clearly further investigations are needed to increase the certainty of these new determinations.

It will be clear to you that when you compare these new age determinations as they stand with the best present value of the Hubble constant for the expansion of the universe (about thirteen billion years) they present a fascinating cosmological problem. The age determination for the globular clusters would have to be reduced by about a factor three if it were to be fitted

to the simplest classical solutions of general relativity for an expanding universe with zero cosmological constant. It is hard for me to believe that our present age determinations could still be that wrong. Nevertheless, we have to remind ourselves that on the basis of the same world model we are trying here to follow the evolution of stars over time intervals quite comparable with the total age of the universe. Can we be quite sure that over such time intervals our present physical laws can be extrapolated safely? What if Dirac should be right and the gravitational constant measured in atomic units should decrease with time? All the theoretical evolution computations would have to be repeated, and it is easy to see that substantially reduced stellar ages might result.

Enough of unsafe flights of the imagination. Let us turn to another example of evolution phases proceeding on the nuclear rate. A number of authors have recently studied in detail stellar models with two energy sources, helium burning in the core and hydrogen burning in the shell. It seems highly likely that during the latter part of their lives, heavier stars will pass through phases represented by such models. These new investigations all seem to show the following striking feature. The numerical results for the double source models appear to be enormously more sensitive to the numerical values employed, such as for the stellar mass, initial composition, and nuclear cross-sections, than are those for the main sequence models. This may well have as a consequence that different stars will follow very different routes in their advanced evolution phases. Accordingly, it will be much harder to predict accurately the advanced evolution phases for any given star, than it was for the earlier main sequence phases. This disadvantage may well be compensated by the likely corollary that a careful comparison of observed and theoretical stars in advanced evolution phases will teach us much more about the goings-on within individual stars than we could learn from the study of main sequence stars.

3. EVOLUTION AT THERMAL RATE

If we now turn to the next faster class of evolution phases, those in which thermal and gravitational energies play a determining role, we should obviously start with the pre-main sequence contraction. During this phase the star changes from a globule of interstellar matter to a star on the initial main sequence. During this contraction gravitational energy is set free. One half of it goes into heating the interior, the other half supplies the luminosity of the star. Model sequences covering this phase have been computed for a variety of stellar masses, and the corresponding theoretical evolution curves in the Hertzsprung-Russell Diagram have been derived. It was exciting, indeed, when Walker was able to extend the photometric observations in young clusters to fainter magnitudes, and discovered that these clusters did, in fact, contain faint stars to the right of the main sequence, as had been expected from the theory of stars still in the pre-main sequence contraction.

This discovery however, was fast followed by the realization that the observed contracting stars were not lying on the narrow, nearly horizontal line in the Hertzsprung-Russell Diagram, as predicted by theory, but rather scattered over a large area stretching from the predicted line downwards, with some extreme stars lying more than three magnitudes below the expected location. Not only do the extremely young clusters with ages of a few million years show this disturbing phenomenon, but more recently H. L. Johnson and others have shown that the same phenomenon appears to exist in the Pleiades with an age of about a hundred million years. It seems to me that these new observations force us to search for a major modification in our present theory of the pre-main sequence contraction.

Spitzer has made a plausible suggestion for this modification, namely to drop the earlier assumption that the mass of a star remains substantially constant during the contraction phase. If we follow this suggestion and assume that in the last portion of the contraction the

star usually either splits or ejects a large fraction of its mass (which incidently is also suggested by the spectroscopic appearance of the T Tauri stars) we can easily explain the observed appearance of very faint stars in the clusters in question, stars so faint that they never could have reached their present observed position in the Hertzsprung-Russell Diagram in the alloted time, if they had had their present low mass and low luminosity throughout the preceding contraction. An alternative explanation of the unexpected appearance of very faint stars in young clusters has recently been suggested by Hayashi. He has pointed out the possibility that very deep convective envelopes may occur during the contraction phases. Such envelopes could produce very high luminosities and hence much faster evolution rates than had been expected for the stars in question. Clearly, the final answer for this puzzle is still in the future.

Recently we have become acquainted with another type of evolution phase in which the thermal energy plays a governing role. This is the helium flash in Population II giants, which Mestel predicted several years ago, and which we have computed through in some detail during the past year in Princeton. May I use this point to emphasize that by far most of the research which I am reporting on in this discourse has not been carried out by us in Princeton but by other astronomers in many different places, and that you would be making a big mistake if you assumed that just because I am reporting this work, I were the author of more than just a small fraction of it. Back to the helium flash. When the degenerate helium core of a Population II red giant gets heated by compression to a temperature of about eighty million degrees, helium burning starts. The energy liberated by the helium burning raises the temperature of the core, which in turn increases the rate of the helium burning. Thus, a thermal runaway occurs. The runaway proceeds so fast that very little of the energy set free can penetrate through the relatively opaque outer layers of the star.

This new situation differs significantly from the evolution phases discussed earlier, if you look at it from the point of view of the energy conservation law. In the main sequence phases the energy lost by the radiative flow is balanced by the nuclear energy generation. In the pre-main sequence contraction the energy lost by the radiative flow is balanced by the gravitational energy set free by the contraction. In the helium flash, however, the loss by the radiative flow is negligible, and the energy liberated by the helium burning goes directly into the non-nuclear internal energy of the star.

The thermal runaway comes to a halt when the temperature reaches about 300 million degrees (and the rate of nuclear energy production corresponds to the luminosity of a whole galaxy). At this point the center of the core becomes non-degenerate, and subsequent energy production by the helium burning leads to an expansion of the core with its automatic cooling and the corresponding calming down of the helium burning. The main net effect of the helium flash thus is the raising of the degenerate core out of its deep gravitational potential well and its transformation into a normal non-degenerate convective core. If this is all, we might well in future skip the laborious computations of the helium flash and jump directly from the state in which the helium flash starts to a state immediately after its end, presumably represented by a model with helium burning in a non-degenerate core and hydrogen burning in a shell. However, another more profound consequence of the helium flash is possible. During the declining portion of the flash a steadily growing convective core developes. Our computations are at present not advanced enough to be sure, but they suggest that this core might well reach the hydrogen-rich outer portion of the star or even contact the deep convective envelope that is characteristic of these giants. If the latter should happen, the star would get convectively mixed from center to surface, would start a new evolution phase, homogeneous in composition though rich in helium, which would place it on the left-hand end of the well-known horizontal branch, and would proceed evolving along that branch toward the right.

An indirect argument may be added in favor of complete mixing at the end of the helium flash. A few years ago Zhevakin and, more recently, Cox and Kippenhahn and Baker have shown that stellar pulsations may be caused by an indirect effect of the second ionization of helium for stars which are rich in helium in their envelopes. As you know, the horizontal branch of the globular clusters contains the RR Lyrae variables. The pulsations of these variables can now be explained if we accept the possibility that convective mixing at the end of the helium flash has brought out into the envelope a part of the helium produced in the core during the preceding evolution phases. If this mixing does not occur, the pulsations of the RR Lyrae variables remain a mystery since the low helium content usually assumed for the initial composition of Population II stars, would hardly suffice to make the helium ionization mechanism effective. Right at this time, I think I am ready to bet that stellar evolution along the horizontal branch proceeds from the left to the right. But you might be wise to suspect that my main motivation is still the fact that almost everybody else seems to bet on the opposite direction.

Whatever resolution there may be to this particular question, we may well expect that short thermal evolution phases scattered between longer nuclear phases during the later portions of a star's life may profoundly affect its evolution and may lead to big differences in the advanced evolution phases caused by rather minor initial differences.

4. DYNAMICAL EVOLUTION PHASES

I know of only one phenomenon which we can be reasonably sure presents a stellar evolution phase proceeding on the fast dynamical rate. This is the super-nova explosion. Clearly the initial phase of this phenomenon proceeds ferociously fast and, equally important, the super-nova explosion causes a profound evolutionary change in the star; a single super-nova explosion suffices, we think, to put the star into a state radically different from its preceding condition. Several proposals have already been made as to the basic cause of the super-nova phenomenon. But perhaps the time is not yet ripe to select the correct one with definiteness, and as far as I know nobody has yet attempted to follow the dynamical evolution of this explosion in any detail.

Another good example of a dynamical stellar process is the outburst of an ordinary nova. Here again such an outburst clearly proceeds at a rapid dynamical rate. In contrast to a super-nova, however, a single nova outburst does not appear to amount to a major evolutionary step; the star several years after an outburst probably differs rather little from its state before the outburst. There exist indications, however, that a single star will undergo many nova outbursts distributed more-or-less regularly over a very long time interval and that the accumulated effects of these outbursts may amount to a substantial evolutionary change. Thus the nova phenomenon may represent the prototype of an evolution phase in which dynamical processes persistently occur within the star, with each individual such process occurring on a fast rate but with the overall resulting evolutionary changes accruing much more slowly.

The third item on my list of dynamics in the stellar interior is pulsations. Radial pulsations are by far the best understood dynamical process occurring in stars. Not only did Eddington already derive their main characteristics, but recently their basic driving mechanism seems to have been found, at least for the classical Cepheids and the short-period variables, as I have mentioned earlier. That much the more disappointing it is that these pulsations, as far as we can discern at present, do not seem to have any evolutionary consequences. They appear to be much like the measles; almost everybody has them at an appropriate time of his development, but in his subsequent life it is of little consequence whether he had them or not. On the other hand, stellar pulsations are certainly a powerful research tool. For example, the period-density relation provides us with an independent check on our models for the relevant

evolution states, and more complicated arguments such as we have just applied to the horizontal branch of the globular clusters can give us valuable hints as to the preceding evolution phases.

Fourth and last on the list of dynamical phenomena are those processes which lead to strong mass ejection from a star. We have already discussed one evolution phase in which such a process may be active, the pre-main sequence contraction. That strong mass ejection may play a decisive role in this early phase was realized only very recently. To the best of my knowledge no detailed dynamical analysis has yet been attempted for this phase.

The present situation is quite different in another phase with substantial mass ejection, that of the red giants. During the past several years a variety of investigations, among them a stimulating spectroscopic analysis by A. Deutsch, have provided more and more indications that mass ejection occurs at an impressive rate in the red giant phase. A number of theoreticians have started to investigate the possible causes of this ejection, and the following picture, though still beset with theoretical difficulties and apparent discrepancies with observational data, has tentatively emerged. The red giants possess deep convective envelopes in which the turbulent velocities in the photosphere are frequently only just sub-sonic. Such strong turbulence will act as an effective source of mechanical waves—be they hydrodynamic or hydromagnetic—of which a good portion may travel upwards and thus provide the energy source for a chromosphere and corona. For the case of the Sun, detailed investigations suggest that such progressive waves are really the cause of the corona. For the red giants much more massive chromospheres and coronas might be expected. Matter will evaporate from a hot corona, and this evaporation may take the form of a steady outward flow of matter in the upper corona and beyond. For the case of the Sun, the existence of such a 'wind' seems fairly safely established. But, the solar wind is so unsubstantial that it will surely not amount to any noticeable mass loss for the Sun during its main sequence lifetime. On the other hand, for the red giants it now seems entirely plausible that their winds are sufficiently strong to reduce their masses by an appreciable factor before the red giant phase is over.

Altogether it would rather seem that for the evolution of the majority of the stars the important dynamical processes are not the cataclismic ones, but rather the weak but persistent ones, and only for a small fraction of all stars does the cataclysmic super-nova phenomenon appear to represent a decisive finale.

5. PROBLEMS AHEAD

I would like to conclude my discussion by pointing out three problem areas which follow closely from the evolutionary processes we have discussed, which I think may be ripe at this time for a detailed attack, and which, I feel, could greatly further our understanding of cosmology as far as this can be furthered through the theory of stellar evolution. I want to imply by no means that these three areas are the only ones worthwhile at present to be worked on in the theory of the stellar interior. For example, the initial formation of stars, the origin of the heavy elements, and the interaction of the evolutions of the components in binary systems are obviously equally exciting problems. The three areas which I would like to mention are simply those that seem to me to cover the most important unsolved facets of the evolution of the majority of individual stars.

The first of these three items is a new attack on the main sequence phases of stars around one solar mass, with the aim of reaching an accuracy substantially higher than it was possible to reach up to now. Only by such an undertaking, I think, can we hope to overcome the present tantalizing situation in which our stellar age determinations based on the main sequence theory have an uncertainty just sufficient to spoil any decisive conclusions in making comparisons with the Hubble constant. Such a new investigation would have to take into

account in much more detail than has been done thus far the outer convection zone of the stars in question. Parallel to such theoretical work there will be needed a corresponding push in the accuracy of the color-magnitude diagrams of old clusters. Only when the theoretical and the observed curves in the Hertzsprung-Russell diagram agree in form much more closely than they do now can we accept the resulting stellar ages with confidence.

While the first problem area was related to evolution on the slow nuclear rate, my second area involves the faster thermal phases which appear to be scattered throughout the advanced stages of stellar evolution. For all of us working in this area, I think it is by now abundantly obvious that we will need substantially improved mathematical methods to cover these phases effectively and securely. It is true that we seem to be able to muddle through these phases with a patchwork of methods and with the help of very large electronic computers. The efficiency of the present methods, however, is so low as to be seriously discouraging. New thoughts in this area appear to be developing at several places, including right here at Berkeley, and optimism in this direction might well turn out to be justified.

My third and last area belongs to the field of dynamical evolution phenomena and covers the processes causing mass ejection from red giants. Exciting first steps have been made in this field. However, we clearly do not have a quantitative theory now which permits us to compute the actual rate of mass ejection from stars. Only when such a theory is developed will we be able to follow a star through its later evolution phases and identify these phases with observed types of stars down to the white dwarfs.

Altogether it seems to me in the whole field of stellar evolution there is only one major mistake we can make at this time, and that is to assume that just because exciting progress has been made in this field in the last decade we now have solved the main problems. I do suspect that we now truly understand the main physical processes relevant for the main sequence, but the same can hardly be said for any other phase of a star's life. And surely we must admit that the main sequence, though well populated, is rather a pedestrian section of the whole of the Hertzsprung-Russell diagram. Indeed, I would think that it must be to you, Professor Hertzsprung, cause of appreciable puzzlement to have watched throughout your life a stream of eager theoreticians working hard on these problems and succeeding to understand even by now only the most obvious feature in the diagram which you plotted for the first time more than fifty years ago.

INVITED DISCOURSE C

given to participants in the General Assembly at 20^h00^m on Monday 21 August 1961 in the Auditorium of Wheeler Hall on the Berkeley Campus of the University of California by

Academician V. A. Ambartsumian

(*President, Academy of Sciences of Armenian S.S.R., Erevan, Armenia* and *Director of the Burakan Observatory*)

on

PROBLEMS OF EXTRA-GALACTIC RESEARCH

INTRODUCTION

The present report deals with the basic facts of extra-galactic astronomy. It should be noted that a true picture of the outer stellar systems (galaxies) was formed in astronomy only about forty years ago. As a result, most basic problems concerning the outer galaxies remain unresolved. We, therefore, formulate in the present report a number of problems which, in our view, seem to constitute the most essential points in the further exploration of the outer galaxies. We shall try to keep as close to the facts as possible and handle, primarily, those problems the solution of which may seem possible in the near future with the means available to us.

It is known that extra-galactic astronomy comes in close contact with cosmology, that is with the theories attempting to describe the universe as a whole. These theories are, undoubtedly, of definite usefulness insofar as several solutions of the equations of Einstein's theory of gravitation are considered, and the question is raised as to the applicability of these solutions to the observed part of the universe. At the same time some of these theories contain rough simplifications and unbounded extrapolations. It is beyond the scope of the present report to make an analysis of these theories and discuss the problems of their further development, although a critical review of the work carried out in this field should be extremely valuable. None the less the facts and the problems discussed below should be of importance to cosmological theories as well.

I. THE PRINCIPAL FACTS ON THE DISTRIBUTION OF MATTER IN EXTRA-GALACTIC SPACE

That the majority of the matter observed in space is concentrated in the stars constitutes one of the properties of the surrounding world. Other bodies contain but a small part of the mass observed.

In the overwhelming majority of cases the observed stars enter, in their turn, into giant stellar groups called galaxies. This is a most significant fact of extra-galactic astronomy.

The stellar population and the dimensions of the galaxies vary over an unusually wide range. The super-giant galaxies of the type of the two brightest galaxies in the centre of the Coma cluster (NGC 4874 and NGC 4889) attain a photographic absolute magnitude of the order of -22. They contain hundreds of thousands of millions of stars, while the dwarf systems of the type of the nearby galaxy in Sculptor are of absolute magnitude $-11{\cdot}0$ and apparently contain only several million stars. However, stellar systems of much lower luminosity exist and might be called sub-dwarf galaxies. The galaxy in Capricorn of absolute magnitude $-6{\cdot}5$, discovered by Zwicky, is an illustration in point. This group seemingly comprises, at most, several tens of thousands of stars and is more than ten million times poorer than some super-giant galaxies. Moreover, it is inferior in population to many globular clusters.

The diameters of the galaxies, as a rule, are included in the range 50 000 pc for super-giants to 500 pc for sub-dwarfs.

The giant and the super-giant galaxies with diameters ranging from 5000 pc to 50 000 pc invariably possess high surface brightness (over 24·0 per square second of arc) and also show an extensive concentration of luminosity towards the centre.

In dwarf galaxies objects with low surface brightness are encountered alongside those with high surface brightness. However, in addition to the systems with high gradient of surface brightness from the border to the centre, there exist also dwarf galaxies with very low gradient, so that such systems look in pictures almost like uniform disks.

Examples of galaxies with low density gradient in the local group are the dwarf stellar systems in Sculptor and Fornax discovered by Shapley. The surface luminosity of these systems is exceedingly low. Later, Baade showed that the galaxies NGC 147 and NGC 185, belonging to the Local Group, also contain a low density gradient. The surface luminosity of these two galaxies is considerably higher than that of the systems in Sculptor and Fornax. Of intermediate surface brightness are two other members of the Local Group: Sextans B ($9^h\,57^m{\cdot}3$, $+\,5°34'$; 1950·0) and Leo 2 ($10^h\,05^m{\cdot}8$, $+\,12°33'$; 1950·0). They also have a very low density gradient. Many objects of low surface brightness and low density gradient are met with in the Virgo cluster. Their linear dimensions sometimes are of the same order as those of the galaxies of average luminosity. For instance, galaxy IC 3475 in addition to its very low surface brightness has a negligible density gradient while its diameter attains 5000 pc. Thus, by dimensions, this galaxy is by far superior to similar objects in the Local Group.

However, it is worthwhile to note that objects of relatively large dimensions with a small density gradient and a low surface brightness are very rare. For instance, in the well-known cluster in Cancer, the largest of such galaxies has a linear diameter of about 2500 pc.

The fact that the absolute majority of stars belong to the galaxies becomes of primary importance if we take into account that the galaxies are, roughly speaking, systems isolated one from another. Usually the distance between neighbouring galaxies exceeds by far the diameters of their central, denser parts. At the same time, external rarified parts of galaxies often penetrate into one another. Besides this topographical isolation, we must also indicate the mutual dynamical independence of the galaxies as stellar systems. The term 'dynamical independence' implies the property under which the motion of the stars in each galaxy is determined, in the main, by its interaction with the other members of the same galaxy. It should also be pointed out that this condition of dynamical independence holds usually only to a certain approximation. The mutual perturbations of two neighbouring stellar systems, the ejections from the central parts of the galaxies, which will be properly considered below, are, to a greater or lesser extent, cases of the violation of this independence.

As the stars belong to the galaxies, likewise the latter, in their turn, form part of such systems of galaxies as the clusters, the groups and the multiple clusters.

Two decades ago it was assumed that in addition to the clusters and the groups of galaxies there exists a general field comprising the greater part of the galaxies—similar to the general star field in our stellar system which is overspread with stellar clusters and associations. Now the existence of the general field itself is in doubt. At any rate, it can be asserted that the clusters, the groups and the multiple systems contain the overwhelming majority of the galaxies of high luminosity.

The clusters we observe can be classed under two types: spherical clusters with a regular, symmetrical distribution of the galaxies about the centre; and loose clusters with an irregular distribution of galaxies. The giant and the super-giant members of the spherical clusters comprise chiefly elliptical galaxies. The irregular clusters contain a high percentage of spirals. Groups of galaxies such as the Local Group or the groups around M 101 and M 81 are, in this respect, very much like the irregular clusters.

For instance, the groups of galaxies associated with M 101 and M 81 virtually contain no elliptical galaxies whatever. They are made up of only spirals and irregular galaxies. A group in Sculptor, studied by de Vaucouleurs, contains only galaxies of the Sc type and some irregulars as well. Our Local Group does not comprise elliptical galaxies of high luminosity either, but it possesses elliptical galaxies of low and moderate luminosity.

It is also interesting to note that our Local Group consists, in fact, of two smaller groups approximately of the size of multiple galaxies. The first group contains our Galaxy, two Magellanic clouds and, apparently, some galaxies of the Sculptor type. The second group comprises the Andromeda nebula with its four satellites and M 33. However, such a division can be ascertained only for galaxies of high and moderate luminosity.

Referring to the dwarf galaxies, they might possibly fill in the space of the Local Group. It should be added that the full mass of the whole Local Group is determined, mainly, by two galaxies which form actually the centres of these sub-groups, that is M 31 and our own Galaxy. On the other hand, in some cases rich clusters of galaxies occur sometimes in twos and in threes, forming multiple clusters.

It has been mentioned above that the galaxies are, as a rule, stellar systems isolated one from another. However, there are cases when this isolation is not observed strictly. Let us indicate the following three categories of such objects:

(*a*) *Interacting galaxies.* This is the case when two galaxies are close to each other and the presence of the one deeply affects the structure of the other. Numerous instances of interacting galaxies are reproduced in the atlas of Vorontsov-Velyaminov. Two interpretations of the interaction under discussion are possible: (i) tidal interactions; and (ii) the division of one galaxy into two. In the latter case the 'interaction' observed should be regarded as the aftermath of the process of division.

(*b*) *Couples of galaxies* interconnected by means of bridges and filaments. Many illustrations of this kind are cited in the articles of Zwicky, who has shown that the filaments are made up of stars. In addition, there are jets flowing out from the central areas of some spherical galaxies. Such jets sometimes contain blue condensations which are known to be the dwarf galaxies. (The high luminosity galaxies NGC 3561 and IC 1182 possess jets containing condensations.)

It turns out that in this case, too, the jet joining the dwarf galaxy to the large one is a kind of filament. In such a case there remains no doubt that the dwarf galaxy has been detached from the main body of the principal galaxy. It seems more plausible, therefore, to regard the bridges and the filaments as resulting from the process of formation of two galaxies from one.

(*c*) *Radio galaxies.* It is known that the radio galaxies were assumed to be cases of accidental collision of a pair of independent stellar systems. It was also assumed that the kinetic energy of the collision of two gas masses, contained respectively in each galaxy, is the source of the energy of radio-emission. The facts, however, contradict this hypothesis. All the data support the view that the radio galaxies form some stage, possibly of short duration, in the process of the internal evolution of the galaxies of very high luminosity.

The radio-emitting activity of the galaxies is, evidently, closely associated with the new formations within them, such as jets and ejections coming from the centre (Virgo A), spiral arms and even complete new galaxies. In other words, in some cases a process of division of the main body of the galaxy and the emergence from it of a new one takes place. That is why radio galaxies often become very narrow pairs, consisting of the old galaxy and the new formation immersed in the old galaxy.

It is to be noted that all the cases of violation of the isolation of galaxies, as referred to above, taken together, constitute only a small percentage of the total number of galaxies. There is every reason to believe that these violations occur only at a certain stage of the evolution of the galaxies, namely when new galaxies come into being.

Notwithstanding the great gains scored in the study of space distribution of the galaxies, many important problems are still unsolved. Here are some of them: do clusters of galaxies form, in their turn, systems of higher order of the type of super-clusters or super-galaxies.

Our Local Group enters, no doubt, into a certain group of clusters with the great cluster of Virgo forming its main part. This great system was named the Super-galaxy by de Vaucouleurs; its dimensions are of the order of 20 million pc. However, nothing can be said so far as to the dynamical unity of this system or the existence of forces that might support such a unity.

It is interesting to observe that the existence of a great number of super-galaxies by no means becomes prominent while making a study of the distribution of galaxies in the sky. In considering this problem one of two possibilities must eventually be realized: (i) the mutual distances between neighbouring super-galaxies are great compared with the linear dimensions of the super-galaxies; or (ii) these mutual distances are of the same order of magnitude as the linear dimensions of the super-galaxies. In the former case a great many such super-galaxies must be clearly outlined in projection on the sky as isolated formations. In the latter case we could trace out only a small number of similar formations in projection on the sky, in the form of isolated systems, and unless we make a deep study of the problem it would be hard to draw conclusions regarding the occurrence of distant super-galaxies.

The observations reveal irregularities in the distribution of clusters and groups of galaxies, which can be accounted for, to a certain extent, by the occurrence of super-galaxies. At the same time it should be stressed that we observe only a few isolated cases of clouds consisting of a number of concentrations; for example, in the southern sky a vast cloud, extending from $l = 160°$ to $240°$ when $b = -40°$.

The irregularities in the distribution of the galaxies in the sky (independent of the absorption in our Galaxy) are clearly shown by the galaxies included in the catalogue of Shapley and Ames (limiting magnitude 13·0). This irregularity is stipulated mainly by the local Super-galaxy. The irregularities become more pronounced in the counts of Shane and Virtanen (limiting magnitude 18·4). The small-scale inhomogeneities are conditioned by the concentrations of the galaxies in clusters. But there are also inhomogeneities of greater dimensions brought about by the tendencies of the clusters to form groups similar to the super-galaxies discussed above.

According to Zwicky and other authors, the irregularities in the distribution of the galaxies

extend up to the boundaries observable by the Palomar Schmidt telescope (almost to the 20th magnitude).

The huge clouds of galaxies in the region of the cluster in Corona Borealis are an illustration in point. However, an investigation of the distribution of the centres of the clusters of galaxies is of great interest when studying the tendencies of clustering of the clusters. Abel has made such a study on the plates of the Palomar Atlas. The results derived confirm the inhomogeneity in the distribution of the clusters.

Zwicky believes that the main cause in the inhomogeneity observed in the distribution of the clusters lies in the patchy distribution of the inter-galactic dust. The arguments he adduces in favour of inter-galactic absorptions in some directions are apparently convincing. Not all the deviations from homogeneity are accountable in this way. That is why the real irregularity in the distribution of the most distant galaxies is something that should be properly taken into account.

These two facts show that the second alternative is realized, that is the distances between the super-galaxies are of the same order as their diameters. Although the existence of independent super-galaxies is to be conceded, nevertheless the following questions remain open:

(*a*) *What percentage of clusters of galaxies enters into these systems of a higher order?* Is there an equally strong tendency towards a clustering of the clusters in the two familiar types of clusters (spherical and diffuse)? Only more detailed photometric and statistic studies could provide answers to these questions.

(*b*) *To what extent do galaxies of low luminosity repeat the space distribution of those of high luminosity?*

The concentration of galaxies in clusters is, as shown above, rather well established in respect to objects of high luminosity. However, beginning at a distance of several million parsecs, objects of low luminosity will be lost altogether among galaxies of remote background, and the solution of the problem will be beset with certain difficulties. Yet some conclusions as to the distribution of objects of low luminosity, especially galaxies of low surface brightness, can be made from the results of the work of Rijves. He established that the distribution of objects with low surface brightness in the Virgo cluster repeats roughly the distribution of galaxies with high luminosity. But we cannot assert whether the galaxies of exceedingly low surface brightness (systems of the Sculptor type or of the Zwicky object in Capricorn) make up one common metagalactic field or concentrate in clusters and groups.

(*c*) *The super-galaxies, referred to above, are objects with a diameter of the order of* 20 *million parsecs*. If they constitute the greatest inhomogeneities in the distribution of the galaxies, space cells, 50 to 100 million parsecs in dimensions, are to be expected to contain approximately equal numbers of galaxies.

It is possible, however, that inhomogeneities of a larger scale occur. The question can be settled only by investigating the distribution of the faintest clusters of galaxies (up to $m = 21$), or by studying the distribution of extra-galactic radio sources. The solution of this problem is extremely important for cosmological theories. For the time being there is no evidence to justify the postulate of homogeneity usually introduced by the cosmologists.

(*d*) *It has already been said above that there are sound proofs in support of inter-galactic dust.* In this connection, the expediency of studying all types of inter-galactic matter is to be underlined. Even already, some species of inter-galactic matter seem to be established as real:

(i) The bright inter-galactic matter, sometimes filling up the central part of the volume, occupied by a cluster of galaxies. All the data testify to the bright matter, as well as the frequently observable bridges and filaments, being made up of stars.

(ii) Inter-galactic globular clusters, some of which are encountered at a distance of over 100 000 parsecs from us.

(iii) Huge clouds of relativistic electrons ejected from the interior of the galaxies. For instance, the radio source of Centaurus A consists of three such clouds, while the source Cygnus A consists of two. Each of these clouds surpasses in dimensions the normal galaxies. Doubtless, most of the clouds of this type have already dispersed in inter-galactic space.

(iv) Absorbing dust. However, we have no data on the dimensions of separate dust clouds.

(v) Neutral hydrogen, which is only so small in amount that the radiation emitted (in the line $\lambda = 21$ cm) has not been so far detected with certainty.

There is no doubt that each of the types of inter-galactic matter deserves a special study.

II. THE BASIC FACTS REFERRING TO THE KINEMATICS AND THE DYNAMICS OF THE SYSTEMS OF GALAXIES

Our knowledge of the motions in the world of galaxies is restricted to the radial velocity of about one thousand galaxies. We have no data on transverse velocities. None the less, the data on radial velocities, obtained almost exclusively at the observatories of Mount Wilson, Palomar and Lick, raise the most difficult problems ever dealt with by astronomy.

The whole complex of the galaxies observed represents one part of a grandiose system which we name the Metagalaxy. This concept of a Metagalaxy is of significance, irrespective of whether there exist galaxies outside this system or not. The fact of the expansion of the Metagalaxy, constitutes an important inference made from our knowledge of the radial velocities of the galaxies. Hubble's law

$$V_r = Hr$$

deduced from the empirical data, holds good for values of r, up to almost two thousand million parsecs. This circumstance signifies the approximate homogeneity of the observed expansion.

All efforts to find an explanation for the redshift, other than the Doppler effect, have been futile. That is why, when treating the large scale properties of the Metagalaxy, the phenomenon of expansion should be given proper consideration.

Of course, Hubble's law is correct only for mean velocities. In addition to the velocity, as defined by Hubble's formula, every cluster and every galaxy has its own peculiar velocity. Thus, in the Local Group, where the distance between the galaxies is small, the relative velocities are mainly determined by the peculiar motion of individual members. But even the nearest clusters of galaxies and groups are receding from us, which is evidence of the smallness of their peculiar velocities in comparison to the regular velocities of recession given by Hubble's formula.

The numerical value of the constant H is of great importance, since a knowledge of it enables us to determine the absolute distance of the remotest clusters. Unfortunately, its precise value is unknown. It is very likely to be somewhere within the limits of

$$60 \text{ km/sec/megaparsec} < H < 140 \text{ km/sec/megaparsec}$$

and we can assume, with some risk, that it is included in the narrower interval

$$70 \text{ km/sec/megaparsec} < H < 100 \text{ km/sec/megaparsec}$$

in conformity with the results of Sandage (1958). We shall not discuss here the difficulties involved in the determination of the value of H; we do point out, however, that in any case Hubble's law makes it possible to give a correct estimate of *relative distances*.

The second important fact regarding the motions of the galaxies is the occurrence of some

dispersion of the velocities in each cluster, related to the internal motions of the galaxies within them.

If the clusters are in a steady state, or are going to become steady, then their total energy E must be negative

$$E = T + U < 0$$

where T and U represent respectively the kinetic and potential energies of the system. On the other hand, if $E > 0$, then such a system cannot come to a steady state and, at least, some of its members must escape from it.

Recent investigations have shown that, for certain groups and multiple systems, the kinetic energy of internal motions determined from the radial velocities exceeds by far the probable value of the absolute magnitude of the potential energy, calculated on the assumptions that the whole mass of the cluster (or group) is concentrated in its galaxies and that the ratio of mass to luminosity $f = M/L$ for the given type of galaxies is of the same order that is found from the rotation of galaxies. It follows therefrom that some groups and clusters possess positive total energy and will be dispersed into space. Such a conclusion has been arrived at, for example, for the clusters in Virgo and Hercules, and also for the nearby group of galaxies in Sculptor. The latter case, analysed in detail by Vaucouleurs, is outstanding, for the kinetic energy exceeds the calculated absolute value of the potential energy by one and a half or two orders of magnitude.

Insofar as the positive energy must lead to the escape of some members and, at times, to the total disintegration of the cluster, it can be presumed that there is something common between the instability of the cluster, on the one hand, and the expansion of the Metagalaxy, on the other.

In this respect an intermediate part is to be played by the systems of the type of Local Super-galaxy. Its component parts are known to recede from one another. For instance, the cluster in Virgo or the M 81 group recede from the Local Group of galaxies.

What has been said about the sign of the absolute internal energy of the clusters of galaxies holds good for multiple systems as well. Apparently some multiple systems also have a positive total energy. All these facts force us into the belief that the corresponding galaxies are comparatively young—their ages being of the order of 10^9 years.

However, one more peculiarity of the assembly of multiple galaxies (triples, quadruples, etc.) engages our attention, regardless of the sign of the total energy. It is known that the great majority of the *multiple stars* have configurations of the 'usual' type, while the configurations of the 'Orion Trapezium' type make up an insignificant percentage ($< 10\%$). On the other hand, nearly half of the *multiple galaxies* have trapezium-like configurations. As the trapezium-like systems are, as a rule, unstable we can infer that the time, elapsed since the formation of these multiple groups, is not greater than a few periods of revolution of such a multiple system, which, in its turn, is of the order of 10^9 to 5×10^9 years.

Finally, the assumption of negative energy for all double galaxies sometimes entails improbably great values for the mass of the components (Page); hence there is reason to believe that some of the double galaxies also possess positive energy.

In very close pairs, such as the radio galaxies, considerable differences in the velocities of the components are noticed; thus in the radio galaxy Perseus A this difference reaches 3000 km/sec. In this way these pairs also possess positive energy. We apparently observe in this case the formation of such a pair out of one galaxy.

Further accumulation of data on the radial velocities of galaxies will make possible the

solution of many unresolved questions of their kinematics and dynamics. Some of these questions are listed below:

(*a*) *A more precise determination of the constant of the redshift law.* This will provide the scale of extra-galactic distances.

(*b*) *A determination of the character of the redshift law for very large distances.* We must observe, no doubt, a violation of linear dependence. The sign of the deviation from the linear relation and whether the magnitude of this deviation is independent of direction are important factors in the basic problems of cosmology.

(*c*) *It is of significance to determine the peculiar velocities of the centres of gravity of the separate clusters of galaxies*, that is the deviations of their observable velocities from Hubble's formula. This is of great importance for the solution of problems connected with the possible genetic relations between neighbouring clusters. But to determine these deviations it is essential to develop further the methods of precise determination of the distances of the remote clusters, independently of Hubble's law.

(*d*) *To solve many questions of the dynamics of multiple galaxies and of clusters it is essential to determine their masses.* Unfortunately, in the case of distant galaxies entering into the above-mentioned systems, we determine the masses statistically, assuming negative energy and also the applicability of the virial theorem.

It is necessary to determine the masses of the galaxies, at least in the nearest clusters, irrespective of this assumption. At the same time, means should be found to enable us to evaluate, at least, the upper boundaries of the probable inter-galactic mass in each system (clusters or groups).

(*e*) *The inconsistency between masses of systems, defined by the virial theorem, and masses, determined from the luminosities of the individual members of the system, is most prominent for some irregular clusters and groups of galaxies* (clusters in Virgo, Hercules, the group of galaxies in Sculptor, in Leo etc.). On the other hand, according to Zwicky, rich spherical clusters show no signs of expansion.

To reach a final decision on these problems a greater number of radial velocities in some of the nearest rich spherical clusters should be obtained.

III. SOME FACTS ON THE NATURE OF GALAXIES AND THEIR CLUSTERS

Observations show that a great diversity of form and internal features are encountered in the galaxies. To gain a fuller insight into their nature, it is important to have a complete, but simple, system of classification of galaxies. It is quite evident that the deeper the physical meaning of the criteria forming the basis of the classification, the more useful it will prove in solving problems of extra-galactic astronomy.

The wide-spread classification of Hubble is based only upon a study of the outer forms of the observed galaxies. It turned out to be of extreme usefulness for, until quite recently, all our information concerning the overwhelming majority of the galaxies was confined to data on the form, the integral brightness and the apparent diameter. The last two parameters do not, by themselves, constitute characteristics of the system in so far as the distance remains unknown. In recent years, however, we have succeeded in judging approximately the absolute brightnesses and the linear diameters of a great many galaxies entering into rich clusters, as it became known that the brightest members of these clusters are always super-giants with an absolute magnitude of order of $-21{\cdot}0$. If we compare this value with the apparent magnitude of the brightest members, we can make a very rough estimate of the distance and, thereby,

of the luminosity and the absolute dimensions of all the remaining members. It was stated at the beginning of this report that the range of the luminosities of the galaxies within the clusters is very great. Gradually, it became clear that the attribution of a given galaxy to the category of super-giants, giants, objects of moderate luminosity, dwarfs and objects of extremely low luminosity (of the type of the Zwicky object in Capricorn) is in most cases much more essential than the recognition of its form. Let us recall once more that a super-giant galaxy contains millions of times more stars than any galaxy of extremely low luminosity.

To understand better the properties of the galaxies, it is substantially significant to study their central parts and particularly to verify the existence of dense central nuclei of small dimensions. It is also desirable that new attempts of classification should give a proper consideration to luminosity criteria. The assignment of the class should take into account the role of the central parts and possibly of the nucleus itself. Probably there are also other, so far unknown, parameters which are extremely important in describing the state of the galaxy.

The classification suggested recently by Morgan, which takes into account the degree of concentration of luminosity, is, to a certain extent, in line with one of these desiderata; but the assignment of a Morgan class leaves the luminosity indefinite. Recently Van den Bergh has made an attempt to construct a parameter determined by the observable forms of the galaxy which, in essence, defines its luminosity. This is a valuable principle. However, Van den Bergh's classification is not universal and involves only late-type spirals. It is to be assumed, therefore, that new classifications will be proposed in future which will take into account the most important parameters of each galaxy.

The concepts of the existence of sub-systems in galaxies and of various types of stellar population is a remarkable achievement of the second quarter of our century (Lindblad, Kukarkin, Baade). In a number of galaxies, such as the systems of the type EO, we notice rather a high degree of homogeneity of the population; in such cases it can be maintained that the whole galaxy is composed of only one sub-system. This is true particularly for such members of the Local Group as the one in Sculptor, and galaxies M 32 and NGC 147. Unlike the view expressed sometime ago by Baade, we do not observe systems in nature consisting wholly of populations of the first type (the population of the spiral arms). In most cases, the galaxies represent superpositions of two or more sub-systems, containing various types of population.

Thus the lenticular galaxies (SO) consist of two sub-systems, made up of stellar populations of both the spherical component and the disk. The giant spirals of the M 31 type are composed of the spherical component, the disk and the spiral arms. Possibly a more detailed division is needed; but at this place we should like to emphasize *the phenomenon of superposition* of the various sub-systems.

The data available indicate that the various sub-systems follow different paths of evolution. There is reason to believe that the average age of the stars of different sub-systems varies too. It turns out that, if the dynamical interaction is not considered, each of the sub-systems leads its own life. It is exactly this factor that assumes importance in describing the galaxies as composite systems, resulting from the *mere superposition of the sub-systems.*

There is no correlation between the degrees of development of the different sub-systems of the galaxies. This verifies the relative independence of the different sub-systems entering into the same galaxy.

Thus the spherical sub-system of M 31 does not sensibly differ in its richness and dimensions from the normal galaxy of EO type of absolute magnitude about $-19{\cdot}0$. Nevertheless

the latter has no population whatever of a flattened sub-system and spiral arms, whereas M 31 possesses powerful spiral arms and a rich disk population.

Systems of an intermediate position are also of interest from this standpoint; in such systems one of the sub-systems is quite well developed while the other is comparatively poor. A striking illustration is offered by NGC 5128 (radio source Centaurus A) which on over-exposed plates looks like an elliptical galaxy but, as a matter of fact, contains in its central part a poorly developed flattened sub-system, including a lot of absorbing matter. The work of the Burbidges, based on measurements of radial velocities in this flattened sub-system, has revealed that the equatorial plane of the latter is nearly perpendicular to that of the elliptical sub-system; this bears testimony to the independence of the sub-systems. NGC 3718 is another interesting illustration. The spiral arms of this galaxy are of small power but, unlike NGC 5128, extend far beyond the boundaries of the volume occupied by the spherical sub-system; the plane of concentration of the dark matter is inclined at about 25° to the equatorial plane of the elliptical sub-system, which is further evidence in favour of the independence of the sub-systems.

Opposite examples might also be produced in which the spherical system is under-developed while the flattened system is very prominent. The Large Magellanic Cloud could apparently serve as an example; that there is a spherical sub-system in this cloud is inferred from the existence of at least three dozen globular clusters similar to those in our Galaxy and in M 31. Unfortunately, other objects of the spherical sub-system are very hard to uncover against a background consisting of the population of the flattened sub-system. It is therefore difficult to say which type of elliptical galaxy resembles the spherical component of the Large Magellanic Cloud; judging by the number and distribution of globular clusters this must be an elliptical galaxy of moderate luminosity ($M \sim -16$), having a low density gradient. It is well known that when passing from the super-giant elliptical galaxies to those of moderate and low luminosity, objects with low density gradient become more frequent.

Mention has been made above of the comparative independence of the various sub-systems entering into the same galaxy. But in one respect the bond between the sub-systems is always observed with great strictness. We have in mind the common centre. The centre of the spherical sub-system coincides with that of the disk and also with the region out of which the spiral arms emerge. As is evident from observations of the nearest galaxies of high luminosity, this centre is usually the location of a nucleus only several parsecs in dimensions (less than the diameter of the common globular cluster). It seems natural, therefore, that the formation of separate, almost independent sub-systems is somewhat linked with the occurrence of the above-mentioned nuclei.

No traces of nuclei have been reported in a number of galaxies; such is the case, for example, with NGC 185 and with Sculptor. But let us consider the luminosities of the nuclei. The absolute photographic magnitude of the nucleus of M 32 is $-11{\cdot}6$; in M 31 it is $-11{\cdot}1$ and in M 33 it is $-10{\cdot}3$. In NGC 147 it is $-5^{m}{\cdot}0$. One gathers the impression that the luminosity of the nucleus decreases with the diminution of the density gradient. It is to be expected, therefore, that in NGC 185 and in the systems of the Sculptor type, as probably in the Magellanic Clouds, the nucleus must have a still lower luminosity than in the NGC 147. If it is of order -2, it is evident that the nucleus will be lost among the stars. Let us note that in the Magellanic Clouds the nucleus may remain unnoticed even if it is of magnitude -5; it is therefore premature to insist on the absence of nuclei in these systems. But if the nuclei do exist they must be of small power.

It has been noted above that usually the concentricity of the sub-systems in each galaxy is observed very strictly. However, there are cases of deviation from this rule; NGC 4438, in

the Virgo cluster, is a pertinent example where the two sub-systems are clearly shifted in respect to each other.

There is a certain similarity between the galaxies and the clusters. This lies in the fact that the member galaxies in clusters can be attributed to two different types of population, just like the stars in galaxies. To the first type belong the spiral galaxies and the irregulars, while to the second belong the elliptical and the lenticular galaxies (SO).

Large spherical clusters of galaxies, such as the one in Coma, are rich in populations of the second type. The loose clouds of galaxies like the Ursa Major Cluster, one of the nearest to us, have almost no elliptical galaxies of high luminosity. The nearest to us, a group of galaxies in Sculptor ($m-M = 27{\cdot}0$) studied by de Vaucouleurs, is not only deprived of elliptical galaxies but contains no galaxies of So, Sa and Sb types either. Only spirals of late subdivisions are included in this group. The large irregular cluster in Virgo contains giant elliptical galaxies as well as giant spirals.

Then comes the question: *is it possible to speak of the superposition of different sub-systems of galaxies in one cluster?* It must be admitted that combination of two quasi-independent sub-clusters into one are not observed; nevertheless, certain observations clearly favour this view. Thus in the Coma cluster one of the central galaxies (NGC 4874), which is a supergiant of the So type, is apparently surrounded by a symmetrical cloud of elliptical galaxies of lower luminosity. Externally this group is very much like galaxy NGC 4486, surrounded by globular clusters. In this case, however, the latter are replaced by elliptical galaxies of moderate luminosity; and this dense group of elliptical galaxies, with NGC 4874 in the centre, overlies a large cluster of galaxies, possessing a small density gradient.

For irregular clusters of galaxies we can presumably discover many more phenomena testifying to the superposition of separate groups. The chain of bright galaxies M 84, M 86, NGC 4435, 4438 and others in the Virgo cluster is an example in point; this chain is not an accidental formation, as stated by Markarian a few years ago, but overlies the Virgo cluster as an independent group.

It is highly probable that the irregular clusters of galaxies generally represent results of combination and superposition of a number of more-or-less independent groups, out of which their irregular form arises.

It must be recalled, in this connection, that there exist clusters (or groups) made up of one central galaxy surrounded by a smaller or greater number of objects of low luminosity. The group around M 101, for example, belongs to that category. We emphasize this fact because, in such cases, the common origin of the central galaxy and its faint satellites admits of no doubt. However there are, in addition, groups consisting almost exclusively of super-giants; Stephan's Quintet is a pertinent example. Unlike the M 101 group, no galaxies of low luminosity appear around these super-giants. Of course, it is possible that here we have a case of discontinuity of the luminosity function, and that this system contains some galaxies with an absolute magnitude fainter than the detection limit. The facts mentioned above, in conjunction with what has been said about the exceptional position of M 31 and our Galaxy in the Local Group, emphasize the great cosmogonic significance of the super-giant galaxies in clusters and in groups.

It is also clear from the foregoing that, besides investigating rich clusters of galaxies, it is very important to have as much data as possible for the comparatively poor groups. In particular, it is essential to find out whether there exist many isolated groups, composed exclusively of galaxies of low luminosity; if such groups are not abundant this would signify

that the cosmogonic processes going on in a galaxy of high luminosity are essential for the formation of surrounding dwarfs.

In spite of certain gains achieved in the investigation of the character of the stellar population of galaxies and various sub-systems, it is to be admitted that only the first steps have been taken in this direction.

We are in urgent need of further data on the composition of the population based on spectroscopic evidence (on the lines contemplated by Morgan and Mayall) and also on the quantitative analysis of the continuous spectrum (Markarian *et al*).

Another question of importance is the analysis of the nature of the arms of galaxies. Among galaxies with arms of the same degree of openness and length we find objects both very rich and very poor in O-associations. To discover a correlation between the nature of the arms and the other parameters of the galaxies would get close to realizing the cause of these differences.

Of particular interest are the barred spirals (SB). To our regret, we do not fully realize the difference between the population of the bars and the arms. It is only known that usually the colour of the bars is considerably redder than the colour of the arms and that the latter, therefore, contain a larger number of stars of recent formation. It is especially important to find out to what extent the bars are rich in open clusters and super-giant stars.

IV. AN EXTENDED UNDERSTANDING OF THE PHENOMENA OF SUPERPOSITION

We have already spoken of the particular cases in which the centres of the sub-systems comprising the giant galaxy are shifted relative to one another. However, we know of other galaxies which are double but are in fact linked together by means of a material medium and can, therefore, be regarded as single systems. M 51 and NGC 7752–7753 are good examples. It is natural to think that in these instances we are concerned with diverging centres of sub-systems of one single galaxy. In the case of IC 1613, on one side of the main mass of the galaxy, there is a super-association which can be regarded either as part of the main galaxy or as a separate satellite galaxy. It is highly probable that this super-association, consisting of hot giants, was formed much later than the remaining galaxy. (We have almost the same situation in galaxy IC 2574. To the north of the main part of this galaxy is a bright super-association, connected with it by means of a faint arm.) It can be presumed in this connection that the evolution of the galaxy is stipulated by the consecutive formation of the various sub-systems. One or other of the sub-systems, and sometimes the group of the sub-systems itself with a new centre, may become the satellite of the principal galaxy. This view leads to the idea that the formation of the satellite, and the origin of the new sub-system within the limits of the given galaxy, are related phenomena. Moreover, these phenomena can supposedly accompany one another. Thus, where the spiral arms join the centre of the given galaxy to the satellite it is natural to assume that the formation of the spiral arm and the satellite coincide in time.

After all, a satellite, of the type of the dwarf system in Sculptor, revolving around some giant galaxy differs but little in scale, and nature of population, from a globular stellar cluster which doubtless evolves from inner processes within the galaxy. Therefore, it is natural to assume that satellites of the Sculptor type have a similar origin.

V. PHENOMENA OF INSTABILITY IN THE GALAXIES

Up to the present we have spoken of the galaxies as stable formations. But unstable phenomena of great interest also take place in galaxies, particularly in the super-giants.

We do not refer here to the processes of star formation in associations, although they are sometimes pronounced; we mean more rapid, readily-observable changes. It is interesting to

note that the greater part of these unstable phenomena is linked with the nuclei of the galaxies and can even be regarded as the manifestation of activity of these nuclei.

(*a*) *Neutral hydrogen flows out from the central part of our Galaxy.* This phenomenon was uncovered by the Dutch astronomers through observations made at 21 cm. A similar phenomenon of gas outflow from the nucleus of M 31 was detected by Munch, following an investigation of the line λ 3727. In both cases the outflowing mass is of the order of one solar mass a year; oddly enough, this result is difficult to reconcile with the data on the mass of the galactic nuclei in question (of the order of 10^7 $M_\odot$).

(*b*) *In a number of galaxies, with nuclei of high luminosity as stated by Seyfert, the emission line* λ 3727 *is remarkably widened.* This corresponds to velocities of motion of the order of several thousand kilometres a second; these velocities exceed those of escape. This is why we are concerned with a powerful outflow of gas, ejected with high velocity from the centre and then dispersing into infinity. Here, the amount of the outflowing gas supposedly far exceeds the corresponding amount for our Galaxy and M 31. The blue galaxies of Haro, in which the emission lines are intensive around the region of the nucleus, are expected to be of a similar nature.

(*c*) *In the very centre of the radio-galaxy NGC* 4486 *we also observe* λ 3727 *and deduce rather a heavy outflow of gas with a velocity of about* 500 *km/sec.* If we compare this with the radial jet, springing up from the centre of the galaxy and containing condensations radiating in intensive radio-emission, we come to the conclusion that these condensations are ejected with high velocities from the central nucleus of the galaxy. The polarization of light in these condensations points to the presence of high-energy electrons. These condensations are formations of much larger scale than the Crab nebula; the power of their radio-emission, measured in absolute units, is tens of millions of times greater. If we visualize that the duration of the radio-emission, must be, in this case at least, a thousand times more, we conclude that the supplies of energy in these condensations exceed the total supply of the energy of the Crab nebula by thousands of millions of times. In other words, by their energy and masses, these condensations must be objects representing smallscale galaxies, in agreement with their photographic absolute magnitudes.

Were these condensations ejected from the nucleus of the galaxy as real clouds of relativistic electrons or, which is more probable, were objects ejected from the nucleus, forming continually new currents of such electrons? This is another question. However, the very fact that such large-scale condensations may burst out from the nucleus of the giant galaxy is of great interest. This can hardly conform with our information about the masses of the nuclei of the galaxies.

(*d*) *The position in other radio galaxies is much more difficult to interpret.* Even the galaxy NGC 1275 (Perseus A) is known to belong to the class of Seyfert galaxies in which the line λ 3727, observed in the central regions, is widened. In other words, there is, in this case too, an intensive outflow of matter from the nucleus. The existence of two nuclei in the radio galaxy Cygnus A points seemingly to a process of nucleus division that took place recently; in connection with the views expounded above this will lead to the formation of sub-systems with various centres, with a consequent formation of a double galaxy.

In any case NGC 5128 (Centaurus A) also demonstrates that the nuclei of galaxies are able to eject either huge clouds of relativistic electrons or some condensations of matter capable of giving rise to such clouds in the future. One way or another, the radio galaxies are systems in which the central nuclei exhibit tremendous activity—including sometimes the formation of new condensations, new sub-systems and probably new galaxies. We can, therefore, assuredly

speak of the *cosmogonic activity of the nuclei* although we are unaware at the expense of which masses such an activity is displayed.

(*e*) *We know of giant galaxies with jets bursting out from the central regions.* In some cases these jets contain *blue galaxies* of absolute magnitude of order -15, that is of higher luminosity than the condensation in NGC 4486. NGC 3561 and IC 1182 serve as examples of such galaxies. The ejection of these condensations is one more form of the cosmogonic activity of the nuclei of the galaxies.

(*f*) *That the spiral arms arise from the nuclei of the galaxies proves that their formation is also directly connected with the nucleus.*

(*g*) *Radio observations of the centre of our Galaxy, made by Parijsky and others, show that the state of the nucleus, known to be composed mostly of late-type stars, differs markedly from the state of other groupings of similar stars (such as the globular clusters).* The nucleus of our Galaxy is the source of thermal radio-emission while the surrounding region, with a diameter of the order of 500 parsecs, is the source of a heavy non-thermal emission. These facts indicate that the physical state of the nuclei is quite different from that of common stellar groupings.

One of the important problems confronting us in the study of the outflow of matter and ejections from the nuclei of the galaxies is the quantitative evaluation of the ejected masses. This refers equally to those galaxies, of which the central parts show emission lines, to the radio galaxies and to other examples with discrete ejections.

The few facts at our disposal show that these data may conflict with the law of conservation of energy (and matter) in its present form, and may perhaps require a generalization of this law.

VI. CONCLUSION

We note that the activity of the nuclei determines the most important processes in the life of large galaxies. This activity assumes several different forms as discussed above; however, two of them deserve special mention. One concerns the formation of the spiral arms, while the other is concerned with the formation of the stars and the stellar clusters of the spherical components. These phenomena seem to occur at different stages of development and are accompanied by corresponding changes in the nuclei. It is to be noted, at the same time, that the very process of formation of a given type of sub-system must vary under different circumstances. Thus M 32 does not apparently contain globular clusters while another satellite of the Andromeda nebula (NGC 205) comprises at least nine globular clusters. It is most surprising that globular clusters occur in the galaxies with a low density gradient. If we take for granted the hypothesis of the formation of galaxies from initially diffuse clouds, it would seem natural that dense formations, such as the globular clusters, should originate in systems with very high density regions, that is where high density gradients exist. Nonetheless, such qualitative reasoning cannot, of course, be considered quite adequate. *The number of globular clusters, per unit of luminosity of the spherical population, varies in different systems.* We have, therefore, an additional parameter to characterize the spherical systems and sub-systems. How this parameter is related to others of the same system (integral luminosity, density gradient) will become evident from observations.

Statistical data concerning multiple galaxies and clusters of galaxies show that these systems could not form by the capture of formerly independent galaxies. Hence a common origin is to be ascribed to the components of these systems. This problem was dwelt upon in detail in our Solvay report of 1958.

In the light of the data on the ejection from the nuclei of condensations, later on becoming complete galaxies of moderate or low luminosity, and also on the division of the nuclei, one can presume the formation of multiple systems and whole groups consequent upon the splitting of one initial nucleus into several. This division is likely to recur consecutively.

Where there is a central galaxy of high luminosity in the group, the formation of faint galaxies must be related mainly to the activity of the nucleus of the high luminosity galaxy.

That there is high activity of the nuclei of super-giant galaxies is proved by the fact that radio galaxies usually form one of the brightest members of the cluster to which they belong. If there is one dominant galaxy in the corresponding cluster this must be the radio galaxy itself.

Observations reveal that, although all the large clusters contain super-giant galaxies, only a small part of the latter are radio galaxies. Thus the radio-emitting activity must be a relatively short-lived phase in the evolution of the galaxies. The ejection of the radio-emitting agents is apparently a phenomenon accompanying the outflow from the nuclei of more powerful masses, and possibly taking place at a certain stage of the particular cosmogonic process.

Although extra-galactic astronomy has already explored certain forms of the activity of the nuclei, our information on the various types of this activity is scanty. Still smaller is our knowledge of the parameters characterizing the integral properties of these nuclei—luminosity, mass, colour, dimensions, rotation; after all, we know nothing about the internal structure of these nuclei. In this respect, there is open the widest range of exploration in the field of extra-galactic astronomy. Here are some of the questions and problems still outstanding:

(*a*) *Do all the galaxies possess nuclei? If not, which are then the features that characterize the non-nuclear galaxies?*

(*b*) *The determination of the integral characteristics of the nuclei for a possibly large number of galaxies.* The practical difficulty of doing this for galaxies of high density gradient should be properly visualized. At the same time, it is pointed out that the nucleus of most galaxies of the Sc type are of such prominence that they can be explored without considerable influence from the peri-nuclear central condensation.

(*c*) *The determination of the correlation of the integral parameters of the nuclei with those of the galaxies.*

(*d*) *An exploration of the spectra of the nuclei in galaxies, showing emission lines, phenomena of rotation and outflow.*

(*e*) *An investigation of the inter-relationship between the nucleus and the bar in barred galaxies and of the relation between the bar and the phenomenon of outflow from the nucleus.*

(*f*) *The investigation of galaxies with multiple nuclei; and a study of the radial velocities of the separate components of such nuclei.*

(*g*) *The dependence of the total number of globular clusters upon the nature of the nucleus of the galaxy.*

Although we have formulated some conceptions concerning the formation of the galaxies, nevertheless we have attempted to adhere to the facts and to refrain from unfounded speculations. The analysis of the facts indicates that the phenomena concerning the formation of the galaxies are so unusual that they could not be predicted on the basis of any theoretical preconceived proposition. Here we again meet an outstanding phenomenon being repeated in the history of astronomy. As one enters the realm of new phenomena, new qualitative regu-

larities are found which overstep the limits of past conceptions. This makes every such realm more interesting. Therefore, we should bring together, still more minutely, facts and observations. The increase of observational data, the assembly of more precise information about the real objects, the accumulation of considerable information about the structure of the various parts of the galaxies, and a thorough analysis of this information, can help us in solving these difficult problems, some of which have been discussed here.

PART 4

REPORTS OF MEETINGS OF COMMISSIONS

COMPTES RENDUS DES SEANCES DES COMMISSIONS

3. COMMISSION DES NOTATIONS, DES UNITES ET DE L'ECONOMIE DES PUBLICATIONS

Report of Meeting, 17 August 1961

CHAIRMAN: D. Barbier

SECRETARY: R. J. Northcott

The following members were present: J. B. Sykes, F. Zagar. The General Secretary, D. H. Sadler, was present for some of the discussion.

A letter was read from M. F. Subbotin, the President of the Commission, to the General Secretary. This advocated the dissolution of the Commission.

The following topics were discussed:

1. Professor O. Thomas suggested the standardization of the method of drawing the lines between stars in constellations. No seconder.

The discussion indicated that these lines are of some use to people when first learning the constellations, and that there is no need to require the lines always to be drawn in the same way.

2. Professor O. Thomas suggested the use of the metric light year (10^{13} km) as a unit of distance. No seconder. The members present felt this would complicate the units.

3. Professor J. Kleczek suggested the compilation of a glossary of astronomical terms. No discussion of this was necessary because Commission 5 has reported that such a list has now been published.

4. Professor M. F. Subbotin suggested that there is no need for the compilation of a new list of notations.

5. Professor M. F. Subbotin suggested the dissolution of Commission 3. This provoked considerable discussion. It was agreed that the Commission had been useful in the past, but that at present there was little action required by the Commission. Some members felt strongly that there was no need to dissolve the Commission at present, and that it could act as a co-ordinator for notations for other Commissions and Scientific Unions. It was agreed that the part of the title "Economy of Publications" does not represent the work of the Commission in practice.

A vote was taken on Professor Subbotin's suggestion for the dissolution of the Commission: in favour, 1; against 2, abstained, 1.

The General Secretary pointed out that the Executive Committee was anxious to simplify the work of the Union, and that decreasing the number of Commissions was one way of accomplishing this. The small attendance at this meeting was evidence of the decreasing usefulness of Commission 3.

After a short discussion concerning names proposed for the posts of President and Vice-President of the Commission, the meeting adjourned.

[Subsequently, the Executive Committee decided to recommend to the General Assembly that the Commission be dissolved; and this was agreed.]

4. COMMISSION DES EPHEMERIDES

Report of Meeting, 16 August 1961

PRESIDENT: W. Fricke
SECRETARY: R. L. Duncombe

The meeting opened with an introductory report by the President. The Commission was informed of the following three items:

1. The "Consultative Committee for the Definition of the Second" met at the Bureau International des Poids et Mesures in Paris on 11 and 12 April 1961. Among the recommendations adopted by this Committee is the following of special interest to Commission 4:

   "Le Comité Consultatif pour la Définition de la Seconde,
   considérant que la précision avec laquelle peut être déterminée la seconde des Ephémérides est inférieure à la précision que permettrait l'emploi d'étalons atomiques, recommande aux Laboratoires de pousser leurs recherches sur les étalons atomiques de fréquence assez activement pour qu'une nouvelle définition de l'unité de temps puisse être soumise à la Douzième Conférence Générale des Poids et Mesures."

   The astronomers who are members of the "Consultative Committee" supported the recommendation. Therefore, there seems to be little doubt that a new definition of the unit of time will be introduced at the twelfth General Conference of Weights and Measures. No discussion is proposed on this item.

2. It has been noted with special satisfaction that in the *Japanese Ephemeris* for 1962 the ephemerides of the Sun, Moon and planets have been reproduced from the advanced proofs of the *Astronomical Ephemeris* which were provided by H.M. Nautical Almanac Office. This procedure is much welcomed by the Commission, since it is in complete conformity with its recommendation that multiple and independent calculation of basic astronomical data for the Ephemerides be avoided as far as possible.

3. G. M. Clemence is at present forming a new theory of the motion of the Earth. In view of the known deficiencies in the present theory the President proposes that Clemence's new theory be adopted as the basis of the published ephemerides as soon as possible after its completion.

A progress report on the formation of the new general theory of the motion of the Earth was given by G. M. Clemence. He stated that the first-order theory is now complete and that it is hoped to have the higher-order portion finished within a year. In view of this report recommendation no. 1 (given below) was unanimously adopted by the Commission.

In accordance with the newly adopted By-laws, the membership of Commission 4 has been enlarged. The nominations of W. Fricke for President, and G. M. Clemence for Vice-president, were submitted by the Executive Committee for the information of the Commission. On the recommendation of the Executive Committee, the Commission approved the following members of the Organizing Committee; Danjon, Fernandez de la Puente, Kovalevsky, D. K. Kulikov and Sadler.

On the determination of ΔT, the difference between Universal Time and Ephemeris Time, Sadler commented as follows:

'There is now available a system of atomic time, denoted in principle by the abbreviation A.T., which is an essentially continuous measure of time based on an adopted value for the

frequency of the caesium oscillator. There are in fact two independent systems, denoted by A.1 and T.A.1, which are in good agreement. This measure of time, A.T., is linearly connected with Ephemeris Time, E.T., within the limitations of the possible physical difference between the nature of the astronomical and atomic time scales; over a period of several years the linear relationship is certainly adequate to within a few parts in 10^{10}.

'The transmissions of A.T. directly provide the physicist with measures of frequency and of time-interval. By comparison with Universal Time (U.T.), observed by transits of stars to within a few milli-seconds, it also provides the geophysicist with a clear picture of the irregularities in the rotation of the Earth. E.T. is no longer a requirement for these purposes.

'Moreover, the constants in the linear relationship between E.T. and A.T. are to be determined from the observed values of E.T.; the precision of their determination increases with the number of observations of E.T. and with the length of the interval over which comparisons with A.T. are valid. At any one time, E.T. can now be derived from A.T. with a far higher precision than that with which it can be directly observed.

'If the difference between Universal Time (U.T.) and Atomic Time (A.T.) is denoted by ΔA, in the sense A.T. = U.T. + ΔA, then the difference $\Delta T - \Delta A$ is a slowly-varying linear function of time; and ΔT may be obtained from the observed values of ΔA with far higher precision than it can be determined by a single night's observation of the Moon. Values of ΔT so derived will almost certainly be adequate for the reduction of astronomical observations, for the calculation of local circumstances of eclipses, and for similar requirements; they will also form a surer basis for the extrapolation, over a few years, of the value of ΔT used in the preparation of navigational ephemerides.

'There would thus appear to be no longer a requirement for the urgent availability of observed values of ΔT. Moreover, if the only use for Ephemeris Time is astronomical, the precision required in its determination should be related to the precision with which it can be used. It is true that the highest precision is desirable to reduce the length of time required to determine whether there is a significant difference between the astronomical and atomic time scales; but other factors may impose a lower limit on this.

'The above considerations are relevant to the precise method of defining ΔT, and the possible centralization of responsibility for issuing authoritative values of ΔT. It is now clear that each individual investigator should be free to derive his own values from the observations; the important factors are that the methods of derivation and application should be consistent, and that the basis should be precisely stated.

'Ephemeris Time is the time-argument of the ephemerides of the Sun, Moon and planets, so that a precise knowledge of E.T. is in principle necessary for some space research; but other sources of uncertainty (for instance, the value of the astronomical unit) are likely to be more important.

'In this connection it must be emphasized that the time-argument of the ephemerides of artificial satellites, and thus the time-system which their motions define, cannot be precisely Ephemeris Time. The connection with E.T. can be directly determined only by observations of both the Sun and satellite over a long period of time. E.T. can be indirectly determined by observations of both the Moon and satellite over a shorter period of time; but the precision is then absolutely limited by the uncertainty in the connection between the motions of the Moon and the Sun. However, it is the comparison with the system of Atomic Time, and not with Ephemeris Time, that is of both practical and theoretical importance.'

Danjon commented that in order to derive Ephemeris Time it is necessary to determine the longitude of the Moon. For this purpose he advocated the formation of a central bureau, charged with the duty of determining Ephemeris Time.

Clemence pointed out that the only long-term determination of E.T. so far had been made by Brouwer, and since there is no generally accepted method for dealing with this problem, it seems unadvisable to have such a bureau. It was agreed that this was a problem for consideration by Commissions 17 and 31 also.

Aoki proposed a change in notation to distinguish the ΔT and E.T., determined in practice by observations of the Moon, from the true ΔT and E.T. defined by the motion of the Sun. Mikhailov pointed out that any such change should be submitted for the consideration of Commissions 17 and 31. A committee, on behalf of Commission 4, drew up recommendation no. 2 (given below) which was submitted to, and approved by, Commissions 17 and 31.

Fricke made a statement on the introduction of FK 4 into *Apparent Places of Fundamental Stars* (APFS). As announced in the Report of the Commission the 'Fourth Fundamental Catalogue' (FK 4) has been completed at Heidelberg. While the printing and publication of the catalogue will still take some time, the Astronomisches Rechen-Institut is already prepared to deliver on request positions and proper motions of FK 4 stars for 1950·0, on punched cards, to the ephemeris offices and to other users who urgently need the catalogue.

The first volume of APFS to contain printed values based on FK 4 will be that for 1964. The Astronomisches Rechen-Institut will publish the differences 'FK 4 − FK 3' for the year 1962, before the end of 1961. The differences can then directly be added to the apparent places in the volume APFS for the year 1962 to give apparent places on the system of FK4. The determination of Universal Time will therefore be based on the system of FK 4, commencing with 1962 January 1 (according to Resolution no. 59 of the tenth General Assembly).

In view of this report recommendation no. 3 (given below) was unanimously adopted by the Commission.

Danjon pointed out that the change from FK 3 to FK 4 introduces a discontinuity in the determination of Universal Time, and that since it is generally agreed that there is already available a much better value of the aberration constant (20″·51) it is regrettable that it is too late now to introduce both changes at the same time. To emphasize the importance of this correction, he pointed out that the present aberration constant introduces an error of a few milliseconds in Universal Time as determined at Paris. He further stated that a new conference on astronomical constants to be held in 1963 would consider the adoption of the new value of the aberration constant.

In regard to the exchange of astronomical data in machine-readable form, Fricke pointed out that Commission 7 had appointed a committee to recommend exchange procedures. The chairman of this committee, W. J. Eckert, made the following statement.

'The committee would appreciate any guidance from Commission 4. The committee has concluded three alternatives:

1. Try to establish a central agency for the exchange of records.
2. Collect and publish information concerning the availability of records.
3. Treat machine-readable records the same as any other research facility and assume that exchanges will be arranged by individuals on their own initiative as at present.

The latter point of view is strengthened by the fact that in January the General Secretary of the Union circularized all Members with a request that anyone interested in making records available communicate with the Committee. No replies have yet come to the Chairman.'

It was proposed that any helpful suggestions by the members of the Commission be made directly to Eckert.

In regard to the compilation of a list of fundamental constants, it was pointed out that an historical list will be available in the *Explanatory Supplement to the Astronomical Ephemeris and to the American Ephemeris and Nautical Almanac*, and Fricke proposed that a modern list be compiled by the national ephemeris offices themselves.

Commission 4 unanimously approved the following proposed changes in the *Connaissance des Temps*, submitted by Kovalevsky.

Beginning with the volume for 1963; (*a*) the apparent places of stars that are currently published will be discontinued, and (*b*) the mean places, for the beginning of the tropical year, of all the stars in the Preliminary Supplement to the FK 4 will be included.

The *Draft Report*, as amended in the President's report, was approved unanimously.

RECOMMENDATIONS

1. It is recommended that, upon completion, Clemence's new theory of the motion of the Earth be adopted as the basis for the published national ephemerides.

Il est recommandé que, lorsque la nouvelle théorie du mouvement de la Terre par Clemence sera terminée, celle-ci soit adoptée comme base pour les publications des éphémérides nationales.

2. The provisional value of ephemeris time that is obtained by comparing the Moon's mean longitude, given by observations, referred to the equinox of FK 4, with the positions tabulated in the *Improved Lunar Ephemeris* be denoted by E.T. 0. The difference E.T. 0 — U.T. 2 is denoted by ΔT_0.

La valeur provisoire du temps des éphémérides, obtenue en comparant la longitude moyenne de la Lune résultant d'observations rapportées à l'équinoxe du FK 4, avec les positions données par l'*Improved Lunar Ephemeris* est appelée T.E. 0. La différence T.E. 0 — T.U. 2 est appelée ΔT_0.

3. It is recommended that mean and apparent places of fundamental stars published in national ephemerides shall be based on FK 4 as soon as this is technically possible.

Il est recommandé que les positions moyennes et apparentes des étoiles fondamentales qui sont publiées dans les éphémérides nationales, soient basées sur le FK 4 aussitôt que ce sera faisable.

5. COMMISSION DES ANALYSES DE TRAVAUX ET DE BIBLIOGRAPHIE

Compte rendu de la Séance, 16 août 1961

PRÉSIDENT: D. Ya. Martynov.

SECRÉTAIRE: A. Dermul.

Sont présents outre le Président et le Secrétaire: MM. P. Bourgeois, Brasch, Cherentsov, W. Fricke, O. G. Gingerich, Mlles M. Harwood et R. Northcott, M. et Mme C. Luplau Janssen, MM. V. Kourganoff, E. Rybka, B. Sternberk, J. B. Sykes, J. Witkowski et H. Wright.

Au sujet du premier point à l'ordre du jour (*Bibliographie de l'astronomie pour la période* 1881-1898), M. Dermul, secrétaire de la Commission, donne un aperçu de l'état d'avancement des travaux. A côté d'une vingtaine de pays dont la contribution peut être considérée comme terminée, on constate que celle de nombreux autres, parmi lesquels certains dont la production astronomique pendant cette période est fort importante, n'ont pas encore envoyé la leur, ou même n'ont encore rien fait parvenir.

La Commission décide d'envoyer un nouvel appel à ces pays, et de clôturer le manuscrit au 31 décembre 1962, après quoi il sera remis à l'impression tel qu'il sera à cette date. Il est entendu que les contributions qui parviendront après cette date feront l'objet d'un ou de plusieurs suppléments. Une résolution dans ce sens sera présentée au Comité exécutif.

Le deuxième point de l'ordre du jour concerne les *Astronomical News Letters* (ANL). Le Professeur Kourganoff fait savoir que les quatre premiers numéros de cette année ont été distribués, mais qu'il propose de cesser la publication. Le Comité Exécutif s'est d'ailleurs déclaré favorable à la discontinuation des ANL.

La question de la traduction des ouvrages russes fait l'objet d'une discussion animée à laquelle prennent part MM. Fricke, Sykes, Kourganoff et Bourgeois. S'il faut reprendre la publication des ANL, dit le Professeur Kourganoff, il sera nécessaire de l'établir sur un tout autre plan. Ce travail est trop coûteux et trop peu rémunéré.

M. Sykes ajoute qu'il existe en Grande-Bretagne un organisme (l'ASLIB) qui peut fournir d'utiles renseignements sur les publications qui ont été traduites et il engage les intéressés à écrire à ce sujet au directeur de ce centre de traductions. M. Bourgeois propose de signaler à l'ICSU l'existence de ces centres. M. Kourganoff propose de mettre à la disposition des traducteurs la partie restant disponible du crédit de 5000 dollars qui avait été alloué pour la publication des ANL. M. Bourgeois remercie le Professeur Kourganoff et le félicite pour le grand travail bibliographique qu'il a fourni pendant tant d'années.

3e point de l'ordre du jour: *Bibliographie des bibliographies astronomiques*. Le Dr Kulikovsky dépose sur le Bureau un exemplaire du tome 5 de l'ouvrage de Mme Lavrova sur l'histoire de la bibliographie de l'astronomie qui a paru en U.R.S.S. en 1959 et qui contient environ 100 pages citant 316 sources bibliographiques se rapportant à l'astronomie. M. Martynov ajoute que Mme Lavrova prépare une table des auteurs de la première partie de la Bibliographie de Houzeau et Lancaster; ce travail sera prêt pour l'impression le 1er janvier 1963.

4e point de l'ordre du jour: la *Bibliographie des binaires spectroscopiques*. Ce travail a été exécuté sur la recommandation des Commissions 5 et 42 lors de l'Assemblée de l'UAI de Moscou (1958), sous les auspices de l'Observatoire Engelhardt (Kasan) et de l'Institut Stern-

berg (Moscou) par MM. Korytnikov, Lavrov et Martynov. Le Professeur Martynov dépose sur le Bureau un exemplaire du 1er volume, couvrant la partie du ciel comprise entre les A.R. 0^h et 6^h0^m. Le Professeur Kourganoff exprime sa satisfaction d'apprendre que ce travail touche à sa fin.

5e point: Les éditeurs du *Referativni Journal* et de l'*Astronomischer Jahresbericht* insistent à nouveau pour que toutes les institutions astronomiques leur envoient régulièrement deux exemplaires de toutes leurs publications.

6e point: La *Radio-bibliographie.* En l'absence de Miss Carpenter, qui avait demandé l'inscription de cette question à l'ordre du jour, le Président déclare que le Dr F. J. Kerr (Australie) a déjà réuni une nombreuse série de références sur ce sujet et qu'il se propose de la publier.

7e point: *Les observatoires astronomiques et les astronomes.* En l'absence du Dr G. Dimitroff, qui se serait occupé d'une nouvelle édition de ce répertoire, M. Bourgeois fait ressortir qu'il s'agit ici d'un travail très long, très coûteux et aussi très ingrat, les observatoires ne répondant que difficilement au questionnaire qui leur est envoyé. On a rédigé un premier supplément, qui pourra être distribué prochainement. Si le Comité exécutif désire que ce Répertoire soit complété ou bien réédité sur une nouvelle base, il conviendrait d'en discuter dans une réunion restreinte. Le Professeur Kourganoff propose que ce comité restreint, ou plutôt ce groupe de travail, comme le Président voudrait le nommer, serait composé du président de la Commission 5 et de MM. Bourgeois, Dimitroff et Kourganoff.

Sur la proposition du Dr Kulikovsky la Commission demandera au Secrétaire Général de l'Union de s'adresser aux représentants des divers pays pour qu'ils se chargent de rassembler les données nécessaires. M. Bourgeois suggère qu'on introduise une résolution dans ce sens au Comité exécutif.

8e point: Le glossaire polyglotte des termes d'astronomie, par le Dr J. Kleczek. En l'absence de l'auteur le Dr Sternberk informe la Commission de ce que l'ouvrage a déjà été achevé et imprimé et qu'il sera publié très prochainement par les soins de l'Académie des Sciences de la Tchécoslovaquie. Répondant à quelques remarques de la part du Président, il affirme que l'auteur a soumis son manuscrit, aux fins de vérification, à certaines institutions astronomiques de l'étranger. La Commission prend acte de cette déclaration et la portera à la connaissance de l'ICSU et de la Commission 3 de l'UAI.

9e et dernier point: *nomination d'un nouveau président.* Le Président attire l'attention de l'assemblée sur le fait que son mandat est arrivé à expiration. Il propose de confier la présidence pour le nouveau terme de trois ans au Professeur Kourganoff en reconnaissance des éminents services qu'il a rendus à la Commission 5 pendant tant d'années.

L'assemblée marque son accord unanime, mais le Professeur Kourganoff, tout en la remerciant sincèrement, exprime le désir formel de ne pas être investi de cette charge. Plusieurs autres candidatures sont alors avancées et, comme d'après les nouveaux statuts de l'Union le bureau des Commissions doit comporter également un vice-président, l'assemblée décide de présenter au Comité des nominations deux candidatures: celle du Dr J. B. Sykes et celle du Dr C. E. Luplau Janssen.

6. COMMISSION DES TELEGRAMMES ASTRONOMIQUES

Report of Meeting, 17 August 1961

PRESIDENT: E. Buchar.
SECRETARY: K. A. Thernöe.

Professor E. Buchar, President of the Commission opened the meeting by recalling that two of its members had died since the last meeting in 1958: Dr J. Bobone of the National Observatory in Cordoba, and Miss J. M. Vinter Hansen, Director of the Central Bureau for astronomical telegrams.

No interruption of the activities of the Central Bureau had been caused, however, through the death of Miss Vinter Hansen, as, thanks to arrangements made by Dr A. Reiz, Director of the University Observatory in Copenhagen, the direction of the Bureau was entrusted to Mr K. A. Thernöe, of the same institution. The Draft Report was approved; it was generally agreed that the services of the Bureau, which had so far proved satisfactory, should proceed along the same lines. However, information concerning artificial celestial bodies should be included, only when such objects would have a small daily motion.

The following were proposed as additional members of the Commission:

Professor D. Ya. Martynov, Director of the Sternberg Astronomical Institute, of Moscow University.

Mr K. A. Thernöe, University Observatory, Copenhagen, the latter being proposed as Director of the Central Bureau.

For the following period of six years the following were proposed: as President: Dr A. R. Hogg, Mount Stromlo Observatory; as Vice-President: Dr F. L. Whipple, Director of the Smithsonian Astrophysical Observatory.

The discussion dealt mainly with the economic status of the Central Bureau, and the following resolution was submitted to the Executive Committee for consideration by the Finance Committee.

In view of the increasing costs of the valuable service provided by the Central Bureau for Astronomical Telegrams, Commission 6 recommends that the subsidy be increased from $1588 to $2000 for a three-year period, and that the Central Bureau charge a service fee to subscribers adequate to cover the costs of the service.

[This resolution was approved, and incorporated in the report of the Finance Committee.]

7. COMMISSION DE LA MECANIQUE CELESTE

Report of Meetings

PRESIDENT: D. Brouwer.

SECRETARY: M. S. Davis.

First meeting, 16 August 1961

President Brouwer opened the meeting at $14^h\ 05^m$. Dr J. Kovalevsky was appointed official translator in the English, French and Russian languages and Dr M. S. Davis was appointed secretary.

President Brouwer regretfully announced the death of the members: Milankovitch, Vernič, and the former member von Zeipel.

After a brief discussion of typographical errors in the *Draft Report*, the President announced the following new Organizing Committee as well as recommended officers:

President: Y. Hagihara (Japan).

Vice-President: W. J. Eckert (U.S.A.).

Organizing Committee: G. A. Chebotarev (U.S.S.R.), J. Kovalevsky (France), G. Lemaître (Belgium), P. J. Message (Great Britain), K. Stumpff (Germany), F. Zagar (Italy).
No opposition being expressed, the committee was taken as thus approved.

COMMUNICATIONS

Professor Martin of Trieste proposed, in a letter to the President and with the support of Professor Heinrich of Prague, that a Sub-Commission on 'Evolution of Double Stars' be formed to deal with problems related to Celestial Mechanics. In the discussion that ensued, Dr Clemence agreed with the substance of the proposal but felt that there were probably not enough members to form a separate section. Professor Zagar thought that if this were done the door would be open to the formation of many Sub-Commissions. Professor Chebotarev pointed out that under the new rules new Sub-Commissions could not be formed—only working groups: The question as stated in the letter was then put to a vote and was defeated.

A communication from Professor Fabre was read by Dr Kovalevsky. It suggested that density models of the Earth be improved by analysis of artificial satellite observations to bring about better accord between the models used by geophysicists and those used by astronomers.

Another communication from Professor Belorizky stated that Commission 7 should concern itself more with problems in Celestial Mechanics rather than organizational matters. There was general agreement with his statement.

Professor Brouwer summarized significant progress in Celestial Mechanics since the last meeting of the Commission. In particular he indicated the following noteworthy mile-stones:

1. The new, more precise, determinations of the coefficients that appear in the expression for the Earth's potential.
2. Important progress in application of high-speed computers to problems in Celestial Mechanics.
3. Three-body Problem. Merman's new representation by convergent series similar to Sundman's methods.

4. Clemence's Theory of Mars. The error now does not exceed 0^{s}·0013 in the longitude and 0″·002 in the latitude.

5. Satellite theory. Petrowskaja's proof that for m ⩽ 0·21 Hill's series for the variation orbit are convergent.

6. Kovalevsky's use of a numerical integration to build a general theory of Jupiter VIII.

7. Makover and Bokhan's mass determination of Mercury from the motion of comet Encke-Backlund.

8. Duncombe's discussion of the observations of Venus (1750-1949).

9. Littlewood's treatment of the convergence and asymptotic properties of the solutions of the three-body problem.

Professor Brouwer invited discussion on these questions or any others of general interest to the Commission. It was decided that Dr Sarkian would present his paper at the next meeting of the Commission at which time Dr Eckert would present his report.

Professor Brouwer opened discussion on the form to recommend for the force function. Sir Harold Jeffreys suggested that the summation sign be preceded by a + sign instead of the − sign. He felt that this was called for since (i) some of the $\mathcal{J}$s are negative anyway and (ii) because comparisons with the value of g would be simpler. Dr Herrick did not believe the minus sign was seriously needed. He suggested that longitude be uniformly measured eastwards. Professor Chebotarev pointed out that at the Institute of Theoretical Astronomy the plus sign is always used and that the notation for the coefficients is:

$C_{n,m}$ when longitude-dependent

$-C_{m,0}$ when longitude-independent

Professor Brouwer remarked that confusion could be removed by defining

$$-\mathcal{J}_m = C_{m,0}$$

in the manner suggested by Chebotarev. Dr Kozai indicated that his use of $\mathcal{J}$ and C as proposed would conflict with other established uses. Dr Garfinkel defended the use of the minus sign on historical grounds and also because the leading coefficient has a positive sign.

Professor Brouwer appointed the following committee to discuss this question and to bring in recommendations at the next meeting of the Commission:

Hagihara (chairman), Garfinkel, Sir Harold Jeffreys, Kozai, Chebotarev, Hori.

The Abbé Lemaître presented a paper on the 3-body problem. By using the transformation

$$\tau = \int \frac{dt}{r_1 r_2 r_3}$$

the Levi-Cività regularization may be put in a symmetric form which permits the extension of the eccentricity into the 3-body problem.

A second paper by Abbé Lemaître described a method of numerical integration using a Lagrangean type formula and retaining one extra difference for reducing the size of the coefficients by a factor of about 4, as well as producing a more random distribution of signs in the formula. This has the effect of reducing the accumulation of error due to rounding.

After some discussion of these papers the meeting was adjourned at $15^{h}\,35^{m}$.

Second meeting, 21 August 1961

The meeting was opened by President Brouwer at $9^h\,00^m$. Dr Eckert presented the following report of the committee dealing with material in machine-readable form. A number of suggestions for standardization was made. After some discussion, unanimous approval was given to Dr Eckert's report.

REPORT BY DR W. J. ECKERT

In spite of the poor response to the notice in IAU *Information Bulletin* No. 5 of February 1961, there appears to be considerable desire on the part of astronomers for more information concerning the availability of machine-readable records.

The Committee proposes:

1. Members of the Committee will write to the observatories in their respective geographical areas requesting information concerning records that are available for exchange.
2. Information received will be consolidated and a list of the available records will be published in an IAU *Information Bulletin.*
3. Astronomers may obtain information concerning available files and advice or assistance in obtaining them by writing to the appropriate member of the Committee.
4. Most members of the Committee feel that comparatively few machine programs are suitable for exchange and in very few cases can they be exchanged without the direct co-operation of the writer of the program. The Committee is willing to list in its publication unusual programs suitable for exchange.

Letters will be written by the following Committee members:

G. M. Clemence or M. S. Davis: U.S.A., Canada, Latin America

D. H. Sadler: British Commonwealth (except Canada)

J. Kovalevsky: France, Belgium, Holland, Spain

P. Naur: Denmark, Sweden, Norway, Finland

W. Fricke: West Germany, Switzerland, Italy

M. F. Subbotin: U.S.S.R., Poland, East Germany, Bulgaria, Rumania

S. Hamid: Arab Countries

Material will be collected, edited and published by: W. J. Eckert and W. Bidelman

REPORT OF COMMITTEE ON NOTATIONS

Professor Hagihara then reported that the committee on notations, which had been appointed at the first meeting of the Commission, had met twice with Sir Harold Jeffreys, Chebotarev, Garfinkel, Kozai and himself present. The committee found it desirable to unify notations for the Earth's gravitational potential and recommended the following:

1. *Axial symmetry*

$$U = \frac{\mu}{r}\left[1 - \sum_{n=1}^{\infty} \mathcal{J}_n \left(\frac{R}{r}\right)^n P_n(\sin\beta)\right]$$

2. *General Case*

$$U = \frac{\mu}{r}\left[1 + \sum_{n=1}^{\infty}\sum_{m=0}^{n}\left(\frac{R}{r}\right)^n P_n^m(\sin\beta)\{C_{n,m}\cos m\lambda + S_{n,m}\sin m\lambda\}\right]$$

$$\text{where } P_n^m(x) = (1-x^2)^{\frac{1}{2}m}\frac{d^m}{dx^m}P_n(x)$$

$$\text{and } \int_{-1}^{+1}\left[P_n^m(x)\right]^2 dt = \frac{2}{2n+1}\frac{(n+m)!}{(n-m)!}$$

3. *Alternative Form*

$$U = \frac{\mu}{r}\left[1 + \sum_{n=1}^{\infty}\sum_{m=0}^{n}\left(\frac{R}{r}\right)^n p_{n,m}(\sin\beta)\{A_{n,m}\cos m\lambda + B_{n,m}\sin m\lambda\}\right]$$

$$\text{where } p_{n,m}(x) = \left(\frac{(n-m)!}{(n+m)!}\right)^{\frac{1}{2}} P_n^m(x)$$

4. Longitude be measured positive to the East.

5. Recommends the computation and circulation of tables of the quantities

$$P_n^m(x),\ \left(\frac{(n-m)!}{(n+m)!}\right)^{\frac{1}{2}} \qquad n, m = 0, 1, 2, \ldots 8$$

by the Smithsonian Astrophysical Observatory.

In all the above formulae, R represents the equatorial radius of the Earth.

The members of the Commission present agreed that the recommended notation did not pertain to the quantities μ, R, β.

In the discussion which ensued, Dr Herget asked why the expression in 2 does not degenerate to that in 1. Professor Hagihara replied that this form was retained to pay respect to former work in the field and Professor Brouwer added that the use of $\mathcal{J}$ has been standard for a long time. Dr Herget felt that by recommending this form, it would be perpetuated in the future. Dr Kovalevsky remarked that in this context longitude should be measured to the east only. Otherwise the possibilities of errors would be very large. Dr Herrick made the following suggestion:

$$C_{n,0} = -\mathcal{J}_n = C_n$$

His recommendation was that the zero subscript be dropped in the coefficient $C_{n,0}$.

Herrick's suggestion was adopted followed by the adoption of the above recommendations of the committee.

Professor Sarkian then presented his paper on "Additional Accelerations in Celestial Mechanics".

Abbé Lemaître, at the suggestion of Professor Brouwer, elaborated on his method of numerical integration.

The proceedings of the Commission were adjourned at $11^h\,00^m$.

8. COMMISSION DE L'ASTRONOMIE DE POSITION

Report of Meetings

PRESIDENT: F. P. Scott

SECRETARIES: R. d'E. Atkinson and P. Sémirot

First meeting, 16 August 1961

The Commission met at $11^h\,00^m$ under the chairmanship of the President Mr F. P. Scott.

The *Draft Report* was adopted as originally printed, with the addition of I. A. Dyukov, 25 June 1961, to the names of deceased members, and with a few minor amendments.

Dr M. P. de Barros reported on the Mirror Transit Circle built under his direction at Oporto. The instrument is substantially complete, but its performance has not been rigorously tested, and owing to shortage of staff no clear prospect is seen either of doing this or of putting it into effective use if the tests proved satisfactory. The Commission adopted Resolution 1 given below unanimously.

Professor W. Fricke reported on the completion of the fundamental catalogue FK 4, giving the numbers of new catalogues incorporated since the FK 3, both for individual star-corrections and for systematic ones, and outlining the differences from FK 3; these are much smaller, and smoother, than the FK 3 – NFK ones, but the southern stars are still inadequately observed. A full account will appear in the Publications of the Astronomisches Rechen-Institut.

Dr W. Gliese tabulated the mean errors of the FK 4, as obtained from discordances between individual fundamental catalogues. The errors vary with declination, but not with right ascension. South of $-25°$ they increase, and beyond $-70°$ they become very considerable, owing to the discordance between the Cape and Cordoba systems. The differences were also obtained between the individual catalogues of one instrument and the mean of all work with that instrument only. The resulting graphs ($\Delta\alpha \cos\delta$, at different epochs, as a function of δ) give a clear picture of the stability of each instrument. The Washington 6-inch is conspicuously more stable (though not necessarily more free from permanent systematic error) than the other three instruments studied in this way. A full report will appear in the Publications of the Astronomisches Rechen-Institut.

Second meeting, 17 August 1961

It was announced that the President of the Commission, for the ensuing 3-year term, would be Mr F. P. Scott, with Dr R. H. Stoy as Vice-President, and that the Organizing Committee would consist of Dr R. d'E. Atkinson, Dr J. R. Lévy, Professor S. Slaucitajs, Dr G. van Herk and Professor M. S. Zverev.

It was announced that Dr G. Fayet had completed a Catalogue of 969 Intermediary Stars between $+5°$ and $+15°$ of declination, based on observations with the Brünner meridian circle at Nice, between 1912 and 1914.

Dr B. Guinot presented an analysis of 60 000 Paris astrolabe observations of 360 stars in FK 3 and 211 in FK 3 Supp. The mean observational error in α is $\leqslant \pm 0^s{\cdot}005$ for 80% of

the stars, and in δ it is $\leqslant \pm 0''\cdot07$ for 75%. The mean values of the differences (Astrolabe − FK 3), for intervals of 2^h in α and 10° in δ were shown as a surface, and were also shown as graphs both for FK 3 and for FK 4. The differences, corrected for the above astrolabe scatter, would imply mean errors of $0^s\cdot025$ and $0''\cdot16$ in the FK 3 and of $0^s\cdot014$ and $0''\cdot09$ in the FK 4. The largest features in the FK 3 differences are much reduced in the FK 4, but most of those that still remain are also found at Neuchâtel and Pulkovo (photo-electric). He urged other observatories having astrolabe observations to analyse them also in this way, or else to forward them to Paris for the purpose. The importance of the star-places so obtained was stressed by various members, both present and absent, and the Commission decided to prepare suitable resolutions on the subject (see below).

Dr J. R. Lévy discussed methods of reduction in "differential" programmes. The results may depend on the size of the region used for comparison in each case, and the fundamental stars actually observed in each region. He suggested that the resulting ambiguity would be avoided if very few fundamental stars were employed, preferably distributed in a very regular pattern. These stars would thus form a first-order network to which other fundamental stars would be referred.

A report was presented from Dr K. N. Tavastsherna on the Pulkovo reduction of 2500 Backlund-Hough stars observed at Melbourne between 1928 and 1941 and only partially reduced there. The observations, consisting of about 30 000 in α and 20 000 in δ, together with those for the instrumental constants, have all been sent to Pulkovo. So far, only the declinations have been worked on; the reductions from apparent to mean place and the evaluation of the instrumental constants are complete and punched on cards, and a trial reduction of 30 stars led to a mean error for one observation of about $\pm 0''\cdot50$. It is hoped to complete the work in 5 years, and that fundamental places will result which will be of value for proper-motion discussions.

Professor S. Slaucitajs reported that the Lick meridian circle originally taken to La Leona has been moved to La Plata for re-lapping of the pivots and other reconditioning. Meanwhile the La Plata instrument will be sent to La Leona. This will delay all La Plata programmes by some months.

Mr A. N. Adams reported on the method of recording R.A. and Dec. micrometers now being adopted on the Washington 6-inch and 7-inch instruments. The micrometer screw carries a selsyn designed to be good to 1/1000 rev.; this controls a coded disk read by brush-contacts on command from the clock (or from the observer, for Dec. and for instrumental constants). The reading goes to a transistorized memory, from which the values can be punched. So far, the planned accuracy has not quite been attained, but nearly so, and improvements are in hand. The variable-speed R.A. drive is a precision ball-and-disk integrator.

Mr F. P. Scott spoke on the four additional star-lists (*a*) Bright Stars, (*b*) Double Stars, (*c*) Latitude Stars, and (*d*) PZT Stars. He announced that the commitments as printed must be revised: the observatories of San Fernando, Nicolaiev, and Bucharest will withdraw, in order to work on the Southern Reference Stars programme (SRS). The question of a central collection and analysis of the observations of these lists was discussed, but no final decision was reached.

Dr E. P. Fedorov presented some remarks from Professor M. S. Zverev, and supported them himself as President of Commission 19, on the need for more extensive meridian circle work on the latitude and PZT stars, especially from the point of view of studying non-polar variations. The Sternberg Institute has prepared lists of 2 000 and 1 000 stars respectively, in these categories, and these are being re-observed, but the number of participants is in-

sufficient. He requested support from the Commission and also proposed a small working group to study the accuracy requirements. (See below).

Dr R. d'E. Atkinson reported that outline proposals for the design of a Mirror Transit Circle at Herstmonceux, together with photographs of the mirror and axis already completed and tested, were on view in the Exhibition Room. At the request of the Ottawa astronomers, an informal discussion was arranged on such instruments in general, with special reference to the Ottawa one, and it was found necessary to hold a second meeting also.

Third meeting, 22 August 1961

The Chairman announced that the former Sub-Commission 8*a* had now been re-constituted as a Working Group, with Professor D. Brouwer as Chairman and with membership as before.

Dr B. Guinot announced that the seismological observatory at Wellington had decided to resume astrolabe observations as from April 1962 and that the observatory at São Paulo had decided to install an astrolabe. The Commission welcomed these announcements very cordially. The Commission then adopted Resolutions 2 (chain of astrolabes) and 3 (astrolabe results) unanimously. (See below).

The Chairman appointed a Working Group consisting of Dr E. P. Fedorov (Chairman), Dr R. d'E. Atkinson, and Dr P. Melchior, to study the accuracy-requirements for meridian-circle observations of the declinations of latitude-stars. Resolution 4 was then adopted. (See below).

The Chairman reported on the present state of the AGK 3R programme. All observatories are very far on in their observing programmes, the overall total being now about 95% complete; a very large fraction of the reductions is also expected to be complete by 1963·5. The final reduction procedure will, however, probably differ somewhat from that originally envisaged, in view of the fact that the FK 4 is now definitely available. Two proposals have emerged from correspondence:

(1) That all individual observations of fundamental stars and of reference stars be centrally collected (at Washington) and used first to make minor further improvements in FK 4; the reference-star observations would then be adjusted, night by night, to this rectified fundamental system.

(2) Professor P. Lacroute had proposed that reference stars and fundamental stars should all be used to revise the instrumental constants of each night, by comparison of each star's preliminary place for that night with its preliminary places for all other nights. Speaking on this proposal he said that trial runs at Strasbourg had shown that the weights of the instrumental corrections were increased by about 20 to 30%, and he claimed that some systematic night-errors were eliminated. The final result would not be exactly on the FK 4 system, but could be rigorously compared with it.

The Chairman considered that this method would be longer, and raised the question whether the completion of the AGK 3 programme should wait for this, and also whether it should wait for all KSZ observations. Professor Lacroute stated that his analysis could not start until receipt of the last set of observations made at all declinations. The Chairman considered that electronic computers made it reasonable to contemplate using both methods independently, and the comparison should be valuable. He proposed Resolution 5, which was carried. (See below).

He then reported on the proposed Southern Reference Star programme (SRS). The list of commitments given in the Draft Report could now be extended as follows:

Observatory	Range
Bergedorf southern	0° to −90° (possibly)
Bordeaux	0° to −20°
Bucharest	0° to −10°
Nicolaiev	0° to −20°
San Fernando	0° to −30°
Tokyo	−15° to −30°
Abbadia (Hendaye)	

Professor M. S. Zverev and Dr A. A. Nemiro requested (by letter) that all southern observations be sent to Pulkovo and the results published in U.S.S.R. They also considered that FK 4 is not adequate for southern stars, and that new fundamental observations and a complete discussion are required. The Chairman felt that northern observatories making southern observations would complete their task well before a fundamental discussion would be possible, and he would propose to treat these like the AGK 3R programme, and as soon as possible. After discussion, Resolution 6 was adopted. (See below). It was stated that Pulkovo proposed to photograph the whole southern sky with a Maksutov camera of two metres focal length, having a field 4½ degrees square. The following were appointed as an Expediting Committee for the entire S.R.S. programme: Mr F. P. Scott (Chairman), Professor D. Brouwer, Dr P. Sémirot, Dr R. H. Stoy, Dr J. E. B. von der Heide, Professor M. S. Zverev; with Professor W. Fricke as consultant.

It was announced that Pulkovo had prepared a "Bright Star List" in two parts, north and south of −30° respectively. It consists principally of FK 3, FK 3 Supp., and Backlund-Hough stars. There appeared to be some risk that the latter might be neglected, but it was considered important to keep them up. Resolution 7 was discussed and carried. (See below).

RESOLUTIONS ADOPTED BY THE COMMISSION

1. Commission 8 has noted with great interest the virtual completion, since the last General Assembly, of the "Mirror Transit Circle" at the University of Oporto. This pioneering project has been carried through with great courage and perseverance, and the Commission expresses the most earnest hope that means may be found to subject the instrument to the necessary tests and to bring it into appropriate operation at a very early date.

2. Commission 8 notes with regret that although astrolabe observations are of recognized value for improving fundamental catalogues, particularly in the southern hemisphere, no practical effect has been given to the resolutions in favour of establishing a chain of astrolabes, which were adopted at the tenth General Assembly in Moscow and at the second Astrometric Conference in Cincinnati. The Commission repeats this recommendation once again.

3. In view of the fact that many astrolabe observations have not yet been discussed for the purpose of improving star-places, Commission 8 urges the authors in question either to undertake this analysis or to notify the Paris Observatory that they do not propose to do so; in the latter case the Commission understands that the Paris Observatory will itself undertake the work.

4. Commission 8 recommends that on the basis of the findings of the Working Group appointed to consider meridian observations of latitude stars, a sufficient number of observatories having meridian circles be urged to make the necessary number of observations.

5. Commission 8 recommends that: (*a*) the individual observations of the AGK 3R stars, and of the fundamental stars used in their reduction, be made available to the U.S. Naval Observatory, for the formation of a reference-star catalogue rigorously related to the system of

the FK 4; (*b*) the individual observations thus collected at the U.S. Naval Observatory be made available by it to the Strasbourg and Pulkovo Observatories.

6. For the purpose of forming catalogues of the Southern Reference Stars, Commission 8 recommends: (*a*) that the individual observations of Reference Stars and Fundamental Stars in the zone 0° to −30° be made available to the U.S. Naval Observatory and that those in the zone −30° to −90° be made available to the Pulkovo Observatory; (*b*) that the U.S. Naval Observatory and the Pulkovo Observatory exchange as many of these observations as may be requested by either, to meet the requirements of their catalogues and to obtain a good connection with the AGK 3R catalogue.

7. Commission 8 recommends that the "Bright Star List", 0° to −90°, be observed during the Southern Reference Star programme.

9. COMMISSION DES INSTRUMENTS ASTRONOMIQUES

Report of Meetings

PRESIDENT: G. E. Kron.
SECRETARY: Neville Woolf.

First meeting, 16 August 1961

This was a short business meeting, following a meeting of Sub-Commission 9*a* under the chairmanship of W. A. Baum. Discussion of the *Draft Report* was called for, but there was no discussion and the *Draft Report* was considered to be acceptable.

It was announced that G. Dimitroff had offered to make a list of the world's observatories, and that information about astronomers and instruments was also required. It was also announced that there would be a change in the constitution of the Commission, in that the two Sub-Commissions 9*a* and 9*b* would become Working Groups of the main Commission 9.

There was a proposal from Rösch concerning a change in the name of Commission 9 (see *Draft Report*). The proposal was brought up for discussion, but there was no discussion. There was also a proposal from Dunham that an informal symposium be held on the problems of coudé spectrographs. It was decided to hold this discussion at a second meeting of the Commission.

There was no further business. The meeting was brought to a close by a description of the St Andrews 37-in.—37-in. Schmidt Cassegrain telescope by Stibbs.

Second meeting, 21 August 1961

During a short business session, an organising committee consisting of Rösch, Kron, Hall, and McGee was selected. The remainder of this session was turned over to the discussion of the problems of coudé spectrographs. Speakers were Aller, Bowen, O. C. Wilson, Hiltner, Fehrenbach, Feast, Berg, and Woolf. There was sufficient discussion to make the content of the meeting of some interest, and it is planned to have the complete minutes mimeographed and distributed to members of Commissions 9 and 29.

9*a*. SOUS COMMISSION DES CONVERTISSEURS D'IMAGES

Report of Meetings, 16 and 19 August 1961

PRESIDENT: W. A. Baum.
SECRETARY: J. D. McGee.

Sub-Commission 9*a* met at 9^h00^m on 16 August 1961, under the Chairmanship of Dr W. A. Baum, President of the Sub-Commission.

In opening the session the Chairman referred to the change in status of the Sub-Commission in the future, when it would become a committee of Commission 9.

Before beginning formal business the Chairman proposed that a telegram of congratulations should be sent to Professor A. Lallemand on his recent election to the French Academy of Science. The proposal was carried unanimously.

The Chairman then called for corrections to the *Draft Report* to appear in Vol. A of the *Transactions*. These were collected for transmission to the General Secretary.

The remainder of the session was devoted to the following reports on work in progress by: M. F. Walker of Lick Observatory; J. A. Hynek of the Northwestern (Dearborn) Observatory; W. A. Hiltner of Yerkes Observatory; and G. Wlérick on behalf of several of his colleagues in France.

The Sub-Commission met again at 9 a.m. on 19 August 1961, when the following further progress reports were presented by: J. Rösch, Pic du Midi; J. Hall, Lowell Observatory; J. D. McGee, Imperial College; W. A. Baum, Mount Wilson & Palomar Observatories and Imperial College; G. Kron, Lick Observatory; J. H. DeWitt of Dyer Observatory, Nashville, Tennessee.

M. A. Tuve outlined a proposal, that he hoped to have adopted and financed in the U.S.A., for having a few types of image-intensifier tube manufactured on a reasonably large scale. In this way he hoped tubes might become available for astronomers, both in the U.S.A. and in other countries.

The following are summaries of the reports given as listed above.

TRAVAIL EFFECTUÉ À L'OBSERVATOIRE DE PARIS

M. Duchesne, L. Gallouet and B. Guinot

A l'Observatoire de Paris, en juin et juillet 1961, M. Duchesne, L. Gallouet et B. Guinot ont obtenu une série de spectres de Venus avec la caméra électronique de A. Lallemand. Ces spectres sont destinés à la détermination de la constante de l'aberration par la mesure interférométrique de la vitesse radiale. Ils ont été obtenus en 15 minutes de pose, avec un gain en temp de pose de l'ordre de 30, par rapport aux plaques 103aD. En outre la qualité des spectres est bien meilleure que par la photographie classique. Les auteurs projettent d'appliquer cette méthode à Mercure, dont la vitesse radiale atteint le triple de celle de Venus.

REPORT ON WORK WITH LALLEMAND ELECTRONIC CAMERA AT LICK OBSERVATORY

M. F. Walker

Instrumentation. During 1960–61 a number of improvements have been made in the technique of operating the electronic camera. These include semi-automatic refilling of the liquid air Dewars on the camera, the use of a titanium ion pump, vacuum storage of the nuclear plates prior to use, extreme precautions in the cleaning and preparation of the tube and in the elimination of corona discharges around the tube during operation. As a result of these improvements, it is now possible to preserve a single photo-cathode for two successive nights of observation and to expose each plate up to four or, under the best conditions, six hours, before parasitic blackening of the plate becomes excessive.

The speed of the tube was re-measured and found to be about 40–60 times that of Kodak 103ao at 4000Å and for exposures in the range of 10-100 minutes with the tube, the range usually employed at the telescope. The speed-gain over the photographic plate is of course a function of the exposure time owing to the reciprocity failure of the tube.

This increase in the signal-to-noise ratio has made it possible to obtain spectra of stars down to $m_{pg} = 16$ with the electronic camera attached to the focus of the 20-inch camera of the coudé spectrograph of the 120-inch reflector, using a grating giving 48 Å/mm on the photocathode and 65 Å/mm on the nuclear plates.

Observations. Among the observing programmes carried out, two of the most significant are the following:

(*a*) *AE Aqr.* High time-resolution spectra have been obtained to investigate the spectroscopic changes occurring during one of the explosions which are characteristic of this system. Simultaneous photo-electric observations with the Crossley reflector were used as a guide to determine when to expose the plates. With a cathode of only moderate sensitivity, exposures at minimum light ($m_{uv} \approx 12{\cdot}5$) required 20-30 minutes and at maximum light ($m_{uv} \approx 11{\cdot}0$) 12-15 minutes. The plates show that during an outburst, the emission lines of H and Ca II became stronger and broader, either symmetrically or asymmetrically to the red or to the violet, indicating that the explosion occurs in a localised spot on or near the surface of one of the stars and sometimes on the side toward the observer and sometimes on the side opposite. Also, a hot continuum appears which falls in the late-type absorption spectrum of the companion.

High time-resolution observations of this sort are only possible by means of an image tube.

(*b*) Five faint, gravitationally contracting stars in the Orion Nebula cluster and NGC 2264 which have ultra-violet excess have been observed. In order of decreasing UV excess they are: VY Ori, LT Ori, MO Mon, YY Ori and IP Mon. In all except IP Mon (which has a UV excess of only 0·3 mag and an essentially normal spectrum) there is either direct or indirect evidence of material falling into the stars. It appears that in these stars infall is more important than ejection, unlike the majority of T Tau stars. In at least three of the stars the underlying late-type absorption spectrum is partially or totally obscured by a blue continuum. The nature of the UV excess is not yet clear; it could be the effect of extreme wings of Balmer emission lines whose central intensities are cut down by self-absorption, but it cannot be caused by confluence of the lines themselves. In any case, it is tempting to suggest that both the excess and blue continuum might result from the infall of material.

Ch. Fehrenbach, M. Duflot, M. Chopinet

Reported on the results of observations, at the Observatory of Marseille, on spectra of galaxies and planetary nebulae using the Lallemand Electronic Camera.

PHOTOGRAPHIE DES ÉTOILES DOUBLES AU MOYEN DE LA CAMERA ÉLECTRONIQUE

J. Rösch, G. Wlérick and *Mlle. C. Boussuge*

La caméra électronique de Lallemand a été utilisée à l'Observatoire du Pic du Midi pour la photographie des étoiles doubles serrées. Associée à un réfracteur de 60 cm de diamètre, elle a permis d'obtenir des images d'étoiles de 7^{e} magnitude en 1/8 de seconde, bien que le spectre secondaire de l'objectif convienne mal à la répartition spectrale de sensibilité de la photo-cathode.

L'intérêt de cette technique vient de ce que, pour un objectif de ce diamètre (et à plus forte raison pour un diamètre plus grand) et pour une séparation angulaire de l'ordre de 2″ au moins, les faisceaux issus des deux étoiles traversent pratiquement les mêmes masses d'air. En conséquence, l'image de chaque composante, altérée par l'atmosphère, diffère beaucoup, en général, de la figure d'Airy théorique, mais la distribution de l'énergie est la *même* dans les deux images. On a donc deux images quelconques mais identiques (à la différence de magnitude près), qui se déduisent l'une de l'autre par un déplacement rigoureusement égal à la séparation angulaire des composantes. Le fait que l'émulsion nucléaire employée n'ait pas de seuil rapproche encore des conditions idéales.

Les clichés sont mesurés au moyen d'un micromètre à double image spécial, qui permet de *superposer* soit les deux images de la composante A et les deux images de la composante B, soit une image de A et une image de B, de façon à tirer parti de tous les détails de structure pour accroître la précision de la mesure.

PHOTOGRAPHIE ÉLECTRONIQUE DES PLANÈTES

G. Wlérick, J. Rösch, M. F. Dupré and *C. Boussuge*

Au Pic du Midi, en juillet 61, G. Wlérick, J. Rösch, M. F. Dupré et C. Boussuge ont photographié Jupiter et Saturne avec la caméra Lallemand. Avec le réfracteur de 60 cm, ouvert à *f*/60, les temps de pose sont respectivement 1/8 sec et ½ sec. Les clichés permettent la photométrie précise des anneaux de Saturne, y compris l'anneau de crêpe, et une bonne détermination de l'assombrissement centre-bord de Jupiter.

A MODIFIED LALLEMAND IMAGE TUBE

G. E. Kron

An electronographic type of image tube that operates on the Lallemand principle has been built and operated experimentally at the Lick Observatory. An attempt is being made to achieve prolonged photo-cathode performance by dividing the tube into two compartments with a straight-through ball valve. When the valve is closed, the photographic plate can be changed in the one part of the tube while the photo-cathode is protected by the valve in the other.

The valve is, in fact, the anode electrode, and it is also the backbone and chief structural part of the tube. The pierced ball is turned by a stem that protrudes from the valve, and is double-sealed to prevent leakage. The ball itself is suspended between two seals, and the volume trapped outside the ball and between the seals is continuously pumped by a small ion pump. All seals are of PTFE and all are double to prevent leakage.

Good photo-cathodes that have shelf half-lives of several months can be made in the tube. When the tube is used to make pictures, each cycle of plate loading and picture taking reduces the cathode sensitivity by 1% to 5%, depending upon the care with which the plate half of the tube has been evacuated prior to opening the valve. Contaminants introduced along with the photographic plate are immobilized, as in the Lallemand tube, by cooling the plate and plate holder with liquid air.

A new tube has been designed and constructed during 1960–61 at the Mount Stromlo Observatory, in Australia. The valve in this new tube is entirely made of metal, so that the whole tube can be baked to clean it. It is hoped that better cathodes can be made in this tube, and that these cathodes will have a very long shelf-life. Furthermore, it is hoped that the changes in design will eliminate some of the causes of cathode damage with use, and alleviate others.

A LOW-BACKGROUND IMAGE TUBE FOR ELECTRONOGRAPHY

W. A. Hiltner and *W. F. Niklas*

An electrostatically focused electronographic image tube of new design, incorporating a barrier membrane of aluminium oxide to separate the electron-sensitive emulsion from the photo-cathode section of the tube, is described.

A semi-conductive wall coating between the low-potential focus electrode and the high-potential anode equalizes local potential gradients in such a way that the probability of field emission between these electrodes is much reduced. The photo-emissive surface is restricted to the desired area by evaporating the antimony for the photo-cathode externally, thus reducing spurious electron emission from photo-sensitive surfaces deposited on tube elements other than the photo-cathode.

Field emission is responsible for only about 25% of the total background of the tube at room temperature. With the tube at the focus of the *f*/20, 40-inch refractor the sky background

is 160 times greater than the tube background. Further, when a cool tube is in total darkness, it may be exposed for eight hours before the background density is in excess of 0·1. The resolution thus far achieved is 40 lp/mm.

The principal difficulty with the operation of the tube is the need for two kinetic vacuum systems in order that emulsions may be inserted into, and retracted from, the tube. In the laboratory the vacua are provided by two small oil diffusion pumps, but to make the unit completely mobile and free from all utilities, the telescope model will use cyrogenic pumping. It is anticipated that these cyrogenic pumps will operate unattended for intervals of one week or more.

AN IMAGE TUBE WITH LENARD WINDOW

J. D. McGee and *B. E. Wheeler*

In this tube the electron image produced from a photo-emissive cathode is accelerated to sufficient energy to penetrate a mica window capable of withstanding atmospheric pressure, and be recorded on an electron-sensitive emulsion in contact with the end window. A sealed-off tube of this type has the advantage over other electronographic equipment of not requiring any auxiliary pumping equipment and of having a long shelf-life.

For such a tube to be feasible, an operating potential of approximately 50 kV and a mica window less than 8 microns thick are required. Under these operating conditions approximately 80% of the electrons penetrate the end window and about 70% have an energy greater than 10 keV and will therefore be recorded as small clumps of grains on a nuclear emulsion.

The development of a tube constructed entirely of lime-soda glass, employing uniform coaxial electric and magnetic fields to accelerate and focus the electron image, and which is capable of withstanding 50 kV with a very low background, was described.

A method of sealing very thin mica windows, less than 8 microns thick, on to the tube was also described. This was found extremely difficult to accomplish in a conventional circular window, but by sealing the mica on to a curved surface in which a slotted window had been cut, it was found possible to produce windows as thin as 6 microns, which would consistently withstand 3 atmospheres over an area of 1·0 cm by 3·0 cm.

An electron sensitive stripping emulsion (Ilford K2) is used to record the electron image, since a flexible emulsion to press against the curved end window is needed. This involves special techniques.

Finally the performance of the tube was described, special emphasis being given to the excellent resolution obtainable and the ability to detect images of poor contrast by the use of nuclear emulsions of small grain size.

FURTHER DEVELOPMENTS AND PERFORMANCE OF A THIN WINDOW IMAGE TUBE WITH PHOSPHOR OUTPUT

J. D. McGee, *R. W. Airey*, and *B. E. Wheeler*

The tube to be described is a single-stage image intensifier, focused by uniform, co-axial electric and magnetic fields, in which images on the phosphor screen are recorded by direct contact photography through a thin mica membrane.

The present image tube is a development of that previously described by Zacharov and Dowden (Zacharov, B. and Dowden, S. *Advances in Electronics*, **12**, 31, 1960. Academic Press, London and New York.) In order to eliminate contamination of the photo-cathode by gases evolved from the metal parts employed in the original design, an all lime-soda glass tube has now been developed, with special features to reduce background in the image to a very low level. Metallized annular glass baffles are inserted at intervals along the length of

the image tube to suppress secondary electron multiplication which appears to take place because of the migration of stray electrons and ions in the region of the tube walls, and also to shield the photo-cathode from wall fluorescence.

A REPORT ON THE IMAGE ORTHICON USING SLOW READ-OUT

John H. De Witt, Jr.

With the advent of the magnesium oxide target for the image orthicon it became apparent that this type of tube might have uses in the field of spectroscopy and other applications where the photographic plate is not now sky-limited. For the past three years development of a practical light amplifier utilizing this tube has been underway. It has been found that the use of target storage and slow read-out has certain advantages which will be reported upon. By the use of degenerative feedback beam control the signal-to-noise ratio in the output is improved by a factor of two to one.

Recent evaluation of the equipment at the 24-in. Morgan telescope of the Lowell Observatory indicates that gains of 100 or more are possible over fast photographic plates. The chief limitations of the system lie in the field of resolution and dynamic light range. In spite of these limitations it appears that the equipment could have numerous uses in spectroscopy and in the photography of faint objects at the output of long-focus telescopes. For spectroscopy the image is widened electronically in the image section of the tube, thereby eliminating the need to drift the star in the slit.

By utilizing electronic techniques and tubes which are common to the television industry a practically useful system becomes possible without encountering the expense and development effort necessary by other means.

IMAGE INTENSIFIERS WITH TRANSMITTED SECONDARY ELECTRON MULTIPLICATION

W. L. Wilcock, D. L. Emberson and *B. Weekley*

Image intensifiers with transmitted secondary electron multiplication, of design essentially the same as those first made at Imperial College and described by us in *Trans. I.R.E.* NS-7, 126, 1960, have been produced in significant numbers by 20th Century Electronics Ltd., New Addington, Surrey, and are now generally available. Current tubes have Sb–Cs photo-cathodes deposited on the entrance window, five 19 mm diameter edge-supported dynodes of KCl on aluminised Al_2O_3, and a blue (ZnS:Ag) output phosphor. Between stages the electrons are accelerated and focused by uniform co-axial electric and magnetic fields. With 36 kV overall voltage the mean electron multiplication between cathode and phosphor is 3 000 or more, with the result that single electrons from the photo-cathode give rise to scintillations from the phosphor which are easily photographable. With cathode sensitivity 40 μA/lumen the photon gain for blue incident light is about 10^5. Typical dark emission rates lie within the range $10-10^3$ scintillations cm^{-2} sec^{-1}.

For a typical tube the limiting visual resolution with test patterns of equally-spaced black and white lines is 23 line-pairs/mm at 36 kV overall voltage. At lower voltages the resolution falls, reaching a value of 19 line-pairs/mm at 20 kV overall voltage, when the photon gain is of the order of unity. This relative insensitivity of resolution to voltage variation indicates that in present tubes the deterioration of the image is not predominantly due to the inhomogeneity in energy of the secondary electrons, but that other factors make a significant contribution. This conclusion is strengthened by the performance of a recently-prepared 5-dynode tube

which is in all respects similar to the normal tubes, except that the photo-cathode, dynodes and phosphor are more closely spaced. From preliminary measurements with this tube, it appears that the limiting visual resolution does not much exceed that of the longer tubes, although, as expected, the variation of resolution with overall voltage is smaller.

Measurements have also been made of the distribution of intensity amongst output scintillations from the phosphor corresponding to single electrons from the photo-cathode. This distribution is found to be exponential, as for many types of photo-multiplier. It is found that when, by varying the voltage between the photo-cathode and first dynode, the mean electron multiplication of this dynode is reduced by a factor of 5, the mean intensity of the scintillations is reduced by a factor less than 2. This shows that the voltage dependence of the mean electron multiplication of a dynode is due principally to changes in the probability of an incident electron producing no transmitted electrons. The value of this probability is found to be about 0·15 at normal operating voltage.

The cathode sensitivity and electron multiplication of a 5-dynode tube have been monitored continuously during a period of operation sufficiently prolonged to cause permanent damage to the cathode and dynodes. It was found that after an area of 1 cm^2 of the last dynode had been bombarded by a total charge of $\sim 5 \cdot 5 \times 10^{-3}$ coulomb, the mean electron multiplication of the tube had fallen to $\sim$0·75 of its initial value, and the cathode sensitivity had fallen to $\sim$0·67 of its initial value.

POTENTIALITIES AND LIMITATIONS OF IMAGE SCANNING TECHNIQUES IN ASTRONOMY

J. A. Hynek

Two programs of the application of image scanning techniques to astronomical problems are currently in progress at the Northwestern University, under the sponsorship of the U.S. Air Force and of the National Aeronautics and Space Administration, respectively. The first program is being carried out at the Dearborn Observatory directly, where an image orthicon system has been attached to the 18-inch refractor, and the other at the Organ Pass Station of the Dearborn Observatory in New Mexico, where a 12-inch reflector and image orthicon system have been set up especially for these purposes. It is expected that the parameters of operation and effectiveness determined through the employment of these modest instruments can be extrapolated to use with larger instruments without the introduction of a serious scale error.

Enhancement of contrast discrimination, the detection of faint objects, and the study of slow-scan techniques are the specific problems under investigation at the Dearborn Observatory. It has been found that small areas showing a 5% contrast can be transformed into areas of about 90% contrast; this technique is being applied to the determination of albedo differences on the lunar surface at the full lunar phase.

At the Organ Pass Observatory the investigations comprise the determination of limiting stellar magnitudes by use of special techniques, the resolution of spectral class differences in objective prism spectroscopy, and the determination of positional resolution of asteroids and other slow moving astronomical objects.

A fine potential for scanning systems appears demonstrated, especially if the image orthicon tube is improved by the utilization of a "mono-kinetic" scanning beam. Their limitations arise largely from lack of resolution, a matter which can also be remedied by improved scanning systems.

LABORATORY EVALUATION OF IMAGE TUBES FOR ASTRONOMICAL PURPOSES

W. A. Baum

During the past few years various workers have devoted much effort to the testing of image tubes on telescopes and on astronomical spectrographs. It is not sufficient to know only the resolution and the cathode sensitivity. We have to know how different image tubes compare with one another and with unaided photography in detecting typical features in stellar spectra or in recording faint images against the sky background.

An instrument has been built at the Imperial College, London University, for making quantitative "astronomical" tests in the laboratory. A tiny test-image is projected with a controlled amount of light on to the photo-cathode of a tube being evaluated. In addition to a resolution pattern, the test-image includes three calibrated sequences of simulated spectrum lines, a calibrated sequence of simulated star images against a "sky" background, an intensity step-wedge, a sequence of double stars, a contrast-dilution test, and a scheme for measuring magnification and distortion. Except for the last item, the performance of the tube can be quantitatively specified by simple inspection of the image recorded by the tube.

The instrument was designed for convenience of operation so that tubes can be tested at the time of production. Duplicates of the instrument are planned.

9*b*. SOUS-COMMISSION DE LA QUALITE DES IMAGES

Compte rendu de la Séance, 17 août 1961

PRÉSIDENT: J. S. Hall.
SÉCRETAIRE: J. Rösch.

L'ordre du jour appelle en premier lieu la discussion du *Draft-Report*. Ce rapport figure dans le volume distribué aux membres de l'Union avant l'Assemblée Générale. Le Président propose d'apporter à ce texte quelques adjonctions pour tenir compte des travaux publiés depuis sa rédaction. Cette proposition est acceptée, et l'ensemble du Rapport est adopté.

Le Président expose ensuite que la principale tâche de la Sous-Commission est de discuter les conclusions du rapport sur *le Choix des Sites* établi par le Groupe de Travail créé par le Comité Exécutif de l'Union en 1959 sous la présidence de J. Rösch. Ce rapport a été distribué en mai 1960 à plus d'une centaine de membres de l'Union intéressés à ce problème, et des exemplaires sont disponibles en séance.

Ces conclusions sont essentiellement les suivantes:

(*a*) que le Groupe de Travail soit maintenu en activité au dela de la XI^{e} Assemblée Générale de l'Union;

(*b*) que soit organisé le Symposium dont le principe a été adopté lors de la X^{e} Assemblée Générale;

(*c*) que les observatoires existants s'attachent, au moins à l'occasion de leurs observations courantes, à noter les corrélations entre les conditions atmosphériques locales et la qualité des images;

(*d*) que les observatoires qui consacrent des moyens très élaborés à l'étude de la qualité des images utilisent, conjointement, les instruments des types plus simples employés dans les prospections, de façon à asseoir sur une base plus large les résultats fournis par ces derniers.

A propos du point (*a*), I. S. Bowen exprime l'avis que les principales causes de détérioration des images résident dans le voisinage immédiat du sol, et qu'une connaissance plus complète des phénomènes doit être recherchée dans des études à long terme faites dans les observatoires existants, tandis que des campagnes de prospection faites au moyen de petits instruments peu élevés au-dessus du sol ne doivent pas pouvoir fournir d'informations décisives. J. Rösch, tout en reconnaissant qu'il est important de s'affranchir des effets des couches les plus basses, estime qu'elles ne sont pas seules responsables de la détérioration, et que pour cette raison, les propriétés des couches plus élevées doivent être étudiées en différents lieux. F. Zwicky partage ce point de vue et indique des expériences déjà faites, notamment au moyen de ballons-sondes. Dans le même ordre d'idées, A. G. Wilson mentionne la découverte de "courants-jets" à une altitude de quelques centaines de mètres, et G. P. Kuiper insiste sur l'importance des effets locaux. W. H. van den Bos et W. S. Finsen signalent l'importance de la distinction à faire dans les qualités exigées selon les observations envisagées, et R. G. Giovanelli rappelle particulièrement le cas des observations solaires.

En ce qui concerne le point (*c*) un accord général se manifeste quant à l'utilité des constatations faites à l'occasion des observations courantes. G. P. Kuiper estime qu'il y a intérêt à demander aux observatoires existants ce qu'ils savent, par expérience, des relations entre les conditions atmosphériques et la qualité des images. J. Dommanget signale qu'à Uccle il est tenu registre de ces constatations pour chaque nuit d'observation. A. R. Hogg suggère qu'on demande aux observatoires de généraliser cette pratique, si possible dans des conditions normalisées à définir.

Il est reconnu qu'un grand nombre de questions restent à discuter en détail, notamment en ce qui concerne l'unification des méthodes, et qu'il y a là matière à une confrontation étendue.

En conséquence, la Sous-Commission 9*b* recommandera au Comité Exécutif que soit organisé en septembre ou octobre 1962 le Symposium proposé dès 1958; il pourrait avoir lieu en Italie.

La suite de la séance est consacrée à des exposés de travaux entrant dans le cadre de l'activité de la Sous-Commission.

Mme N. V. Bistrova expose les résultats obtenus avec Mme A. N. Demidova sur la détérioration de l'image du bord solaire et sur les corrélations entre la qualité des images et la structure de l'atmosphère en altitude.

Les interventions suivantes rendent compte de prospections en cours en diverses régions du globe.

J. Stock présente les résultats obtenus au Chili, entre les latitudes 27° et 30°. On a utilisé, en particulier, un système à miroirs du même genre que celui préconisé dans le rapport du Groupe de Travail pour l'exploration plus étendue de la surface d'onde, et dont J. Rösch présente des photographies. Des régions très favorables ont été trouvées vers 2 800 mètres d'altitude. R. P. Cesco rend compte des recherches faites, en utilisant la méthode de Danjon, dans la région sèche de San Juan, en Argentine, à la même latitude que la zone mentionnée par J. Stock, mais à l'Est des Andes. A. R. Hogg expose le programme de prospection en cours en Australie, d'une part près de Canberra pour trouver un emplacement plus favorable que le Mt. Stromlo, et d'autre part dans diverses régions de l'Australie pour trouver le meilleur emplacement possible. Il signale que des recherches sont également entreprises en Nouvelle Zélande.

Enfin, J. N. Torroja présente les statistiques d'observations obtenues à la station d'Izana, dans l'île de Tenerife, en vue de la création d'un observatoire.

10. COMMISSION DE L'ACTIVITE SOLAIRE

Report of Meetings

PRESIDENT: A. B. Severny.

SECRETARY: M. A. Ellison.

Business meeting, 21 August 1961

The President began by referring to the death of Professor A. K. Das and the loss of two members of the Commission by resignation—Dr Mary T. Brück and Dr M. Notuki.

The *Draft Report* was accepted without changes (at the meeting on 16 August).

Dr Fokker presented a report, prepared by himself and Dr Smerd, dealing with the publication of world-wide data of solar radio emission in the *Quarterly Bulletin on Solar Activity*. This report having been discussed and adopted, the following were appointed members of a Steering Committee to advise the new Editor of radio-emission data (Dr Fokker): H. Daene, H. Dodson-Prince, A. Maxwell, M. Pick-Gutman, S. F. Smerd, H. Tanaka, V. S. Troitsky and J. P. Wild. The Secretary emphasised the need for swept-frequency recording in the European zone. Professor Kiepenheuer informed the meeting that suitable equipment, formerly in use at the Fraunhofer Institute, was likely to be brought into operation again shortly by Professor Siedentopf.

Professor Waldmeier reported briefly on the history, present status and administrative control of the *Quarterly Bulletin on Solar Activity*. After a short discussion the Commission resolved that in future the members of the new Inter-union Commission on Solar and Terrestrial Relations should act in the capacity of advisors to the Editor of the *Quarterly Bulletin*.

Dr Roberts read the resolutions passed by Commission 10*a* (see below) in relation to the Hα disk patrol and these were endorsed by the Commission. Professor Kiepenheuer asked that observing stations be given adequate notice of the programme proposed for the International Year of the Quiet Sun (I.Q.S.Y.).

The Commission supported proposals for the rapid publication of sunspot magnetic field data and Professor Kiepenheuer agreed to investigate the possibility of publishing these in an addendum to the Fraunhofer *Daily Maps* which would show the polarities and field strengths in the principal spot groups.

The Commission expressed its satisfaction at the arrangements which had been made for the continued publication of the Fraunhofer *Daily Maps of the Sun* and the Russian *Solar Data*.

Following a discussion on the need for improvements in the estimation of flare importance the following resolution was adopted:

"That a Working Group be appointed to consider all problems concerned with the estimation of flare importance and to make recommendations which could be put into operation from 1 January 1965".

Members of the Working Group were appointed as follows: M. C. Ballario, A. Bruzek, H. Dodson-Prince (Chairman), E. E. Dubov, M. A. Ellison, R. Hedeman, J. V. Lincoln, R. Michard, Y. Öhman, H. J. Smith and C. Warwick. The Group was empowered to take

earlier action if it found that discrepancies were arising between the estimations of different stations through the use of incorrect units or methods of measurement.

The Secretary, in his capacity as Reporter for Solar Activity on the International Committee for Geophysics, gave a short account of the Committee's plans for observations to be made during the International Year of the Quiet Sun—1964–65 (I.Q.S.Y.). He invited the Commission to appoint a small Steering Group to assist him in the planning stages. This was agreed and the following were invited to act: R. G. Athay, A. D. Fokker, H. Friedman, K. O. Kiepenheuer, R. Michard, M. Nicolet and A. B. Severny.

Dr Shapley described the organizations now in operation for the publication of solar data and for the quick exchange of information about outstanding events. In this connection Dr Michard proposed the following resolution which was endorsed by the Commission:

"The Commission, considering the wish expressed by the Comité International de Géophysique and other organisations for world-wide co-operation in geophysics, urges all observers active in the solar patrol to report promptly to the nearest Regional Warning Centre, by telegram or other available fast channel, all flare events of importance 1 + and greater during the coming years of declining solar activity and especially during I.Q.S.Y.".

The Commission resolved to recommend that the annual subvention of 2 700 gold francs, agreed since 1925 by the Union for the publication of the *Cartes synoptiques de la chromosphère solaire*, should be renewed to the Meudon Observatory until the next General Assembly. The Commission also agreed to recommend the annual subvention of 1 000 gold francs to Professor M. Waldmeier for the publication of the *Heliographische Karten der Photosphäre.*

[Both these recommendations were approved, and were incorporated in the report of the Finance Committee.]

The Commission took note that the following members had been appointed to conduct its affairs over the next three-year period: President: A. B. Severny; Vice-President: M. A. Ellison; Organizing Committee: K. O. Kiepenheuer, R. Michard, W. O. Roberts, Zd. Svestka, and M. Waldmeier.

Report of Meeting, 16 August 1961

The following communications were read at the meeting. Nos. 1 and 2 dealt with new observational techniques and 3 to 5 with recent research items unpublished.

1. *R. B. Leighton.* Spectro-heliographic records of magnetic fields and radial velocities on the disk.

2. *A. Dollfus.* The solar photo-electric polarimeter.

3. *R. W. Kreplin.* X-ray and Lα observations of solar flares with satellites.

4. *H. Friedman.* A new X-ray photograph of the Sun.

5. *M. A. Ellison.* The flare nimbus and changes in the Hα striation patterns.

Report of Meeting, 19 August 1961

The following accounts were given of recent research projects, mostly unpublished.

1. *R. G. Athay and G. E. Moreton.* The rapid evolution of flares and the abrupt disappearance of filaments after the explosive phase. (Presented by R. G. Athay).

2. *R. R. McMath, H. Dodson-Prince and O. Mohler.* The examination of bombs (mustaches). (Presented by *H. Dodson-Prince*).

3. *R. E. Loughhead.* The rapid changes in sunspots.

4. *H. Zirin.* The spectrum of the flare of 1960 November 14.

5. *M. C. Ballario.* On the classification of solar flares. (Presented by *G. Righini*).

6. *S. Lukyanov, A. B. Severny, A. Babin, G. Sidorov, N. Steshenko* and *V. Sinitzin.* The comparison of line profiles in flares and in laboratory pinch. (Presented by *A. B. Severny*).

7. *M. R. Kundu.* Correspondence between X-ray emission producing SIDs and 2800 Mc/s bursts.

8. *J. C. Noyes.* The characteristics of solar active regions associated with flares producing low-energy solar protons.

10*a*. SOUS-COMMISSION DE CINEMATOGRAPHIE DES PHENOMENES SOLAIRES

Report of Meeting, 17 August 1961

PRESIDENT: W. O. Roberts.

SECRETARY: M. N. Gnevyshev.

The meeting was opened by the President, who called attention to the fact that this was the last meeting, *per se*, of the Sub-Commission for Cinematography of Solar Phenomena, presided over for so many years by Dr Lyot. He pointed out that the work of the Sub-Commission, under the IAU reorganization, will be carried on by a Working Committee, or otherwise as the parent Commission 10 may decide. The President also paid tribute to Dr McMath for his pioneering work in solar cinematography.

CONTINUOUS MOTION PICTURE OF DISK ACTIVITY

The President recalled the long-standing goal of the Sub-Commission, to assist the preparation of a continuous, unbroken film of solar disk Hα activity on a 24-hour per day basis for an extended period. He then called on Dr H. Smith to report on work of the Special Working Committee entrusted with this task. Dr Smith reported on work subsequent to the formal report previously submitted. The Working Committee had elected the period 6–20 July 1959 for a trial movie, as one of the great periods of activity in Solar Cycle 19. Twelve observatories in eight countries have contributed films to the combined effort. There are numerous small-time gaps, usually of the order of one hour, but coverage is approximately 90% complete. Final editing is in progress at Sacramento Peak Observatory. Numerous disparities of image size, orientation, density and contrast must yet be removed, and a uniformly advancing clock must be superimposed on the images. These difficulties are, however, being surmounted, and approximately 20 000 individually adjusted frames of film are being completed. The final prints are expected to be ready to distribute in mid-1962. The master negative will be stored in the IGY Data Center A, and duplicate copies will be available there. The quality of the final prints will not equal the original films, of course, because of the need for multiple copying and for other photographic manipulations.

Dr Smith emphasized the degree to which future efforts of this sort would be enhanced by uniform standards of size, orientation, registration, density and contrast. Dr Michard also appealed for establishment of uniform standards for these characteristics. The President expressed thanks to the Working Committee for its excellent progress. The report of Dr Smith was accepted by the meeting.

CORONAL INTENSITY STANDARDIZATION

The President then opened discussion of the matter of coronal intensity standardization, the subject of the Working Committee headed by Dr Rösch. Dr Trellis reported for Dr Rösch the work of the Committee.

The Working Committee studied the relation of coronal intensity scales of all active coronal observatories. The work revealed that there appear to be substantial changes, on occasion, of coronal intensities in periods as short as a few hours. However, the large dispersion of coronal observations of the same coronal intensities is still evident. Dr Trellis emphasized the need, suggested by this work, for photo-electric photometry for such observations, which would presumably be more nearly free from accidental errors. An instrument for this purpose has been constructed at Paris Observatory, and will be used in the period immediately ahead.

The report of Dr Rösch's Working Committee can be obtained from the President or directly from Dr Rösch. The President thanked Dr Trellis for the report.

Mr Hansen reported that calibrating filters have been made available from the World Data Center at Boulder, Colorado, for coronal standardization by photographic methods.

The President then invited Dr Bell to describe briefly her analysis of the latitude of coronal peak intensities for the period of observation of Climax and Sacramento Peak Observatories. Her data show that the maxima of coronal activity progress from higher latitude to lower, in unbroken sequence, from approximately four years before the minimum of solar activity. This result confirms the earlier results of Dr Trellis.

CENTRALIZATION OF DATA AND FILMS

The President then introduced the subject of centralization and exchange of data and films of Hα and other disk solar activity. He pointed out that the IGY organizational schemes had been highly effective. The experience suggests a continuing need for data to uniform standards, rapidly centralized. Particularly is this so with the increased use of artificial satellites for geophysical research, and with world-wide interest in manned satellites.

Dr Michard then summarized his studies of the completeness of solar flare patrol operations in recent years. He suggested that critical time zones for further coverage are in summer at $01^h\,30^m$ to $06^h\,00^m$ U.T., in winter also at $12^h\,00^m$ to $16^h\,00^m$ U.T. He urged improved coverage in India, China and by earlier observations, if possible, at U.S.S.R. stations such as Ussuriysk, Tashkent and Alma Ata. He also spoke with hope of possible further coverage in Eastern North America, in the Canary Islands, and at Huancayo, Peru.

Extended discussion confirmed the needs for further patrol work in the years ahead, and particularly during the IQSY period (1964–65). The discussions led to unanimous adoption of the following resolution:

> "The Sub-Committee notes with satisfaction the effectiveness of the co-operative solar flare patrols of the IGY and the IGC-1959, and the continued co-operation of many observing stations in voluntary cinematographic flare coverage and data centralization; the Sub-Commission also notes the increasing demand for accurate solar flare data and for patrol of other abrupt solar Hα phenomena during the IQSY period, and through the solar activity minimum; the Sub-Commission therefore commends continued efforts towards complete flare and disk coverage on a co-operative international basis; the Sub-Commission notes in particular the importance of filling the major time gaps by further patrol coverage from China, the U.S.S.R., India, Latin America and Eastern North America; it further urges preparation by the World Data Centers of a full catalog of films available at co-operating stations."

SPECIFIC RECOMMENDATIONS

The Sub-Commission then turned its attention to several specific recommendations. In addition to the recommendations mentioned in the Sub-Commission report, the members adopted, by unanimous vote, the following resolution:

"The Sub-Commission recommends the preparation by the World Data Centers of a co-operative catalog of records of swept-frequency solar radio noise telescopes, covering all longitudes, and emphasizes the great importance to solar physics, space physics, and solar-terrestrial research of the widest possible international co-operation to assure full observational coverage."

The final meeting of the Sub-Commission concluded with enthusiastic endorsement of a resolution by Dr Dodson-Prince to send, on this occasion, telegrams of greeting and appreciation to Dr L. d'Azambuja, Dr R. McMath, Dr G. Abetti and Madame Lyot for their devoted support of the historic goals of the Sub-Commission. The President agreed to send such messages immediately upon the close of the session.

12. COMMISSION DE LA RADIATION ET DE LA STRUCTURE DE L'ATMOSPHERE SOLAIRE

Report of Meetings

PRESIDENT: L. Goldberg.

SECRETARY: Miss E. A. Müller.

First meeting, 16 August 1961

Draft Report. The President announced that any errors in the *Draft Report* should be corrected at this meeting and additions could be included only if they were very brief. The *Draft Report* was approved by all members without any changes.

SCIENTIFIC DISCUSSION

The first paper on the agenda was given by R. Tousey on the spectrum of the Sun between 170 and 700Å which was obtained by W. E. Austin, J. D. Purcell, and R. Tousey of the Naval Research Laboratory on 1961 June 21. The rocket reached a peak altitude of 197 km. Stray light background fog was completely eliminated by placing an aluminum film of 1000 Å thickness in front of the slit of the spectrograph, which employed a 40cm radius 600 line/mm grating at 85° incidence. The aluminum film was opaque for λ850Å and transmitted from 700Å to the L III edge at 170Å. Approximately 50 emission lines were photographed between 170 and 310Å in first and second orders, and some in third and fourth orders. From 310 to 700Å only a few lines were recorded, because of attenuation by N_2 remaining overhead. Wave-lengths have been established to one or two tenths of an angstrom. Surprisingly few lines agree with lines in the Ultra-violet Multiplet Table of Mrs Moore. He II (1) at 304Å, possibly He II (2) at 256-7, and several higher members of this series are present. The lines near 336 and 361Å may be the D lines of Fe XVI. Faintly present are O VI (4) at 173·08, 172·93Å. A moderately strong line at 182·3Å appears to be Hα of C VI. The spectrum agrees well with H. E. Hinteregger's photo-electrically scanned spectrum, but contains more lines and has ten or more times greater resolution. To the questions by H. Zirin, J. T. Jefferies, and G. Athay, Dr Tousey answered that the relative intensities in the different orders have not yet been determined, the decrement in L II was not yet reduced to intensities and that the flight was not high enough to secure accurate total line intensities.

Referring to Dr Tousey's identification of the emission line at λ256-7 with He II Ly β, R. N. Thomas commented that J. B. Zirker and R. N. Thomas tried to predict the relative intensity of He II Ly α:Ly β, and that they found a value much greater than observed. Charlotte Pecker suggested that $2s2p^2\ {}^2P\text{-}2s^22p\ {}^2P^\circ$ of Si X at 256·6 lies as close to the emission feature as does He II Ly β (256·3). She and Thomas made a preliminary calculation of this Si X emission line including just collisional excitation of the ^2P level. For values of n_e giving reasonable agreement with H. E. Hinteregger's observed intensities of the emission feature—(which lie in the range $n_e \sim 10^9$)—they found large optical depths in the line, so the calculations are now being extended to include coronal self-emission as an excitation mechanism. Mrs Pecker points out that with the excitation of this ^2P level one should observe other transitions from this level than to the ground term, and other transitions involving terms intermediate to the ^2P and ground terms. In a detailed analysis of the rocket spectra of W. A. Rense, she has found a large number of wave-length coincidences that suggest the presence of these transitions in the solar spectrum. A particularly interesting one is the forbidden transition $^2P\text{-}^2S$, arising from the same upper level as the λ256·6 line. Preliminary calculations by Mrs Pecker and

Thomas suggest a different sensitivity of the emission in visual (forbidden) and rocket (permitted) lines to the value of n_e if the optical depth is high enough, thus a sensitivity of the intensity ratio of these lines to coronal condensations. Mrs Pecker emphasizes the extreme utility of such intercomparison of rocket UV and visual lines in investigating the problem of coronal condensations, and therefore the necessity for adequate discussion of the transfer problem to include coronal self-emission. Similar investigations were carried out of the ions Mg VIII and Al IX which have the same configuration, and attempts are being made to get better structure of the Fe XIV term diagram. Dr Tousey pointed out that on his spectrograms the emission line identified with He II Ly β at 256 is rather diffuse on the long wave-length side and that the line 256·6 of Si X may very well be there but much weaker.

Z. Suemoto then reported on a model of the chromosphere proposed by F. Moriyama and extended by Moriyama and Suemoto to the transient region chromosphere-corona. The observed radio emission data of the quiet Sun at sunspot minimum in the dm and cm range are combined with the optical observations of the brightness distribution of the helium lines and the Balmer continuum. The proposed model is a spicular model in which the radio emitting regions as well as the helium emitting regions occupy about 10% of the entire solar disk. Adopting the electron density of the order of 10^{11} at an electron temperature of 20 000°, and subsequent densities in such a way as to ensure the pressure balance, they find the geometrical thickness of the whole transient layer to be of the order of about 100 km. This model is supported by their 1958 eclipse observations of the flash spectrum in which the spicular structure is revealed even for weak hydrogen and helium lines down to about 1500 km.

The next paper was given by M. Rigutti on the (0.0), (1.0) and (2.0) bands of the CN red system ($\sim \lambda$ 10000 Å) in the solar spectrum. The spectra were obtained at the Dominion Observatory in Ottawa in 1959 with the grating spectrograph and a simple carbon arc in air as a source. The (0.0) band was observed in the second order with a dispersion of about 1·2 Å/mm, and the (1.0) and (2.0) bands were observed in the third order with a dispersion of about 0·6 Å/mm. The origin of the bands and the observable transitions were computed and the results were compared with the observed solar spectrum. With a good degree of certainty it was possible to identify 32 solar lines pertaining to the (0.0) band and 5 solar lines belonging to the (1.0) band of CN. The analysis of the (2.0) is in progress. The physical characteristics of the CN molecule are being studied by J. G. Phillips by means of electronic computers.

A brief discussion followed among R. N. Thomas, L. Goldberg, Miss E. A. Müller, and J. C. Pecker on the influence of non-LTE on the Fe abundance in the solar atmosphere. We refer to the Report of the meeting of Sub-Commission 29*a* of 22 August when this problem was discussed in more detail.

M. Minnaert then reported on a study of the central intensities of Fraunhofer lines. The Utrecht Atlas and the McMath-Hulbert photo-electric tracings of the solar spectrum in the visible region are compared. Corresponding central intensities measured in both records differ appreciably if the lines are not corrected for instrumental profile. However, one must bear in mind that the instrumental profile for the Utrecht Atlas is about five times wider than that for the Michigan tracings. After correcting the lines for instrumental profile, Minnaert finds very good agreement between the central intensities of both records. J. Waddell commented that reliable central intensities of strong lines, that is, correct to within 0·1% can only be achieved by the complete elimination of scattered light and the effects of Rowland ghosts, such as is performed in the system of the Sacramento Peak Observatory. He wondered about the degree of accuracy in the observed agreement of the central intensities in the two records. Professor Minnaert answered that for faint and medium strong lines the central intensities were certainly correct within a few per cent. He believes that some of the scatter

observed in the results is due to real changes in the lines and requires further investigation. To the questions by J.-C. Pecker and by F. W. Jäger, Professor Minnaert answered that the method of Voigt functions and Elste's tables were employed to correct for instrumental profile and that stray light and ghosts were taken into account as well as possible. R. Michard pointed out that the central intensity of a Fraunhofer line fluctuates by 10-15% because of the granular structure of the solar atmosphere and that a mean value of the central intensity is only of statistical value.

The last contribution to this session was given by R. Giovanelli reporting on some work by P. Wilson in Sydney, who had developed methods for applying the theory of radiative transfer in non-uniform media to the study of the distribution of the source function and of the attenuation coefficient in photospheric structures such as granules and penumbral filaments. As a starting point, he requires the center-limb variation of contrast, which must be corrected for the contrast transfer function of the telescope. For a visual demonstration of the loss of resolution due to foreshortening towards the limb one of Schwarzschild's granulation pictures was re-photographed at various angles to the normal with cameras simulating telescopes of various diameters. The simulated center-limb photographs show changes rather like those actually observed. Dr Giovanelli points out that it appears to be an open matter at present whether the observations reflect anything other than the combination of foreshortening and finite telescope resolution or whether they do reveal information on the three-dimensional structure of the photosphere. R. B. Leighton believes that the elongation of the granulation observed towards the limb is probably due to foreshortening, whereas J. Rösch claims that one can observe real solar features near the limb.

Second and third meetings, 18 and 19 August 1961

ACTING CHAIRMAN: J. W. Evans

THE SOLAR GRANULATION

Both sessions were devoted to a discussion on the topic of the Solar Granulation, the program being as follows.

A. Continuum Studies of Granulation

1. *J. Rösch.* Results drawn from Photographs of the Photosphere obtained from the Ground.
2. *M. Schwarzschild.* Results drawn from Photographs of the Solar Granulation taken from the Stratosphere.
3. *C. Macris.* Mean Distance Between Photospheric Granules and Its Change With Solar Activity.

B. Spectral Line Studies of Granulation

1. *N. V. Steshenko.* The Investigation of the Magnetic Fields and Radial Velocities in the Photosphere and Chromosphere.
2. *O. C. Mohler.* The Fine Structure of the Solar Chromosphere.
3. *R. B. Leighton.* Oscillations in the Solar Atmosphere.
4. *J. W. Evans* and *R. Michard.* Oscillatory Motion in the Upper Photosphere.

C. Photospheric Models

1. *K. H. Böhm.* Photospheric Models Incorporating Granulation.

D. Fraunhofer Line Profiles

1. *J. E. Blamont.* A New Method to Measure Fraunhofer Line Profiles.

A. CONTINUUM STUDIES OF GRANULATION

Paper 1—J. Rösch

J. Rösch described some results derived from photographs of the photosphere taken from the ground at the Pic du Midi, and showed motion pictures of the granulation which formed the basis of his investigation. Referring to Dr Giovanelli's remark during the first session of this meeting Dr Rösch stressed the fact that pictures taken at various angles to the normal of a plane image of photospheric granules do not truly reproduce the pictures of the photosphere taken at the same angles, since the solar granules are three dimensional. The elongation of the granules appears only at very great angles and even on pictures quite near the limb bright granules can be recognized which probably pertain to plage regions. This indicates that also near the limb solar features can be observed and that limb photographs of the granules can give information about the variation of the photospheric structure with depth. The study of the morphology of the granules includes the different shapes (coffee grain, rosette, horseshoe, rings, etc.) and the mean diameter d of the granules which is obtained from the mean distance of the centers of neighboring granules. The observed intensity ratio I_M/I_m between the brightest and the least bright points yields the mean temperature fluctuation ΔT after correction for the limits of the instrumental resolving power. The results derived for two effective wave-lengths are collected in the following table:

Wave-length, λ	Mean diam. d	I_M/I_m	In 80% of the cases	I_M/I_m corrected	ΔT
4610 ± 20Å	2″·5	1·14	$1{\cdot}10 < I_M/I_m < 1{\cdot}18$	1·22	250°
6000 ± 100Å	2″·6	1·16	$1{\cdot}13 < I_M/I_m < 1{\cdot}19$	1·25	350°

The difference in ΔT found in the two wave-lengths reflects the different photospheric levels to which they refer and should be used in determining the variation of the optical depth with wave-length. Near the limb the intensity ratio (granule/background) is more difficult to determine because of (*a*) the decrease in contrast, and (*b*) the presence of bright granules of plages which should be treated separately. A preliminary study yielded a contrast of about 5% at 6″ from the limb, and at 20″ from the limb the contrast was about 8% for ordinary granules and about 20% for the granules of plage regions. In the λ6000Å region about 20% of the granules show a tendency to bisect, the average distance between the two parts being 1″·0 and about 10% of the granules are ring shaped with a mean diameter of 1″·6. The evolution and lifetime of the granules can best be studied individually on a film composed of 28 pictures taken at one minute interval. A film composed of pictures taken every 3 seconds does not show any real changes in the granules but only deformations due to atmospheric turbulence. In general one observes that after a granule is formed its diameter begins to increase until it reaches about 2″ at which moment it breaks up into several small granules which vanish at the place they appeared. This evolutionary cycle occurs within about 10 minutes, but granules of average dimension have been seen to subsist up to 20 minutes.

Paper 2—M. Schwarzschild

M. Schwarzschild reported on some results obtained from granulation photographs taken with a 12-inch balloon-borne telescope during 6 flights made in 1957 and 1959. An impersonal statistical analysis was carried out which gave the auto-correlation function of the granulation intensity in space as well as in time. The auto-correlation function of photospheric brightness as a function of distance at one given time yields the average diameter of the granules, which is defined as twice the distance in which the auto-correlation function drops to one half. Dr Schwarzschild pointed out that this definition of the average size of the granules should not

be confused with Dr Rösch's definition which is based on the distance between centers of granules. The auto-correlation function of photospheric brightness as a function of time at one given place yields the average life-time of granules, which is defined as twice the time interval in which the auto-correlation function drops to one half. The life-time appears to be a function of the size of the granules, the larger granules live longer than the smaller ones. Finally, the space correlation function was used to derive the r.m.s. intensity fluctuation, $\{(\Delta I)^2\}^{\frac{1}{2}}$, which after correction for instrumental profile gave the r.m.s. temperature fluctuation, $\{(\Delta T)^2\}^{\frac{1}{2}}$. Schwarzschild's results are collected in the following table:

Mean diameter d	Life-time mean t	$\{(\Delta I)^2\}^{\frac{1}{2}}$ (observed)	$\{(\Delta I)^2\}^{\frac{1}{2}}$ (corrected)	$\{(\Delta T)^2\}^{\frac{1}{2}}$
700 km	8 min.	± 0·046 ± 0·050	± 0·073 ± 0·072	± 90° K

Dr Schwarzschild stressed the fact that Dr Rösch's intensity contrast is not the same as the r.m.s. intensity fluctuations used in this investigation. Therefore, he expects Dr Rösch's ΔT to be at least twice as large as the r.m.s. temperature fluctuation derived here which most probably is not greater than 100 °K at a mean wave-length of λ5450Å ± 400Å.

Paper 3—C. Macris

The third paper on the solar granulation observed in white light was given by C. Macris who reported on a possible variation of the size of the photospheric granules within a solar cycle. On a series of photographs of excellent quality the mean distance of the granules was measured and correlated to the mean area of sunspots as determined by Greenwich. It was found that the observed variation of the mean distance of the granules as a function of spot area can best be represented by a hyperbola rather than by a straight line. Dr Macris pointed out that the material employed was not at all homogeneous. The observations were made by various astronomers and under different conditions. The results seem to indicate, however, that the size of the granules—and hence the number of granules—is a function of the solar activity. He stressed the importance for further more numerous and homogeneous observations of the photospheric granulation during the period of one entire solar cycle.

Discussion

R. N. Thomas enquired whether center-limb variations of the intensity and temperature fluctuations had already been studied. F. N. Edmonds replied that he had begun such studies on Dr Schwarzschild's 1957 photographs and found that the r.m.s. intensity fluctuation remains constant from the center to about $\theta = 20°$, then increases to a maximum at about $\theta = 50°$, decreases to a minimum at about $\theta = 75°$ and then increases again near the limb. He believes, however, that the observed increase near the limb is probably due to another effect than the center-limb variation of the intensity fluctuation. The r.m.s. temperature fluctuation that he derived is 200 °K at the disk's center and 250 °K at about $\theta = 50°$. J. Rösch remarked that during the eclipse of 1961 February 15 they took center-to-limb pictures in order to measure the variation of the contrast across the solar disk. These measurements are now in progress.

B. SPECTRAL LINE STUDIES OF GRANULATION

Paper 1—N. V. Steshenko

The first paper concerning spectral line studies of granulation was given by N. V. Steshenko. He described an investigation of the longitudinal magnetic fields and radial velocities in the photosphere and chromosphere carried out mainly by W. E. Stepanov with the magnetograph

and the radial velocity recorder of the Crimean Astrophysical Observatory. Observations in the H_3 and K_3 lines of Ca II showed that in the chromosphere large regions exist of ascending and descending gases which extend up to 200 000 km. The motion in these regions has the character of large-scale turbulence. The characteristic scale of the elements is 5 000–20 000 km and their life-times are of the order of seven hours. In the undisturbed chromosphere the total flow of the ascending mass is practically equal to that of the descending gases. In flocculi the flow of the descending gas exceeds that of the ascending gas by a factor of 4. Apparently the excess of the descending mass is compensated by the ejection of matter during non-stationary processes (flares, moustaches, surges). In the chromosphere a correlation is found between the magnetic fields and the motions in the gases. The photosphere was studied mainly in the light of the Fe I line $\lambda 5250$Å. In the photosphere the velocity fields and the magnetic fields have much more complicated structure and no correlation between them is recognizable. The regions of ascending and descending gases extend to about $1{\cdot}5 \times 10^5$ km. The largest velocities were observed over sunspots where values up to 450 km/sec were measured. Dr Steshenko also briefly described his attempt to measure magnetic fields of separate granules. The measurements in the Fe I line $\lambda 6302$Å were made relative to the nearby telluric line. A quarter wave-length plate was placed in front of the slit of the spectrograph, thus producing two images of the spectrum with opposite polarization. The accuracy of the magnetic field measurements is hampered by turbulence in the spectrograph producing errors of up to $\pm$ 23 gauss. The conclusion drawn from the best quality observations are that (1) in individual granules of 1″–1″·5 in diameter the longitudinal magnetic fields, if they exist, are of the order of 40–60 gauss, (2) in groups of granules with diameters of 3″–6″ the longitudinal fields are of the order of 50–60 gauss and, as a rule, the strongest fields coincide with the regions of largest radial velocities.

Discussion

In the discussion that followed this paper, M. Schwarzschild stressed the importance of Dr Steshenko's results, if they can be substantiated, because the theoreticians expect turbulent magnetic fields in the photosphere which should be observable in the granules. To R. Giovanelli's question as to whether the results refer to quiet or active regions, Dr Steshenko replied that the observations were made over quiet regions. R. B. Leighton reported that he also had looked for longitudinal fields in granules. He observed field strengths in the neighborhood of sunspots which are similar to Dr Steshenko's values, but he found no fields exceeding 20 gauss in granules of quiet regions. Also, R. Michard mentioned that he had not detected longitudinal fields in individual granules, but that in groups of granules he had observed fields up to 50 gauss. Trying to settle the argument H. Zirin suggested to Dr Steshenko that his observations may refer to small groups of bright granules which possibly belonged to small plage regions of which we know that they are connected with magnetic fields. Dr Steshenko claimed, however, that the regions he had studied did not necessarily contain bright granules, but that he had simply selected randomly small groups of granules.

Paper 2—O. C. Mohler

In his paper on the fine structure of the solar chromosphere O. C. Mohler first gave a summary of what had been learned about the chromospheric structure from spectroheliographic observations of various investigators starting with the work of L. and M. d'Azambuja in Meudon. Some additional conclusions can be drawn from motion pictures in the Hα and the K line of Ca II which were produced at the McMath-Hulbert Observatory. They show that the life-times of the moving granulations are long, changing conspicuously in size and brightness but remaining recognizable for hours. In the polar regions the changes in configuration, size and brightness are less rapid than in the equatorial belts. Interpreted as velocities, the changes correspond to 600–700 m/sec. These velocity measurements, however,

are difficult and the values not exact. The undisturbed Sun apparently undergoes quasi-periodic changes that may either be real, or the result of variations in image quality. Spectroheliographic results must be compared and identified completely with the small structures that are observable near the centers of the strong Fraunhofer lines. Dr Mohler, therefore, drew attention to the main results that were obtained in recent years from direct photographs of some representative lines secured with the McMath-Hulbert vacuum spectrograph. He then reported on the recent investigation of the Na D_1 line by Edith Müller who found random velocities of 360, 404, and 438 m/sec at distances from the line center of 80, 50, 0 mÅ, respectively. These results indicate an increase in random velocities of the small structures with height, in the region where D_1 is formed. The directions of the shifts in the core are not correlated with the directions of the shifts in the outer line regions. Furthermore, measurements made to trace the change in correlation of the shifts at different distances from the line center show that high correlation is achieved only in the outermost wings of the line. In sum, he results derived from measurements of the small-scale structures within the spectrum lines indicate that (1) random velocities from 200-1000 m/sec are found; (2) the brightness of the individual elements and their velocities show very low correlation; (3) for metallic lines the random velocities increase with height in the atmosphere; (4) Hα, Hβ and K of Ca II show no height dependence of velocity; (5) preferred sizes of the elements in the uppermost layers of the chromosphere are 6″ and 20″. The comparison of the spectroheliographic and spectrographic results imply some sort of chromospheric structure based on the photospheric granulation. The structure seems to extend continuously from the level of the photosphere to the level of formation for the centers of Hα and K. At low levels the motions are somewhat systematic and are arranged in ascending and descending streams, but at the highest levels the situation is confused and motions of descent may even dominate. Possibly periodic variations of the vertical velocities may be superposed on a continuous outward flow. There seem to be no parts of the chromosphere that are at rest with respect to the photosphere.

Discussion

R. G. Athay asked whether or not the motions observed in Hα were completely random. Both O. C. Mohler and R. B. Leighton agreed that the situation in Hα was very difficult to interpret and that there may exist organized motions rather than purely random, inasmuch as there seems to be an indication of a correlation between direction of motion and brightness. R. N. Thomas made a strong motion for detailed investigations of small-scale structures in all levels of the photosphere and chromosphere in order to substantiate the connection of the photospheric granulation with the chromospheric inhomogeneities. R. Giovanelli drew attention to some results that he and J. T. Jefferies had obtained from pictures of velocity distributions in the chromosphere which were prepared in Sydney by suitably processing filtergrams secured with a 1/8Å bi-refringent filter in the wings of Hα. At a resolution of 5″-10″ they found that at each of the intervals $\Delta\lambda$ = 0·2, 0·5, 0·7, and 1·0Å, the direction of motion correlates well with the local brightness of the chromosphere, dark chromospheric granules almost always showing downward motion. Strong downward motions occur in columns descending from top to bottom of the chromosphere, coinciding with the dark points forming the large-scale chromospheric network. There are also isolated rising columns which, however, have not been detected at the lowest levels and have less obvious connection with brightness features. Between these columns, from bottom to top, a finer-scale velocity structure develops, providing the dominant velocity pattern in the upper regions.

Paper 3—R. B. Leighton

R. B. Leighton then reported on his investigation of the oscillations in the solar atmosphere. He obtained spectroheliograms showing the line-of-sight component of local velocities by

using an adaptation of a technique previously employed for studying magnetic fields. The photographs indicate that the entire solar surface is covered with a network of large-scale velocity "cells" which involve predominantly horizontal motions. Within each cell, the matter moves from the center toward the outer boundary. The mean diameter is about $1{\cdot}5 \times 10^4$ km; typical velocities are about 0·5 km/sec and the life-times of the order of many hours. The mean separation between two such cells is about $3{\cdot}5 \times 10^4$ km. There are about 5 000 of them on the whole Sun. There is a similarity between these cells and the bright chromospheric network seen on Ca II spectroheliograms. Their properties suggest that they constitute a "super granulation" system of convection currents originating at considerable depths within the Sun. Several kinds of observations of the small-scale velocity field strongly suggest that three essential factors are observed which are involved in the transport of energy from the photosphere to the chromosphere: (1) A strong correlation between brightness and velocity is observed in the lower levels of the photosphere, with bright elements moving upward. The corresponding mechanical energy transport amounts to about 1 watt/cm^2. The correlation passes through zero within the wings of the Na D_1 line and is reversed at higher levels. (2) The small-scale vertical velocities are not at all random but are strongly oscillatory in their time behavior with a period of 296 ± 3 sec. The energy contained in the oscillation is about 160 joules/cm^2 and the oscillation decays with a time constant of about 400 sec. (3) There is a corresponding oscillation in the brightness elements of the lower chromosphere.

Discussion

Answering L. Goldberg's question, Dr Leighton said that according to his observations the ratio of the horizontal to vertical components is of the order of 0·4, whereas Dr Michard finds that both components are of the same order of magnitude. This is a question of level in the solar atmosphere to which the observations refer. M. Schwarzschild emphasized the great importance of Dr Leighton's observations which suggest oscillatory motions in the solar atmosphere, and J. C. Pecker reminded the audience of the fact that such oscillatory motions had been predicted theoretically already over ten years ago by L. Biermann and by E. Schatzman.

Paper 4—J. W. Evans and R. Michard

R. Michard then described a detailed study by J. W. Evans and himself of two time-sequences of high-dispersion solar spectra taken at 40 seconds intervals. A motion picture of these spectra secured with careful guiding during periods of good image quality at the Sacramento Peak Observatory formed the basis of their investigation of local oscillatory motions in the Sun's atmosphere. The detailed study of the lines Mg b_2, Ti I λ5173·75, and Fe I λ5171·61 lead to the following preliminary results. The details of Doppler shifts are accurately reproduced in all lines, except for some systematic differences in amplitude. Oscillatory and roughly sinusoidal motion constitutes most of the sight-line velocity field at the center of the solar disk. In curves of velocity against time for a given point, sinusoidal elements persisting during one to two periods are frequently found. Strong "wave" motion occupies roughly 1/3 of the time for any point and also 1/3 of the solar surface at any time. In between are spaces and times with small, more or less erratic, velocities. The mean value of the periods of oscillation is found to be 260 ± 30 sec for the Ti line and 236 ± 30 sec for the Mg line, and the difference between the two lines is expected to be real. The mean value of the amplitudes of the waves is 0·80 km/sec for the Mg line and about half this value for the faint Ti line. This is in good agreement with the ratio of the r.m.s. velocities for the two lines at the center of the disk. The Fe line shows intermediate values between the Mg and the Ti line. The dimensions of wave fronts range from 1000 to 5000 km. The velocity curve of the Mg line lags behind the faint Ti line by about 10 to 12 seconds, indicating that the wave is progressing upwards. No relation between period and amplitude of the waves and no evidence of strong damping was

found. The observations can be interpreted in terms of longitudinal pressure waves propagating in the solar atmosphere, generally upwards, with more or less the theoretically expected change of phase and amplitude with height. There seems to be evidence that each bright granule before fading produces a wave motion which begins with a violet shift. The mean lag between peak granule brightness and violet shift maximum is 40 sec. The center-to-limb observations of time-sequence spectra indicate a sharp limb decrease of observable wave motions. This decrease, however, is influenced by different factors and does not necessarily mean a strong predominance of vertical wave propagation. The elements near the limb show no oscillatory character and the life-times of the most pronounced shifts exceed the 10 minutes duration of the sequence. The horizontal velocity component appears to be independent of depth. The authors also pointed out the importance of the image resolution for observing the wave motions which will be blurred by inadequate resolution.

C. PHOTOSPHERIC MODELS

Paper 1—K. H. Böhm

The observational papers on solar granulation were followed by K. H. Böhm's theoretical paper on photospheric models including the effects of granulation. The first type of studies he considered are those which infer the observed granulation data upon the physical properties of the photosphere. He critically discussed the observational data of the continuum and the line spectra and he pointed out the difficulties involved in the interpretation of the various observations. He then examined the two lines of thought in the theory of granulation: (*a*) the overshooting of convective motions from the hydrogen convection zone into the upper stable part of the photosphere, and (*b*) the assembly of acoustic and probably gravity waves which have been generated by the turbulent motions in the hydrogen convection zone. The second type of studies examines the hydrodynamics of the solar hydrogen convection zone and the waves generated by non-stationary convection. Dr Böhm critically discussed the well-known mixing-length theory and the more recent methods suggested by Malkus and by Schwarzschild, Ledoux and Spiegel which both make use of a Fourier analysis of the turbulent velocity field. He then reported on a program in progress under his direction at Berkeley using the IBM 704 in which the Fourier analysis method is extended to the more complicated case of the solar hydrogen convection zone. The calculations take into account simultaneously the facts that in the solar hydrogen convection zone (1) the density, temperature, radiative conductivity and excess temperature gradient vary by several orders of magnitude, and (2) the overshooting into the stable photosphere is possible. The preliminary results show that the most unstable eddies are no longer those with a scale comparable to the thickness of the whole zone as is the case in an almost homogeneous atmosphere. Neglecting viscosity and radiative conduction he finds that the most unstable modes are those with an infinitely small horizontal scale and which are confined to an infinitely thin layer at the top of the convection zone. When the radiative conductivity is taken into account, the scale of most of the unstable modes becomes finite, because the temperature fluctuations are smoothed out by radiative conduction in the smallest eddies. Simplified calculations gave 300 to 400 km for the scale of the most unstable modes. This indicates that the observed size of the granules may be partly already understood as being the size of the fastest growing eddies. The overshooting turns out to be larger for larger eddies than for smaller ones. Furthermore, he finds that the motions become essentially horizontal above $\tau = 0{\cdot}5$ which is in agreement with the observations.

D. FRAUNHOFER LINE PROFILES

Paper 1—J. E. Blamont

The last paper on the agenda was a brief report by J. E. Blamont on a new method of measuring profiles of Fraunhofer lines. The magnetic scanning method which he had previously

employed to measure the sodium day-glow was applied to study the profile of the strontium resonance line at $\lambda 4607$ Å. An atomic beam of Sr is illuminated by sunlight between the poles of an electromagnet which displaces the position of the resonance line due to the Zeeman effect. The resonance line of the beam is observed parallel to the field by a photomultiplier and a circular analyzer. The profile of the line was observed several times with a resolution of the order of 10^{-3} Å and a signal-to-noise ratio of the order of 15. The stability of the beam permits observations to be carried out during several hours. Preliminary results indicate a redshift at the center of the solar disk which corresponds to the predicted value of the relativistic redshift.

DISCUSSION

J.-C. Pecker called attention to the fact that most determinations of velocity distributions refer to higher photospheric levels than the measurements of intensity fluctuations which are made in the continuum spectrum. Fraunhofer lines which originate in deep layers, such as for instance the infra-red oxygen lines, should be used to determine the velocity distribution of those layers in which the intensity fluctuations can be studied. Referring to Dr Böhm's paper, Dr Pecker mentioned that for a three-stream model one needs to know essentially two parameters aside from a mean model derived from continuum observations. These two parameters are the $\Delta T = T_{\text{hot}} - T_{\text{intermed}}$ and the horizontal scale h which fixes the dimensions of the hot, cold, and intermediate columns. The observations of the granulation yield the approximate values $\Delta T \sim 100°$ and $h \sim 700$ km. However, the center-to-limb observations of spectral lines made by Lefèvre and Pecker lead to $h \sim 300$ km for $\Delta T \sim 500°$ (Böhm's model). If one takes smaller values of ΔT even smaller values of h are found. This contradiction may be reconciled if one considers differences in excitation temperature for the granules and the inter-granules, *i.e.*, if one makes a distinction between the $(T_{\text{exc}} - T_e)$ of the granules and of the inter-granular regions. The effects could be calculated by methods similar to those developed by R. N. Thomas and his colleagues at Boulder and at Paris.

J. Rösch commented that they hope to increase their definition (at most by a factor of 2) in order to obtain more accurate measurements of the r.m.s. intensity fluctuations. He pointed out that his method of determining the ΔT from granulation pictures refers to some kind of a three-stream model in which, indeed, he finds the horizontal dimensions of the columns in good agreement with those suggested by Dr Pecker.

R. Michard opposed Dr Pecker's comment on the difference in excitation temperature in the line and in the continuum which may influence the ΔT. Instead Dr Michard stressed the evidence for oscillatory fluctuations in brightness at the line center which are much more important.

K. H. Böhm said that one should allow for pressure fluctuations but they may not influence the line profiles appreciably. A brief discussion followed between R. Lüst and K. H. Böhm on the relative proportion of energy going into longer and shorter acoustic waves.

R. G. Athay suggested that if the observed Doppler shifts in the Fraunhofer lines are due to progressive waves, then two effects should stand out in the data: (1) the maximum Doppler velocity should show a phase lag from faint to strong lines that is of the order of a minute or so; and (2) the strong lines with saturated Doppler cores should show a Doppler shift that moves progressively from the wings of the lines to the centers, again with a time scale of the order of minutes.

Some final comments on the granulation problem were delivered by M. Schwarzschild. He stressed the importance of accurate measurements of the r.m.s. intensity fluctuations, such as Dr Rösch is planning. However, he considered Dr Böhm's theoretical calculations to be the most effective attack to the problem of the physical properties in the photosphere. Dr Schwarzschild then suggested to stick to the formal separation of the two types of modes, the

convective and the wave modes. The intensity fluctuations observed in the granulation seem to be almost entirely due to the convective mode. On the other hand, the velocity distributions indicate that they are due in part by wave modes. The papers by Leighton and by Evans and Michard show the outstanding feature that the wave mode has a preferred period. Dr Schwarzschild suggested the model of a "leaky standing mode" which may be described as bumps by convection modes which leak upwards. He also mentioned that chromospheric pulsations may very well exist. Dr Michard agreed with Dr Schwarzschild on the existence of two types of modes which are revealed in the velocity distribution: the horizontal component does not seem to vary from center to limb, and the vertical component shows oscillatory motions.

Fourth meeting, 23 August 1961

CHAIRMAN: R. Giovanelli.

In this session an international co-operative program was discussed for observing chromospheric granulation. The chairman of the session was Dr R. Giovanelli who pointed out the necessity for such a co-operative effort in order to study the large-scale chromospheric structures observed in Hα which last for periods of 12 to 24 hours. The requirements for such a program are:

(*a*) Good weather during a period of a couple of weeks, and good seeing conditions.

(*b*) A monochromator or filter with a narrow passband, preferably of 0·2 Å width.

(*c*) Willingness to take a minimum of two Hα pictures per day during a pre-selected period of a couple of weeks.

Dr Giovanelli stressed the importance of a narrow passband which is necessary for separating the different structures observed in different regions of the Hα line. The Hα fine structure is very much the same in the range between −0·2 and +0·2 Å from the Hα line center. The appearance of Hα pictures taken between about −0·5 and −0·4 or +0·4 and +0·5 Å from the line center is quite different; long chains of very small fine dark dots appear between brighter regions. Further away from the line center, between about ±1·0 and ±0·7 Å the structures become much simpler.

Members of the Commission who are willing to join in this co-operative program were asked to specify their Hα images, to quote the period of best weather conditions at their location, and to suggest other observatories which perhaps may join in the program. Thus the following preliminary list was made:

Observatory	Observer	Specifications	Period of Good Weather
Sydney	Giovanelli	0·2Å passband	Sept.—June
Arcetri	Righini	full disk, 66 mm image	May—Sept.
Capri	Kiepenheuer	0·5Å passband small part of disk	Oct.—March
Lockhead	Moreton	small part of disk	Jan.—Dec.
Pulkovo	Gnevyshev	spectroheliograph 5 cm image	—
Crimea	—	spectroheliograph 10 cm image	May—Sept.
Tokyo (?)	—	0·5Å passband	poor seeing
Sacramento Peak (?)	—	full disk	Sept.—Nov.
Mt. Wilson (??)	—	—	May—Sept. early morning
Meudon (??)	—	80 mm image	?
McMath-Hulbert (??)	—	—	?

It was concluded that the best months for the program were May, June and September. K. O. Kiepenheuer pointed out the difficulties involved in the analysis of the observations taken with different instruments.

A Working Committee of three members was formed:

R. Giovanelli, chairman; K. O. Kiepenheuer; A. B. Severny,

and it was decided that this committee would write a letter to all interested observatories concerning the co-operative program and including samples of pictures showing the essential features that one wishes to study.

12*a*. SOUS-COMMISSION DES ECLIPSES DU SOLEIL

Report of Meetings

PRESIDENT: R. O. Redman.

SECRETARY: J. Houtgast.

First meeting, 17 August 1961

DRAFT REPORT

In opening a brief discussion on the *Draft Report*, the President apologised for a number of omissions, which would be rectified. The Report was then adopted without further correction.

COMMUNICATIONS

Athay called attention to chromospheric observations that we still need. The chief shortcomings are in the ultra-violet and infra-red. We need measurements over a greater range of height, both for lines and continuous spectrum, including the Balmer continuum; line profiles of increased accuracy; studies of the relative behaviour of certain lines of He I, Ca I, Mg I, etc. He would like to see more study of central intensities, starting in the Fraunhofer spectrum of the disk and extending through the transition to the chromosphere, and also of coronal intensities down to heights as low as possible. He stressed the importance of more knowledge of variations of the chromosphere through the solar cycle. He showed some of the results obtained from the H.A.O. eclipse observations.

Houtgast reported observations made by Dutch observers during the eclipses of 1959 October 2 and 1961 February 15. These include photo-electric measurements of the darkening at the limb by T. de Groot and photographic observations by Koelbloed of the higher Balmer lines, the wings of H and K of Ca II, and of the transition from photosphere to chromosphere in some parts of the spectrum. Hα and Hβ were obtained in different phases of the 1961 eclipse, with high resolution (0·8 Å/mm).

Houtgast would like more measures of Hα and K in the high chromosphere, say between 10 000 and 15 000 km, because the observations of 1954 indicate an increase of the logarithmic gradient above 10 000 km for the K line and a comparison with Hα should lead to interesting conclusions about the state of the chromosphere at that height.

As to the low chromosphere, he emphasised the need for high time-resolution and for that reason intended at the next opportunity to use the moving film technique.

Suemoto said that he has a great deal of material still in course of measurement, from the 1958 eclipse, where he had photographed the chromospheric spectrum with a slitless spectrograph, using a large grating at high incidence. The observations show many details in the

chromospheric arcs of the stronger emission lines. He is concentrating at present on the height distribution and has found that the irregularities associated with spicules become conspicuous above 1 500 km.

Jefferies emphasized the importance of measurements of the He I line at 10 830 Å.

Waldmeier showed photographs of the intermediate-type corona of 1961 February 15. The more pronounced long streamers were in the northern hemisphere, whereas near the south pole there were diffuse patches and polar rays. At the time of the eclipse there were many polar faculae in the north, but none in the region of the south pole. Most of the northern polar rays and the northern polar faculae appeared west of the Sun's axis. An intimate connection between polar coronal streamers and polar faculae was suggested.

Laffineur reported on photography of the corona of 1961 February 15, using light around 6300 Å. A rotating diaphragm in the focal plane was used, cut so that the coronal surface brightness in the photograph would on the average be constant out to a radius $2{\cdot}5\ R_\odot$. The pictures show interesting structure, including a dark elliptical envelope around a large prominence, long polar rays and dark radial lanes in the corona.

Zirker showed a number of photographs of spicular structure in emission lines of the chromosphere. The photographs were taken at the Sacramento Peak Observatory outside eclipse.

Second meeting, 21 August 1961

The President gave a summary of existing questions and problems, with suggestions for needed observations, and then invited discussion.

Pecker recommended search for a discontinuity in the chromospheric continuous spectrum, near 4800 Å, similar to that found in the spectra of F-type stars. He also stressed the need for more measurements of prominence spectra.

Jefferies said that much information about prominence spectra could be obtained outside eclipses but that eclipse observations are needed of weak He I and He II lines. Observations of the ratio of triplet to singlet lines in He I, and their relative gradients with height in the chromosphere, would be very desirable. The importance of He I lines lies in their sensitivity to temperature variations.

Zirin confirmed the need for He II line strengths in prominences.

Thomas wanted height gradients in both the Balmer and the Paschen continuum. He thought that there is a sharp rise in temperature at about 1 000 km and also a change in chromospheric structure. Below 1 000 km the continuous radiation near 4 700 Å is probably mostly from H^- and there is hydrostatic equilibrium in a rather homogeneous chromosphere. Above 1 000 km the continuum is caused mostly by electron scattering. To verify this model, observers should concentrate upon all emissions from levels between 750 and 2 000 km, and aim at a height resolution of 20 km.

Suemoto has investigated the height distribution of the excitation temperature and of the ionization temperature up to 1 500 km. He finds a minimum temperature at 100-200 km. From the central intensities of medium strength lines he finds $T_{exc} = 4000°$ at $h = 0$.

Zirker wanted profiles of chromospheric lines for which $\log E(h) < 13{\cdot}00$, at $h > 2500$ km. There is an inconsistency between the temperatures determined from profiles (50 000°) and from total intensities (15 000° – 20 000°).

Newkirk called for measurements of the magnitude and orientation of the polarization in coronal emission lines, in order to determine the magnetic field in the corona.

Zirin asked for a determination of the distribution with height of the intensities of coronal emission lines; he wished to know the height at which collisional broadening changes to radiative broadening.

Rösch reported photography of the Sun at the Pic du Midi Observatory during the partial phases of the eclipse of 1961 February 15. He showed how the 'instrumental' profile at the limb, caused chiefly by scintillation arising in the Earth's atmosphere, depends on the position angle.

Wlérick summarized observations made at the St Michel Observatory during the total solar eclipse of 1961 February 15. They comprise: with the 60 cm telescope, gradient of the continuum; 80 cm telescope, polarization of the green coronal line; 120 cm telescope, photographs of the corona and of prominences in the red; 193 cm telescope, coronal spectrum in the red and infra-red; Schmidt telescope, photographs of the corona in the infra-red. The two spectra taken with the 193 cm telescope cover the region 5800–8800 Å, and will permit photometry of the continuum and of the emission lines. The line at 6535 Å, attributed to Mn XIII, is confirmed. A weak line at 6917 Å may possibly be due to A XI.

Righini made 3 cm radio observations at Arcetri during the same eclipse, in both linear and circularly polarized radiation, using a 2 m paraboloid. In the partial phases there was an excess of linear polarization; near the middle of totality there was more circular polarization.

14. COMMISSION DES ETALONS DE LONGUEUR D'ONDE ET DES TABLES DES SPECTRES

Report of Meetings, 16 and 19 August, 1961

PRESIDENT: G. Herzberg.
SECRETARY: J. G. Phillips.

Business meeting

Silent tribute was paid to the memory of two members lost by death since the 1958 meeting, F. A. Jenkins and A. McKellar.

The *Draft Report* was discussed in detail. No extensive changes were required.

The President described the reorganization of the Commission, in accordance with the new statutes of the IAU. In the future it would consist of, (*a*) a President, a Vice-President, and five members of an organizing committee, and (*b*) members of the Commission. It was resolved to propose to the Executive Committee the following new name for Commission 14: 'Commission des Données Spectroscopiques Fondamentales' (Commission on Fundamental Spectroscopic Data). It was further resolved to establish a Committee on 'Transition Probabilities and Cross Sections', with M. G. J. Minnaert as Chairman, to replace the former Sub-Commission 14*a*. No Committee was set up to replace the former Sub-Commission 14*b* for the present. Finally, a Committee on "Standards of Wave-lengths" was formed with B. Edlén as Chairman.

Relations with the Triple Commission for Spectroscopy were discussed. Dr Herzberg reviewed briefly the history of the Triple Commission. Mrs Sitterly commented that some organization was needed to avoid duplication of effort. It was generally agreed that the Triple Commission had an important function in ensuring that the desires and needs of all groups would be met before some decision was finalized.

Considerable discussion ensued from the proposal of Terrien (by letter) to re-define the angström unit in line with the new definition of the metre or to abolish it altogether since it will now be identical with 10^{-10} m. Almost all present favoured retention of the Å unit as a short-hand name for 10^{-10} m. No significant change is introduced by this re-definition. A resolution for this purpose was submitted to and accepted by the General Assembly (see Part 2).

Scientific meeting

The main part of the meetings was devoted to the presentation of a number of reports on some of the questions raised in the *Draft Report*. Only those portions of these reports which go beyond the *Draft Report* are included here.

REPORT ON THE PRIMARY STANDARD

K. M. Baird

The International Metre is now based on the $2p_{10}$-$5d_5$ radiation of Kr^{86} following ratification of a new definition by the Eleventh General Conference of Weights and Measures (see *Report*, Vol. **11A**, p. 97). Metrologists now have a standard which, because of the ideal form of its definition, is likely to be adequate for a very long time depending on the development of new techniques. A simple practical means has been recommended by the International Committee on Weights and Measures to enable the realization of the standard at present to an accuracy estimated at better than one part in 10^8, which corresponds to 5×10^{-5} Å.

The following is a discussion of the reasons for considering that the standard can now be realized to an accuracy of 1 in 10^8 and what possibility of improvement exists.

The recommended lamp, developed at the Physikalisch-Technische Bundesanstalt, uses a hot cathode discharge in a 2 to 4 mm diameter capillary immersed in nitrogen at its triple point. The characteristics of the line and the effect of conditions of operation have been very much studied and are very well known. Kosters and Engelhard established that there were two types of shift: one, a red-shift, dependent on lamp temperature (vapor pressure limited) and current density and the other a red- or blue-shift depending on the direction of observation, attributed to Doppler effect resulting from impact of exciting electrons.

The dependence of the emitted wave-length on the various factors which determine the operating conditions has been measured at several laboratories. The results have generally been expressed by equations for the difference between the emitted wave-length and the extrapolated (unperturbed) wave-length in terms of the lamp current density, the temperature of the lamp and the pressure of the Kr pressure in the lamp.

The magnitudes of these shifts reported by various authors lead to the following differences between the primary standard (unperturbed wave-length) and the line produced as recommended:

Institution, date and reference	Shift due to current and pressure	Shift due to Doppler effect	Net
PTB (1958) **(12)**	$-0{\cdot}014$ m^{-1}	$+0{\cdot}020$ m^{-1}	$+0{\cdot}006$ m^{-1}
NRC (1959) **(1)**	$-0{\cdot}012$	$+0{\cdot}013$	$+0{\cdot}001$
PTB (1959) **(7)**	$-0{\cdot}023$	$+0{\cdot}020$	$-0{\cdot}003$
PTB–BIPM (1960) **(8)**	$-0{\cdot}020$	$+0{\cdot}019$	$-0{\cdot}001$
NSL (1960) **(4)**	$-0{\cdot}015$	$+0{\cdot}014$	$-0{\cdot}001$
NRC (1960) **(2)**	$-0{\cdot}007$	$+0{\cdot}014$	$+0{\cdot}007$
NPL (1961) **(19)**	$-0{\cdot}023$	$+0{\cdot}016$	$-0{\cdot}007$
NRC (1961) (3mm capillary)	$-0{\cdot}011$	$+0{\cdot}013$	$+0{\cdot}002$

These results indicate a reproducibility well within $1:10^8$ or $0{\cdot}016$ m^{-1} if standard operating conditions are reasonably adhered to. However, one is inclined to doubt the value of the equations reported for the wave-length shifts, at least in-so-far as the practical realization of the standard is concerned, because they are likely to be misleading as to accuracy when used outside the intended range. Some work at NRC strengthens this impression and enables one to draw the following conclusions:

(1) The fact that a pressure dependent shift is obtained for zero current density, j, shows that the equations cannot be entirely correct since they give $\Delta\nu = 0$ for $j = 0$ independent of the pressure, p.

(2) The observation that the capillary diameter affects the shift as a function of j indicates that j is not a sufficiently descriptive parameter for an accuracy of $1:10^9$.

(3) The Doppler shift at a given temperature depends on the capillary diameter. In addition, in a D.C. lamp there is a pressure difference between the ends of the capillary dependent on the length of capillary.

(4) An asymmetry of the line probably exists but its measurement is extremely difficult. In view of this asymmetry one should specify the part of profile used.

In view of these results conditions must be specified more closely in order to achieve an accuracy of perhaps 2 or $3:10^9$, and it would appear ill-advised to use simple equations to represent corrections to the primary standard.

It has been found that different lamps cannot be compared to better than about one part in 10^8 because of geometrical effects. On the other hand, the standard is adequate today. An

accuracy of 1 in 10^{10} may be possible in the future with sufficiently detailed specifications. A detailed report of the recent work at NRC is being published in the *Journal of the Optical Society of America.*

In a discussion following Baird's report, Kessler questioned the desirability of tying the new standard to a particular "cook-book" tube as source. New sources, such as the optical masers and atomic beams, might be developed that may be future improvements over the adopted source. In reply, Baird defended the present source and pointed out that the new standard was not to be tied to any particular source, but that if a particular source were properly specified its relation to the ideal standard could be known to the accuracies referred to; he maintained that the accuracy claimed ($1:10^8$) was very conservative. He agreed that development of improved sources should be attempted but the accuracy at present attained meets current needs.

The question of the intensity of the Kr lamp was raised, since it is weak compared with the Hg^{198} source. Baird pointed out that the mercury source is made bright at the expense of line sharpness, and that the intensities are comparable when optimum line sharpness is sought.

REPORT ON CLASS A SECONDARY STANDARDS

K. G. Kessler, W. G. Schweitzer, Victor Kaufman and R. L. Barger

In this report three studies conducted at NBS on Hg^{198} wave-lengths were described. In the first study the wave-lengths of the 2537 Å and 3132·7 Å lines emitted by an atomic beam of Hg^{198} have been measured relative to the 6057 Å line of Kr^{86}. A full description of this work has been published (**3**). The results are quoted in the *Report*, Vol. **11A**, p. 99. Standard deviations of the final results, determined from the scatter of the measurements, ranged from 0·00003 to 0·00004 Å. The systematic errors are probably about equally large. In the second study the wave-length of the 2537 Å radiation passed by a Zeeman filter was measured relative to the 6057 Å line of Kr^{86} (**10**). The Zeeman filter cell was a 25 mm quartz cell containing Hg^{198} vapor. The cell was operated at a temperature of 80°C in a field of 900 gauss. The light source was a similar cell 1mm thick containing Hg^{198} vapor, illuminated by two Hg^{198} electrodeless discharge tubes. The radiation passed through the filter was the resonance radiation from this cell. The reference line was the 6057 Å line of Kr^{86} from a standard lamp. The light from the Kr^{86} and Hg^{198} sources was combined into a common image by imaging the Kr^{86} lamp inside the fluorescent cell. The width at half height of the 2537 Å line was 0·005 cm^{-1}, approximately. The wave-length in vacuum of this radiation relative to the 6057 Å line was found to be 2537·26875 ± 0·00003 Å.

In the third study the wave-lengths of 27 lines in the spectrum of Hg^{198} were measured relative to the Kr^{86} line at 6057 Å (from a standard lamp). These measurements were made with Hg^{198} electrodeless discharge tubes containing argon gas at pressures of $\frac{1}{4}$ and 3 mm Hg. The Hg discharge tubes were of two types. The tube containing argon at a pressure of 3 mm Hg was 10 cm long and made from 5 mm I.D. fused quartz. The tube containing argon at a pressure of $\frac{1}{4}$ mm Hg was similar with an additional gas reservoir of 26 cc at one end to minimize gas loss due to clean-up. Both tubes contained 1 mg of 99·7% pure Hg^{198}. These tubes were operated inside a quartz water jacket through which water at 6 – 9 °C was circulated. Excitation was with 2450 Mc radiation through a diathermy unit. The interferometer used was a vacuum interferometer maintained at a pressure below 5μ Hg. The diameter of the aluminum-coated plates was 100 mm, and spacers of 21·5, 52·0 and 110·4 mm length were used. The auxiliary dispersing instrument was a 1·5 m Gaertner prism spectrograph. The region from 2537 Å to 6057 Å was covered on one 14-inch plate. A beam-splitting mirror was used to combine the radiation from the Hg^{198} and Kr^{86} sources so that each passed through

the same optics. Exposures were simultaneous. An analysis of the data shows that for a series of exposures of the same line with the same spacer, the standard deviations range from 0·00005 to 0·00010Å. A study of exposures taken with different spacers shows, however, that there are systematic errors present of the order of 0·00008. A few of these errors can be identified in terms of weaker interfering lines. The Hg^{198} line at 5792Å shows evidence of interference from the weaker line at 5790Å. The wave-length of the Kr^{86} line at 6013Å shows an erratic behavior as a function of spacer length. This line has been doubly classified, both as $2p_{10}-5d_3$ and as $2p_6-5s_5$. A close scrutiny of some of the stronger exposures revealed a weak secondary component for this line. The data given in Table 11 have been corrected for the dispersion of phase change.

Table 11. Preliminary Values of Hg^{198} Wave-lengths Relative to Kr^{86} 6057·8021Å in vacuum

	spacer and pressure				spacer and pressure		
λ_{vac}Å	21·5 mm 3 mm Hg	110·5 mm 3 mm Hg	110·5 mm 1/4 mm Hg	λ_{vac}Å	21·5 mm 3 mm Hg	110·5 mm 3 mm Hg	110·5 mm 1/4 mm Hg
2537	·26886		·26877*	3028	·37144		·37120
2577	·06221			3126	·57625	·57626	·57613
2652	·83260	·83261	·83243	3342	·44228	·44236	·44221
2654	·47294		·47280	3651	·19681	·19680	·19666
2655	·92081		·92071	3655	·88066	·88067	·88061
2753	·59694		·59686	3664	·32428	·32438	·32431
2804	·29662			4047	·71469	·71468	·71455
2857	·77651			4078	·98940	·98940	·98928
2894	·44660	·44658	·44648	4340			·44460
2926	·26978		·26953	4348			·71800
2968	·15000	·14999	·14988	4359	·56249	·56247	·56225
3022	·37987	·37985	·37969	5462	·27066	·27068	·27046
3024	·35708		·35687	5771	·19836	·19839	·19829
				5792	·26854		·26834

* This value was derived from measurements using an interferometer spacer length of 52 mm.

In the discussion of Kessler's report, Baird cautioned against regarding the atomic beam as having the improvement in precision *vis-à-vis* the Kr^{86} standard claimed by Kessler: it is not necessarily true that one gets better precision of measurement with a sharper line; also, one must not forget the many systematic effects which may be coming in, such as, for example, the asymmetry of the Fabry-Perot fringe systems. Kessler in turn cautioned against the possible asymmetry of broad lines. Littlefield commented that the work of Kessler was valuable since more short wave-length standards are needed. In reply, Kessler expressed the hope that NBS would go to the vacuum ultra-violet. Herzberg reported that NPL plans to go to 500Å. Baird asked about the cost of these sources to the average laboratory. Kessler estimated that the emission beam would probably prove to be too expensive, but he felt that the Zeeman absorption filter would be well within the financial resources of the average laboratory.

REPORT ON Th, Fe AND Cu II STANDARDS

T. A. Littlefield

Edlén (**6**) has distinguished two types of secondary standards, Class A and Class B. Class A needs to be known to better than 0·0001Å while Class B need only be known to 0·001Å. In the present report the wave-length range has been extended into the infra-red and the vacuum ultra-violet. In these wave-length regions it is doubtful if these criteria are still valid. It is perhaps unfortunate that we tend to think in terms of wave-lengths when in fact wave-numbers

are required for the analysis and interpretation of spectra. It would seem to be advantageous to define the two classes of standards in terms of wave-number rather than wave-length.

If at 4000 Å the accuracy is 0·0001 Å, the wave-number accuracy is 0·0006 cm^{-1}. It might therefore be desirable to adopt 0·001 cm^{-1} for Class A standards and 0·01 cm^{-1} for Class B standards. This implies that the wave-length precision required at various wave-lengths will vary over quite wide limits as shown in the table. It will be observed that the

λ (Å)	$\Delta\lambda$ corresponding to $\Delta\nu = 0{\cdot}001$ cm^{-1}
20000	0·004
10000	0·001
5000	0·00025
2000	0·00004
1000	0·00001

wave-length precision required in the VUV is very high indeed, ten times better than anything available at present.

On this criterion the VUV standards at present available can be regarded only as Class B. In the infra-red, however, the agreement is such that a number of lines of Ar, Kr^{86} and Hg^{198} might already be regarded as Class A standards. In principle this precision should be possible with an interferometer of the echelle or reflecting echelon type, but instrumental errors will prevent this from being fully realized at shorter wave-lengths.

Iron seems likely to be superseded by thorium for the very good reasons already stated in the *Report*. No further work on the iron spectrum is therefore desirable as the effort would seem to be more profitably directed to an extension and refinement of the thorium measurements. Two sets of thorium measurements in the region 7000–2650 Å (see *Report*) are available and those which differ by 0·0005 Å or less might well be regarded as provisional standards. The measurements above 7000 Å should be regarded as preliminary at this stage, as only one set of interferometric values is available. The excellent work of Zalubas (**22**) in providing grating measurements has greatly facilitated the work with the interferometers. It is interesting to note that while one group of authors (M.S., D.S.G.) used a high-frequency discharge through thorium halide, the other (L.W.) used a sealed-off Schüler tube cooled with liquid nitrogen. Both sources are very easy and convenient to use.

The thorium spectrum is rich and many hundreds of strong lines have yet to be measured. An automatic measuring machine is being constructed in Newcastle to handle the situation. The fringes will be scanned photo-electrically and the output digitized so that a Ferranti Pegasus computer can be used to measure the fringes and calculate the wave-lengths. The need is for further independent measurements above 7000 Å, while in the range 7000–2700 Å more wave-lengths are required and possibly some refinement of those already reported will be needed.

No comparable wave-lengths seem to be available in the 2700–2000 Å region. The germanium wave-length measurements by Van Veld and Meissner (**21**) seem to offer the best possibilities for this region, but others should be considered.

Two sets of copper spark wave-lengths (R.M.A. and L.W.) have been calculated from independent measurements in the infra-red and ultra-violet. Agreement seems to be limited to the third decimal place. In Newcastle it was found that the precision was only about one-twentieth of what can normally be achieved. This is attributed to hyperfine structure (resolved and unresolved), and to the temperature width of the lines, which limits the precision to 0·02 – 0·03 cm^{-1}. These are, therefore, little better than good grating values. Much the

same conclusion was reached by MacAdam in 1936 when he measured the same spectrum directly in the VUV by using a reflecting echelon. It seems likely that the precision of this earlier work was limited more by the spectrum than by the optical equipment. For this reason a further attempt is being made to measure VUV wave-lengths directly by using more favorable sources such as germanium and argon.

In the discussion, Edlén pointed out that the discrepancies between the two sets of calculated Cu II wave-lengths is probably due to the uncertainty in the position of a single level.

[Reader and Andrew have subsequently commented that the major discrepancies are due to lines arising from the $3d^9\ 4s\ ^3D_3$ level. The determination of this level by L.W. was based on the single transition at 2247Å, which was observed by L.W. and R.M.A. to be a double line. Since R.M.A. used four lines other than 2247Å to get this relative level value, their calculated wave-lengths should be regarded as the more reliable. Littlefield is in agreement with this conclusion (private correspondence). Reader and Andrew still consider the dense Cu II spectrum to be useful for vacuum region standards. They attribute in large measure the greater consistency obtained at Purdue over that at Newcastle to the different operating conditions of the two sources and to the fact that with Fabry-Perot interferometers they were able to examine the lines with several different resolving powers in contrast to the fixed resolution of the reflecting echelon.]

Kessler reported that work is going on at NBS on germanium, extending into the vacuum ultra-violet region. Edlén supported the use of $\Delta\nu$ as a criterion of accuracy. He agreed that direct measurements in the vacuum ultra-violet will be very difficult to the desired accuracy, but that as soon as measurements are available in the visible and infra-red, one can calculate the vacuum wave-numbers by the combination principle. Probably most of the difficulty is due to hyperfine structure. Davis asked Littlefield if he planned to supplement his hollow cathode work on Th with an electrodeless discharge. In reply, Littlefield said that he did not plan to do so, since he favored the hollow cathode source of the thorium spectrum.

REPORT ON INFRA-RED STANDARDS

(*a*) *Atomic Standards—C. J. Humphreys*

Although the International Astronomical Union, and its organizational predecessor, the International Union for Co-operation in Solar Research have had a combined span of existence of more than half a century, during which period the evaluation and adoption of spectroscopic standards of wave-length have been a major function, it was not until the meeting of 1958 that any wave-lengths in the infra-red region beyond the photographic limit were considered. This statement is not intended as a criticism, but merely to highlight the complete lack of experimental material to be considered.

The material to be introduced into this discussion of atomic emission lines in the infra-red region as wave-length standards is divided into three sections. In the first section, available interferometric measurements of lines essentially confined to the 1 to 2 micron region are reviewed; in the second, various possibilities for Ritz standards, comprising calculated transitions based on energy-levels derived from interferometric measurements, and illustrated by Ne I and Ar I, are presented; in the third, a preview is given of some very recent experiments that indicate the feasibility not only of direct scanning, but also of interferometric intercomparisons in the 2 to 4 micron region.

Of the available interferometric measurements, those on the argon spectrum are the most extensive and probably the most reliable. New measurements by the author are compared with independent ones of Rowley and Peck in Table 6 of the *Report*. The agreement is considered good except for three lines: 12806, 13626, and 13316Å. Measurements on all of

these have been repeated since publication and we have found no indication of a change of our reported values by as much as 1 part in 10 000 000.

The level values as provisionally adopted in 1958 are intercompared in Table 12 with new determinations based on the three available independent sets of wave-lengths credited to the various authors. The agreement in general is considered satisfactory. The largest disagreement is in the determination of the $3d_1''$ level which involves two of the lines previously noted as not having fully concordant values, namely 12806 and 13626Å (vac).

Table 12. Argon levels (in cm^{-1}) relative to $1s_5 = 0{\cdot}000$ based on interferometric measurements

Designation	Humphreys and Paul, 1958 as adopted by IAU	Humphreys and Paul, 1959	Littlefield and Rowley 1960	Peck 1960
$2s_5$	20324·715	·713	·7129	·7125
$2s_4$	20499·501	·500		
$2s_3$	21717·879			
$2s_2$	21831·261	·259	·2595	
$3d_6$	18524·007	·006		
$3d_5$	18674·269	·268	·2676	·2686
$3d_3$	18995·166	·164	·1635	·1651
$3d_4'$	19606·394	·394	·3925	·3932
$3d_4$	19876·596	·595	·5952	·595
$3d_1''$	20282·206	·205	·1995	·2033
$3d_1'$	20572·796	·795	·7938	
$3d_2$	21003·973	·972	·9737	·9721
$3s_1''''$	21497·234	·232	·2290	
$3s_1''$	21661·376	·375	·3737	
$3s_1'''$	21678·181	·179	·1787	
$3s_1'$	22223·107	·106		

A number of lines of natural cadmium (based on argon lines as standards) have been observed as shown in Table 13.

Table 13. Natural cadmium vacuum wave-lengths from interferometric measurements

10397·4736Å	14331·1772	15157·9611
13982·2897	14477·2317	

The energy levels of Ne I given in the 1960 report have been slightly modified and extended. From them a large number of very precise Ritz standards in the infra-red can be derived. These are given in Table 14.

For Ar I, in addition to the levels of Table 12, the $2p$ and $3p$ levels were chosen in accordance with the 1957 report and from them the Ritz standards given in Table 15 were obtained.

Kr I has not been examined as a source of standards to the same extent as either Ne I or Ar I. One reason for this is that natural krypton, being a mixture of six isotopes, is potentially not as good a source of standard lines as the other rare gases, since both isotope and hyperfine structure is expected, and some of the photographic infra-red lines are measurably complex. Actually for the radiometric infra-red region natural krypton is expected to provide standards of adequate precision. Preliminary values have been published (9), (11).

Table 14. Infra-red standards of Ne I based on the combination principle

λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)
7053·2366*	8794·9195*	12773·0178*	23962·995*	29722·159
7061·0538*	8833·3321*	12890·6844*	23978·394*	29812·595
7066·7067	8856·2980*	12915·5459*	23984·704*	29939·600
7439·4403*	8867·7405*	13222·8558*	24093·634*	29941·186
7474·4964*	8868·1895*	15234·8758*	24099·022	29949·095
7490·9335*	8921·9495*	17166·6169*	24105·174*	30127·216
7537·8490*	8991·0240*	18215·3025	24156·539*	30135.223
7546·1215*	9151·183*	18904·049	24162·562	30137·975
7835·1854*	9204·284*	18942·752	24168·069*	30207·91*
7841·2114*	9222·588*	18949·841	24225·604*	30208·797*
7842·1463*	9224·111*	19579·1129*	24256·255*	30267·846
7929·2983*	9229·222*	19582·4802*	24316·452	30275·929
7939·1793*	9278·065*	19777·8852	24371.696*	30371·845
7945·3663*	9300·541	20135·994	24378·287*	30603·295*
7946·3264*	9303·405*	20140·249	24390·107*	30611·557
8120·7815*	9313·139*	20144·003	24395·355	30675·42
8131·1459*	9316·529*	20355·793*	24454·571*	30720·047*
8138·6428*	9329·066*	20359·433*	24459·093	31868·669*
8250·9498*	9375·880*	20372·288	24459·847*	33182·211*
8261·6493*	9379·800*	20417·242	24466·125*	33341·824*
8268·3493*	9427·965*	20421·616	24466·388*	33361·568*
8269·3890*	9435·596*	20425·646	24471·669*	33520·467*
8302·6077*	9461·805*	20570·735	24532·484	33909·099*
8303·8414*	9489·2842*	20854·527	24783·270*	33912·273*
8368·0477*	9536·778*	20901·637	24910·590*	33922·419*
8378·6633*	9550·024*	20910·270	24935·534*	34140·752*
8379·9088*	9668·0706*	20967·033	24942·320*	34480·904*
8419·4721*	10298·2389*	21014·655	25006·658*	34499·294*
8420·7407*	10565·302*	21019·288	25071·284	34789·555*
8465·6830*	10623·5747*	21023·379	25168·598*	35517·115
8486·7747*	10801·0008*	21047·038*	25234·848*	35844·684*
8497·6939*	10847·4477*	21714·069*	25235·185*	36481·81
8547·0433*	11146·0715*	22076·370	25284·21	37182·24
8573·7071*	11180·5884*	22177·340	25400·109*	39817·239
8585·2607*	11393·5526*	22253·451*	25531·330*	42183·058
8593·6187*	11412·2580*	22434·245*	25861·968*	44335·910
8637·0188*	11525·9005*	22472·975*	26614·213	45350·302
8637·6895*	11528·1746*	22536·552*	26868·148	45368·448
8649·4162*	11539·503*	22667·997*	27443·246	46063·929
8656·7602*	11604·7125*	22694·052*	27528·284	47159·912
8657·8998*	11617·2600*	23106·817*	27581·064*	47179·536
8681·8764*	11691·201*	23266·649*	27638·403	61466·895
8684·3057*	11770·0132*	23379·377*	27826·404	
8706·5022*	11792·2704*	23571·793*	27979·542*	
8769·9437*	11793·1162*	23642·966*	28394·103*	
8774·0651*	11988·1924*	23708·166*	28539·999*	
8781·1437*	12069·6360*	23714·120*	28752·146	
8783·0323*	12462·7976*	23715·629*	29455·897*	
8784·4128*	12598·4498*	23919·370	29495·635	
8786·1654*	12692·6721*	23957·954*	29676·145	

* Observed lines; the wave-lengths given are the predicted ones.

Table 15. Infra-red standards of Ar I based on the combination principle.

λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)	λ_{vac} (Å)
8877·237*	13234·515*	17449·667*	25346·74	37186·06*
9197·162*	13276·265*	17450·012*	25494·602*	37261·656*
9294·078*	13305·949*	17919·521*	25512·189*	37921·74*
9343·144*	13316·850*	17919·618*	25668·023*	38331·36*
9488·662*	13370·765*	18236·328*	26122·899	38640·832
9954·574*	13371·482	18353·015*	26187·567	38811·29
10256·835*	13503·097*	18432·796*	26550·284*	39329·852
10480·904*	13507·882*	18637·376*	26612·554	39498·745
10676·490*	13547·908*	18750·124*	26843·036*	39804·783
10684·697*	13577·324*	19129·028*	26917·052*	39835·337
10686·330*	13603·050*	19300·183*	27152·861*	40008·658
10703·915*	13626·382*	19822·918*	27293·202	42044·101
10725·164*	13682·290*	19829·128	27363·801*	42343·260
10776·319*	13722·326*	19866·367	27418·954	42402·815
10864·051*	13829·497*	19950·515*	27760·080	42622·276
10883·921*	13911·276*	19971·181*	27791·395	43444·978
10895·344*	13996·633*	19997·688*	27793·527	43660·972
10953·725*	14097·492*	20031·141*	27984·858*	43674·073
11081·901*	14178·587*	20035·563*	28202·444*	45278·146
11251·430*	14253·089*	20074·415*	28245·954*	45512·47
11396·818*	14581·442*	20247·189	28321·769*	45535·495
11444·964*	14723·568*	20322·555*	28435·030*	45574·89
11470·684*	14743·167*	20574·429*	28505·735*	45926·608
11649·055	14837·535*	20621·855*	28538·398*	45949·400
11671·903*	14978·661*	20652·772*	28620·230*	46781·022
11690·803*	15034·621*	20721·991*	28697·871*	47151·686
11722·693*	15035·281	20762·662	28782·933*	49399·623
11899·888*	15050·614*	20816·722*	28843·089*	49529·443
12029·938*	15056·681	20990·015	29134·040*	53912·483
12115·639*	15175·884	20991·839*	29280·665*	55044·135
12143·059*	15176·837*	21041·575*	29796·791*	55606·374
12346·767*	15333·533*	21172·154	30462·070*	56039·363
12380·579*	15357·324*	21338·709*	30921·192	59348·099
12406·221*	15559·709*	21540·086*	30996·228*	61257·246
12442·724*	15739·207*	22045·578*	31333·032*	73924·58
12459·522*	15780·924*	22083·206*	32235·344*	76889·96
12491·079*	15797·471*	22118·663*	32256·30*	77331·927
12557·758*	15821·097*	22215·794	32305·909*	77453·33
12625·072*	15887·500*	22539·68	32333·872*	78393·313
12641·936*	15952·764	23139·519*	32888·638*	81736·007
12705·755*	15993·858*	23141·082	32939·617	82372·594
12736·901*	16127·060*	23191·815	33079·076*	112455·59
12749·719*	16184·443*	23475·842	33148·442*	
12806·237*	16268·513*	23851·548*	33293·448*	
12936·728*	16296·558	23973·060*	35068·106	
12960·202*	16524·381*	24019·782*	36220·99*	
13011·821*	16744·652*	24027·101	36312·640*	
13031·988*	16864·691*	24937·849	36492·381*	
13217·604*	16945·212*	25132·125*	37013·814*	
13231·722*	17406·661*	25140·144	37143·805*	

* Observed lines; the wave-lengths given are the predicted ones.

A number of newly observed lines of Xe I were presented, but the measurements are of low precision since xenon is a rather unfavourable mixture of isotopes which can never yield very sharp lines unless an isotope of even mass number becomes available.

In the discussion that followed the report by Humphreys, Kessler pointed out that it was important to give precisely the operating conditions of the lamp. For example, the mercury lines are affected by pressure effects. Littlefield asked whether natural sources of Xe and Kr were used. Humphreys replied that they were natural. Littlefield further asked whether the isotope effect was noticed in the case of neon. According to Humphreys, it was not found, though the isotope effect might be the cause of some discrepancies in the arrays. Finally, in reply to a question by Edlén on the light source, Humphreys pointed out that it was an electrodeless discharge excited by microwaves and uncooled. The temperature was kept below the ambient, but cooling by liquid nitrogen was not required. The optimum discharge was realized when the pressure was about 1 mm. A lower pressure gave noise.

(*b*) *Molecular Standards—D. H. Rank*

In ordinary photographic spectroscopy the unknown and known wave-lengths are simultaneously impressed upon a photographic plate. The unknown wave-lengths are determined by interpolation between standards and this procedure can be accomplished with very high precision. In infra-red spectroscopy, when using diffraction gratings, it is in general necessary to rotate the grating in order that the various known and unknown wave-lengths pass through the exit slit and may thus be detected. The accurate determination of wave-lengths will depend on the smoothness of the mechanical drive which rotates the grating.

The method invented by Douglas and Sharma (**5**) by which Fabry-Perot channel fringes are impressed on the record simultaneously with the recording of the unknown spectrum solves the interpolation problem in the first order of approximation. However, if the grating drive is not smooth, interpolation between interference fringes will not give accurate wave-lengths. These interpolation difficulties were overcome by causing a small region of the spectrum to scan over the exit slit by making use of the sliding wedge principle (**17**), (**20**).

The disadvantage of the "wedge" scanner is that the region covered by the scanner in the infra-red is only about 1 cm^{-1} or less for a doubly passed grating used at $i \sim 60°$. One solution of the wave-length measurement problem would be to use the wedge scanner in conjunction with the method of Douglas and Sharma (**5**). This solution is technically feasible, and on occasion we have made use of this method which of necessity becomes complicated, slow and laborious. A second solution is to make use of the "echelle" principle which we have discussed in detail in a recent publication (**13**). In this method a fairly coarse grating is used in various high orders near the blaze. The orders are separated by a fore-prism system. Comparatively few molecular lines are then sufficient as standards. For interpolation between these standards the wedge scanner is used.

Diatomic or linear polyatomic molecules possess certain unique advantages as sources of wave-length standards for infra-red spectroscopy. Almost all infra-red spectroscopy is concerned with the measurement of absorption lines. The spectra of certain diatomic and linear polyatomic molecules can be obtained in absorption thus eliminating the need for two separate light sources with the consequent diminution or complete elimination of the displacement error in the wave-length measurements. In the absence of accidental perturbations the measured lines can be fitted to formulae which are both simple and exact. The empirical constants in these formulae are derivable from the rotational and vibrational energy levels, making use of the combination principle applied to the measured band lines.

The fact that the wave-numbers of the band lines are related in such a way that they can be

accurately represented by empirical formulae allows an "averaging" process to be applied to the wave-length measurements which is not possible with wave-lengths derived from measurements of atomic spectra. Thus since it is easily possible that as many as 100 band lines may be measured, the calculated wave-numbers have a much greater relative accuracy than the original wave-number measurements.

In previous papers (**15**), (**16**) the 002-000 band of HCN at 1·53 μ and the 2–0 band of the CO molecule at 2·35 μ were measured interferometrically with a precision of about $\pm$ 0·0007 cm^{-1}. The measured lines were represented by conventional molecular formulae and the smoothed wave-number values are used as standards. They are listed in a previous publication (**18**). With the help of the "echelle" principle, by using these standards as well as several Ne and Hg lines in various orders, a number of other infra-red bands have been measured.

001-000 *band of HCN.* In the previous publication (**18**) we have given measured and calculated wave-numbers of the 001-000 band of HCN. Only 14 band lines could be measured at that time using the 400 lines per mm grating. Most of these 14 lines were measured with respect to known Ne and Hg lines making use of overlapping orders. A few lines were measured against lines of the 002–000 band lines of HCN. Making use of the echelle spectrograph we have now been able to measure 67 lines in this band, the measurement being made to $\mathfrak{J} = 41$. As a check the combination differences $\Delta_2 F''$ from the 001–000 band were compared to those from the 002–000 band and excellent agreement was obtained. Accurate molecular constants were obtained from the $\Delta_2 F''$ values and the combination sums $R(\mathfrak{J}-1) + P(\mathfrak{J})$. The wave-numbers of the band lines calculated from the final molecular constants are given in Table 16. They are considered to be somewhat more reliable than the actual measured lines not reproduced here (see (**14**)).

1-0 *Band of CO.* The previous measurements of the 1-0 band of CO have been somewhat improved. Eleven lines of this band were measured with the echelle spectrograph and PbSe detector using the lines of the 2-0 band of CO as standards. From these wave-numbers, together with the older measurements, slightly revised molecular constants have been obtained (see (**14**)) and from these constants the calculated wave-numbers given in Table 17 have been derived. In all cases, any deviations of the observed wave-numbers from the calculated ones are less than 0·002 cm^{-1}.

N_2O. The accurately measured bands of HCN and CO mentioned above give almost complete coverage of the blaze region of our "echelle" spectrograph (grating of 73·25 lines per mm and $i \sim 60°$ to 66°). However the separation of the "standard" lines is somewhat greater than is desirable in several parts of the blaze. This requires the use of intermediate wave-length markers in order to measure about 30% of the wave-lengths obtainable in the blaze region. It would be desirable to have standard lines considerably more closely spaced so that one could always measure the wave-length of an unknown line directly by means of the wedge scanner. The infra-red bands of the linear molecule N_2O seem to be ideal for this purpose.

We have measured the 201-000, 301-000, 121-000, 200-000, and 120-000 bands of N_2O. There is an advantage in using a large number of bands of the same molecule as wave-length standards since the occurrence of a common lower state provides a valuable check on the accuracy of the wave-length measurements. Lines of the 002-000 band of HCN and the 2-0 band of CO were used as standards. We believe that the wave-numbers of N_2O have an accuracy on an absolute scale of 1 part in 5×10^6. The molecular constants of N_2O and the observed and calculated wave-numbers have been published (**14**).

In the discussion that followed the paper by Rank, Herzberg asked whether all measurements were based on the green line of Hg. Rank replied that they were, and this seemed to provide quite adequate precision. Herzberg asked whether Rank could rely on the overlapping-order

technique, and Rank reported that no difficulties with this technique had been found; the grating used was of very high quality. As an additional comment, Rank mentioned that all of their measurements were taken with a vacuum spectrograph.

Table 16. Calculated wave-numbers in the 001-000 band of HCN

J	$R(J)$	$P(J)$	J	$R(J)$	$P(J)$
0	3314·4132	—	20	3368·6455	3248·4853
1	17·3279	3308·5212	21	71·1283	45·1274
2	20·2216	05·5440	22	73·5893	41·7503
3	23·0942	3302·5461	23	76·0271	38·3535
4	25·9457	3299·5275	24	78·4430	34·9386
5	3328·7761	3296·4885	25	3380·8366	3231·5041
6	31·5852	93·4289	26	83·2077	28·0508
7	34·3729	90·3489	27	85·5563	24·5786
8	37·1393	87·2485	28	87·8823	21·0876
9	39·8843	84·1279	29	90·1858	17·5780
10	3342·6077	3280·9871	30	3392·4666	3214·0497
11	45·3096	77·8262	31	94·7247	10·5030
12	47·9898	74·6453	32	96·9600	06·9378
13	50·6483	71·4443	33	3399·1725	3203·3542
14	53·2851	68·2235	34	3401·3622	3199·7524
15	3355·9001	3264·9829	35	3403·5290	3196·1325
16	58·4931	61·7225	36	05·6728	92·4944
17	61·0643	58·4421	37	07·7937	88·8384
18	63·6134	55·1429	38	09·8915	85·1644
19	66·1405	51·8238	39	11·9662	81·4726
20	3368·6455	3248·4853	40	3414·0178	3177·7632
			41	3416·0463	3174·0360

Table 17. Calculated wave-numbers in the 1-0 band of CO

J	$R(J)$	$P(J)$	J	$R(J)$	$P(J)$
0	2147·0831	—	15	2199·9317	2082·0037
1	50·8579	2139·4281	16	2203·1616	77·6511
2	54·5975	35·5482	17	06·3540	73·2658
3	58·3016	31·6336	18	09·5087	68·8480
4	61·9700	27·6844	19	12·6256	64·3979
5	2165·6028	2123·7008	20	2215·7045	2059·9155
6	69·1996	19·6829	21	18·7454	55·4011
7	72·7604	15·6309	22	21·7481	50·8547
8	76·2850	11·5449	23	24·7124	46·2766
9	79·7733	07·4251	24	27·6381	41·6668
10	2183·2251	2103·2715	25	2230·5252	2037·0255
11	86·6403	2099·0845	26	33·3735	32·3529
12	90·0187	94·8640	27	36·1829	27·6491
13	93·3601	90·6103	28	38·9531	22·9142
14	96·6645	86·3234	29	41·6841	18·1484
15	2199·9317	2082·0037	30	2244·3757	2013·3519

REPORT ON VACUUM ULTRA-VIOLET WAVE-LENGTH STANDARDS

B. Edlén

For various reasons the interferometric determination of wave-lengths meets with great difficulties in the vacuum ultra-violet, and so far no useful interferometric measurements have been made much below 2000 Å. Therefore, the only means of extending the system of standard wave-lengths into the VUV by direct measurements has been the method of overlapping diffraction orders in grating spectra. The accuracy of this method is limited, however, by unpredictable coincidence errors that may be small for high-quality gratings, but are probably never quite negligible.

Fortunately, the Ritz combination principle provides an efficient solution of the problem. The method implies that the relative values of the energy levels of a particular atom are derived from accurately measured wave-lengths in the long-wave region, and then the wave-number for a short-wave line is obtained as the difference between the two appropriate levels. This possibility of calculating accurate wave-lengths in the VUV was recognized and pointed out by Paschen as early as 1911, shortly after Ritz had announced the combination principle.

Although the method can be used, of course, for extending the system of standards in any direction, it works particularly well toward shorter wave-lengths, because of the fact that the wave-number accuracy is essentially conserved, and therefore the wave-length error varies approximately as the square of the wave-length. To illustrate we take the second member of the resonance series in Mg II. The wave-number of this transition, $3s-4p$, may be obtained as the sum of $3s-3p$ (λ 2800, $\Delta\lambda\approx 0{\cdot}003$ Å, $\Delta\sigma\approx 0{\cdot}04$ cm^{-1}), $3p-4s$ (λ 2900, $\Delta\lambda\approx 0{\cdot}003$ Å, $\Delta\sigma\approx 0{\cdot}04$ cm^{-1}), and $4s-4p$ (λ 9200, $\Delta\lambda\approx 0{\cdot}01$ Å, $\Delta\sigma\approx 0{\cdot}01$ cm^{-1}). Allowing for some cancellation of errors we have for $3s-4p$, at λ 1240, $\Delta\sigma\approx 0{\cdot}06$ cm^{-1}, or $\Delta\lambda\approx 0{\cdot}001$ Å. Thus, the wave-length error, $\Delta\lambda$, of a calculated "Ritz" standard is in general substantially smaller than that of the measured wave-lengths from which it is derived.

Ritz standards, of various degrees of accuracy, can be obtained from any reasonably accurate and complete description and analysis of an atomic spectrum. The situation with regard to VUV standards should, therefore, improve almost automatically as the number of carefully-studied atomic spectra increases. Naturally, the usefulness of a particular spectrum as a source of Ritz standards will depend on various circumstances, such as the occurrence of narrow fine structure or hyperfine structure, the number and spacing of easily excited lines, the stability of the wave-lengths against changing excitation conditions, and the convenience with which it can be produced and superposed on the spectrum to be measured.

The short-wave limit of calculable wave-lengths in a given spectrum usually occurs at about one-half of the shortest wave-length that is required as a basis of the calculation. By using suitable spectra and including in the calculation VUV lines measured by interpolation between already established VUV standards it should be entirely possible to extend the system of standards all the way down through the VUV.

A brief survey of available VUV standards was made in the Moscow report of this Commission, and additional material is included in the present *Report*.

In the discussion following this report, Kessler asked whether a list could be provided of elements suitable for this purpose. Edlén pointed out that there would be very few that would *not* be acceptable as sources of standards. C, N and O, as well as Si, occur as impurities in most VUV spectra and are for that reason of special interest. Ge I has proved to be very useful down to 1630 Å. In Zn I, Cd I and Hg I the lines of the principal series (*e.g.* 1849 Å of Hg I) can be accurately calculated. One could also mention the second spectra in the iron group (Fe II, Cu II etc.). Herzberg called attention to Ar II as being a very good source of standards.

Finally, Rank pointed out that one could also carry out the *inverse* of this process, *i.e.* calculate far infra-red bands from near infra-red bands. This has actually been done by Rank, Skorinko, Eastman and Wiggins (**18**) for the 010-000 band of HCN, thus obtaining very precise standards (to better than $\pm 0{\cdot}003$ cm^{-1}) in the region 624–803 cm^{-1}.

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14*a*. SOUS-COMMISSION DES TABLES D'INTENSITES

Report of Meeting, 16 August 1961

PRESIDENT: M. J. Minnaert

SECRETARY: H. Zirin

Sub-Commission 14*a* will now become a working committee of Commission 14 and be called the Working Committee on "Transition Probabilities and Cross-sections."

There were no corrections to the *Draft Report.* The President noted that data on collision cross-sections appeared for the first time, and that these should be improved and extended in the future. He recommended that the membership of the committee should be increased to deal with this topic.

Dr Seaton pointed out that if the work of the committee is to be so enlarged, it involves a very large task. Cross-sections are much more difficult to compile and evaluate than *f*-values.

Professor Aller reviewed the current situation on *f*-values of astrophysical interest. He pointed out particular atoms whose lines satisfy the three conditions of: having astrophysical interest; being amenable to accurate experimental techniques; and being within the possible range of theory. Such atoms are C, N, O, Ne, and A. Some atoms, such as Ca, Fe, and Pb have reasonably good *f*-values, but many others which do not were noted. Professor Aller also pointed out the discrepancy between various methods of measurement of *f*-values such as shock tubes and molecular beams. [Professor Aller's paper is appended to this report.]

Professor Greenstein commented on the need for *f*-values of various ions of Fe for studies of cooler stars. In particular, *f*-values for weak lines are needed, because these lines are free of self-absorption.

The President asked if the committee should make up a list, perhaps using the revised multiplet tables, of lines for which new *f*-values were urgently needed. Professor Greenstein commented that the actual lists of lines in observed spectra should be used. In the discussion it was noted by Dr Branscomb that the physicists working in the field look to the committee to inform them which lines are important.

Dr Kessler of the National Bureau of Standards reported on the NBS programme of compendia of transition probabilities. A bibliography has been compiled on unpunched cards, and persons desiring a bibliography on any ion should write to: Atomic Physics Data Center, National Bureau of Standards, Washington 25, D.C.

Dr Branscomb addressed the committee on the programme of laboratory astrophysics at the National Bureau of Standards. A broad programme is underway at NBS to provide data on atomic properties, statistical processes, diagnostic methods, and theoretical interpretations for astrophysics, aeronomy and cosmophysics. The *f*-values are being measured by the use of stabilized arcs, shock tubes, and high-temperature plasmas. Photo-detachment cross-sections are being studied both theoretically and experimentally, and there is also theoretical work on photo-ionization. The well-known work on theoretical and laboratory measurements of collision cross-sections is being continued. Finally, Dr Branscomb gave the committee some examples of the bibliography being compiled by the Atomic Physics Data Center mentioned by Dr Kessler.

Dr Branscomb also pointed out the need for a review article on the present situation in astrophysical *f*-values in a journal accessible to physicists, such as the *Reviews of Modern Physics*. The President agreed to transmit this suggestion to the Organizing Committee.

Professor Allen discussed the use of the *f*-sum rule in transition probabilities. In cases with one or two electrons, one can obtain a good approximation. In general, it is best to use the quantity *gf*. With the *f*-sum rule, one can at least rule out grossly inaccurate *f*-values.

Dr Naqvi spoke on the continuation at Harvard of the work of Dr Layzer (reported on in volume X of the *Transactions*) on calculation of *f*-values by means of screening factors.

SOME URGENT NEEDS IN *f*-VALUE DETERMINATIONS

Lawrence H. Aller

The development of improved, high-dispersion spectrographic equipment for solar and stellar work has enabled astronomers to get accurate data on line profiles not only at different points of the solar disk, for stars over a big range in apparent as well as absolute brightness, but also for peculiar stars, stars with extended envelopes, and gaseous nebulae. Spectroscopy

of the solar corona and chromosphere from space platforms in the near future promises a wealth of data on the intensities, origins, and distributions of lines emitted from these regions, which so far have proven so difficult to interpret.

To assess these data it is essential that we know certain atomic parameters, cross-sections for electronic collisional excitations or de-excitations, collisional damping constants, and radiative transition probabilities or *f*-values. For studies of extended envelopes, the first and third mentioned must be known but the second is of no importance, while for the wings of strong lines the second and third are fundamental. In order to study deviations from LTE in the chromosphere and in extended stellar envelopes, appropriate parameters for collisional and radiative ionizations must also be known. Here we confine our attention to *f*-values, since without them we can make no progress at all.

We may measure either relative or absolute *f*-values. Absolute *f*-values are of course needed for all abundance work, but good relative *f*-values (particularly for elements of the iron group) are useful for getting excitation temperatures and for the construction of empirical curves of growth. Often, the situation is that absolute *f*-values are measured for strong resonance lines, while relative *f*-values are obtained for other lines. Then the absolute *f*-values of all lines may be obtained. Studies of this kind have been carried out for calcium and iron, for example, but many more investigations are needed.

It is not likely that all *f*-values we want can ever be measured, particularly for highly ionized atoms. Hence we must rely on theory but we must measure some lines that are (*a*) of astrophysical interest, (*b*) that can be measured by accurate techniques, and (*c*) can be calculated by theory. The best candidates for attention are probably such light elements as C,N,O, F,Ne, Si, P, S, Cl, and A whose lines appear in the Sun and hot stars. For these elements, absolute *f*-values can be obtained from arcs, shock tubes, life-time measurements, etc. These ions are sufficiently simple that the theory is of some use for them (see *e.g.* Biermann and Trefftz, Garstang, Layzer, Varsavsky, and Green). Even the Bates-Damgaard calculations are better than expected.

Experimentally, neutral neon and argon are easiest to handle, since they both exist in monatomic form. They can be studied in arcs (Olsen) or shock tubes (Doherty) and should be suitable for life-time measurements. Hence these gases should be useful as checks on or indicators of the validity of different types of experiments or theoretical methods. Lines of Ne I are observed in B stars and A I lines could probably be used in the infra-red. For higher stages of ionization, Ne II, A II, A III, etc. the *f*-values may be measured by magnetically driven shocks.

Of these elements silicon is probably the most important, since silicon lines are observed over a wide range of excitation from Si I to Si IV; hence they are useful as spectral class and temperature indicators. Around B2, lines of Si II, Si III, and Si IV all appear; hence these lines are useful for such studies as deviations from LTE.

Carbon, nitrogen, and oxygen in various stages of ionization are important in all stars from the Sun to those of spectral class O. The first few ionization stages can be obtained in high-voltage shock tubes; higher stages can be handled by theory. Because of their high cosmic abundance these elements are represented in a large variety of objects: normal stars, stars with extended envelopes, and gaseous nebulae. For example, the Orion nebula and certain planetaries such as NGC 7009 show recombination lines of O II; hence *f*-values are needed for the interpretation of such spectra.

Sulphur presents a particular problem; its forbidden lines S II and S III are among the strongest in gaseous nebulae. Reliable *f*-values for permitted lines of S I, S II, and S III are

urgently needed. From a geochemical point of view, the sulphur content of the Sun as compared with that of chondrites and the lunar surface is of interest.

Experimental *f*-values are difficult to measure for chlorine and fluorine because of the corrosive character of these gases. Phosphorus is rare and relatively less important than the other elements.

For investigations of the satellite ultra-violet, we need *f*-values for resonance transitions of ionized atoms of abundant elements. Some of these *f*-values can be found by theory but many can be measured experimentally, in arcs and shock tubes, with spectrographs in a completely evacuated chamber.

Alkali and alkaline earth metals present special problems. Transition probabilities are well known for resonance lines of Li, Na, K, Rb, and Cs, but for Ca, Mg, and Sr there are discordances. Subordinate line *f*-values are needed for Na, K, Ca, and Mg, although a good set of *f*-values for subordinate lines of Ca have been obtained (Olsen). These elements are sufficiently simple that theoretical transition probabilities can also be computed. For example the coefficient of continuous absorption has been calculated for Ca I and Ca II.

Lines of the iron group of elements dominate the spectra of cooler stars. Because of the great number of levels and transitions involved, they are especially useful for studies of structures of solar and stellar atmospheres, temperature distributions, deviations from LTE, etc. Except for those of the very highest temperature, lines of ubiquitous iron appear in the spectra of all stars—even extended envelopes and gaseous nebulae where forbidden lines dominate. A curious and difficult problem is posed by the fact that although Fe I *f*-values appear to be well-established, the solar abundance of this element seems to come out too low as compared with chondritic meteorites, suggesting defects in our adopted model atmosphere or deviations from LTE. The absolute *f*-values have been measured (for elements of the iron group) only for resonance lines which are much too strong to be used for abundance studies. Hence one has to rely on weaker lines whose relative *f*-values have been measured; often these relative *f*-values are poorly determined, because the excitation temperature is in error or because of some cause such as deviations from LTE in the experiment. Examples of troubles of this sort, encountered for Cr, Ti, and Ni are given by Goldberg, Müller, and Aller (1960). Urgently needed are accurate measurements of absolute *f*-values for resonance lines of Sc, Ti, V, Cr, Mn, Co, Ni, and Cu—and good determinations of relative *f*-values, preferably by several different methods. Data are needed not only for neutral atoms, but also for ions, *e.g.* Ti II, V II, Cr II, and Fe II. Errors in some of these elements, *e.g.* copper, seem to be particularly serious. The solar abundance of Cu seems much too high (suggesting that the *f*-values adopted were correspondingly too low) as compared with chondritic meteorites.

Rare elements are represented in the Sun and stars only by their resonance or strong subordinate lines. Some elements, *e.g.* Sr, are represented by good lines in two stages of ionization (Sr I and Sr II). Hence their *f*-values should be carefully determined. Among elements of astrophysical interest in the second long period of the periodic table are Zr, Nb, Mo (Tc), Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, and Ba. The most important of these heavier elements, lead, is under intensive investigation, but the discrepancies between various investigations thus far carried out point to some of the difficulties involved. The yttrium *f*-values show discordances of a factor of 500, indicating the necessity of careful experimental measurements. We are not yet in urgent need of *f*-values for rare earths, since the spectra of many of these metals and their ions have not yet been adequately analysed.

The problem is this: for a selected number of lines in a selected group of elements, we should determine by experiment and by theory (if possible) as accurate *f*-values as possible. Among the lighter elements, special emphasis should be placed on C, N, O, Ne, Si, and S in different

ionization stages. For metals of the iron group we should investigate Ti, V, Cr, Mn, Ni, and Cu for both the neutral and singly ionized stages. It is urgent that the *f*-values be measured by more than one technique and every effort be made to eliminate systematic as well as accidental errors.

14*b*. SOUS-COMMISSION DES SPECTRES MOLECULAIRES D'INTERET ASTRONOMIQUE

Report of Meeting, 16 August 1961

PRESIDENT: P. Swings.
SECRETARY: J. G. Phillips.

The *Draft Report* of the Sub-Commission was adopted without amendment.

At the invitation of the President J. G. Phillips described the current status of the program of molecular band analysis being carried out on the Berkeley campus as a joint endeavor of the Physics and Astronomy Departments. After about a year and a half of extensive development, the program went into full production during the spring of 1960. The development consisted of the modernization of the 21-foot concave grating spectrograph of the Department of Physics by the purchase of a new grating from Bausch and Lomb, replacing and re-mounting the slits, and re-aligning the Paschen circle. An extensive series of tests resulted in the determination of observational procedures that would result in the production of spectrograms of the highest possible quality. The thorium halide electrodeless discharge excited by micro-waves was adopted as the source of comparison spectra. In addition, a semi-automatic measuring machine of the Tomkins and Fred type was constructed to aid in the measuring of the plates. Digitizing equipment on the measuring machine and the rental of an IBM 526 Summary Punch made it possible to punch the measurements and central line densities directly onto IBM cards for subsequent processing by the IBM 704 computer. Several programs were developed for the computer for the automatic reduction and analysis of the molecular bands on these spectrograms.

As of June 1961, the status of the production of band analyses is as follows:

1. *CN*. The analysis of the red system is nearing completion. Two sets of exposures were made, with a relatively low excitation discharge-tube source, and with a higher temperature enclosed arc. In all, 23 exposures have been made, comprising 100 plates, in addition to numerous test exposures. The spectral region covered runs from 4500Å to 12000Å. In this interval, 41 bands are suitable for measurement and analysis. The analysis of the low temperature discharge-tube plates is complete, and the analysis of the arc plates is nearing completion. On the discharge plates each of the eight resolvable branches of the bands can be followed, on the average, to the rotational quantum number $N=20$. The higher temperature arc source is making it possible for the majority of the branches to be extended to at least $N=60$.

A limited number of pre-publication copies of the discharge-tube results have been made available to those who can make immediate use of them. Negotiations are under way with the University of California Press for the publication of the complete table. They propose a volume with a page size of $8\frac{1}{2}\times 11$ ins., and suggest an initial printing of 1000 copies, 500 of which would be bound with hard covers.

2. *HgH*. An electrodeless discharge tube source has been developed and used to photograph two band systems comprising 30 bands, 16 of which have been observed and analysed for the first time. An initial set of 60 plates have been measured, reduced, and completely analysed. A second set of plates will be photographed by the end of July, and added to the study.

3. C_2. A discharge-tube source has been studied extensively for optimum production of the Swan bands free of bands belonging to impurities. An initial set of three exposures comprising 15 plates has been made. These will be followed by additional exposures with the discharge-tube, and a complete series with a higher temperature enclosed arc. Measurement and analysis of these plates will start as soon as the study of the red system of CN is completed early in the fall.

15. COMMISSION POUR L'ETUDE PHYSIQUE DES COMETES

Report of Meetings

PRESIDENT: K. Wurm.

ACTING SECRETARY: L. Houziaux.

First meeting, 16 August 1961

DISCUSSION OF DRAFT REPORT

The first meeting was devoted to the discussion of the *Draft Report* and of the suggestions for consideration. When closing this session, the *Draft Report* was unanimously accepted after some minor corrections in the references.

Suggestions mentioned in the *Draft Report:*

1. Monochromatic photometry. It was emphasized by several members that care should be taken to guarantee a real monochromacy and to report the properties of the filter used.

2. Spectra with higher resolution, tail spectra. Dr Swings recommends in particular the region around $\lambda 3600$ Å, which is not yet well known in its general composition. More spectra in the red are also urgently needed. Dr Herzberg points out that the region around $\lambda 3400$ Å contains bands of molecules which we may expect to appear in comets.

3. Spectra of far distant comets. It was recommended that authors who have access to large instruments may keep this problem in mind.

4. Magnitude of nuclei, colours and dimensions. The importance of monochromatic observations in the regions of continuous emission was stressed and the careful study of nearby objects with instruments of large focal lengths.

5. Monochromatic photographs, real extension of CO^+ emission in tail and head etc. Several authors recommended a more consequent change to real monochromactic observations. Dr Swings reported that a 60-cm Schmidt camera now at the Haute-Provence observatory, will be in particular devoted in the future to monochromatic observation. Dr Wurm gave some explanations with regard to the importance of such observations for the development of the physical theory.

6. Continuation of existing series of observations concerning the magnitudes and the shapes of comets. The high value of these series was generally acknowledged.

7. Laboratory investigations of observed and expected molecules. Dr Swings mentioned that Dr Philips at Berkeley is working with the analysis of molecular spectra of interest. Dr Rosen reports that he is carrying through at Ottawa an analysis of the C_3 bands.

8. Polarisation measurements. Dr Vanýsek reported that refined polarimetric observations belong to his programme of comet observations.

GENERAL COMMENTS AND REPORTS

Dr Swings reported that he has identified with certainty in the spectrum of Comet Mrkos the [O I] doublet $\lambda\lambda 6300, 6360$. Dr Roemer added that A. Deutsch has just found these lines also in a spectrum of Comet Wilson 1961 (see A. Deutsch's report below in the report of the second meeting). Dr Herzberg asked whether or not the corresponding forbidden transition of C I has also been observed; Dr Swings answered that nothing can be said about the appearance of the carbon lines since no good spectra of the region of the transition are available so far. Dr Swings and Dr Biermann suggested preparations for the launching of artificial comets

and that contact should soon be made with the corresponding organisations. Dr Whipple recommended that proposals for artificial comets, as well as for space probes, be sent to NASA with a detailed explanation of the importance of such experiments.

At the end of the session Dr Wurm gave a description of a liquid-dye filter which isolates, with about 50% peak transmission, the three strong CO^+ bands in the violet region of the spectrum.

Second meeting, 22 August 1961

At the beginning of the second meeting, which was to be devoted to a colloquium on "The Structure and Development of the Gas Tails of Comets", Dr Swings requested permission to present the following recommendation.

"Commission 15 recommends the study of Encke's Comet by a space probe at its next close approach, in mid-July 1964. Observations should be made of:

(*a*) the nucleus (telescopic appearance, polarisation and color),

(*b*) the head and the near tail (in density and composition, magnetic fields, total density of the neutral particles, plasma frequency, micrometeorites, far ultra-violet emission especially that of H_2 near $\lambda 1300$).

En route to the comet the probe would collect valuable information on the interplanetary space outside of the plane of the ecliptic".

There was general agreement that this recommendation should be brought to the knowledge of members of NASA, and discussed with them.

After the discussion of this recommendation, the President asked Dr Herzberg to take the chair for the colloquium. After a brief introduction, five papers were presented, each of a duration of about twenty-five minutes. The abstracts which follow have been written by the authors themselves.

THE STRUCTURE AND DEVELOPMENT OF THE GAS TAILS OF COMETS

INTRODUCTORY REMARKS

K. Wurm

The gas tails of comets consist of singly-ionized molecules such as CO^+, N^+_2, CO^+_2 and probably some others. It was assumed originally that these ions are created through photo-ionization by solar light, and that their acceleration in a direction away from the Sun is due to light pressure. About ten years ago it became evident that neither of these assumptions is tenable. Early in the history of modern comet research we meet the suggestion of a strong influence by corpuscle streams from the Sun on cometary phenomena. However, this suggestion was not seriously discussed until after the failure of the radiation hypothesis (see L. Biermann, *Zs. f. Astrophys.* **29**, 274, 1951). Although the corpuscular hypothesis has been favorably accepted by many authors, the fact cannot be disregarded that this theory—at least in its present form—does by no means provide a satisfactory explanation of the observational facts, even of the most fundamental ones. Within the theory, only a mechanism of pure collisional interaction (ion-ion and electron-ion) has so far been worked out. It seems rather certain that this mechanism cannot be of any importance because it needs much too high ion densities in the streams, both to account for the ionization and also to explain the repulsive forces. Regarding the latter there remains the possibility of a transfer of momentum by magnetic fields. However, only very vague ideas have been so far mentioned in this respect. These can scarcely be regarded as a contribution to a theory.

In view of this situation, it was suggested that a thorough discussion be devoted to this subject at this meeting. Of the following five papers the first four are intended to state what we have to consider as observational facts with regard to the formation of the gas tails in comets. There remains for the last paper to show which of the observations the physical theory in its present state is able to explain.

2. INTENSITY- AND PARTICLE DENSITY-DISTRIBUTION IN THE HEADS OF COMETS

B. A. Vorontsov-Velyaminov

Objective prism spectra and photographs of Comet 1942*g* (1943 I) have been studied photometrically. They have shown that the brightness distribution within the approximately roundish head changes as ρ^{-1}, where ρ designates the distance from the nucleus. This law of brightness distribution remained the same over two months of observation. With the condensations of the band groups on the objective prism spectrograms the head could be traced up to $3{\cdot}7 \times 10^5$ km from the nucleus. On the other hand on the photographs in integrated light a blackening from the head emission was found up to not less than 6×10^6 km. It seems questionable whether there exists at all a limit of the head emission. Assuming a fluorescence excitation in an optically thin layer, as is established for emission in comets, from the absolute magnitudes of the monochromatic condensations the following total numbers of the most important molecules are derived: N(CN) $1{\cdot}3 \times 10^{31}$, $N(C_2)$ $2{\cdot}7 \times 10^{31}$, $N(C_3)$ $7{\cdot}1 \times 10^{32}$. These are valid for a volume with a radius of $3{\cdot}7 \times 10^5$ km. The partial densities at the border of this volume are: CN—2; C_2—1 and C_3—0·04 molecules per cm^3.

Since the comet was one of small dust content, the very large radius measured on the ordinary photographs must have originated from the emission of molecules.

3. EXTENSIONS (DIAMETERS) OF THE CN AND C_2 HEADS OF COMETS

Wm. Liller

Unpredictable variations in the sizes of the coma of comets, both as a function of time and as a function of radiating molecule, are well established. Perhaps the most striking positive evidence of time-variations is illustrated by two photographs of Comet Schaumasse taken by F. D. Miller in 1952 and in 1960 (*Sky and Telescope*, **19**, 473,1960). The photographs were taken when the comet was 12 and 5 days from perihelion ($q = 1{\cdot}2$), respectively, but in the 1952 photograph the image of the coma appears almost three times larger than in the 1960 photograph.

Perhaps an even more dramatic observation of a time-change was made recently by W. Liller of Comet Burnham (1959 *k*). Using a photo-electric spectrophotometer with a wavelength passband of 99 Å fixed on the C_2 emission shortward of $\lambda 5165$, he obtained intensity scans across the coma of the comet a number of times at three-hour intervals centered on April 27·36. Two scans, separated in time by 65 minutes, leave little doubt that the diameter of the head, as measured at half peak intensity, changed from 5′·5 to 3′·7. Only small changes in size were noted during the remaining half-hour before dawn. D. R. Barber (*Observatory*, **80**, 198, 1960) reports that unusual brightness fluctuations took place on the same night and that the Earth was experiencing a rather intense magnetic storm at the time. The comet being only 0·21 A.U. from the Earth, may well have received a sudden increase in high-energy electromagnetic and particle radiation from the Sun.

Studies of photographic spectra of comets (*e.g.* the *Atlas of Representative Cometary Spectra*,

by Swings and Haser) show clearly the relative sizes of the images of comet heads as seen in different molecular radiations. The usual order of image size (large to small) is listed here:

$$\left.\begin{matrix} CN \\ C_2, NH \\ C_3 \\ CH, NH_2 \end{matrix}\right\} OH$$

The image size in OH can differ considerably from comet to comet over the range indicated by the brackets.

Liller and N. Schultz made monochromatic isophotes of Comet 1959*k* with photo-electric spectrophotometers during its recent close approach to the Earth. Three wave-length regions were selected for study: $\lambda 5100$ (C_2), $\lambda 3900$ (CN), and $\lambda 4850$ (continuum). Isophotal contours, constructed from back-and forth-scans made at the telescope, were expressed in units of the peak intensity. When the comet was 1·02 A.U. from the Sun, the C_2 and CN contours coincided almost exactly. At a solar distance of 0·99 A.U. the comet yielded isophotes in the light of C_2 which were approximately twice the size of the contours made in continuum radiation ($\lambda 4850$). None of the isophotes showed any sign of tail; however, some raggedness in the contours suggests small minute-to-minute variations. A generally high level of solar activity continued throughout the observation.

4. TYPES OF COMET TAILS AND REPULSIVE FORCES

V. Vanýsek

Spectrographic studies of comets have shown that the straight type I tails are made up by ionized molecules (predominantly CO^+) and that the strongly curved tails of type II must consist of scattering dust particles. There exists no difficulty of principle in understanding the appearance and general shape of the type II tails. Their strong curvature leads to repulsive forces of approximately the same magnitude as that of the solar gravitation at the position of the comet. Repulsive forces of this size can be accounted for by the action of light pressure on small dust particles.

The situation is very different with regard to the scarcely curved type I tails. These are normally built up as a bundle of divergent rays and streamers issuing from the central part of the head. The absence of a perceptible curvature, as well as measurements of the acceleration of distinct condensations, have shown that repulsive forces acting on the tail ions certainly reach values of 50 to 100 times the solar gravitation. Whether the much higher values of 10^3 to 10^4 times the solar gravitation (as have been favoured by L. Biermann, P. Stumpff and some other authors) have any significance remains very questionable. Such high repulsive forces were first mentioned in the literature by A. Kopff, in connection with a study of a pair of plates of Comet Morehouse. Dr Wurm informs me that he will explain in his paper, that Kopff's extreme repulsive forces rest on a wrong indentification of two structures on the two plates in question.

We are confronted with the task of explaining repulsive forces of the order of one hundred times the solar gravitation. It has been long known that light pressure fails to be effective enough, there remaining a discrepancy of two orders of magnitude. It is an old idea that corpuscular streams from the Sun may significantly influence cometary phenomena and possibly also cause acceleration of the tail ions. Until the mechanism of the interaction between the solar corpuscles and the cometary ions has been outlined and clarified, such a suggestion is not of much value. The mechanism of a pure collisional interaction has been rather clearly described by Dr Biermann; however, it has recently become evident that this kind of acceleration of the tail ions demands much higher densities in the solar streams than we are allowed to

accept. The next step would be to find, and to investigate critically, the mechanism of an electromagnetic interaction. Streams of solar particles may carry with them magnetic fields. Authors investigating this problem are reminded that the acceleration of the tail ions is a permanently lasting feature of cometary phenomena, and cannot be connected with occasional clouds colliding with the comet.

5. STRUCTURE AND DEVELOPMENT OF THE GAS TAILS OF COMETS

K. Wurm

The gas tails of comets are made up of ionized molecules. Since the tail as a whole must be electrically neutral, we may be certain that there exists an equivalent number of free electrons. The first question which we meet in connection with the formation of the tails concerns the production of molecular ions. It became evident many years ago that photo-ionization by the UV solar radiation cannot account for the creation of the ions. There now exists a general inclination to consider solar corpuscular streams (solar wind) as being responsible for the ionization in comets. As can be shown, however, some observational facts do not support such an assumption. The present author has earlier emphasized that the corpuscular stream hypothesis is scarcely in a position to explain why, on the one hand, the tail ions appear already close to the nucleus, whereas, on the other hand, the heads, which are built up of neutral molecules such as CN, C_2, NH and others, reach such large dimensions as observed. From the extensions of the heads, data about the average life-times τ of the neutral molecules, exposed to the "solar wind" can be derived. From the expansion of spherical halos in Halley's comet there was next derived the figure $\tau = 10^{5.5}$ seconds for the average lifetime of the molecules CN and C_2, for a heliocentric distance of one A.U. This figure rests on the assumption, indicated by the halo observations, that, up to a distance of 200 000 km from the nucleus, the molecules are not suffering an appreciable decay by ionization or dissociation. However, Dr Vorontsov-Velyaminov's results on the real extension of cometary heads, derived from photographs of Comet 1942*g* as mentioned by him above, indicate that there is no appreciable decay up to distances of some million kms from the nucleus. From this we find values of τ for CN and C_2 between 10^6 and 10^7 seconds. Such long life-times exclude proton densities of the permanent solar wind of an order larger than 10^1. To reconcile the large extension of the heads with the appearance of the tail ions close to the nucleus, there remains only the explanation that the ionization occurs by a process within the atmosphere close to the nucleus, and is limited to this region. All particles which escape this process remain neutral.

The tail ions issue from the nucleus region in sharp rays; each ray when first appearing is inclined at a large angle of 45° to 90° to the tail axis. The latter has approximately the same position as the prolonged radius vector. When growing in length the tail rays are steadily turning to the tail axis. It can be shown that the turning of the rays must be connected with a decrease of the component of the initial velocity normal to the tail axis. Despite this continuous movement of the tail rays to the radius vector, there appears no (or only a moderate) piling up of matter along the tail axis. This shows that the ion source which feeds a ray dies out when the ray reaches the tail axis.

Each ray develops independently of the others, which indicates that there exist at the same time many discrete ion sources. The mechanism of ionization remains obscure.

6. THE PHYSICAL THEORY OF COMETS

L. Biermann

It was suggested in 1951 that the acceleration of the plasma tails in comets (type I) has to be ascribed to the interaction with the solar corpuscular radiation, which itself constitutes an ionized, however macroscopically neutral, particle flux. It can be shown that the flux of

momentum of the latter is sufficient, the main remaining question being how the momentum can be transferred to the cometary plasma. Two specific mechanisms were considered in 1951, namely transfer of momentum (1) by thermal electrons and (2) by magnetic fields. The observational evidence available in 1951 gave the impression that the mechanism (1) was more important, but it has since appeared that, in fact, (2) is more likely to be effective. In addition a third mechanism connected with microfluctuations in plasma has come into consideration, but estimates about its effectiveness are not yet available.

As to the mechanism of ionization, an important problem is how to account for the observed rates of cometary ion structures. A general survey of the possibilities of ionization reveals: (1) that ultra-violet solar light under normal circumstances is quite sufficient; (2) that the effectiveness of collisional ionization, assuming the electrons being sufficiently heated, is seriously reduced by a number of competing processes; (3) that the mechanism of exchange of charge proposed in 1953 has a large cross-section just for the range of proton velocities in question. The possibility (4) of binary chemical reactions have been tentatively explored, but those found so far all depend on an independent source of ions. The competition between processes (2) — (4) will require further study.

DISCUSSION

In the discussion following the presentation of the papers, A. Deutsch gave a short report on his new observations of the spectrum of Comet Wilson 1961; the following abstract was written by the speaker himself:

"A spectrum was obtained, at the coudé focus of the 100-inch telescope, of Comet Wilson at dawn on 1961 July 26. The nucleus, looking stellar, was held stationary at the center of the slit during the five-minute exposure. The slit was oriented approximately in the direction of the tail. The spectrum covers the region $\lambda\lambda$5200–6400, and the dispersion is 60 Å/mm. The nucleus produces an over-exposed, narrow streak down the center of the spectrum. A number of emission bands may be seen close to its edges. The outstanding features are the D-lines and [O I] λ6300. These lines cross the whole spectrum, but they are twice as strong on one side of the spectrum as on the other. Moreover, on the weaker (anti-tail) side, they are decidedly tilted towards longer wave-length. The velocity gradient is close to 1 km per second of arc."

The papers gave rise to extensive discussion. Since, however, this did not reveal new viewpoints beyond those already recorded above the discussion is not reported. On the other hand it may perhaps not be out of place to try to give here a brief summary of the general result of the colloquium.

As indicated in the introduction the whole discussion was intended on one hand to elaborate a clearer picture of what we are allowed at present to consider as well-recognized observational facts. From B. A. Vorontsov-Velyaminov's contribution, it has become evident that the gas heads of comets (at medium heliocentric distances around 1 A.U.) have larger dimensions than hitherto generally assumed, and consequently the probability of ionization for neutral molecules, such as CN and C_2, must be rather small, probably less than $\lambda = 10^{-6}$. The paper also gives reliable data about the abundance of molecules in the heads. W. Liller's paper seems to make it highly probable that occasionally intense corpuscular streams from the Sun can partly destroy the emitting particles in the heads. Difficult to understand are his observed minute-to-minute fluctuations in the extensions of the head; if substantiated they could only be explained by a variable contribution of a corpuscular stream to excitation. V. Vanýsek's report exhibits the state of our knowledge concerning the magnitude of the repulsive forces. Whereas those of one-hundred times the solar gravitation are certain, much higher ones can be statistically of no importance. V. Vanýsek emphasizes that these repulsive forces represent

a permanent feature of comet tails, and that they cannot depend on occasional jets of corpuscular radiation from the Sun. The main points of the next paper are the different ionization probabilities observed near the nucleus and at larger distances from it. This forces us to search for the source of ionization within the atmosphere, and to abandon the direct action of an outer radiation. It is further emphasized—and this fits in with the idea just mentioned—that the surprisingly regular development of all tail rays (and the independence which each single ray shows from all others present) can hardly be reconciled with the idea of direct control by an outer influence.

As regards the confrontation of the basic physical theory with the above-mentioned observations, the situation appears rather disappointing. Evidently, we are still in the state of exploring what physical mechanisms are responsible for the creation of the tail ions and the acceleration of these ions (the two most striking processes in comets). The idea that ultra-violet solar radiation can explain the normal ionization, and the circumstances connected with the appearance of the ions, can certainly not be accepted. As explained above, the hypothesis of the corpuscular radiation in its present state also provides no solution, and somewhat larger cross-sections for the proton molecule collision cannot save the situation. Concerning the acceleration of the ions, it can only be said that the mechanism for it remains completely obscure.

It is evident that in such a situation the theory cannot be expected to shed light on the somewhat more subtle observations on the formation and movement of the tail rays, the limitation of the ionization in space, and the nature of the ion sources. Apparently, still more information from observation is needed in order to find the right basis for a physical theory.

16. COMMISSION POUR L'ETUDE PHYSIQUE DES PLANETES ET DES SATELLITES

Compte rendu des Séances

PRÉSIDENT: A. Dollfus.
SECRÉTAIRE: J. H. Focas.

La Commission 16 s'est réunie à Berkeley au cours des sessions suivantes:

Session Administrative I: 17 août 1961: Problèmes de physique lunaire

Session Administrative II: 18 août 1961: Problèmes de physique planétaire

Session du Comité 16*c*: 21 août 1961: Centres de documentations photographiques

Session Scientifique I: 19 août 1961: L'atmosphère de Vénus (première partie)

Session Scientifique II: 23 août 1961: L'atmosphère de Vénus (deuxième partie).

COMPOSITION DE LA COMMISSION 16

La nouvelle composition adoptée par l'Assemblée Générale et par la Commission 16 est la suivante:

PRÉSIDENT: Audouin Dollfus, Observatoire de Paris, Section d'Astrophysique, Meudon (Seine-et-Oise) France;

VICE-PRÉSIDENT: Marcel Minnaert, Directeur de l'Observatoire, Zonnenburg 2, Utrecht, Pays-Bas;

COMITÉ d'ORGANISATION: G. P. Kuiper (U.S.A.), S. Miyamoto (Japon), V. V. Sharonov (U.R.S.S.).

MEMBRES: Voir page 488.

ASSOCIÉS: Baldwin, Carder, Hall, Kharadze, Koziel, Martynov, Mikhailov, Pettengill.

Session administrative du 17 août 1961

Cette session est consacrée aux problèmes de physique lunaire.

Le Président définit les rôles respectifs des Commission 16 "Etude physique des planètes et satellites" et Commission 17 "Mouvement et figure de la Lune", tels qu'ils ont été délimités au cours d'entretiens avec le Professeur Koziel, Président de la Commission 17. Les travaux sur la forme générale du globe lunaire, la triangulation de la surface et la détermination des cotes de nivaux entrent dans le domaine de la Commission 17. Les problèmes de nature du sol, morphologie du relief, origine, cartographie, nomenclature appartiennent à la Commission 16.

Le Président soumet à la discussion le projet de résolution suivant, proposé par différents membres de la Commission:

RÉSOLUTION NO. 1

"Pour l'établissement de nouvelles cartes de la Lune, il est recommandé de se conformer aux conventions suivantes:

(*a*) Les cartes *astronomiques* destinées aux observations télescopiques sont orientées selon les usages de l'astronomie avec le Sud en haut. Les termes Est et Ouest prêtent à confusion et doivent être supprimés.

(*b*) Les cartes *astronautiques* destinées aux explorations directes sont présentées selon les méthodes habituelles de la cartographie terrestre, avec le Nord en haut et l'Est à droite.

(*c*) Les altitudes et les distances sont données dans le système métrique."

English translation

"For compiling new maps of the Moon, the following conventions are recommended:

(*a*) *Astronomical* maps for purpose of telescopic observations are oriented according to the astronomical practice, the South being up. To remove confusion, the terms East and West are deleted.

(*b*) *Astronautical* maps, for direct exploration purposes, are printed in agreement with ordinary terrestrial mapping, North being up, East at right and West at left.

(*c*) Altitudes and distances are given in the Metric System."

Après une courte discussion à laquelle ont pris part, notamment, MM. Kuiper, Rösch, Sharonov, Urey, Edmonson et Wildt, le texte de la résolution est approuvé sans modification, pour être soumis au Comité Exécutif.

L'ordre du jour appelle ensuite l'examen des problèmes de nomenclature des formations lunaires, pour la face tournée vers la Terre aussi bien que pour la face opposée récemment révélée par une sonde spatiale soviétique.

Les règles de désignation doivent conserver les usages et tenir compte des développements à venir de l'observation télescopique, de la recherche spatiale, de l'exploration directe.

Le Professeur Kuiper expose et soumet à la Commission les travaux de révision de la nomenclature lunaire officielle de l'UAI auxquels l'a conduit la publication de son Atlas photographique de la Lune.

Puis le Professeur Sharonov, au nom du Professeur Mikhailov, empêché, présente à la Commission "L'Atlas de l'hémisphère invisible de la Lune" publié par l'Académie des Sciences d'U.R.S.S. d'après les observations relevées par la Station Interplanétaire Automatique soviétique ayant contourné la Lune le 7 octobre 1959.

Il demande la ratification par l'Union Astronomique Internationale de la nomenclature désignant les détails découverts sur la face arrière de la Lune proposée par l'Académie des Sciences d'U.R.S.S.

Le projet de résolution suivant est alors discuté:

RÉSOLUTION NO. 2

1. "Pour désigner les formations de la surface lunaire, il est recommandé de se conformer aux règles antérieures, revues et améliorées de la façon suivante:

(*a*) Les cratères et les cirques sont désignés par des noms d'astronomes ou de savants illustres *décédés*; ces noms sont écrits en lettres latines selon l'orthographe préconisée par le pays d'origine du savant nommé.

(*b*) Les chaînes d'aspect montagneux sont désignées en latin par des dénominations rappelant la géographie terrestre; ces noms sont accordés selon les règles de la déclinaison latine au substantif *Mons*. (Les trois exceptions Mons d'Alambert, Mons Harbinger, Mons Leibnitz sont conservées en raison d'un long usage).

(*c*) Les grandes étendues sombres sont désignées en latin par des dénominations évoquant des états psychiques; ces noms sont accordés selon les règles de la déclinaison latine à l'un des

substantifs appropriés *Oceanus*, *Mare*, *Lacus*, *Palus* ou *Sinus*. (Les exceptions Mare Humboldianum et Mare Smythii sont conservées en raison d'un long usage).

(*d*) Les pics isolés sont désignés comme les cratères, ainsi que les promontoires, ces derniers étant précédés du substantif latin *Promontorium* (Exemple: Promontorium Laplace).

(*e*) Les rainures et vallées portent le nom du cratère le plus proche et sont précédées des substantifs latins *Rima* et *Vallis*. (L'exception Vallis Schröter est conservée).

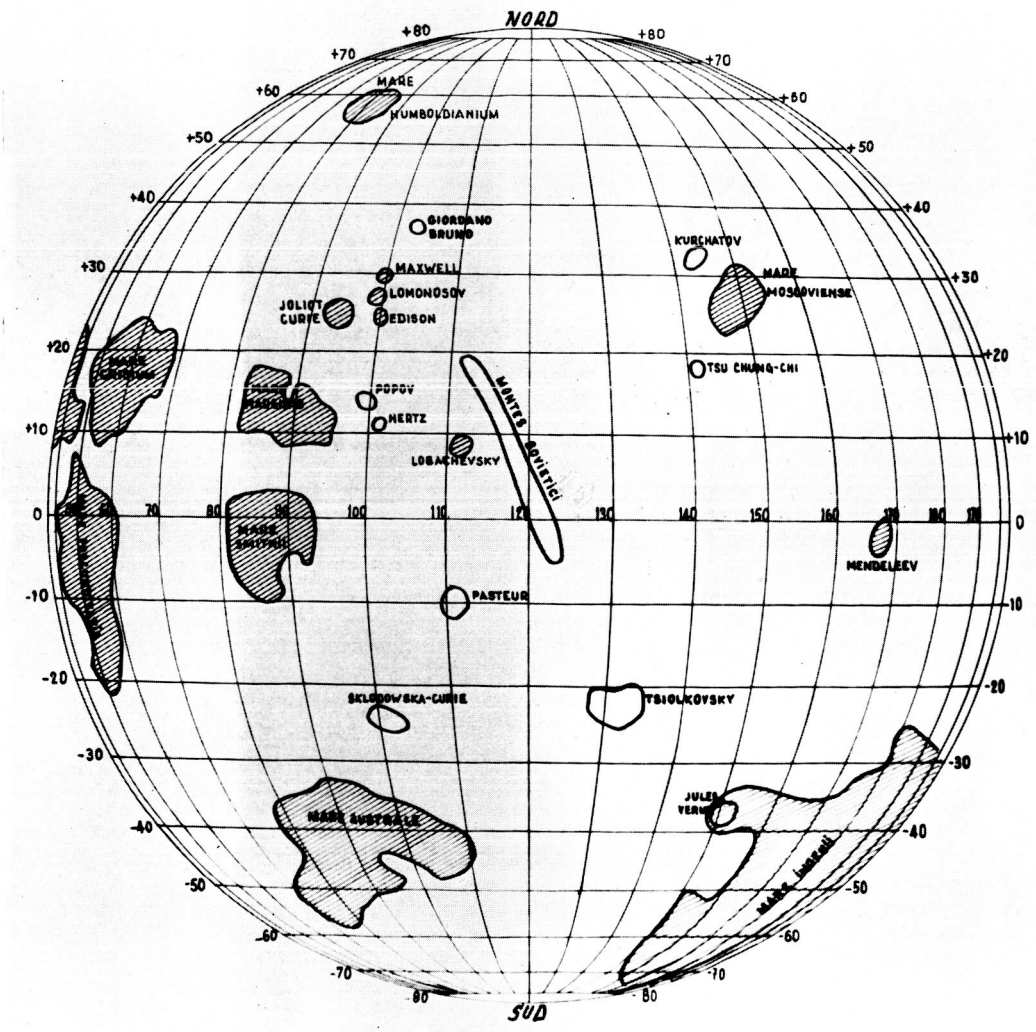
(*f*) Les formations non dénommées peuvent être désignées par leurs coordonnées. Elles peuvent également continuer à être désignées par le nom du cratère le plus proche suivi d'une lettre majuscule de l'alphabet latin pour les cratères, dépressions, vallées, d'une lettre minuscule de l'alphabet grec pour les collines, élévations, pics, d'un chiffre romain suivi de la lettre r (Ir, IIr, etc..) pour les rainures."

2. "Par suite, pour désigner les formations lunaires observables depuis la Terre, il est recommandé d'adopter la Nomenclature selon l'Union Astronomique Internationale (*Named Lunar Formations*, M. A. Blagg and K. Müller, London, 1935) revue et corrigée par la table III du *Photographic Lunar Atlas* (éditeur G. P. Kuiper, University of Chicago Press, 1960), de ne plus ajouter de nouvelles désignations, et d'appliquer les corrections orthographiques suivantes:

Condamine	doit	être	écrit	La Condamine
Lacaille	,,	,,	,,	La Caille
Lahire	,,	,,	,,	La Hire
Lapeyrouse	,,	,,	,,	La Pérouse
Legentil	,,	,,	,,	Le Gentil
Lemonnier	,,	,,	,,	Le Monnier
Leverrier	,,	,,	,,	Le Verrier
Régnault	,,	,,	,,	Regnault

3. "Il est recommandé d'adopter, pour les formations de la surface lunaire non observables de la Terre, les désignations reportées dans *L'Atlas de la Face de la Lune opposée à la Terre* (Editeur N. P. Barabashov, A. A. Mikhailov et Y. N. Lipsky, Moscou 1960), sous la forme reportée dans le tableau suivant et la carte jointe.

Désignation	n° du catalogue	Coordonnées sur la carte longitude °	latitude °
Tsu Chung-Chi	1	141	+18
Kurchatov	2	144	+32
Jules Verne	5	151	−37
Mendeleev	10	167	− 2
Popov	71	99	+14
Hertz	74	101	+11
Edison	83	100	+24
Lobachevsky	88	112	+ 9
Pasteur	95	111	−10
Sklodowska Curie	112	102	−23
Tsiolkovsky	151	131	−22
Lomonosov	177	99	+28
Joliot Curie	183	93	+25
Maxwell	185	99	+30
Giordano Bruno	208	103	+36
Montes Sovietici	103	(de 111	+19
		(à 124	− 5
Mare Ingenii	150		
Mare Moscoviense	152	149	+27



Commission 16, Résolution no. 2: Carte indiquant les désignations de la surface lunaire non observable de la Terre.

Commission 16, Resolution no. 2: Chart showing the recommended nomenclature for the surface features on the reverse side of the Moon.

English translation

1. "For designating the lunar surface features, it is recommended that the previous rules be followed, revised and improved as follows:

(*a*) Craters and rings, or walled plains, are designated by the name of an astronomer or prominent scientist *deceased*, written in the Latin alphabet, and spelt according to the recommendation by the country of origin of the scientist named.

(*b*) Mountain-like chains are designated in Latin by denominations allied with our terrestrial geography. Names are associated with the substantive *Mons* according to the Latin declination rules and spelling. (Three exceptions, Mons d'Alembert, Mons Harbinger and Mons Leibnitz, are preserved due to long usage).

(*c*) Large dark areas are designated in Latin denominations calling up psychic states of minds. These names are associated, according to the Latin declination rules and spelling, to one of the appropriate substantives: *Oceanus*, *Mare*, *Lacus*, *Palus* or *Sinus*. (The exceptions, Mare Humboldianum and Mare Smythii, are preserved, due to long usage).

(*d*) Isolated peaks are designated according to the same rules as for the craters, as well as promontories, the latter being preceded by the Latin substantive *Promontorium*. (Example: Promontorium Laplace).

(*e*) Rifts and valleys take the name of the nearest designated crater, preceded by the Latin substantives *Rima* and *Vallis*. (The exception Vallis Schröter is preserved).

(*f*) Undenominated features can be designated by their co-ordinates. They can equally be designated according to the former classical system, by taking the name of the nearest crater, followed by an upper case letter of the latin alphabet for craters, depressions and valleys, by a lower case letter of the greek alphabet for hills, elevations and peaks, and by a roman number followed by the letter r (Ir, IIr, IIIr, etc..) for the clefts."

2. "Accordingly, for the designation of the lunar surface features observable from the Earth, it is recommended that the International Astronomical Union Nomenclature (published in *Named Lunar Formations* by M. A. Blagg and K. Müller, London, 1935), as corrected in table III of the *Photographic Lunar Atlas* (Editor G. P. Kuiper, University of Chicago Press, 1960), be adopted, that new names be avoided, and that the following orthographic corrections be applied:

Condamine	must be printed	La Condamine
Lacaille	,, ,, ,,	La Caille
Lahire	,, ,, ,,	La Hire
Lapeyrouse	,, ,, ,,	La Pérouse
Legentil	,, ,, ,,	Le Gentil
Lemonnier	,, ,, ,,	Le Monnier
Leverrier	,, ,, ,,	Le Verrier
Régnault	,, ,, ,,	Regnault

3. "For the designation of the surface features on the reverse side of the Moon, it is recommended that the nomenclature reported in the *Atlas of the Far Side of the Moon* (Editors: N. P. Barabashov, A. A. Mikhailov and Y. N. Lipsky, Moscow 1960) be adopted, expressed in terms of the following table and the accompanying chart".

(Names are given in the table of the French version of the resolution, printed above.)

La discussion porte plus particulièrement sur les formes latines à adopter. La désignation "Mare Somniorum" conviendrait pour la traduction du russe en latin de la formation no. 150 du catalogue; cependant, une autre formation de l'hémisphère visible de la Lune porte déjà

ce nom. Finalement, sur la proposition du Professeur Minnaert, la Commission adopte le nom de "Mare Ingenii" pour cette formation.

La Résolution no. 2 est adoptée par la Commission sous la forme reportée ci-dessus et transmise au Comité Exécutif.

Le Président souligne le fait que des problèmes de nomenclature se poseront très probablement à nouveau dans un avenir proche. Afin de préparer les solutions de ces problèmes, il paraît désirable de former un Comité groupant un nombre limité de spécialistes qualifiés.

Cette proposition est adoptée, sous la forme suivante:

Comité 16*a*. *Nomenclature et cartographie de la surface lunaire*

Ce Comité a pour but d'unifier les procédés de cartographie de la surface lunaire et de définir les désignations des nouveaux détails topographiques de la surface, tels qu'ils apparaîtront grâce aux développements de l'observation télescopique, de la recherche spatiale et de l'exploration directe.

Committee 16*a*. *Lunar Nomenclature and Cartography*

The task of the Committee is the standardization of lunar surface cartography, and the designation of newly discovered features expected by improvement of telescopic observations, space-vehicle techniques and direct explorations.

Membres du Comité 16*a*: A. Dollfus, Z. Kopal, K. Koziel, G. P. Kuiper, D. Martynov, A. A. Mikhailov, M. Minnaert.
Members of Committee 16*a*:

Les progrès des techniques d'observation de l'astronomie, et surtout les programmes de recherches spatiales ainsi que l'exploration directe, laissent également prévoir un développement rapide dans nos connaissances sur la nature et les propriétés du sol lunaire.

Les mises au point, colloques et discussions récentes ont mis en valeur des résultats obtenus dans ce sens par différents chercheurs, à l'aide de techniques physiques très diverses; mais ces résultats sont disséminés dans différentes publications et une mise au point d'ensemble n'a pas encore été conclue de ces travaux éparpillés.

Dans le but de dégager une interprétation unique et de développer les recherches, un Comité limité à des membres directement concernés a été créé, sous la coordination du Lunar and Planetary Laboratory of the University of Arizona.

Comité 16*b*. *Nature et structure du sol lunaire*

Le Comité se propose de préciser nos connaissances sur la constitution de la surface du sol lunaire et de reconstituer sa texture microscopique, en discutant les résultats des observations photométriques, polarimétriques, thermiques, radio-électriques, les échos radar, en pratiquant des expériences de laboratoire et en utilisant les méthodes d'observation nouvelles.

Committee 16*b*. *Nature and Structure of the Lunar Surface*

The Committee is appointed for the improvement of knowledge of the composition of the lunar soil and of the physical structure of the surface, by the study of the existing photometric, polarimetric, thermic, radio-electric and radar observations, by laboratory experiments and with the help of new techniques of observation.

Membres du Comité 16*b*: Président, G. P. Kuiper; N. P. Barabashov, V. V. Sharonov, A. Dollfus, M. Minnaert, G. Pettengill, E. M. Shoemaker, W. Sinton.
Members of Committee 16*b*:

Session administrative du 18 août 1961

LA COORDINATION DES OBSERVATIONS PLANÉTAIRES

Cette session est consacrée à la coordination des observations planétaires et à leurs groupements.

La Coopération Internationale pour l'observation collective de phénomènes planétaires existe déjà depuis plus de six ans. Cette coopération a pu être menée à bien par la Commission 16 en bonne partie grâce à des subventions de la part, notamment, de l'Union Astronomique Internationale, de l'Observatoire Yerkes, du Jet Propulsion Laboratory de l'Institut Technologique de Californie auxquels le Président adresse ses remerciements.

Avant d'exposer les résultats déjà acquis par cette Coopération, le Président fait état de l'étude d'un questionnaire d'information adressé par la Commission 16 en 1960 a de nombreux Observatoires, Organismes ou Observateurs professionnels ou privés, dans le but de dégager les ressources, possibilités, désirs et besoins de la coopération. 92 circulaires ont été envoyées. 8 destinataires ont répondu ne pas être directement concernés par le contenu de la circulaire. 40 destinataires ont manifesté des désirs ou possibilités de contribuer aux observations et donné des précisions sur leurs équipements, personnels, temps disponibles, domaines des contributions passées ou futures, etc...

Les travaux récemment effectués dans le cadre de coopération internationale de la Commission 16 sont ensuite passés en revue et résumés par différents auteurs ou membres de la Commission.

(*a*) *Groupement des clichés de la surface lunaire*

Le Professeur G. P. Kuiper, ancien Président de la Commission, rappelle la Résolution adoptée par l'Assemblée Générale de Dublin recommandant la réalisation d'un atlas de la Lune d'après le groupement de tous les meilleurs clichés photographiques disponibles dans le monde. Le Professeur Kuiper a réalisé lui-même cet Atlas qui a été publié. Un catalogue comprenant les diamètres de 12 000 objets de la surface lunaire est préparé, ainsi qu'une liste donnant les coordonnées orthogonales révisées de 5 000 points du disque. 8 000 objets situés à proximité des grandes formations sont désignées par des lettres. Des photographies lunaires rectifiées de la perspective sont en voie de préparation.

(*b*) *Groupement de clichés de la planète Mars*

Le Président de la Commission travaille au groupement et au classement en collections immédiatement consultables de tous les clichés actuellement disponibles sur la planète Mars, depuis 1907.

Les clichés groupés à l'occasion de l'opposition périhélique de 1956 ont été particulièrement étudiés par G. de Mottoni qui expose quelques uns des résultats obtenus. Les 252 clichés utilisés se répartissent entre neuf observatoires de la façon suivante:

Pic du Midi (France)	123	clichés.	H. Camichel, J. Focas, A. Dollfus
Johannesburg (S. Africa)	48	,,	W. S. Finsen
Lick Observatory (U.S.A.)	36	,,	H. M. Jeffers
Bloemfontein (S. Africa)	15	,,	E. C. Slipher
Stalingrad (U.R.S.S.)	10	,,	Bronstein
Merate (Italie)	8	,,	G. de Mottoni et Broglia
Mt Wilson (U.S.A.)	5	,,	R. Richardson
Gênes (Italie)	4	,,	G. de Mottoni
Tokyo (Japon)	3	,,	S. Miyamoto

En raison de la presque concordance des périodes de rotation de Mars et de la Terre, les observations recueillies pendant des nuits consécutives dans un même lieu montrent en permanence à peu près le même hémisphère martien. Au contraire, la documentation précédente, provenant d'observatoires répartis sous des longitudes terrestres très différentes, révèle la planète simultanément sous presque toutes les longitudes. Par suite G. de Mottoni a pu dresser neuf cartes consécutives en projections coniques centrées sur le pôle austral et deux planisphères en projection de Mercator, couvrant l'évolution des taches du sol et des phénomènes atmosphériques durant quatre mois consécutifs. Les différentes phases de la formation et de l'évolution des voiles jaunes exceptionnels apparus dans l'atmosphère de la planète à cette époque ont pu être reconstitutées ainsi que leurs relations avec les aspects de la calotte polaire australe et avec les variations de certaines taches du sol.

Le Professeur Miyamoto expose à son tour les hypothèses sur le mécanisme de la circulation atmosphérique martienne qui peuvent se déduire de semblables observations.

(*c*) *Photographies collectives de Vénus en ultra-violet*

Photographiée à travers des filtres ne transmettant que la lumière violette ou ultra-violette, la planète Vénus révèle des taches attribuables à des nuages élevés dans l'atmosphère. Ces nuages, très mobiles, évoluent si rapidement qu'il n'est pas possible de les reconnaître d'une journée à la suivante, ni, par conséquent, de reconstituer leurs déplacements ou leurs changements d'intensité. Pour éviter cet inconvénient, des clichés recueillis dans les trois centres d'observation suivants ont été groupés:

Pic du Midi (France)	longitude	0°	Observateur:	H. Camichel
Brazzaville (Rep. Congo)	,,	15° Est	,,	: Ch. Boyer
New Mexico City (U.S.A.)	,,	105° Ouest	,,	: C. Tombaugh et B. Smith.

Les observations presque quotidiennes de la dernière station s'intercalent avec celles recueillies dans l'une ou l'autre des deux premières stations de sorte qu'il fut possible déjà de suivre la planète à raison d'une image toutes les douze heures environ pendant les périodes suivantes:

du 16 mai 1959 au 21 mai 1959	: 11 clichés uniformément répartis dans le temps.
du 22 octobre 1959 au 25 octobre 1959	: 6 clichés à peu près uniformément répartis.
du 2 novembre 1959 au 7 novembre 1959	: 11 clichés presque uniformément répartis.

L'examen de ces séries d'images consécutives permet dans certains cas de reconnaître les mêmes formations nuageuses au bout de 12 heures, tandis qu'elles sont le plus généralement méconnaissables au bout de 24 heures. Ces nuages donnent l'impression de changer rapidement d'éclat sur place plutôt que de se déplacer. Selon H. Camichel, les observations recueillies à Brazzaville et au Pic du Midi indiquent quelquefois une récurrence des mêmes configurations nuageuses tous les quatre jours, indice soit d'une rotation rapide, soit plutôt d'un cycle dans l'évolution nuageuse probablement lié à la durée d'existence naturelle de formations atmosphériques.

(*d*) *Mesures polarimétriques*

Les mesures de polarisation pratiquées à l'aide de polarimètres visuels à franges de Lyot permettent de préciser la nature du sol des astres et leurs variations de structure, la densité des atmosphères planétaires, la nature des nuages portés par leurs atmosphères. Elles permettent également de découvrir de faibles nuées ou des impuretés dans les atmosphères planétaires, et de suivre leurs évolutions. Le polarimètre de Lyot est construit par la Société française

Jobin et Yvon. Les observatoires suivants sont ou seront très prochainement munis de polarimètres visuels à franges: Meudon (France); Athènes (Grèce); Naini Tal (Indes); Kwasan (Japon); Gênes (Italie); Harvard (U.S.A.); Tucson—Arizona (U.S.A.).

Le Dr J. Focas expose les résultats déjà obtenus pour l'étude polarimétrique de la planète Mars, par la coopération établie depuis 1954, grâce à l'UAI entre les Observatoires d'Athènes, de Meudon et du Pic du Midi. Plus de 4000 mesures de polarisation ont été relevées en même temps que de nombreuses mesures photométriques, des observations visuelles et des clichés photographiques. Les résultats de cette importante étude sont publiés ailleurs.

Le Dr D. Y. Martynov résume le programme de mesures spectropolarimétriques de la Lune développé par l'Institut Astronomique Sternberg de Moscou à l'aide de polarimètres photo-électriques. Il insiste sur la nécessité de la coopération internationale dans ce domaine.

Le Professeur E. K. Kharadze relate les travaux développés à l'Observatoire de Abastumani par M. M. Dzhapiashvili et L. Xanfomality comme il suit:

"In order to develop the investigations of the physical properties of the Moon and planets, an automatic electronic polarimeter has been constructed by L. V. Xanfomality according to the principles worked out at the Abastumani Astrophysical Observatory. . . . The instrument is designed for the 16-in. refractor in connection with the study of polarizing properties of the surface of the Moon and planets, carried out at the Observatory. Some interesting observational materials have been obtained. Later, efforts will be made to receive the lunar polarization map by the method of picture strips. The first experimental samples of raster and trial pictures of the Moon in different phases have been obtained. There are possibilities of improving this method."

Le Professeur Kharadze se déclare prêt à collaborer avec les activités de l'UAI dans ce domaine.

Le Professeur G. P. Kuiper présente les résultats des mesures de polarisation photo-électriques de la planète Vénus réalisées avec le réflecteur de 36 in. de l'Observatoire Goethe Link par le Dr T. Gehrels. L'auteur est parvenu à tracer les courbes de polarisation pour la lumière de l'ensemble du disque de Vénus, entre les angles de phase 30° et 120°, pour 6 domaines spectraux compris entre 3250Å et 10000Å.

(*e*) *Phénomènes exceptionnels sur Saturne*

L'apparition d'une tache blanche exceptionnelle à la latitude élevée de +40°, observée au Pic du Midi le 27 avril 1960, a été signalée dans les Informations rapides de l'UAI par le Président de la Commission 16 qui a demandé l'observation de ce rare phénomène.

Les nombreuses déterminations de passages reçues donnent la vitesse de rotation précise à la latitude concernée; elles sont brièvement résumées dans le *Draft Report*.

(*f*) *Mesure du diamètre de Mercure*

Le 7 novembre 1960, la planète Mercure se projeta devant le disque solaire. Cette circonstance donnait une occasion exceptionnelle de déterminer avec précision le diamètre très mal connu de la planète. Les observations furent demandées par une circulaire de la Commission 16 qui recommanda plus particulièrement l'emploi du micromètre à double image, ainsi que la méthode photométrique signalée par le Professeur Hertzsprung. Ce dernier procédé donne le diamètre de Mercure par la comparaison photo-électrique des intensités lumineuses recueillies à travers un orifice de diamètre angulaire un peu plus grand que celui de la planète, centré alternativement sur la planète et sur une région solaire voisine. Voici la liste des nombreuses mesures communiquées à la Commission 16:

Auteur	Observatoire	Procédé	Diamètre à 1 U.A.
Léonard Abbey	U.S.A.	micromètre à fil	7″·00
Baretto et Mourão	Rio de Janeiro (Brésil)	,,	nuages
G. P. Kuiper	Arizona (U.S.A.)	double image	6″·68
H. Camichel	Pic du Midi (France)	,,	6″·55
A. Dollfus	Mt Wilson (U.S.A.)	,,	6″·54
J. Focas	Athènes (Grèce)	,,	nuages
J. Rösch et H. Camichel	Pic du Midi (France)	photomètre	6″·71
A. Dollfus et J. L. Leroy	Meudon (France)	,,	6″·69
W. Sinton	Lowell Observatory (U.S.A.)	,,	nuages
C. Tombaugh et B. Smith	New Mexico City (U.S.A.)	,,	nuages

En négligeant la première mesure moins précise, la moyenne des cinq autres déterminations indépendantes donne $6''{\cdot}63 \pm 0''{\cdot}07$, soit une précision de 1% particulièrement remarquable. Les anciennes mesures classiques ne s'accordaient pas à mieux que 5%.

(*g*) *Occultation de Régulus par Vénus*

Lors de l'occultation de Régulus par Vénus le 7 juillet 1959, sept groupes d'observation constitués par le Harvard College Observatory et le Smithsonian Astrophysical Observatory avaient recueilli, dans différentes stations, des déterminations d'instants de contact et des mesures photométriques de l'affaiblissement de l'éclat de l'étoile. Les résultats étudiés par G. de Vaucouleurs donnaient la distance apparente entre l'étoile et le centre du globe au moment où l'éclat de l'étoile est diminué de moitié, soit $8''{\cdot}506$ à 1 U.A., et l'échelle de hauteur de l'atmosphère à ce niveau, soit 6·8 km. Combinées avec certaines connaissances antérieures, ces déterminations indiquent une valeur de l'altitude d'occultation au-dessus de la couche nuageuse de 70 km. La température est $T = 7{\cdot}0 \times \overline{m}$, $\overline{m}$ étant la masse moléculaire moyenne, soit vraisemblablement $T = 297°\text{K}$. Une estimation de la pression atmosphérique à cette altitude donne 2·6 dynes/cm². (Publiées dans *Sci. Rep. Harvard College Obs.* 1961; voir aussi *Nature*, **188**, 28–33, 1961).

Par ailleurs, le Professeur D. Y. Martynov, en utilisant les données précédentes et plusieurs autres observations de contact, donnait $8''{\cdot}41$ pour la distance entre le niveau produisant la disparition de l'étoile et le centre du disque, correspondant également à la valeur la plus probable du rayon de Vénus au niveau de la couche nuageuse. L'échelle de hauteur serait plus faible et par suite les altitudes d'occultations et températures seraient beaucoup plus basses (Publiés dans *A. Ž.*, *Moscow* **37**, 848, 1960 et **38**, 558, 1961; voir aussi *A. Ž.*, *Moscow*, **39**, No. 3, 1962).

La réunion de Commission donna au Professeur Martynov et au Dr de Vaucouleurs l'occasion de confronter leurs conclusions.

L'ensemble des travaux collectifs précédents, très nombreux, fait ressortir le profit d'une coordination étroite dans certains domaines. Cependant, vu le grand nombre de membres de la Commission, il semble désirable, pour faciliter celle-ci, de grouper des responsables déjà engagés dans cette voie ou susceptibles d'y contribuer prochainement, afin de présenter plus particulièrement les différents programmes et pays. La forme convenable paraît être un Comité défini et constitué comme il suit:

Comité 16*c*. *Coopération internationale pour l'observation des planètes*

Etant donné la nécessite d'étudier dans le temps l'évolution rapide de certains phénomènes planétaires et d'effectuer dans certains cas des surveillances continues, le Comité a pour but

d'organiser et de coordonner des observations dans des stations réparties sous différentes longitudes.

Le Comité se propose également le groupement dans certains centres de documentation des collections de clichés planétaires actuellement éparpillés dans différents observatoires.

Committee 16*c*. *International Co-operation for Planetary Observations*

Owing to the need for studying rapid changes and evolution on planetary atmospheres or surface features, and to secure continuous records, the Committee will promote and co-ordinate observations between stations at several longitudes of the Earth.

The task of the Committee also comprises the collection at the International Data Centres of the existing planetary photographs, at present scattered in several observatories.

Membres du Comité 16*c*:
Members of Committee 16*c*: Président, A. Dollfus; J. Focas, Secrétaire (Observatoire National, Athènes, Grèce); G. de Vaucouleurs, A. R. Hibbs, E. Kharadze, G. P. Kuiper, D. Martynov, S. Miyamoto.

La création de ce Comité 16*c* est adoptée.

La fin de la séance est agrémentée d'un certain nombre de communications originales dont voici la liste:

A. R. Hibbs. Programme d'étude de la Lune à l'aide des véhicules Ranger, Surveyor, Prospector, par le Jet Propulsion Laboratory.

W. M. Sinton. L'émission thermique de la Lune pendant les éclipses.

J. W. Warwick. Période de rotation radio-électrique de Jupiter.

M. Ingrao. Récepteur infra-rouge reconstituant l'aspect des planètes par balayage.

G. Wlérick. Emploi de la caméra électronique Lallemand pour la photographie planétaire au Pic du Midi.

Ces communications seront publiées par leurs auteurs.

Réunion restreinte du Comité 16c le 21 août 1961

Les membres de l'Union suivants ont été invités à se joindre aux membres du Comité 16*c*: MM. I. Bowen, Z. Kopal, M. Minnaert, J. S. Hall, G. de Mottoni, A. Whitford, A. G. Wilson, Mrs Wilson. Les trois premiers sont absents ou excusés.

Cette réunion restreinte a pour but la discussion de l'établissement de Centres de Documentation photographique sur les planètes.

De nombreuses collections de clichés planétaires très difficiles à bien réaliser ont été recueillies depuis le début du siècle dans différents observatoires. L'étude synoptique de ces documents permettrait de reconstituer l'évolution des aspects des planètes, et plus particulièrement des phénomènes dont leurs atmosphères sont le siège. Cependant, ces collections de documents sont réparties en différents endroits, et leurs confrontations est actuellement très difficile.

On suggère la création de Centres de Documentation ayant chacun pour but le rassemblement de tous les clichés qui leurs sont accessibles, l'établissement de copies positives transparentes à la même échelle, leurs échanges entre les différents centres. Le but final est de constituer dans chaque centre une série complète de tous les matériaux existant.

A la lumière de la discussion, l'état présent de la question se résume comme il suit:

A l'Observatoire Lowell (U.S.A.). La collection des clichés couvre l'ensemble des années

successives de façon à peu près homogène de 1909 à nos jours. De nombreux clichés sont excellents. Selon les informations données par le Dr Hall, Directeur de l'Observatoire, 756 images ont déjà été tirées en composites. Le Dr E. C. Slipher a entrepris de faire réaliser par trois personnes 50 pages d'images composites planétaires; ce travail est revenu à environ $100 par page. Environ 5000 clichés, principalement de Jupiter, Vénus et Mars, dont la moitié environ consacrés à cette dernière planète, n'ont pas encore été compositées; toutefois les images ne sont pas toutes à retenir.

A l'Observatoire de Meudon (France). Plusieurs milliers de clichés couvrent en grande abondance la période de 1941 à nos jours.

Le travail de reproductions des clichés de Mars est entièrement achevé jusqu'à la dernière opposition. La collection des images positives compositées sur verre est reproduite à l'échelle standardisée de 1″ par mm. N'ont été retenues que les images sélectionnées dont la résolution est supérieure à 0″.4. Cette collection représente 1000 composites de Mars, tous rangés dans un grand classeur et immédiatement consultables.

La collection comprend en outre environ 60 composites d'images de Mars effectués en 1954 et 1956 par Finsen en Afrique du Sud, 98 images simples obtenues par le Dr Jeffers à l'Observatoire Lick et une centaine d'images diverses.

Les collections des négatifs de Mercure, Vénus, Saturne et surtout de Jupiter ne sont pas encore toutes reproduites.

A l'Observatoire Lick. Les images de Mars, Jupiter et Saturne recueillies par le Dr Jeffers sont reproduites en tirages directs mais non encore compositées. De nombreux autres documents y existent encore.

Au Mt Wilson et Palomar. De grandes séries de clichés exécutés à diverses reprises depuis le début du siècle sont disponibles, certains d'entre eux sont très remarquables. Il ne semble pas qu'une mise en valeur systématique ait encore été effectuée. Cependant les films de Mars obtenus en 1956 par Leighton, qui représentent un très grand nombre d'images groupées en quelques nuits, ont fait l'objet d'un très gros travail de reproductions à l'Observatoire Harvard par G. de Vaucouleurs qui a réalisé 740 composites.

Les collections de négatifs recueillis aux Observatoires de Yerkes, McDonald, Tokyo, Kwasan, Stalingrad, Asiago, Monte Mario, Juvisy, dans le New Mexico et ailleurs seraient également à regrouper.

Les observatoires de l'Union Soviétique sont particulièrement bien placés pour combler les écarts en longitude qui séparent les stations européennes et japonaises. Selon le Professeur Martynov, les observatoires soviétiques sont prêts à collaborer aux travaux de l'Union Astronomique Internationale mais il n'existe pas actuellement de grandes collections de clichés planétaires disponibles en Union Soviétique; la qualité des images ne semble convenable qu'en été. De nouveaux grands instruments sont en service maintenant, en particulier en Crimée, en Géorgie, etc.. et ils pourraient participer à la prise de nouveaux clichés.

Il semble raisonnable aux membres présents de débuter le travail par l'établissement de deux Centres, l'un aux Etats-Unis à l'Observatoire Lowell, l'autre en Europe à l'Observatoire de Meudon.

Le Professeur Kuiper se déclare prêt à entreprendre, pour l'Union Astronomique Internationale, la partie du travail concernant les Observatoires américains. Le Président de la Commission pourra se charger, dans une certaine mesure, des autres observatoires et du Centre de Meudon.

Dans le but d'aider l'établissement des échanges de clichés, les Membres présents suggèrent et adoptent la proposition d'une résolution rédigée comme il suit:

Résolution No. 3

"Le Comité de la Commission 16 "Coopération internationale pour l'observation des planètes" désire faciliter cette coopération par l'établissement prochain d'au moins deux centres de documentation, l'un aux Etats-Unis, l'autre en Europe; entre temps, il demande aux Observatoires disposant de grandes collections de photographies planétaires de les rendre disponibles pour de telles études, vu la nécessité d'une répartition complète en longitude".

English translation

"The committee appointed by Commission 16 on "International Collaboration for Planetary Observations" desires to facilitate international collaboration on planetary studies by the eventual establishment of at least two data centres, one in the United States and one in Europe; and meanwhile requests observatories having large collections of planetary photographs to make these available for such studies as require a full coverage in longitude".

Sessions scientifiques des 19 et 23 août 1961

L'ATMOSPHERE DE VENUS

Les discussions scientifiques sont consacrées entièrement à la planète Vénus. Le Professeur H. C. Urey est invité à assurer la présidence des séances et à coordonner les débats.

Le rapport suivant concerne seulement les communications originales dont les auteurs ont demandé expressément la publication et envoyé un résumé.

Professeur D. Y. Martynov

1. There is disagreement between the theoretical value of refraction at the cloud level in the atmosphere of Venus and the observed value. The former is obtained as large as 13′ or 15′, as a result of the determination of the amount of CO_2 content from the intensity of the infra-red bands. This estimate is 1000 atm.-meter, which is equivalent to a pressure of 127 mm/Hg. The necessary formula to derive the horizontal refraction was given by F. Link.

But the observation of the "Lomonosov effect" due to refraction of light in the atmosphere of Venus at the beginning and the end of transits across the solar disk give values of horizontal refraction between 0′·3 and 0′·8, according to Sharonov and Link. These values refer to the cloud level.

The contradiction may be overcome if we assume that the observed CO_2 absorption bands originate in much lower levels than the apparent cloud level. Accordingly, it is stated that the structure of the clouds on Venus do not form a continuum but result from separate formations, so that we can observe between them the atmospheric layers beneath the cloud level.

2. Professeur V. A. Kotelnikov and collaborators secured radar contact with Venus during the last inferior conjunction, in April 1961.

The wave-length was 38 cm and the pulse frequency about 50 c/sec. During all the 4 or 5 days of observations, the reflected signal was found to be about 5 times wider than the signal generated by the locator. The effect is interpreted as a Doppler broadening due to the rotation of the planet. The resulting period of rotation is found to be about 11 days. If the hypothetical orientation of the axis of rotation derived by Kuiper and Richardson is taken into account, the resulting period lies between 9 and 11 days.

Professeur V. V. Sharonov

L'étude du "Phénomène de Lomonosov" au moment des contacts lors des passages de Vénus devant le disque solaire donne une valeur de la réfraction horizontale dans l'atmosphère de Vénus au niveau des nuages comprise entre 0'·3 et 0'·8. Cette faible valeur semble en contradiction avec l'allongement des cornes du croissant au voisinage de la conjonction inférieure, qui atteint facilement jusqu'à 90°. Cet allongement est un phénomène de crépuscule, la zone crépusculaire surpassant celle de la Terre. Pour faire s'accorder ces données l'auteur avait proposé un modèle atmosphérique a trois couches. La couche supérieure est pure et contribue seule à la réfraction responsable du phénomène de Lomonosov. La couche moyenne, étant composée de poussière de glace, est fortement diffusante et donne lieu à l'allongement des cornes. La couche inférieure est de nouveau transparente.

Pour étudier la structure de la couche diffusante, des mesures photométriques visuelles ont été réalisées. On a trouvé que le maximum de brillance pour chaque rayon du disque se trouve au bord extrême du limbe éclairé et non entre ce bord et le terminateur comme on pouvait le penser d'après les mesures photographiques. Le point le plus brillant du disque se trouve au bord du limbe sur la ligne médiane des cornes du croissant.

Dr H. Camichel

Les photographies de Vénus obtenues par Ross depuis 1927 montrent en lumière ultraviolette des taches mouvantes et variables. Dans le but de suivre l'évolution de ces taches et de rechercher les règles de leurs variations, la planète a été photographiée en ultra-violet au Pic du Midi depuis déjà 10 ans. Les séries d'observations ont été complétées par celles réalisées conjointement à Brazzaville (Congo) par M. Ch. Boyer. L'étude des clichés révèle que l'aspect des configurations claires et sombres peut souvent se reproduire après un intervalle de quatre jours, et ceci plusieurs fois de suite, le déplacement des taches paraissant avoir lieu dans le sens rétrograde.

Toutefois l'hypothèse d'une rotation rétrograde en 4 jours se heurte à de sérieuses objections.

L'auteur recommande vivement une coopération pour l'observation régulière et continue de Vénus depuis des Observatoires répartis sous différentes longitudes, selon le programme exposé plus haut (session du 18 août).

Dr W. M. Sinton

Spectra of Venus have been obtained with the infra-red spectrometer attached to the Lowell 42-in. reflector, during spring of 1961. In Figure 1 a spectrum of Venus and a spectrum of the Sun are reproduced; both are taken with equally wide slits. Gain changes were made during the recording of the spectra in order to keep the deflections within the confines of the recorder chart. These changes, however, were identical in the two spectra.

In the region free from CO_2 absorptions extending from 1·0 to 1·8 μ the reflectivity of Venus appears to be essentially constant. In the region between 1·9 and 2·7 μ this reflectivity is slightly reduced, and in the region 2·7 to 3·5 μ the reflectivity is greatly reduced.

A possible explanation of these results is given in terms of the scattering of sunlight by ice crystals, having a radius of 2·5 μ given by B. Lyot. Absorption bands for ice correspond to the 1·9 and 2·7 μ water absorption bands, but they are shifted to longer wave-lengths. For example, the ice bands corresponding to the 2·7 μ water bands are at 3·1 μ. Deirmendjian, Clasen and Viezoe (*J. opt. Soc. Amer.* **51**, 620, 1961) have computed the Mie scattering

coefficients for absorbing particles at different angles. Their calculations and the known absorption coefficients for ice seems to support the explanation of the infra-red reflectivity of Venus by scattering from ice crystals.

At the time of inferior conjunction the temperature of the dark hemisphere of Venus was determined at $3{\cdot}75\mu$ by comparison of the observed radiation with that from a black-body. The measured temperature of -38 °C. is in good agreement with the radiometric temperatures

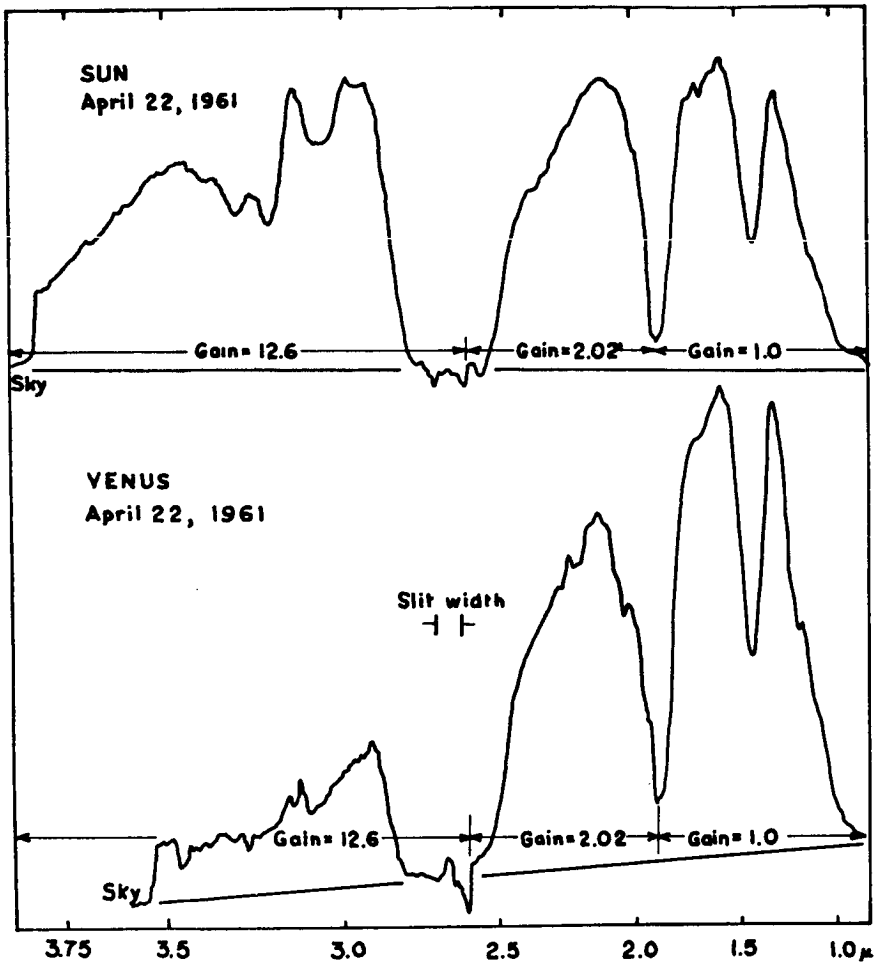


Fig. 1. Spectra of the Sun and Venus obtained with the infra-red spectrometer.

deduced from 8 to 13μ measurements. This agreement implies that the radiometric temperature applies to the top of the clouds, assumed to be composed of ice crystals.

Figure 2 shows spectra of Venus, the Sun and the Moon between $1{\cdot}9$ and $2{\cdot}5\mu$. The $2{\cdot}0$ band of carbon monoxide with head at $2{\cdot}345\mu$ appears in the Venus spectrum, resolved into its P and R branches. Because of the weakness of these bands, six more spectra were taken for confirmation. The author considers that a significant amount of CO is present in the atmosphere

of Venus. He has not fully satisfactory laboratory spectra of CO at his disposal at the moment, but from those available, the estimate of the amount of CO present in the spectrum is about 15 cm-atmosphere, corresponding to about 4 cm-atmosphere in a vertical path on Venus. The amounts are not corrected for any pressure broadening.

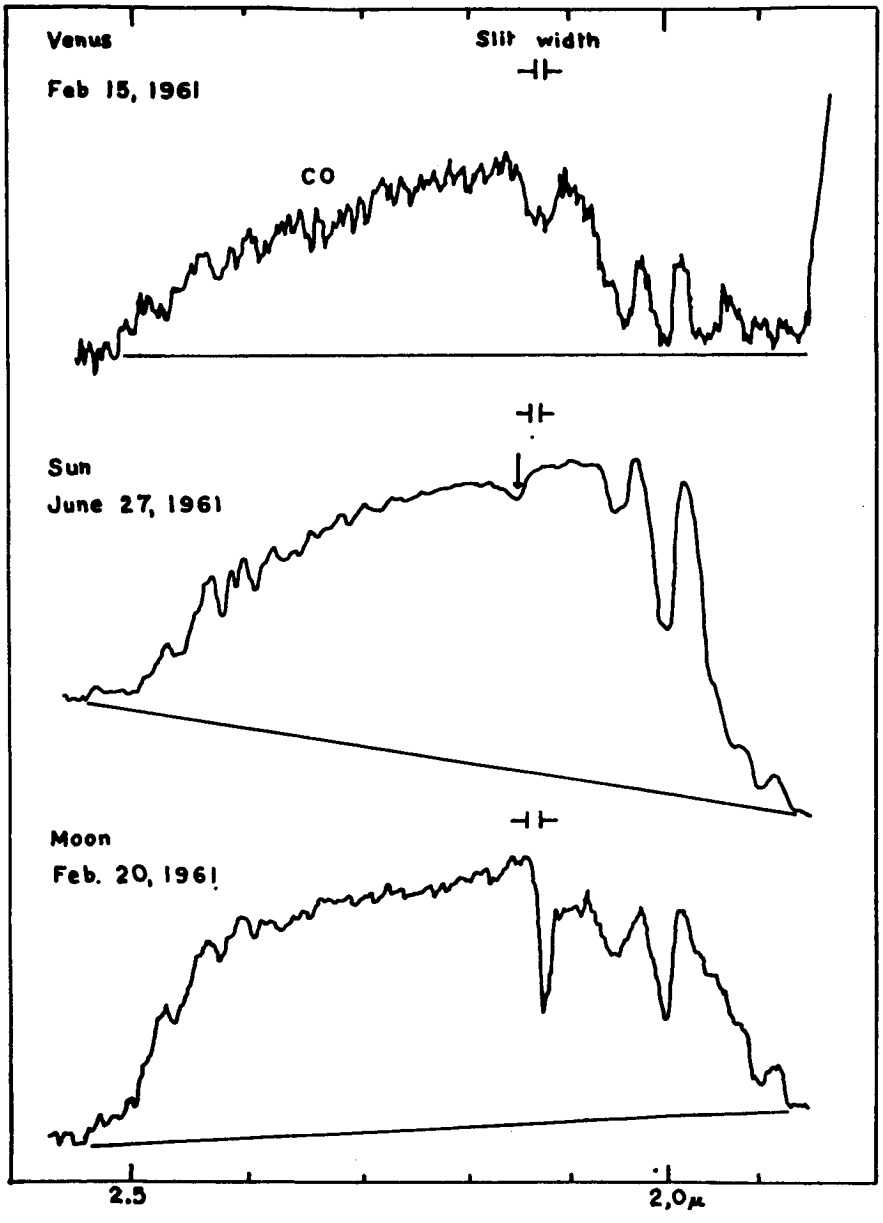


Fig 2. Spectra of Venus, the Sun and the Moon obtained with the infra-red spectrometer.

Dr C. C. Kiess

In 1956 and 1957 spectrograms of Mars and Jupiter were obtained with a concave grating spectrograph of high dispersion installed at the Slope Observatory of the U.S. Weather Bureau at Mauna Loa. The observations were made about six to eight weeks before the oppositions of the planets, when their radial velocities would be sufficient owing to the Doppler-Fizeau effect to shift their spectra by appreciable amounts from that of the Moon. In the region from 5800 to 8800 Å no lines of oxygen or water vapour were observed in the planets' spectra. Subsequently when the spectrograph was set up at Georgetown College Observatory, similar negative results were found for Venus. In the case of Jupiter the NH_3 and CH_4 bands were well resolved; and four lines in the rotational-vibrational structure of the quadruple band of H_2 near 8200 Å were measured.

However, the blue and violet regions of the spectra of these three planets decrease in intensity progressively, relative to that of the Moon, with decrease in wave-length towards and beyond the H and K lines. This effect closely resembles the absorption of white light by gaseous N_2O_4, as reported by several investigators.

Measurements of a low-dispersion spectrogram of Venus in the region from Hβ to 3500 Å, show that the wave-lengths of the blended continua separating blended groups of absorption lines agree with those reported by Kozyrev for the features in the spectrum of the dark side of Venus. Kozyrev has attributed these emission lines to N_2^+ in the airglow of Venus. We suggest alternatively that they are due to scattered light in his spectrograph from the bright side of the planet.

Eléments de la première Discussion

Le Président Urey ouvre à la discussion l'ensemble des communications précédentes:

Dr Öpik: Le problème de la réfraction dans l'atmosphère de Vénus et de l'allongement des cornes du croissant discuté par le Professeur Sharonov a déjà été traité par le Dr Öpik lui-même dans le journal russe *Myrovédénié* en 1917. En contradiction avec l'explication proposée par le Professeur Sharonov, le Dr Öpik pense que, au niveau où se manifeste une réfraction sensible, l'absorption des rayons lumineux dans l'atmosphère doit être déjà très considérable, ce qui diminue beaucoup l'effet observé. L'allongement des cornes causé par la diffusion par les partidules en suspension dans l'air doit commencer à se produire déjà à une altitude très grande, alors que la réfraction y est insensible.

La discussion s'engage entre les Professeurs Sharonov, Öpik, Martynov et, ultérieurement, G. de Vaucouleurs, d'où il ressort que les phénomènes d'absorption, assez complexes, ne peuvent pas être entièrement éclaircis.

Le Dr C. Sagan rappelle les recherches entreprises par L. R. Malling et S.W. Golomb, au Jet Propulsion Laboratory, pour étudier les échos radar sur Vénus. Les mesures relevées entre le 10 mars et le 10 mai 1961 sur la longueur d'onde 12·5 cm ne révèlent aucun élargissement par effet Doppler, ce qui indiquerait une vitesse de rotation très lente. Au contraire, les résultats russes révèlent sur 38 cm un élargissement très notable. Le Dr Sagan demande si, dans la discussion, il a été tenu compte des propriétés de rugosité de la surface du sol de Vénus, responsable des échos. Le Professeur Martynov regrette de ne pas être assez informé à ce sujet.

Le Professeur V. V. Sharonov évoque le peroxyde d'azote, envisagé par le Dr Kiess comme absorbant de l'ultra-violet, pour expliquer la coloration de la planète Mars, parce que les raies d'absorption, observées par le Dr Kiess, sont très faibles et ne peuvent pas avoir une influence sensible sur la couleur du disque.

Le Professeur Herzberg confirme son accord avec le Dr Kiess sur l'explication des émissions

spectrales dans la partie non éclairée du spectre de Vénus annoncée par le Dr Kozyrev. La diffusion dans le spectrographe doit suffire à expliquer les apparences de raies d'émission. Répétant l'observation, le Dr Newkirk a trouvé des émissions différentes, reportées dans le *Draft Report*. Depuis la rédaction de ce *Draft Report*, le Dr Newkirk a encore réalisé de nouvelles observations plus précises, et n'a plus retrouvé aucune émission.

Par ailleurs, la décroissance d'intensité du spectre de Vénus en ultra-violet pourrait être expliquée également par la présence de NO_2 ainsi que par la diffusion.

Dr A. Dollfus

L'ensemble des observations polarimétriques, visuelles et photographiques effectuées ou recueillies par l'auteur semblent pouvoir s'expliquer en supposant l'atmosphère de Vénus constituée de la façon suivante:

A une altitude au-dessus du sol non déterminée, mais où la pression atmosphérique pourrait être voisine de 0·1 atm., se trouve la limite supérieure de la couche de nuages. Ces nuages sont de grandes formations à structure probablement complexe, et souvent striées en bandes ou en rouleaux comme le révèlent les mesures de polarisation. Leurs dimensions moyennes valent environ 3000 km. Ces nuages évoluent rapidement par variations d'éclat ou déplacements, et se transforment en une trentaine d'heures; ils sont visibles comme des taches claires sur les photographies ultra-violettes et couvrent un peu moins des deux tiers de la surface. Entre ces nuées, la lumière pénètre plus profondément pour éventuellement atteindre confusément le sol. Mais l'atmosphère est très polluée de sorte que l'éclat est le même pour la lumière visible, ce qui rend ces nuages inobservables. En lumière ultra-violette au contraire, les rayons qui pénétrent plus profondément dans l'atmosphère entre les nuages sont plus affaiblis, de sorte que les voiles apparaissent brillants.

Au-dessus de cette couche nuageuse complexe, l'atmosphère devient plus pure. Les mesures de polarisation indiquent que la quantité de gaz au-dessus de la couche nuageuse est voisine de 1000 mètres-atmosphère. Dans cette région, l'air continue à supporter quelques voiles probablement ténus, révélés eux aussi par la polarisation.

Les nuages de la couche principale doivent être formés, dans leurs parties supérieures, par de petites particules transparentes de 2 à 3 microns de diamètre, éventuellement des cristaux de glace, que l'on pourrait rapprocher des nuages noctilucents de la haute atmosphère terrestre. L'auteur cherche actuellement à doser la quantité de vapeur d'eau décelable dans l'atmosphère de Vénus par la mesure spectrophotométrique de la bande 1·4 microns de la vapeur d'eau grâce à des observations pratiquées à grande altitude à bord d'une nacelle étanche enlevée par un nouveau dispositif de ballons stratosphériques.

Dr C. Sagan

Some of the existing information on the physical environment of Venus was presented. Three models of the atmosphere and surface were discussed critically. On the *Greenhouse Model* (Sagan), the surface is illuminated by visible solar radiation penetrating the clouds, but the opacity of the atmosphere and cloud layer is so great that infra-red radiation has difficulty in escaping and the equilibrium temperature of the surface reaches 600 °K. On the Greenhouse Model the visible cloud layer is composed of ice crystals. The *Aeolosphere Model* (Öpik) proposes that the surface of Venus is heated to 600 °K. by friction of gas and dust in the lower atmosphere. The lower atmospheric dust layer is driven by winds in the region above the visible clouds which represent the top of the dust layer. The *Ionospheric Model* (Jones) attributes the high microwave brightness temperatures to free-free transitions of electrons in a dense ionosphere. If the surface temperature is about 300 °K. the microwave spectrum and phase data are quantitatively explained. The Greenhouse Model has the possible difficulties

that the required atmospheric opacity may not be achieved and that convection may reduce the strong vertical temperature gradient. The Aeolospheric Model is in apparent disagreement with the phase variation in microwave brightness temperatures and with Sinton's recent spectroscopic identification of ice crystals in the visible cloud layer. The Ionospheric Model requires electron densities of about 10^9 cm^{-3}; no appropriate ionization source seems available. Furthermore, in order to explain the existence of radar returns from Venus, it must be postulated that a hole exists in the night-time ionosphere of Venus. To decide the correctness of the models proposed, searches for the following critical experimental data (to be obtained from space probes) are recommended: (1) microwave limb-brightening; (2) microwave emissions phase effects; (3) active radar phase effects; (4) twilight airglow; (5) infra-red emission windows; and (6) polarimetric and spectrometric characterization of the visible cloud layer.

Dr E. J. Öpik

Dr Sagan has already given a brief review of my model of the atmosphere and aeolosphere of Venus which does justice to my work (**1, 2, 3**) except for a few details. I have used about 25 different observational criteria; all of them agree with, or are accounted for by my model, none contradicting. This cannot be said about some other models which often disregard, or choose to alter, contradicting observational evidence.

The evidence is heavy against any significant amount of water vapour in the Venusian atmosphere. Spectrophotometric and photometric data, including the distribution of light on the disk of the planet, suggests that its clouds cannot consist of water droplets or ice crystals, but rather of dust stirred up from the surface. Calcium and magnesium carbonates may be the chief ingredient of the dust.

The low albedo in the ultra-violet, the CO_2 absorption bands at 0·80, 1·05, 1·20, 1·43 and 1·60 μ from which atmospheric pressure at reflecting level could be estimated, the temperatures derived from the rotational bands of CO_2 at 0·8 μ and from thermal radiation at 8–13 μ as well as other data point to two main reflecting levels of the Venus clouds. The upper (ultra-violet) level, at a pressure of 0·08 atm. and a temperature of −39 °C., is about 13 km above the lower or main (visual) level, where the pressure is 0·6 atm. and the temperature around +67 °C. The surface is about 22 km below the main cloud level; the surface temperature is that of the microwave observations, + 300 °C., and the pressure is of the order of 4·5 atm. The region between surface and clouds is packed with dust stirred up by the winds. The dust prevents any significant amounts of solar radiation from reaching the surface where the only source of heating is wind friction (still by two orders of magnitude greater than the internal heat supply). Hence the name "aeolosphere" proposed for this region.

A crucial point in the interpretation is the assumption that the observed microwave radiation originates at the planet's surface and provides a measure of its temperature. There have been reports of a strong variation of the microwave radiation with phase, implying a difference of several hundred degrees between the sunlit and dark sides of the planet, a difference which is not reflected in the infra-red thermal radiation. The probable error in the observations of the phase effect was large. If the observation is significant, it would mean that the radiation and the inferred temperatures do not refer to the surface. With the considerable atmospheric mass of the planet, even in the case of slow synchronous rotation, atmospheric currents would efficiently equalize the surface temperature within a few degrees centigrade, if some solar heat penetrates to the surface and within a few tenths of a degree if wind friction is the sole source of heat at the surface. Differences of some hundred degrees are impossible. Either the observations are inadequate, or the radiation (its variable component at least) does not come from the surface. I would prefer the first explanation; the alternative would make the microwave radiation a complete puzzle.

Commenting on recent radar observations of Venus from Jet Propulsion Laboratory, California, I would like to say that, if the narrow specularly reflected Doppler profile at 12·5 cm wave-length is interpreted by assuming a degree of smoothness of the windswept surface of Venus equal to that of the great plain on Earth and not that of the Moon, a period of rotation of the order of 10-30 days is still possible. The parallel band system observed in the ultra-violet at the upper cloud level, if ascribed to climatic zones due to Coriolis deflection of wind as on Earth, does not admit of a longer period. The same holds for the observed temperature-variation over the dark side of the planet, interpreted as nocturnal cooling (1). The mass of the atmosphere involved in nocturnal cooling is that overlying and closely adjacent to the main cloud level, where solar radiation is absorbed; it corresponds to a pressure of about 1 atm. irrespective of the mass below, which does not participate in the diurnal variation; the estimate holds therefore independently of the extent of the aeolosphere. In view of this, the radar observation rather proves the extreme smoothness of the solid surface of Venus, without giving a clue to the actual rate of rotation.

We have heard a report by Professor Martynov on similar U.S.S.R. observations which led to a period of rotation of the order of 10 days. Unfortunately the U.S.S.R. representative was unable to explain the technical details of the observations, or to comment on the discrepancy between the result and the American value. The U.S.S.R. radar wave-length was 38 cm. If at this wave-length diffuse scattering from the surface of Venus was stronger than in the American observation at 12·5 cm, and if the U.S.S.R. calculation was based on the total width of the diffusely reflected Doppler profile (stated to be 400 c/s) and not on the specularly reflected component, I think the U.S.S.R. and American results can be reconciled. [A later report by Professor V. A. Kotelnikov actually confirms this suggestion.] In any case, the period of rotation of Venus must be somewhere near 10 days and not synchronous with its period of orbital revolution.

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Dr E. F. McClain

Recent observations of the radio-emission of Venus at the Naval Research Laboratory in Washington are summarized:

1. Observations were made near the 1961 inferior conjunction at $\lambda = 4{\cdot}3$ mm by Grant and H. H. Carlbelt using a 10-foot reflector. The reductions are difficult and are not yet complete, but preliminary results indicate a black-body disk temperature from Venus of about 300-400 °K., very much like the previous results at $\lambda = 8$ mm.

2. A summary of the observations made at wave-lengths near 3 cm and 10 cm at the conjunctions of 1956, 1958, 1959 and 1961 by C. H. Mayer, T. P. McCullough and R. M. Sloanaker and at 3 cm at the conjunction of 1958 by L. E. Alsop, J. A. Giordmaine, C. H. Tounes was given. The new observations made between March 1961 and August 1961 are in preliminary form but verify the previous observations in the suggestion of a small decrease in black-body disk temperature, at inferior conjunction. It was also pointed out that no large variations in the radio-emission of Venus have been observed either day to day, hour to hour or year to year. Observations made with an antenna whose plane of polarization could be rotated gave a negative result, and show that the 3-cm emission of Venus is not linearly polarized by more than a few per cent.

Eléments de la deuxième Discussion

Le Professeur H. C. Urey, président de la Séance, ouvre la discussion en examinant le problème de la rugosité du sol de Vénus. Il est probable que les mécanismes du volcanisme sont du même ordre de grandeur sur Vénus et sur la Terre; le volcanisme crée un travail à la surface qui peut engendrer des reliefs accusés. Cependant, l'absence d'eau liquide supprime de nombreuses causes d'érosion et doit diminuer la rugosité. L'érosion aeolienne doit conduire à une diminution de la rugosité. En l'absence d'eau, le vent produirait des dunes régulières ainsi que l'a remarqué le Dr Öpik.

Le Dr C. Sagan, répondant à une question de l'assistance, précise que, dans les deux premiers modèles d'atmosphère qu'il a décrit (Greenhouse Model et Aeolosphere model), l'émission radio-électrique observée sur 8 mm doit provenir du niveau de la couche de nuages. Il faut supposer que la pression atmosphérique au sol est suffisante pour qu'il y ait absorption par le gaz ou bien intervention d'une autre cause d'absorption.

Le Dr E. J. Öpik confirme que, dans le modèle Aeolosphérique qu'il décrit, la radiation 3-cm est supposée venir du sol, les radiations infra-rouges comprises entre 8 et 15 microns de la partie supérieure des nuages, et la radiation 8-mm d'un niveau intermédiaire. Les voiles de poussière présents dans l'atmosphère doivent suffir à donner l'absorption nécessaire.

Le Professeur H. C. Urey pense que la couche supérieure de l'atmosphère pourrait contenir de l'oxygène et de l'oxyde de carbone; il envisage le cas de la formation ou de la décomposition de l'ozone.

Le Dr E. J. Öpik rappelle les mesures des magnitudes de Mars et Jupiter effectuées en fusée pour $\lambda = 2700$ Å. Les valeurs élevées trouvées indiquent une contribution importante de la diffusion moléculaire et par suite une transparence de l'atmosphère qui caractérise l'absence d'ozone. De semblables observations n'ont pas encore été effectuées sur Vénus Elles seraient très vivement souhaitées.

Selon le *Dr C. Sagan*, le CO_2 est déjà dissocié à l'altitude où se produisent les disparitions d'étoiles par occultation, et par suite il ne peut y exister d'ozone.

Le Professeur H. C. Urey examine le cas d'un excès de carbone; après perte de l'hydrogène, des molécules hydrocarbonnées pourraient subsister au-dessous des nuages. Il faudrait examiner s'il est possible de déceler des bandes de méthane ou d'éthane vers 3·5 microns.

Le Dr Sagan rappelle l'hypothèse proposée par Y. Mintz selon laquelle l'atmosphère toute entière pourrait être composée de CO_2, la surface étant un océan d'hydrocarbures recouvert de nuées absorbantes de même nature. Les observations spectrales ultra-violettes et surtout infra-rouges semblent exclure maintenant cette hypothèse.

Le Professeur H. C. Urey rappelle également l'hypothèse proposée il y a une douzaine d'années par R. Wildt, attribuant au formaldéhyde les nuages de Vénus. Il apparaît maintenant que CH_2O est trop peu stable et ne pourrait exister dans l'atmosphère qu'en quantité infime.

17. COMMISSION DU MOUVEMENT ET DE LA FIGURE DE LA LUNE

Report of Meeting, 17 August 1961

PRESIDENT: K. Koziel.

SECRETARY: Flora M. McBain Sadler.

The *Draft Report* was approved without modification.

The President read the following additional report received from Pulkovo Observatory:

'The photography of the Moon by the Markowitz method has been continued. An instrument for the automatic photo-electric measurement of these photographs has been constructed by N. F. Bystrov and used with great effect. A method was proposed for obtaining the figure of the lunar disk from photographs taken at full moon (or during an annular solar eclipse). H. I. Potter and N. F. Bystrov have found from the measurements of photographs taken on 1958 September 27-28 a value for the flattening of 1/1200, the major axis of the ellipse being directed towards the north-west in position angle 324°.'

The President proposed that the Organizing Committee for Commission 17 should consist of himself as President of the Commission, Th. Weimer as Vice-President, A. A. Nefediev and C. B. Watts; and this proposal was unanimously adopted.

He also reported that the Organizing Committees of Commissions 16 and 17—both interested in the problems of the Moon—agreed in a joint session to form several special-purpose committees consisting of the members of both commissions and of other interested astronomers. Of these the following two should operate as a part of Commission 17:

Selenodesy. Chairman: K. KOZIEL; Members: D. W. Arthur, M. S. Hunt, Z. Kopal, A. A. Mikhailov, H. I. Potter, G. Schrutka-Rechtenstamm, Th. Weimer.

Internal Structure of the Moon. Chairman: Z. KOPAL; Members: Harrison Brown, K. Koziel, G. P. Kuiper, B. J. Levin, G. J. P. MacDonald, E. M. Shoemaker, H. C. Urey.

The purpose of these committees is to provide certain specific information, the need for which has become evident at recent international meetings—such as the conference on the problems of lunar topography at Bagnères-de-Bigorre in April 1960, or the IAU Symposium No. 14 held at Leningrad in December of the same year. The creation of these committees was approved without dissention. The President then called on Professor Kopal to outline some of the proposed tasks.

Z. Kopal gave a brief account of the proceedings of a conference on current problems of selenodesy and topography of the Moon, which was held at the Observatoire du Pic-du-Midi between 19 and 23 April 1960. Dr Jean Rösch, Director of the Observatoire du Pic-du-Midi, acted as chairman of a gathering which included Drs Camichel, Campen, Carder, Dollfus, Hunt, Kearns, Kopal, Koziel, Rackham, Ring, Schrutka-Rechtenstamm and Weimer.

One of the main aims of this conference (the Proceedings of which, edited by Z. Kopal and E. B. Finlay, should shortly be available for distribution as an *Astronomical Contribution from the University of Manchester*, Series III, No. 90) has been to discuss the ways in which the existing systems of three-dimensional co-ordinates on the surface of the Moon could be improved in the near future. As a result of extensive discussions held on this occasion it was recommended:

(*a*) To reduce anew all past heliometric observations of the crater Mösting A with the aid of an electronic computer, in order to improve our present knowledge of the libration constants of the Moon. This task is to be undertaken shortly by Professor Koziel at the University of Manchester in England.

(*b*) To select a system of 100-200 lunar control points of second order, defined by the position of small craters (5-10 km in diameter) which are sufficiently shallow and geometrically well-defined to enable us to measure accurately their positions; and to employ the lunar plates taken with the Markowitz cameras during the IGY to determine the positions of such craters with respect to a fundamental frame of reference as represented by the neighbouring stars. This problem has since been under active investigation by Drs Weimer and Hunt.

(*c*) To use the shadows cast by the irregularities of the lunar surface in oblique illumination by the Sun for determination of relative heights above the osculating surface of the local mean selenoid (as defined by three or more adjacent points of second order). Extensive work along these lines has been in progress at the University of Manchester since 1958 (Professor Kopal and Mr Rackham), using photographic material secured at the Observatoire du Pic-du-Midi; and a comprehensive mathematical analysis of the problem is being published by Kopal in Chapter VII of the forthcoming compendium on *The Moon* (Academic Press, London and New York, 1961).

An interesting discussion followed in which Atkinson, Mikhailov, Markowitz, Heyden, Gold, Dollfus and B. C. Murray took part. It was emphasised that it was necessary to have measures of the control points both with respect to the Moon's limb and with respect to the stars. There were suggestions that it might be desirable to build large instruments specially for the purpose and, taking a long-term view, suggestions were made as to the use of artificial satellites for solving some of the problems involved.

Sir Harold Jeffreys gave a short account of his recent work on "The Figure of the Moon," a full account of which is published in *M.N.*, **122**, 421, 1961. In reply to a question from Eckert he confirmed that he had included Brown's additional terms in his work.

R. G. Hall presented a report on the Moon-Position Photographic Programme of the U.S. Naval Observatory. A total of 1118 plates taken at Washington from 1952 June to 1961 July 1 has been reduced. In connection with the IGY programme beginning 1957 July 1, other plates from various observatories have been measured as follows: U.S. Naval Observatory 1048, Cape Observatory 471, Paris Observatory 213, Royal Greenwich Observatory 116. In addition, plates have been received from Curacao, Hawaii, Helsinki, Mount Stromlo, Naini Tal, Ottawa, Perth, San Diego, San Fernando, Sao Paulo, Tokyo and Uppsala.

The results show strong systematic effects which are probably due to the fact that the shape of the Moon departs appreciably from sphericity. It is expected that these effects will be reduced when the limb corrections, being derived by Watts, are applied.

In a joint experiment with Essen and Parry of the National Physical Laboratory, Teddington, a value of 9 192 631 770 ± 20 cycles per second of E.T. was derived for the frequency of caesium, based on Moon observations made at the U.S. Naval Observatory from 1954·0 to 1958·5. A re-determination based on observations from 1955·5 to 1960·5 gives the same value within the errors of observation.

S. Arend fait part de ce que J. Dommanget, à l'Observatoire royal de Belgique, a tenté de déterminer la forme géométrique moyenne de demi-profils lunaires. Se servant de deux clichés obtenus en 1924, au moyen d'un héliographe par E. Delporte, et de trois clichés, pris en 1960 par lui-même à l'aide de l'équatorial de 45 cm d'Uccle (f = 7 m), il a représenté chaque fois une trentaine de mesures faites sur le pourtour de chaque demi-profil lunaire par

une ellipse en sorte que la somme des carrés des distances à l'ellipse des points mesurés soit minimale. Il a tenu compte de la réfraction différentielle. L'excentricité des ellipses et l'orientation des axes de celles-ci par rapport à la direction nord de l'axe de rotation de la Lune, sont les suivantes:

Date	Observateur	Profil	Excentricité	Angle au pôle
14 février 1924	Delporte	W	0·09	−17°·7
12 mars 1924	*id.*	W	0·08	−16°·5
17 février 1960	Dommanget	E	0·11	− 5°·3
6 mars 1960	*id.*	W	0·10	−32°·6
3 mai 1960	*id.*	W	0·15	−73°·4

La moyenne des excentricités se monte à 0·106 ± 0·024 (e.m.), ce qui correspond à un aplatissement de l'ordre de 1:180. Il y a surtout lieu de retenir que les grands axes sont tous situés dans le même quadrant, qui est celui où se trouve le cirque Tycho.

Weimer drew attention to the large discrepancy between this result and the value of 1/1200 obtained by Potter at Pulkovo. In reply to Buchar, Arend said that differential refraction had been applied. In the subsequent discussion, in which Dollfus, C. A. Murray, Mikhailov, Weimer and Markowitz took part, it was suggested that more plates at full moon or during annular eclipses were required, and that the separation of the east and west limb observations weakened the solution.

S. Arend signale encore qu'à l'Observatoire royal de Belgique, J. Dommanget et lui-même, ont été amenés à reconsidérer le problème de la détermination précise des instants des contacts extérieurs des éclipses de Soleil. A l'occasion des réductions des observations des éclipses du 1959 octobre 2 et du 1961 février 15, faites à Uccle par la méthode des cordes, il est apparu une similitude très nette entre les résidus trouvés par chacun des deux observateurs. J. Dommanget a montré que ceux-ci s'expliquent très bien par la présence des irrégularités du profil lunaire et que celles-ci peuvent affecter sensiblement, *de façon systématique*, les instants conclus pour les instants des contacts. S. Arend, considérant une éclipse fictive dans laquelle les effets des échancrures et des aspérités du bord lunaire furent numériquement introduits, a examiné diverses méthodes de calcul susceptibles de mieux moyenniser ces effets de façon à obtenir des résultats précis. Les deux auteurs ont été amenés à mettre au point des méthodes qu'ils espèrent utiliser avec succès au cours des prochaines éclipses.

J. Witkowski reported on a new method developed at Poznań Observatory for determining the Moon's physical libration. The basic idea is to determine the Moon's rotation relative to the stars by measuring the shadows of the lunar mountains in the vicinity of the terminator. The length of the shadow and its azimuth determine the selenographic co-ordinates of a mountain's summit for the time of observation, as the Sun's selenocentric co-ordinates are known. The Moon's physical libration may be derived from the differences in the selenographic co-ordinates thus obtained for different times of observation. In practice allowance has to be made for the fact that the shadows are distorted by the uneven surface of the Moon and that the azimuths are difficult to determine with sufficient accuracy. It is most convenient and effective to measure the shadows for great zenith distances of the Sun, when the length of the shadow is changing rapidly.

It is estimated that there are about 1000 suitable mountains on the Moon to which this method could usefully be applied. The method has the advantage of being free from errors due to irregularities of the Moon's limb. The details and necessary formulae are at present being developed, and a paper by W. Szulakowski giving full details should appear in 1962 in *Acta Astronomica.*

19. COMMISSION DE LA VARIATION DES LATITUDES

Compte rendu de la Séance, 19 août 1961

PRÉSIDENT: E. P. Fedorov.
SECRÉTAIRE: B. Guinot.

Programme de travail fixé par le Président:

1. Discussion sur la fusion des Commissions 19 et 31.

2. Discussion sur la réorganisation du Service International des Latitudes en Service International du Mouvement Polaire.

3. Approbation d'un Comité d'Organisation fixé comme suit: G. Cecchini, E. P. Fedorov, B. Guinot, W. Markowitz, C. A. Murray.

4. Réduction des observations de latitude faites à Rio de Janeiro de 1924 à 1931.

RAPPORT SUR LA SÉANCE

Le Professeur Fedorov signale que le rapport de la station d'Ukiah a été omis dans le *Draft Report*. Après cette correction, le *Draft Report* est adopté à l'unanimité. Puis on ouvre les discussions sur le programme indiqué ci-dessus.

Réorganisation du SIL

Le Professeur Fedorov rappelle deux résolutions prises à Moscou en 1958, concernant: (*a*) la publication d'articles sur la latitude; (*b*) l'organisation d'un symposium pour discuter de l'avenir du SIL.

Le symposium a été tenu à Helsinki en 1960. Une première série d'articles a été publiée par les soins de l'Académie des Sciences de l'U.R.S.S. (On the present state and the future of latitude investigations, Moscow, 1960). D'autres articles, ainsi que le compte rendu du symposium ont été publiés dans le *Bulletin Géodésique* (no. 59, 1961). A l'issue du symposium des résolutions ont été adoptées par l'UGGI. (voir p. 86). Ces résolutions doivent être maintenant discutées par l'UAI.

Le Dr Markowitz ouvre la discussion sur la résolution no. 5, dont il explique le sens. Ou bien le mouvement séculaire du pôle est réel et l'on doit utiliser une origine fixe, ou bien il ne l'est pas et l'on doit rapporter le mouvement au pôle moyen. D'où les deux modes de présentation contenus dans la résolution no. 5.

Le Professeur Fedorov signale que la résolution no. 5 ne contient pas une définition du pôle fixe. Il compare le problème du mouvement du pôle à la détermination du mouvement du pôle céleste sur la sphère des fixes, par l'observation des déclinaisons de 3 ou 4 étoiles seulement; il faut fixer un pôle initial. De plus, par suite des mouvements propres, on n'aurait pas une représentation du mouvement du pôle céleste. Or le Professeur Danjon a montré que les stations des latitudes variaient. Il est impossible d'avoir un pôle de référence fixe et la Commission 31 doit garder le pôle moyen.

Le Dr Stoyko dit qu'on doit aussi préciser la formule à utiliser pour calculer les coordonnées du pôle et qu'il y a, par exemple, de grands changements suivant qu'on utilise par formule avec le terme z ou sans.

Le Dr Markowitz estime qu'on doit laisser le détail des formules au Comité d'Organisation, mais il fait remarquer que, puisque les résultats ont été publiés avec le terme z, on doit inclure ce terme dans les formules.

Le Professeur Fedorov estime qu'on peut concevoir le même terme z pour les stations internationales mais non pour les stations indépendantes du SIR. Certains astronomes pensent même qu'il n'y a pas de terme z.

Le Dr Markowitz répond qu'il n'avait en vue que les résultats du SIL.

Le Professeur Danjon déclare que le Comité d'Organisation n'a pas à règler de questions scientifiques.

Le Professeur Mikhailov remarque, au sujet de la résolution no. 8, que l'étude proposée ne donnerait d'information qu'à un instant donné. Il demande ensuite le sens exact de la résolution no. 10.

Le Professeur Danjon rappelle les anomalies de la réfraction au cours de la nuit observées à Tananarive. Dans les résolutions 8 et 10, il faut entendre les variations avec le temps.

Le Professeur Mikhailov estime qu'on devrait alors le dire dans le texte de la résolution. D'autre part, l'étude de la gravité doit se faire dans la station même et non pas autour.

Le Professeur Danjon trouve que le texte établi est clair et insiste pour qu'on le conserve sans modifications.

En ce qui concerne la résolution no. 3, le Professeur Fedorov propose les statuts suivants pour le SIMP.

"*Buts du Service.* Le SIMP est une organisation scientifique placée sous l'autorité de la FAGS et chargée des travaux suivants:

(*a*) d'avancer l'étude de tous les problèmes relatifs au mouvement du pôle,

(*b*) de rassembler les observations astronomiques qui peuvent être utilisées pour déterminer ce mouvement,

(*c*) de les analyser et d'en faire la synthèse,

(*d*) de calculer les coordonnées du pôle,

(*e*) de distribuer les donnés sur demande,

(*f*) de publier les données initiales et les résultats obtenus."

Le Professeur Fedorov souligne que les résultats des stations indépendantes et des mesures de temps doivent être utilisés. Il rappelle qu'on était tombé d'accord à Helsinki sur le fait que l'organisation du SIL n'était pas satisfaisante parce qu'une seule personne était responsable. On avait proposé d'adjoindre au Directeur un Conseil Scientifique pour le conseiller sur les principes des méthodes à adopter. Le Professeur Fedorov propose l'organisation suivante:

"*Composition du Service:*

1. Le Service comprend un certain nombre d'observatoires astronomiques qui désirent coopérer dans l'étude du mouvement polaire en fournissant au Bureau de Calculs défini en (3) les données d'observation.

2. La direction scientifique est exercée par un conseil qui consiste en un Président nommé par FAGS et 5 membres: 2 représentants de l'UAI, 2 représentants de l'UGGI et le Directeur du Bureau de Calculs. Le Conseil doit déterminer les principes sur lesquels la détermination du mouvement du pôle doit être basée et conseiller le Directeur du Bureau de Calculs sur l'application de ces principes pour calculer les coordonnées du pôle.

3. Le Directeur du Bureau de Calculs doit:

(*a*) élaborer des méthodes pour combiner les données d'observation afin d'obtenir la polhodie et les soumettre au Conseil Scientifique du Service;
(*b*) rassembler les observations et calculer les coordonnées du pôle;
(*c*) fournir les résultats à ceux qui les désirent;
(*d*) tous les deux ans, présenter au Conseil Scientifique un rapport sur le travail effectué par le Bureau de Calculs et s'enquérir des modifications qui devraient être apportées aux méthodes et à l'organisation du travail;
(*e*) publier les coordonnés du pôle ainsi que les données brutes d'observation à partir desquelles elles sont calculées et décrire la méthode employée."

Le Dr Markowitz demande si le Conseil Scientifique diffère du Comité d'Organisation de la Commission.

Le Professeur Fedorov répond que le Conseil Scientifique est responsable non seulement devant l'UAI, mais aussi l'UGGI. Le Professeur Fedorov lit ensuite une lettre du Professeur Cecchini: le Professeur Cecchini a accepté de conserver la direction du SIL jusqu'en 1962 et de réduire les observations de la période 1942–1962 mais il n'a pas l'intention de rester au delà. Il se pose donc le problème du choix d'un nouveau directeur. C'est le Comité Exécutif de l'UAI qui décidera.

Le Dr Randic demande quelle est l'opinion du Comité Exécutif.

Le Professeur Fedorov donne la liste des pays candidats: Belgique (s'est retirée), Etats-Unis, France, Japon, Union Soviétique. Il ne peut rien dire de plus.

Le Professeur Mikhailov demande qu'on adresse une lettre de vœux au Professeur Cecchini Il a l'approbation générale.

Finalement aucune modification aux résolutions approuvées par l'UGGI n'a été apportée et ces résolution sont adoptées par la Commission.

Réduction des observations de Rio de Janeiro

Le Professeur Fedorov rappelle qu'une série d'observations a été faite à Rio de Janeiro, mais qu'elles n'ont pas été réduites. Les astronomes brésiliens demandent qu'on les aide à achever les calculs. Il s'agit d'observations faites suivant la méthode de Talcott avec une lunette zénithale des latitudes.

Le Dr Moraes ajoute que ces observations sont en grand nombre (plus de 10 000 passages).

Le Professeur Mikhailov demande si les astronomes de Rio souhaitent l'aide de l'UAI ou d'une organisation locale et le Professeur Fedorov demande quelle résolution serait utile.

Dans la discussion qui suit, le Dr Moraes précise qu'il serait suffisant que l'UAI affirme que la réduction de ces observations serait utile. Il demande aussi le concours d'une personne pour participer au travail.

Approbation du Comité d'Organisation

La liste de noms proposée est approuvée.

Fusion des Commissions 19 et 31

Le Dr Markowitz rappelle que la proposition de réunir les Commissions 19 et 31 fut faite par le Professeur Fedorov. Le travail des deux Commissions est très lié et il y aurait des avantages certains à les réunir.

Le Dr Markowitz donne son opinion: il trouve que cette fusion n'est pas souhaitable pour deux raisons:

(*a*) Le travail sur le temps comprend l'étude de la vitesse de la rotation de la Terre, mais aussi des problèmes qui n'ont pas de point commun avec la variation de la latitude: temps des éphémérides, signaux horaires, méthodes de contrôle des fréquences.

(*b*) Le travail du Président de la Commission deviendrait trop lourd. Il pense qu'une fusion serait en tous cas prématurée. Il remarque en outre que les commissions fusionnées devraient dépendre aussi de l'UGGI.

Le Professeur Danjon appuie le projet du Professeur Fedorov.

Le Professeur Fedorov indique brièvement les raisons de sa proposition. Le mouvement polaire et la vitesse de rotation de la Terre doivent être traités en un seul problème, comme l'a fait C. A. Murray, par exemple. Ce problème doit être envisagé par une seule commission.

Les opinions étant partagées, on procède à un vote des membres de la Commission 19: 3 votants approuvent le projet du Professeur Fedorov, 5 le repoussent.

Le Professeur Witkowski estime que la fusion proposée est prématurée.

Le Professeur Fedorov propose alors une résolution dont le sens est le suivant: La Commission 19 reconnait qu'il est souhaitable en principe de fondre les Commissions 19 et 31, mais qu'il est nécéssaire de repousser cette fusion à la prochaine Assemblée Générale de l'UAI. Cette résolution est adoptée.

Au Professeur Witkowski qui propose de changer le nom de la Commission 19, le Dr Markowitz répond que c'est inutile tant qu'il n'y a pas de réunion avec la Commission 31.

20. COMMISSION DES POSITIONS ET DES MOUVEMENTS DES PETITES PLANETES, DES COMETES ET DES SATELLITES

Report of Meetings

PRESIDENT: S. Arend.

SECRETARY: P. Herget, with the assistance of E. Rabe.

INTERPRETER: S. D. Gossner, for first meeting; J. Kovalesky, for second meeting.

First meeting, 18 August 1961

President S. Arend opened the meeting and welcomed the members present. He paid tribute to the following deceased members of the Commission: A. Dubyago, A. Patry, and Mlle J. Vinter Hansen. He announced the selection by the Executive Committee for the coming triennium of Paul Herget as President, and Mme Yakhontova as Vice President. The following were elected as members of the Organizing Committee of the Commission: S. Arend, D. Brouwer, F. K. Edmondson, W. Fricke, H. Hirose. The following were elected as members of the Working Committee for Comets: J. G. Porter, Chairman; M. P. Candy, F. Kepinski, L. Kresak, S. G. Makover, and Miss E. Roemer.

The President then briefly reviewed the *Draft Report*, calling attention to a recent summary report of the observing programme of the Goethe Link Observatory, covering the years 1954–61 and prepared by F. K. Edmondson, and a manuscript collection of 2000 accurate positions of minor planets, recently reduced by Mme Laugier, Nice.

Referring to page 177, line 8, (see Vol. XIA) Miss Roemer indicated that an accuracy of $0^{\circ}{\cdot}25$ was needed, except that in unusual and special circumstances a search might extend to $1^{\circ}{\cdot}5$ on either side of the ephemeris. On page 179, line 9, for "doubles identifications" read "doubles designations". On page 183, line 16, read "Mlle E. Roemer s'efforce d'obtenir chaque fois au voisinage de la nouvelle lune une . . . ".

The President reiterated the importance of identifications, such as were made by the late A. Patry and others. It was reported that the "Identifizierungsnachweis" prepared at the Heidelberg Astronomisches Rechen-Institut will be printed before the end of the year. Herget exhibited a copy of "Elements of Unnumbered Planets", recently prepared at the Cincinnati Observatory.

The Chairman then invited discussion of the different recommendations and suggestions listed on page 186 of the *Report* (Vol. XIA).

Concerning page 186, item 1 was discussed, and the secretary offered to consult K. A. Thernöe, Copenhagen. Under item 2, Brouwer indicated that he simply thought that the matter should periodically be under review. Marsden referred to the need in cases of large eccentricity which can only be observed near perihelion, and Arend suggested that special ephemerides should be given in the MPCs. Under item 3, Herget described the method Patry used, and the justification for this request. Most of all, a successor to Patry is needed to make use of the accurate motions demanded in this recommendation.

Edmondson indicated that for pairs of plates more accurate motions could be given, without requiring the reduction of accurate positions. The President expressed the hope that the recommendation will be followed by all observers.

Herget summarized a report from Mme Yakhontova, which indicates that the Leningrad Institute of Theoretical Astronomy is prepared to produce ephemerides for 1059 planets; that for 238 other planets ephemerides are produced without perturbations; and that for 308 other planets the collaborators are expected to provide the ephemerides, namely Cincinnati, Tokyo, and for (1566), (1580), and (1620), S. Herrick. This is a considerable change in responsibility from the assignments adopted in 1948, and it is mentioned in order to give formal recognition to this new distribution of ephemeris computations, and to the large share assumed by the ITA.

The number of provisional designations assigned per year is now about half of what it was six or eight years ago, showing a substantial decrease in the total amount of minor planet observing. Herget suggested that a repetition of the Kuiper Survey of 1950–52 might be undertaken as an economical means of securing some reliable positions for nearly all of the ordinary minor planets.

Second meeting, 21 August 1961

The following resolutions were adopted:

Commission 20 recommends that the Minor Planet Center in Cincinnati continue issuing the Minor Planet Circulars, and that a sum of $750.00 per annum be made available for defraying the necessary expenditures. [This resolution was approved, and incorporated in the report of the Finance Committee.]

Commission 20 wishes to stress the importance of the work of identifications of minor planets, especially as carried on with such great success by the late A. Patry, and recommends most strongly that this work should be continued.

Concerning page 186, item 1 (see Vol. XIA) Thernöe has agreed to print a special IAU card, calling attention that telegraphic comet positions are understood to be referred to the equinox at the beginning of the year, unless another equinox is given in the place provided near the end of the message. It is therefore necessary to specify 1950·0 when this equinox is used, in accordance with the precepts of the formerly adopted resolution. Porter agreed that no formal action or changes are required.

Miss Roemer stated her willingness to observe, on request, faint satellites and special objects down to magnitude 18 (and in extreme cases to 20·5). J. Kovalevsky asked for observations of J VIII, Brouwer asked for J IX (for Hori's work); and Herrick expressed his appreciation for similar valuable observations made in the past. Wilkins inquired about observations of the satellites of Mars, and Kuiper described his series observed in 1952 and 1956.

Porter reported that the *Catalogue of Cometary Orbits*, 1960, will be off the press soon. He displayed a proof-copy. It contains 829 sets of elements; and much credit is due M. P. Candy, B. Marsden, and other BAA (British Astronomical Association) members for its completion and for their thorough efforts to remove errors of all sorts. The President extended to Dr Porter the thanks of the Commission for this valuable catalogue.

The Commission adopted items 4, 5, and 6 on page 186 (see Vol. XIA). The purpose of 5 (*a*) is to permit daily motions to be computed easily. Under 5 (*b*), Miss Roemer requested references, if possible, and she indicated that, in general, the effects of phase angle may be omitted.

Porter discussed briefly his report on page 188. He asked for reports of all cometary orbit work which is being undertaken. Some duplication of effort would be a good thing and would serve as a valuable check. He urged that we abandon the concept of a "definitive orbit" and the custom of granting "proprietary rights" to any one investigator who announces his intention to compute an orbit. The reports of Commission 20 and Sub-Commission 20*a* were adopted.

President Arend expressed the hope that Dr Porter's new position as Chairman of the Working Committee for Comets would serve to continue the good relations of the RAS (Royal Astronomical Society) and the BAA with the work of Commission 20. Upon his own retirement as President of the Commission he thanked all who had co-operated, both the theoretical workers and the observers, and expressed his wishes for a successful future of the Commission.

The meeting adjourned.

21. COMMISSION DE LA LUMINESCENCE DU CIEL

Report of Meeting, 18 August 1961

ACTING PRESIDENT: F. E. Roach.
SECRETARY: W. Steiger.

In the absence of Commission President J. Dufay, F. E. Roach served as Acting President. W. Steiger was appointed acting secretary for the meeting. The Executive Committee of the IAU has appointed D. Barbier as President and P. Swings as Vice-President for the next triennium. The Commission appointed the following as the Organizing Committee: Chamberlain, J. Dufay, Krassovsky, Nicolet, Roach. [At the request of Professor Swings, the Executive Committee later appointed F. E. Roach as Vice-President.]

The Commission regrets the loss by death of J. Cabannes.

BUSINESS SESSION

1. The question as to the proper Commission for the responsibility of zodiacal light studies was discussed. It was agreed that the zodiacal light should be the joint responsibility of Commissions 21 and 22. Commission 21 has a vital interest in the problem because of the presence of the zodiacal light as an important component in the light of the night sky. Commission 22 is concerned with the physical interpretation of the zodiacal light observations in terms of the distribution of particles in the solar system. Siedentopf was asked to head a Committee to report on the status of zodiacal light research at the next triennial meeting.

2. The Commission concurred in a recommendation by Chamberlain that Commission 21 should sponsor a symposium on the theoretical interpretation of upper atmosphere emissions sometime before the next triennial meeting. A symposium committee consisting of Chamberlain (chairman), Blamont, Krassovsky, and Nicolet was appointed. Preliminary discussion indicated the desirability that this symposium be held in Paris in June or July 1962.

3. S. Chapman presented the following resolution which was approved by the Commission:

"Commission 21 urges that inactive all-sky cameras be set up at night-sky stations even in geomagnetic latitudes as low as 30°. They should be put in operation on rare occasions when auroras become visible."

RESEARCH REPORTS

1. *D. Barbier.* A summary of the night-sky phenomena at 6300 Å from sunset to sunrise was presented. The discrete phenomena which have been isolated include the pure twilight effect, the western sheet, the sub-polar sheet, the intertropical arcs, and the stable mid-latitude auroral arc. The western sheet and inter-tropical arcs are very well correlated with ionospheric data. (D. Barbier, *Ann. Géophys.*, **17**, 3, 1961).

2. *A. Delsemme* reported on studies of the 6300 Å emission at Lwiro (Congo). In particular he stressed the relationship between the intensity of 6300 Å and F-region ionospheric parameters. (A. and D. Delsemme, *C. R. Acad. Sci. Paris*, **250**, 383, 1960).

3. *J. Dufay, M. Dufay* and *Nguyen Huu-Doan.* See appended paper.

4. *L. Wallace.* A review was given of upper atmosphere temperature based on studies of OH rotation-vibration bands. The interpretation of temperature changes being accounted for by the $H + O_3$ reaction was challenged.

5. *L. Fishkova* (presented by E. K. Kharadze). See appended paper.

6. *H. Elsässer.* A discussion was held on the discrepancy between the measured intensity of the Milky Way (Elsässer and Haug, *Z. Ap.*, **50**, 121, 1960) and the predicted intensity from star counts (Roach and Megill, *Ap. J.*, **133**, 228, 1961).

7. *H. Siedentopf* reported on the present situation of the zodiacal light observations and discussed the possibilities of getting new information by observing from high-flying airplanes and satellites. He then discussed the optical properties of different models for the interplanetary medium consisting of dielectric and metallic particles and free electrons. The discussion of the dependence of brightness and polarization on the elongation was based on calculations of the scattering functions of spherical particles of H_2O, SiO_2, Fe, Ni made at the Astronomical Institute of the University of Tübingen by Dr R. H. Giese with an electronic computer. The paper will appear in *Z. Ap.*

8. *N. Richter.* Recent laboratory studies of scattering by particles of various kinds were briefly reported. (See report of meetings of Commission 22.)

9. *H. Tanabe.* A study of the gegenschein from observations at Maruyama (Japan) and at Fritz Peak (U.S.A.) indicated a seasonal variation of intensity and position consistent with the hypothesis that the intensity is a function of the distance of the Earth from the invariable plane of the solar system.

VARIATIONS D'INTENSITÉ DE LA RAIE Hα DANS LE SPECTRE DU CIEL NOCTURNE

Jean Dufay, Maurice Dufay et Nguyen Huu-Doan

Nous avons étudié systématiquement, à l'Observatoire de Haute Provence (latitude N.43°56′, longitude E.23^m, altitude 680 m), les variations d'intensité de la raie Hα dans le spectre du ciel nocturne. Le collimateur du spectrographe à réseau précédemment décrit *C.R. Acad. Sci. Paris*, **250**, 4191, 1960 (dispersion 49Å/mm) était dirigé directement vers le ciel, à 15° de l'horizon nord. Un léger voile préalable des films Eastman-Kodak 103aE nous permet d'abréger les poses et d'obtenir un spectre en une seule nuit; l'été nous avons du en outre élargir un peu la fente, dont l'image sur le spectre est ainsi passée de 1·5 à 2·2 puis 2·5Å.

Les 28 spectrogrammes obtenus du 12 janvier au 17 juillet montrent tous la raie Hα fine, entre les raies de rotation $P_1(3)$ et $P_2(4)$ de la bande (6,1) de OH. (La présence de la Lune au-dessus de l'horizon pendant une partie de la pose doit être évitée, car elle a pour effet de réduire l'intensité de la raie Hα, qui apparait en absorption dans le ciel lunaire. Les clichés de 1960 qui ne montraient pas la raie Hα avaient été influencés par un faible clair de Lune.) De janvier à mars, son intensité a augmenté assez régulièrement par rapport aux autres émissions nocturnes et est passée par un maximum en avril. Elle a diminué ensuite plus rapidement et parait s'être stabilisée en juin et juillet. La raie était particulièrement forte du 9 au 18 avril. Le 16 et le 18 son intensité photographique dépassait celle de toutes les composantes de la bande OH (6,1) et atteignait presque l'intensité de [O I] 6364Å (figure 1(*b*)).

En nous basant sur les intensités absolues moyennes des raies de la bande OH (6,1) données par G. Kvifte (*Geofysiske Publikajoner*, **20**, no. 12, 1959.), nous pouvons estimer qu'à 15° de l'horizon nord, l'intensité de Hα a varié de 5 à près de 20 rayleighs de janvier à avril 1961. C'est exactement l'amplitude trouvée par S. Prokudina à Zvenigorod (latitude de 51° N.) (Voir *Trans. IAU* **11A**, 191, 1961). A Alma-Ata, en décembre 1957 et janvier 1958, R. X. Haynoullina et Z. V. Kariahina (*Acad. Sci. Kasakstan. Informations de l'Institut d'Astrophysique*, **10**, 52, 1960) ont mesuré, pour Hα à 20° de l'horizon, des intensités comprises entre 4·1 et 6·4 rayleighs.

Nous ne trouvons aucune relation entre l'intensité de Hα et celles d'autres radiations de la luminescence nocturne: [O I] 5577, [O I] 6300–6364, Na (D), bandes de OH.

Seule la raie [N II] 6583 Å, présente sur 15 de nos clichés (entre janvier et mai), se trouve visiblement renforcée en même temps que Hα, comme l'a déjà noté Kvifte (*loc. cit.*), lorsqu'il a signalé, pour la première fois, la présence des raies interdites de N II dans le spectre du ciel nocturne (voir figure 1(*b*)).

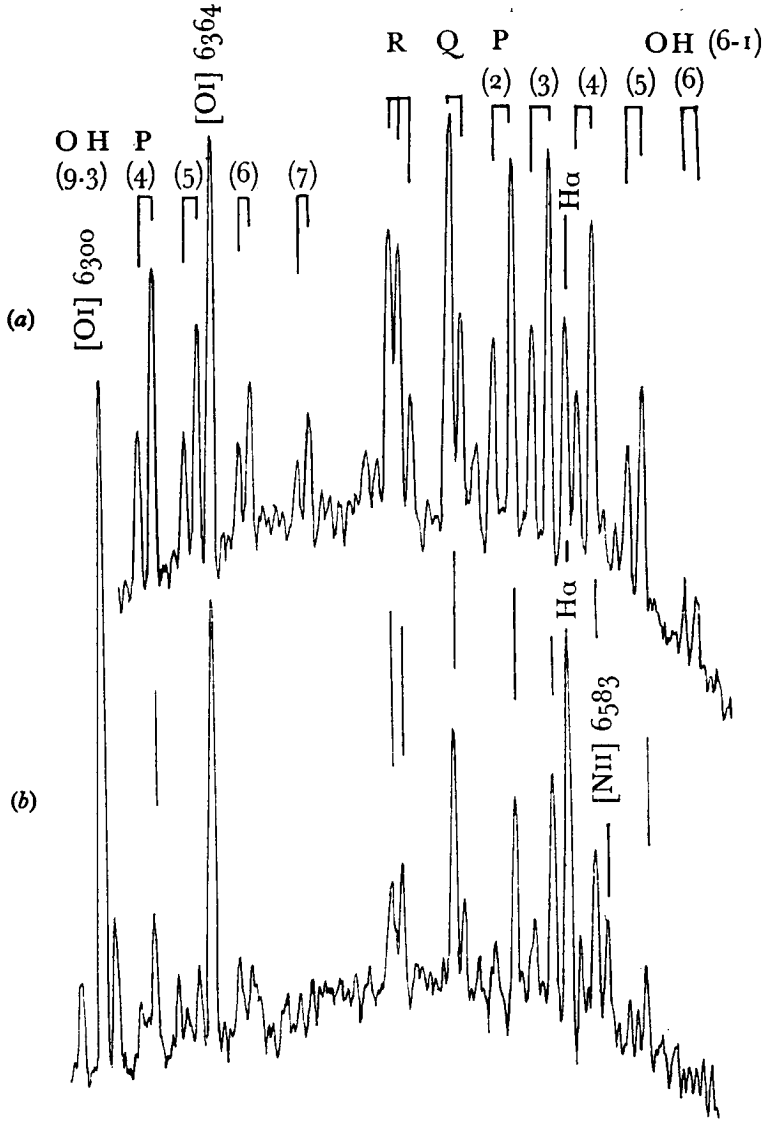

Fig. 1 (*a*) Spectre du 12 janvier 1961 (pose 10 heures).
(*b*) Spectre du 18 avril 1961 (pose 6 heures 45 minutes).

Nos observations ne montrant aucune corrélation entre l'intensité de la raie Hα et l'agitation magnétique et l'activité solaire, il importe d'examiner la contribution possible des régions

galactiques H II qui peut être importante en raison du champ assez restreint du spectrographe à réseau. (C'est elle que nous avions invoquée pour expliquer la présence de la raie Hα sur un de nos spectres du ciel à faible dispersion pris en 1949; J. Cabannes, J. Dufay et M. Dufay, *C.R. Acad. Sci. Paris*, **230**, 1233, 1950). Compte tenu de l'ouverture angulaire du collimateur et de la longueur de la fente horizontale, la région du ciel dont on photographie le spectre correspond à une aire d'un peu plus de 30 degrés-carrés (4°·5 en hauteur, près de 7° en azimut). Les régions H II de déclinaison comprises entre 58°·75 et 63°·25 peuvent donc intervenir; elles traversent le champ en un peu plus de 1 heure. (Notre spectrographe fonctionne ainsi à la manière des spectrographes nébulaires de Struve, mais avec un champ beaucoup plus étendu; *Ap. J.*, **86**, 614, 1937.)

Si les régions H II étaient, en moyenne, uniformément réparties entre deux petits cercles parallèles au plan galactique, l'intensité de la raie Hα serait proportionnelle à la durée du passage dans le champ de la zone considérée. Les courbes obtenues en calculant, pour diverses époques, la durée du passage de la zone galactique comprise entre les latitudes + 10° et −10°, ou +5° et −5°, ressemblent effectivement à la courbe figurant les variations de l'intensité de Hα en fonction du temps: même croissance progressive de janvier à avril, même décroissance plus rapide ensuite. La durée du passage est maximum vers les 16–18 avril.

Mais le fait qu'en juillet la Voie Lactée ne passe plus dans le champ semble bien indiquer qu'à partir de cette époque la raie observée, dont l'intensité parait alors stable, est uniquement d'origine atmosphérique ou géocoronale.

Les régions H II brillantes et étendues susceptibles de passer dans le champ sont en nombre restreint: il s'agit principalement du groupe de nébulosités voisines de NGC 7635 ($\alpha \approx 23^h18^m$, $\delta \approx +60°49'$, 1961·0), de IC 1805 ($\alpha = 2^h31^m$, $\delta = +61° 20'$) et IC 1848 ($\alpha = 2^h54^m$, $\delta = +61° 18'$). Le premier groupe intervient de janvier jusqu'à la fin d'avril, IC 1805 de février au début de juin, IC 1848 de mars jusque vers le 15 juin. La durée du passage des 3 régions H II atteint son maximum en mars et en avril. A temps de pose constant leur influence serait sensiblement la même durant ces deux mois. Mais les poses duraient environ 9 heures en mars et 6·5 heures seulement en avril. Par suite l'intensité de la raie Hα reçue pendant la durée constante du passage des nébuleuses, doit devenir plus grande par rapport aux autres émissions nocturnes, quand la durée totale de la pose est réduite.

Une vérification intéressante peut être fournie par la mesure de la vitesse radiale de la raie Hα, mais nos clichés ne permettent pas de la déterminer avec précision. Les mesures paraissent cependant significatives lorsque la raie est assez forte. Ainsi nous trouvons respectivement le 16 et le 18 avril $V_r = -23$ et $V_r = -18$ km/s, avec une erreur certainement inférieure à ± 10 km/s. Courtès (*Ann. Ap.*, **23**, 115, 1960) a mesuré, par interférences, la vitesse radiale héliocentrique de Hα dans IC 1805 et IC 1848: −48·0 et −32·8 km/s. Compte tenu du mouvement orbital de la Terre, ces valeurs conduisent pour le 18 avril aux vitesses radiales géocentriques −37·2 et −19·5 km/s, avec lesquelles nos mesures s'accordent assez bien.

Deux spectres de février et trois spectres de juillet, où la raie Hα est faible, et les mesures incertaines, nous donnent au contraire des vitesses radiales sensiblement nulles: −6 km/s et −4 km/s, avec une incertitude d'au moins ± 10 km/s, comme si la composante atmosphérique ou géocoronale de Hα était alors prépondérante.

L'interprétation des spectres publiés par Kvifte (*loc. cit.*) confirme d'une manière tout à fait probante la contribution des régions H II. Ses poses ont été faites à Ås, Norvège (latitude N. 59°40', longitude E.43^m), dans des azimuts et à des hauteurs variés, en projetant au moyen d'un objectif à court foyer, l'image du ciel sur la fente verticale du spectrographe immobile, (dispersion 35 Å/mm). Les indications données par l'auteur permettent en général d'identifier les régions du ciel observées.

Parmi les 8 clichés reproduits, deux montrent la raie Hα forte sur toute la hauteur de la fente, la première avec une condensation locale marquée, où [N II] 6583 est aussi renforcée. Pendant la seconde moitié de cette pose (no. 3, 20 janvier 1958, durée 2^h30^m), la région d'Orion, couverte de plages d'émission est passée dans le champ et la condensation peut correspondre à la grande nébuleuse. Pendant la pose no. 4 (21 janvier 1958, durée 5^h10^m), la Voie Lactée était presque constamment dans le champ, en particulier au Nord de α Cygni (avec la nébuleuse América NGC 7000) où les régions H II sont aussi très brillantes et étendues.

Un troisième cliché (no. 1, 16 janvier 1958, pose 10 heures) où la raie Hα est faible sur presque toute la hauteur de la fente, montre un renforcement très localisé mais très intense de Hα, [N II] 6583 et [N II] 6548. La Voie Lactée a traversé le champ pendant peu de temps dans la région d'Orion.

Un spectre (no. 8, 16 février 1958, pose 7^h15^m), dont la définition est particulièrement bonne, présente au contraire une raie Hα très faible (plus faible que la raie $P_2(4)$ de la bande OH (6,1)). Il a été pris entièrement hors de la Voie Lactée.

Les 4 autres spectrogrammes, où l'intensité de Hα est tantôt comparable à celle de $P_2(4)$, tantôt à celle de $P_1(4)$, correspondent soit à des poses faites à des latitudes intermédiaires, soit à des poses où des régions galactiques souvent pauvres en émission, sont passées rapidement dans le champ.

Nous avons entrepris de répéter ces observations, en projetant l'image du ciel, avec un objectif de courte longueur focale, sur la fente de notre spectrographe, monté sur une table équatoriale qui suit le mouvement diurne. Les deux premiers spectres obtenus ainsi en visant près de α Cygni (6 et 7 août 1961) montrent très nettement la raie Hα et la raie N II 6583 localisée aux environs de la nébuleuse América. Hα est beaucoup plus forte que les raies atmosphériques [O I] 5577 et 6300 Å qui s'étendent uniformément sur toute la longueur de la fente. La durée des poses (4^h45^m) était trop courte pour faire apparaître, près du zénith, les bandes de OH et — a fortiori — la raie Hα si elle est aussi émise dans la haute atmosphère.

En résumé, les importantes variations d'intensité de la raie Hα, observées en Haute Provence, de janvier à juillet 1961, en visant à 15° de l'horizon nord, doivent être attribuées essentiellement au passage de régions H II dans le champ du spectrographe et l'attention des géophysiciens doit être attirée sur la contribution des émissions galactiques, qui dépend naturellement de la région visée, mais aussi de l'ouverture relative du collimateur du spectrographe.

Il n'est donc pas encore possible de se prononcer sur l'importance réelle des variations propres de la raie Hα atmosphérique ou géocoronale, dont l'existence est par ailleurs bien confirmée par les poses faites hors de la Voie Lactée.

Le rapport des intensités de la raie près de l'horizon et près du zénith (en dehors de toute région H II) pourra renseigner sur l'altitude de cette émission. Les premières observations seraient en faveur d'une origine atmosphérique plutôt qu'interplanétaire ou même géocoronale.

La covariance des raies Hα et [N II] 6583 Å s'explique aisément si cette dernière ne provient que des régions H II, où elle accompagne habituellement Hα. Mais on ne sait pas encore si les raies interdites de N II sont émises ou non, avec une faible intensité, dans la haute atmosphère.

ON INVESTIGATIONS OF THE INTENSITY OF THE OH BANDS, OH ROTATIONAL TEMPERATURE AND Hα 6562 Å EMISSION LINE IN THE NIGHT AIRGLOW

L. M. Fishkova

Observations of airglow had been systematically carried out at the Abastumani Astrophysical Observatory (of the Georgian Academy of Sciences) during 1953–60. (**1,2**).

Electro-photometric observations of the OH emission were carried out in near infra-red (9000–10550Å). The total absolute intensity of the OH bands (8–4), (3–0), (9–5), (4–1) in kilo-rayleighs (kR) was measured. This intensity changed considerably during the period of investigation from minimum value ~ 9 kR (March 1954) to maximum value 38 kR (November 1958) and its mean value was equal to 19·5 kR. Seasonal variations of intensity of the OH bands were observed with the greatest maximum in November, and some maxima, with smaller amplitude, having a tendency to appear in July, August or September. The minimum of OH emission takes place in March, April or May. The seasonal variations of intensity have the character of sharp emission flashes, occurring at the same time of every year.

A connection of the intensity of the OH emission (I_{OH}) with solar activity was detected. (From January 1953 to December 1960, I_{OH} was changing parallel to solar activity; at the time of minimum (1954–5), the mean annual value of the total absolute intensity of the OH bands (8–4), (3–0), (9–5), (4–1) was 15 kR and at the time of maximum (1958–9) it was 23·6 kR).

(In the years of minimum solar activity the seasonal variations are smoother, the minimum in April and the maximum in November appearing quite distinct; in the years of maximum solar activity great perturbations are observed, many additional maxima appear but the November maximum is as usual the largest).

The seasonal variations of OH rotational temperature (T_{OH}) were obtained. (The mean value of T_{OH} for Abastumani ($\phi = 41° 45'$ N.) during 1958–60 was equal to 240° ± 10° K. T_{OH} had a minimum in summer (220° K) and reached a maximum value in November (290° K); the latter coincided with the main seasonal maximum of intensity of the OH bands. In summer, T_{OH} is low and the dependence between T_{OH} and I_{OH} is absent. But when $T_{OH} < 250°$ K, I_{OH} depends on T_{OH} and a linear dependence between log I_{OH} and $1/T_{OH}$ is observed.

The activation energy for the reaction working in this case was calculated from the slope of the straight line (log I_{OH}, $1/T_{OH}$) and found to be 2·2 ± 0·6 kcal/mol. This value is close to the activation energy of the ozone-hydrogen reaction. It is possible that this reaction is mainly responsible for the November maximum of the OH emission.

The ratio of the intensity of the OH bands, OH(9–3)/OH(6–1), has been measured. This ratio decreases from a value $\sim 2{\cdot}0$ in January 1958 to a value $\sim 0{\cdot}8$ in May 1959.

The variations of 6562 Å H I narrow-line intensity in the airglow spectrum during 1958–60 were investigated. This line is always present in the airglow spectrum, but its intensity changes considerably during the year. At the direction of observations $z = 67°$N., Hα intensity is minimum in winter (~ 2 R) and maximum in summer, in July (20–30 R).

From simultaneous observations in two directions, $z = 70°$N and $z = 20°$S., a value of the ratio $I_{H\alpha}(70°)/I_{H\alpha}(20°) = 1{\cdot}73 \pm 0{\cdot}14$ was obtained. This result is in good accordance with the hypothesis of narrow Hα origin in the airglow spectrum, as a result of resonance scattering of the solar Lα in the geocorona and in the upper atmosphere at altitudes of 80 – 120 km, and also with Lα – isophotes obtained from rocket measurements.

If one excludes the November data (maximum OH) and July data (maximum Hα), then a noticeable correlation between $I_{H\alpha}$ and I_{OH} is observed.

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22. COMMISSION DES METEORES ET DES METEORITES

Report of Meetings

ACTING PRESIDENT: L. Kresák.
SECRETARY: J. G. Davies.

First meeting, 16 August 1961

The meeting was opened by Dr Kresák explaining that the Executive Committee had asked him to be Acting President of the Commission, as Dr Fedynsky was unfortunately unable to attend.

The future of the present two Sub-Commissions, 22*a* and 22*b*, was discussed with regard to the changes of the By-Laws of the Union. At a suggestion by Dr Whipple it was agreed that Sub-Commission 22*a* should become a 'Committee on Meteorites' within Commission 22. The main task of this Committee should be to produce a three-yearly review of work in the field of meteoritics and to provide a point of contact with meteorite experts who are not astronomers. At a suggestion by Dr Millman it was agreed that Sub-Commission 22*b* should become a 'Committee on Terminology and Notations' within Commission 22, with the task of unification of the terminology and notations used in meteoric literature in different languages.

The recommendations summarized by the President in the *Draft Report* were discussed; several additional recommendations have been submitted and considered. At a suggestion by Dr Whipple it was agreed to combine the original four recommendations, relating to future observations by means of the artificial Earth satellites into a single, more general resolution. The final version of the recommendations, as discussed, amended and approved, is printed at the end of the present report.

Dr Richter drew attention to the lack of attention to problems of the Zodiacal Light by any Commission of the IAU. The extent to which studies of the Zodiacal Light should be included in the reports of Commission 22 was considered. It was felt that observations of the Zodiacal Light are rather more within the scope of Commission 21; however, investigations into the physical nature of the Zodiacal Cloud, as one of the components of interplanetary matter, should be reported by Commission 22 in the future.

Second meeting, 19 August 1961

Proposals for the President, Vice-President and Organizing Committee of Commission 22, and for the Presidents and Vice-Presidents of the two Committees, were submitted by the Acting President and approved by the members of the Commission as follows:

COMMISSION 22: Dr V. V. Fedynsky, President; Dr P. M. Millman, Vice-President; Dr Z. Ceplecha, Dr A. C. B. Lovell and Dr F. L. Whipple, Members of the Organizing Committee.

COMMITTEE ON METEORITES (22*a*): Dr E. L. Fireman, President; Dr E. L. Krinov, Vice-President.

COMMITTEE ON TERMINOLOGY AND NOTATIONS (22*b*): Dr L. G. Jacchia, President; Dr B. Y. Levin, Vice-President.

Changes in the membership of the Commission and the appointment of the members of the Committees were left to the new Organizing Committee. The President, in co-operation

with the Organizing Committee, will prepare a current list of the members of the Commission for the *Transactions*.

The *Draft Report*, having been distributed among the attendants at the first session on 16 August, was discussed section by section. Some changes and additions were proposed and approved. The Acting President and the Secretary will correct the proofs accordingly and submit them to the President.

Taking into account the International symposium on the 'Astronomy and Physics of Meteors' to be held at the Smithsonian Astrophysical Observatory immediately after the General Assembly, the scientific programme of the meeting was restricted to one report, presented by Dr N. Richter. Dr Richter reported on his laboratory experiments on the optical properties of clouds of particles of different composition, size, shape, and concentration, including specimens of meteoritic matter. The values of the albedo and polarization at different phase angles, as obtained by Dr Richter, were presented in a series of diagrams.

RECOMMENDATIONS

1. To study experimentally in laboratories, and also by means of rockets and satellites, the physical parameters entering into theoretical and analytical work on meteor investigations, namely:

(*a*) the accommodation coefficients for gases and solids in the range 1 eV – 100 eV;

(*b*) the inelastic excitation and ionization cross-sections for atom-atom collisions;

(*c*) the macroscopic behaviour of the excitation mechanism (air-density dependence of the luminosity-producing mechanism).

(Proposed by R. N. Thomas, F. L. Whipple.)

2. To undertake observations of micro-meteorites from Earth artificial satellites and cosmic rockets in order to determine:

(*a*) the energy and momentum of the particles simultaneously;

(*b*) the distribution of radiants;

(*c*) the variations in rate, particularly at the times of meteor showers; and to collect and recover micro-meteoric particles.

(Proposed by T. R. Kaiser, L. Kresák, Z. Ceplecha, S. Chapman.)

3. To realize the study of the physical properties of the first suitable bright comet, using direct measurements by means of a cosmic rocket which penetrates to the comet. (Proposed by Z. Ceplecha.)

4. To undertake special radio-echo observations of meteor numbers, simultaneously with the recording of micro-meteorites using Earth artificial satellites. (Proposed by S. M. Poloskov.)

5. To combine photographic, radar and spectral observations of meteors to obtain complete data of individual meteors, mainly with respect to the physical processes of meteor flights. (Proposed by Z. Ceplecha.)

6. To study telescopic meteors by photographic- and image-amplification techniques in the red spectral region. Such observations should be compared with telescopic, visual, and radar observations. (Proposed by Z. Ceplecha, C. L. Hemenway.)

7. To introduce systematic programmes of fireball photography with all-sky cameras equipped with rotating shutters and distributed at mutual distances greater than 100 km, in order to determine orbits and to recover newly-fallen meteorites. (Proposed by Z. Ceplecha.)

8. To realize the same programme of simultaneous photographic and radar studies of meteors in different latitudes, for comparative study of the physical parameters of the upper atmosphere. (Proposed by V. V. Fedynsky.)

9. To realize a wider distribution of meteor wind equipment to yield the large-scale circulation in the 80–100 km region. (Proposed by T. R. Kaiser.)

10. To study by all techniques the atmospheric regions of strong auroral luminosity and ionization, which may reveal new phenomena. (Proposed by S. Chapman.)

11. To use meteor trails simply as radar targets of the absorption and magnetoionic effects in the D-region of the ionosphere. (Proposed by T. R. Kaiser.)

12. To study the influences of interplanetary dust in promoting recombination of ions and electrons, or atomic combinations and reactions. (Proposed by S. Chapman.)

13. To ensure that amateur astronomers do not become discouraged or indifferent to visual observations of meteors for the determination of the hourly rate and magnitude distribution, and for the study of fireballs and persistent trains. (Proposed by C. P. Olivier.)

14. To refer and discuss in future all publications on Zodiacal Light as an important component of interplanetary matter and to keep contact on this subject with Commissions 12, 15, 20, 21, 43, and 44. (Proposed by N. Richter.)

22*a*. SOUS-COMMISSION DES METEORITES

Report of Meeting, 17 August 1961

PRESIDENT: F. L. Whipple.
SECRETARY: Z. Ceplecha.

The President reported that, in accordance with the decisions of the Executive Committee, the Sub-Commission would be dissolved. It had, however, been agreed that the Sub-Commission should become a 'Committee on Meteorites' within Commission 22.

22*b*. SOUS-COMMISSION POUR NORMALISER LA TERMINOLOGIE ET LES NOTATIONS CONCERNANT LES METEORES

Report of Meeting, 17 August 1961

PRESIDENT: P. M. Millman.
SECRETARY: L. Jacchia.

One meeting of Sub-Commission 22*b* was held in Berkeley at 16^h on 17 August, 1961, with an attendance of fifteen astronomers who are working in the field of meteoric astronomy. The *Draft Report* was carefully discussed and, in addition to some of those named in this report, the following contributed to the discussion: Miss M. S. Burland, A. F. Cook, J. G. Davies, G. Guigay, I. Halliday, C. L. Hemenway, Miss D. Hoffleit, C. Hoffmeister, J. Hoppe,

E. L. Krinov (by mail), P. G. Kulikovsky, E. J. Öpik, F. L. Whipple, Miss F. W. Wright. After some revisions to the *Draft Report*, a final report was adopted as reproduced in *Trans. IAU* **11A** p. 228.

Under definition J of Table 1 in the report, it is understood that the observed magnitude is corrected for distance to a standard of 100 km, and for atmospheric absorption to a standard of one vertical atmosphere. The word 'track' was informally suggested, and generally agreed to, for use in referring to the path of a meteor as it appears on a photographic plate.

The Sub-Commission is indebted to Dr L. Jacchia who acted as secretary and as general interpreter for any one of half a dozen or more languages.

23. COMMISSION DE LA CARTE DU CIEL

Compte rendu de la Séance du 17 août 1961

PRÉSIDENT INTÉRIMAIRE: Pierre Sémirot.
SECRÉTAIRE: W. J. Luyten.

Sémirot présente les excuses de Couderc, Président de la Commission 23, et celles de Paloque qui n'ont pas pu assister à la réunion. Les membres de la Commission formulent des voeux pour le prompt rétablissement de Couderc et lui témoignent toute leur sympathie.

Sémirot fait part du décès de Jules Baillaud et de Akbar Ali. Baillaud a consacré toute sa vie à l'astronomie et à sa mort sa famille a trouvé à son chevet les épreuves du catalogue de la zone $+35°$ qu'il préparait pour l'impression. La disparition de Baillaud est une perte cruelle pour la Commission 23 dont il fut le Président pendant de nombreuses années, mais son activité et son dévouement pour la science qu'il aimait doivent être un exemple pour les jeunes astronomes.

En exécution des décisions de l'UAI le Comité Exécutif a procédé aux désignations suivantes:

Président: P. Sémirot.
Vice-Président: G. J. Järnefelt.
Membres du Comité d'organisation: P. Couderc, A. N. Deutsch, F. Fernandez de la Puente, H. Kox, W. J. Luyten, H. W. Wood.

O'Connell qui avait été désigné regrette de ne pas pouvoir faire partie de ce comité à cause de ses multiples tâches.

Le programme des matières qui seront étudiées au cours de la réunion est écrit au tableau noir et comprend la discussion du *Draft Report*, la présentation du budget de la carte du ciel et l'examen de toutes les suggestions ou voeux émis depuis la parution du volume III (1928) des transactions de l'UAI. Les progrès accomplis dans les méthodes de mesures et de calculs et la mise en service de nouveaux instruments pourraient permettre l'exécution de travaux qui paraissaient impossibles.

DRAFT REPORT

Fracastoro désirerait la suppression du mot 'Turin' à la page 233. Il faudrait lire: un projet analogue est élaboré pour la zone de Catane.

Eichhorn désirerait inclure une note se référant à ses importants travaux sur les erreurs systématiques de la zone de Helsinki et de la zone Nord de Hyderabad. Cela est impossible puisqu'il est admis que le *Draft Report* ne doit subir que de légères modifications.

Sémirot présente une note de Paloque sur l'avancement des travaux exécutés à Toulouse.

Le *Draft Report* est adopté et Sémirot transmet les félicitations de Couderc aux astronomes qui ont travaillé consciencieusement et avec zèle à la réalisation du catalogue photographique et à son utilisation.

FINANCES

Les comptes établis par Couderc sont approuvés. Les dépenses sont prévues pour l'intervalle 1961–4 afin d'assurer la publication de la zone $+35°$, du tome VIII de la zone de Melbourne, de la zone de Tacubaya et la photocopie de quelques fascicules de Catane.

CALCUL DES CONSTANTES DES CLICHÉS DU CATALOGUE PHOTOGRAPHIQUE

Les constantes publiées dans les catalogues photographiques sont provisoires. Il a été montré par Heckmann, Dieckvoss, Kox, et Sémirot qu'un nouveau calcul améliore les coordonnées équatoriales des étoiles du catalogue. Heckmann dit qu'une nouvelle réduction est intéressante parce que l'on peut ensuite déterminer des mouvements propres absolus; 180 000 mouvements propres ont ainsi été calculés à Hambourg; Dieckvoss ajoute que les cartes IBM relatives à ces étoiles ont été envoyées à l'Observatoire de Washington.

Stoy désirerait attendre que le catalogue de l'AGK 3 soit terminé pour entreprendre le calcul des constantes.

Eichhorn pense que le problème d'un nouveau calcul des constantes n'est pas aussi facile qu'il paraît. Il est nécessaire d'employer des termes quadratiques et d'autres termes pour tenir compte des effets de distorsion, de coma, de distance au centre, de magnitude et de type spectral. Il faudrait utiliser des étoiles repères très faibles et actuellement l'Observatoire de Yale détermine leurs positions. Une étoile de magnitude comprise entre 10 et 13 par degré carré serait nécessaire pour calculer les constantes selon sa méthode. Tous les astronomes sont d'accord pour admettre l'ampleur d'un tel travail et Heckmann fait remarquer que l'AGK 3 contiendra beaucoup d'étoiles ayant ces magnitudes. La proposition d'Eichhorn est repoussée.

Eichhorn accepterait de faire une nouvelle réduction de tous les clichés et Herget participerait à ce travail à la condition qu'après enquête auprès des astronomes intéressés sa nécessité soit bien mise en évidence. Heckmann et Sémirot proposent une collaboration entre Eichhorn et Herget pour étudier le problème.

CALCUL DES COORDONNÉS ÉQUATORIALES ET DES MOUVEMENTS PROPRES DE TOUTES LES ÉTOILES DU CATALOGUE

Si un nouveau calcul des constantes a reçu l'approbation unanime des astronomes, il n'en n'est pas de même du calcul des coordonnées équatoriales et des mouvements propres de toutes les étoiles du catalogue.

Les clichés du catalogue et de la carte du ciel ont rendu de tels services que tous les astronomes étaient d'accord en 1938 pour mesurer les mouvements propres de toutes les étoiles. Leur opinion n'a point varié mais étant donné l'ampleur du travail il paraît difficile d'engager toute l'activité d'un observatoire pendant de nombreuses années. Il est conseillé d'étudier les mouvements propres de certains champs, d'étoiles particulières ou des étoiles à grand mouvement propre, mais il est évidemment laissé toute liberté aux astronomes pour calculer s'ils le désirent et s'ils en ont la possibilité les coordonnées équatoriales et les mouvements propres de toutes les étoiles.

Heckmann pense que le problème des mouvements propres absolus est résolu par les programmes d'observations de Deutsch et de Vasilevskis. Deutsch annonce que l'on a déjà commencé à prendre des photographes des nébuleuses extragalactiques dans l'hémisphère Sud et que l'on reprendra des plaques dans une vingtaine d'années.

DÉTERMINATION DE LA MAGNITUDE DE TOUTES LES ÉTOILES

Les astronomes présents pensent que les clichés du catalogue ou de la carte se prêtent très mal à cette détermination.

NÉCESSITE D'UN NOUVEAU CATALOGUE PHOTOGRAPHIQUE

L'entreprise de la carte du ciel a été commencée trop tôt, cependant les astronomes, grâce à elle, ont acquis de l'expérience et il est inutile de recommencer le travail par les mêmes méthodes. Le programme de Lick convient parfaitement et répond à la question posée.

RECENSEMENT DES CLICHÉS

La discussion sur le recensement des clichés est très animée. Velghe désirerait que l'époque de la prise des clichés soit donnée sur les fiches. Eichhorn propose d'établir un bureau central où seraient déposées toutes les cartes IBM (une pour chaque plaque) pour tous les clichés qui existent. Sémirot a établi un catalogue de recensement d'après les directives données à Moscou. Ce catalogue réduit ne répond pas au but poursuivi parce qu'il est matériellement impossible de faire figurer tous les clichés. Deutsch, Luyten, O'Connell, Stoy, Sémirot sont d'accord pour admettre qu'un catalogue ou le projet d'Eichhorn serait trop coûteux. Luyten fait remarquer que les plaques du "Palomar Survey" seront les meilleures sources de détermination des mouvements propres pour les étoiles faibles et cela dimunue l'intérêt du recensement.

Dans cette discussion on conclut d'un commun accord que faute de moyens financiers il est impossible d'établir un recensement détaillé de tous les clichés.

RECOMMANDATION

Le principe du calcul des constantes des clichés du catalogue photographique est admis. Pour assurer l'homogénéité des calculs le travail serait confié à Eichhorn et Herget qui conviendraient des meilleures solutions à adopter.

24. COMMISSION DES PARALLAXES STELLAIRES ET DES MOUVEMENTS PROPRES

Report of Meeting, 16 August 1961

PRESIDENT: K. Aa. Strand.
SECRETARY: H. L. Giclas.

The meeting was called to order by the President.

The first order of business was the organization of the Commission under the new Statutes of the Union.

The nomination by the Executive Committee of A. N. Deutsch as President and W. J. Luyten as Vice-President was approved. The nomination of the Organizing Committee consisting of V. V. Lavdovski, W. W. Morgan, K. Aa. Strand, P. van de Kamp, and S. Vasilevskis was also approved with the recommendation that A. Hunter be also nominated to this committee.

The next order of business was the additions or corrections to the *Draft Report*, which was approved without changes.

The President then invited the members of the Commission to report on their work.

van de Kamp said that he was continuing his investigation into the systematic errors of parallaxes as determined with the refractor. He was studying the effect of ventilation of the telescope tube and dome, and the effect on the seeing of using apertures of 12 and 18 inches, which, however, could only be used on the brighter stars.

Miss Lippincott spoke of the extension of the telescope tube to some 6 feet beyond the dome, with holes cut near the objective end of the tube to aid the flow of the air through the full length of the 15-foot extension.

Vasilevskis described a new double-slide camera built for the 36-inch refractor of the Lick Observatory, and enumerated some of the programs which could be carried out with this new camera.

V. Osvalds reported that he would very much like to modernize the Leander McCormick telescope but that he found it difficult to get the support of the authorities of the University of Virginia for a sustained astrometric program, which did not have the appeal that the more spectacular space-age programs did.

The President said that the Leander McCormick telescope had made very valuable contributions to the field of trigometric parallaxes and proper motions, and that it was of extreme importance to keep the telescope active in this field. He hoped that the telescope could be remounted and furnished with electro-mechanical controls similar to the 26-inch Naval Observatory refractor, which has become a very effective instrument.

van de Kamp wished to emphasize that the Leander McCormick telescope had a magnitude range in which very effective contributions could be made.

Osvalds then remarked that the University was not against a remodeling of the telescope, but that the general consensus was that an astrometric program on parallaxes and proper motions was not considered particularly suited for graduate research.

Several others spoke on behalf of continuing the astrometric programs at the University of Virginia and, at the suggestion of van de Kamp, it was agreed upon to request Professor Oort, as President of the Union, and the General Secretary to write to the University of Virginia and emphasize the importance to astronomy of continuing the astrometric work at the Leander McCormick Observatory.

H. K. Eichhorn reported that the parallax program was being continued at the Van Vleck Observatory, and that a high-speed electronic computer was used for the reduction of the data. Since a grating was used to compensate for magnitude differences possible errors introduced by the grating images were being investigated, in addition to errors arising from coma, colour and magnitude differences. The grating had a magnitude difference of 2·5 between central image and first-order spectrum and their separation was 0·4 mm.

W. W. Morgan reported on the determination of spectroscopic parallaxes. U,B,V narrow-band photometry makes it possible to obtain the equivalence of spectral type, and thereby the luminosities and distances of the early-type stars. He said that simple line equivalents and abundances of the elements have now become useful and he would like to know from D. L. Crawford how efficient this method was for determining absolute magnitudes. Crawford replied that his work was in progress. From narrow-band photometry of 50 Å band width on the CN and G bands, both of which depend upon composition and luminosity of the star, the absolute magnitudes could be determined at the present time with the same precision as those of the standard stars. There appeared to be no cosmic scattering.

D. Brouwer reported that parallax plates are still being taken with the 26-inch refractor at Mount Stromlo, but that it would be necessary to discontinue the program after the 20-inch astrograph would go into operation which he hoped would happen within the next 2 or $2\frac{1}{2}$ years. The new telescope would be located about 100 miles from San Juan in Argentina.

The President reported that the contract for the mounting of the 60-inch astrometric reflector to be located at the U.S. Naval Observatory, Flagstaff Station, would soon be awarded. The observatory building is under construction and the quartz disks for the primary and secondary mirrors had been delivered by Corning Glass Works. Both disks were found to have bubble content and strains well below the limits set by the specifications, so that figuring could start shortly.

H. L. Giclas gave an account of the photographic proper motion survey at the Lowell Observatory: The results from the first 100 plates had been published in *Lowell Bulletins* Nos. 102 and 112. Up to the present 110 plates have been measured, which constitutes approximately 40% of all the plates to be examined in the Northern Hemisphere. From these plates a total of 5579 stars have been found with proper motions larger than 0″·27 per year. Of these, 2207 have no previous proper-motion history. 28 stars have proper motions larger than 1″·0 per year, and 345 have motions larger than 0″·5 per year. A total of 66 new pairs with common proper motion have been found as well as 37 companions to already known proper motion stars.

The President reported that the Luyten proper motion catalogue (LTT) for the Northern Hemisphere had been published with the support of the IAU upon the recommendation of the Commission.

W. J. Luyten then asked the Commission to vote on the following resolution: "The Commission on Parallaxes and Proper Motions expresses the wish that the complete catalogue of proper motions found in the Bruce Proper Motion Survey be fully published and distributed to all observatories. The catalogue has up to the present time been published in mimeographed form and only in a limited edition."

By unaminous vote it was agreed upon to present the resolution to the General Assembly. [This was not accepted by the Resolutions Committee, but it is included in the collected Resolutions in Part 2.]

S. Vasilevskis reported on the progress of the automatic measuring machine for the Lick Observatory. He felt that the machine would be completed within a year. He also mentioned that he knew of several other automatic machines which were being manufactured at the present time.

The President mentioned that he had followed closely the machine developed by the Link Division of the General Instrument Co., which he found especially promising.

V. Osvalds asked whether, if several of these automatic machines were being built, it would be possible for small institutions, which could not afford to purchase them, to get access to them.

The President replied that he was hopeful this could be arranged informally and on an individual basis.

The President said that the proceedings of the double-star symposium (IAU Symposium No. 17), which had just been held, would be published in *PASP*. He also called attention to the announced Joint Discussion No. 1 "Stellar Motions and Stellar Dynamics."

There being no further business, the meeting was adjourned.

25. COMMISSION DE PHOTOMETRIE STELLAIRE

Report of Meetings

Meeting of Commission 25, 18 August 1961
Joint Meeting with Commission 37, 21 August 1961

PRESIDENT: R. H. Stoy.
SECRETARY: R. H. Hardie.

Professor Hertzsprung and Professor Stebbins were welcomed to the meeting of the Commission. Copies of *Lowell Observatory Bulletin* No. 113 and of Part VII of Volume XVII of the *Publications of the United States Naval Observatory* were distributed to Members of the Commission, and their contents were briefly explained by Hoag and H. L. Johnson. These publications give the results of the joint work of the Lowell and U. S. Naval Observatories on galactic clusters.

The following Organizing Committee was agreed in terms of the new Constitution of the Union:

President: V. B. Nikonov

Vice-President: A. W. J. Cousins

Organizing Committee: H. Haffner, R. H. Hardie, G. E. Kron, K. Osawa, J. M. Ramberg, E. Rybka and A. G. P. Velghe.

DRAFT REPORT

The *Draft Report* was adopted with only a few minor corrections. A number of topics arising from it were then discussed.

The first of these was the convertibility of observed ultra-violet, blue colours. Cousins pointed out that simple transformations of the form

$$(U - B)_a = \alpha(U - B)_b + \beta$$

are only possible when the observational equipments involved are closely matched. In nearly every practical case, the relation between $(U - B)_a$ and $(U - B)_b$ is multi-valued for spectral types A and F. The ambiguity can sometimes be avoided, however, by using a transformation of the type

$$(U - B)_a = f_1(U - B)_b + f_2(B - V)_b$$

If the differences between the two systems involved are not large, linear functions will give satisfactory results. When the differences are larger and when it is possible to segregate the stars according to luminosity class and population type, a transformation of the form

$$(U - B)_a = k(U - B)_b + F(B - V)_{bo}$$

appears to be workable, k being the ratio of the slopes of the reddening lines in the two systems and $(B - V)_{bo}$ the unreddened colours.

Haffner asked if there was any reason for continuing with refractor $(U - B)$ colours such as those that had been determined at the Cape. Eggen emphasised that such colours now existed for many stars and thought that it would be unwise not to make use of them, especially as they had many of the same properties as the $(U - B)$ obtained with an aluminised reflector.

Stoy said that at the Cape both types of $(U - B)$ colours were being determined and that there was no intention of discontinuing $(U - B)$ observations with the refractors. For many purposes $(U - B)_c$ gave all the information that could be expected from a second colour and the observed refractor system had the great virtue of stability and consequent ease of reduction. It has been found that for normal stars conversions between the two systems could be made without serious loss of accuracy by the transformations that Cousins had mentioned.

The second topic to be discussed was the difficulty that had been encountered in reconciling the various series of photometric observations of Cepheids and super-giant stars. Schmidt mentioned that this matter had been investigated at the Bonn Observatory where Schmidt-Kaler had combined the observations of various observers to form a catalogue of 250 stars of types FO – M6, Ia – II. In the course of this work, which will be fully reported in the *Astronomische Nachrichten*, it had been found that transformations of the form

$$(B - V) = \alpha + \beta C + \gamma E_{B-V}$$

were needed and were adequate in that they gave residuals smaller than $0^m{\cdot}02$. The term depending on the interstellar reddening is probably due to small differences in effective wavelengths caused by different cut-offs in the ultra-violet. Such a term was also found necessary for the conversion of measures which had been nominally made on the U,B,V system. Thus, in the case of measures made by Hogg in Australia it was found that

$$(B - V) = (B - V)_{\text{Hogg}} - 0{\cdot}15\, E_{B-V}$$

Schmidt-Kaler's work has shown quite clearly that if one wants to get colour indices of heavily-reddened stars which will be reproducible with high precision, it is necessary to define highly-reddened standard stars and to determine the coefficient γ empirically. *It is therefore highly desirable that the Morgan-Johnson standard system should be supplemented by a number of considerably reddened stars of different spectral types.*

REPORTS AND DISCUSSION

Hogg reported briefly on some four-colour work done at Canberra using standard U,B,V filters plus a fourth filter B' which cuts out slightly more ultra-violet light than the normal B filter. It had been found that the $(B - B')$ colour varied rapidly with spectral type and luminosity class indicating that transformation difficulties did not result from differences in the U filter alone but were sensitive to the cut-off point of the B filter.

When the question of the constancy that could be expected from standard stars was raised, *Cousins*, reporting on recent E-Region observations, confirmed his previous statement that many stars are remarkably constant. Omitting stars previously noted as variable or suspected variable, there are only 19 out of 302 stars for which the newly determined magnitudes differ by more than $0^m{\cdot}01$ from those given in *Cape Mimeogram* No. 11. He pointed out, however, how dangerous it is to rely too much on the constancy of any particular star and said that several standard stars should be used for any particular piece of work. This point was emphasised by *Eggen* who thought that many more standards were needed in the northern hemisphere.

A written report received from *Serkowski* gave further information about the observed variations in brightness of the 'Ten-Year Standard' stars used at the Lowell Observatory in the study of the Sun as a variable star. Serkowski's diagram, which appears to include and revise the material given in *Lowell Bulletin* No. 96, indicates that for the sixteen stars in the diagram the total variation in magnitude is $0^m{\cdot}02$ or less. These variations are considerably smaller than those suggested in the original paper. The improved magnitudes and colours that Serkowski has found for eight of the primary standards of the U,B,V system are as follows:

HR	Star	V		ΔV	$B-V$		$\Delta(B-V)$	n
		m	m	m	m	m	m	
3249	β Cnc	3·534	±0·002	+0·014	+1·477	±0·001	−0·003	36
3454	η Hya	4·299	·002	−·001	−0·195	·001	·000	37
4456	90 Leo AB	5·947	·003		−0·159	·001		27
4550		6·448	·003		+0·753	·002		30
5685	β Lib	2·608	·003	−·002	−0·109	·002	−·001	28
5854	α Ser	2·640	·002	−·010	+1·170	·002	+·002	29
5947	ϵ Crb	4·144	·002	−·006	+1·231	·001	+·001	28
6092	τ Her	3·895	·003	+·005	−0·151	·002	+·001	29

ΔV and $\Delta(B\text{-}V)$ are the corrections which should be applied to the values given by H. L. Johnson and D. L. Harris in *Ap. J.*, **120**, 196, 1954. n denotes the number of nights. Only those nights were used on which at least 6 different primary standards were observed and an extinction coefficient determined. The errors given are mean errors.

Haffner reported on his work at the Boyden Observatory for the programme of fainter U,B,V standards that was formulated in 1957 at the Stockholm Symposium on the 'Co-ordination of Galactic Research'. Haffner concentrated on a pair of A and K stars of about the eighth photographic magnitude in each of the nine E Regions. Observations were made on 17 nights but the final results depend only on 10 nights which were selected for their good, homogeneous quality. On these nights the series of observations covered from 8 to 16 hours of right ascension and each E-Region pair was observed up to 6 times per night. The zero-points were determined from 18 Morgan-Johnson stars between declinations + 15° and − 30° which were observed close to the meridian and evenly distributed between the E-Region observations.

The Boyden values of V, $B-V$ and $U-B$ for the 18 E-Region stars are given in the following table. They are supposed to represent the Morgan-Johnson system within less than $0^m{\cdot}01$ and within the colour range of unreddened late B and early K stars. The weights p

E	Q	HD	α (1950)			δ		Sp.	V	$B-V$	$U-B$	p
									m	m	m	
1	46	7795	1h	14m	47s	42°	48′	B9	7·842	−0·086	−0·326	9
	30	7706	1	13	58	42	16	K0	6·573	+1·205	+1·265	9
2	4	25653	4	00	39	44	48	A2	8·185	+0·132	+0·091	9
	27	25301	3	57	42	44	03	G5	6·830	+1·101	+0·977	9
3	5	46817	6	31	46	45	20	A0	8·030	+0·124	+0·059	8
	37	46652	6	30	53	45	16	K0	7·148	+1·069	+0·860	8
4	6	80484	9	16	45	44	25	A0	8·331	+0·092	+0·064	12
	30	80527	9	17	01	44	48	K0	7·182	+1·106	+0·934	12
5	2	105498	12	06	07	44	39	A0	8·055	−0·024	−0·228	14
	27	105852	12	08	27	45	09	K0	6·609	+1·086	+0·836	14
6	4	128726	14	36	44	45	32	A0	8·057	+0·034	−0·077	17
	33	128413	14	34	56	45	39	K0	6·836	+1·168	+1·207	17
7	16	157477	17	22	02	45	13	A3	8·099	+0·242	+0·150	21
	32	157487	17	22	02	44	44	K0	7·64	+1·25	+1·14	—
8	8	191273	20	07	22	43	45	A3	7·828	+0·249	+0·104	14
	29	191117	20	06	38	44	03	K0	6·933	+1·023	+0·807	14
9	1	216009	22	46	57	44	41	A0	8·059	+0·045	+0·042	12
	30	216406	22	50	22	45	25	K0	6·858	+1·113	+1·063	12

given in the last column have been calculated from the number n of observing nights ($5 \leqslant n \leqslant 7$) and the number z of observations per night ($z \leqslant 6$). The internal mean errors of unit weight are $\pm$ $0^m{\cdot}018$, $\pm$ $0^m{\cdot}015$ and $\pm$ $0^m{\cdot}015$ respectively for V, $B - V$ and $U - B$. The K star selected as standard in E 7 proved to be variable. It was therefore omitted from the final list and replaced by Q 32 for which the Cape data reduced to the Boyden system are given.

Schmidt explained his proposal to revive a project which, in one form or another, has been suggested several times in the past. This is to establish comprehensive magnitude sequences in conveniently placed areas. These would be especially useful for photographic photometry and for the inter-comparison of photometric systems, while for photo-electric photometry they would be very much more convenient than standards scattered all over the sky. Schmidt suggested the following desiderata for the choice of stars and areas:

1. Areas should be observable from both hemispheres and at all times of the year. This means that there will have to be a number of areas in the equatorial belt and well separated in right ascension.

2. Each area should be small enough to be covered by a single photographic exposure. This limit will depend on the instrument concerned, but a diameter not exceeding 2° or 3° is indicated.

3. The stars selected must be observable by both small and large instruments. The upper limit of brightness could be about 7^m and the lower 16^m.

4. All spectral types and luminosity classes should be represented in the sequences.

5. One or more of the areas should be in regions of obscuration so as to provide material for determining how colour excess affects the transformations between different colour systems.

Willstrop said that Redman had raised the question of the provision of faint standards in restricted areas that could be used for calibrating Schmidt camera plates because the conditions at Cambridge were not often suitable for photo-electric photometry in which stars are compared consecutively. It was therefore not practicable at Cambridge to adopt the ideal method of establishing a photo-electric sequence in each Schmidt field investigated. He thought that the construction for the Royal Observatory, Edinburgh, of a twin 16-inch reflector especially designed for the measurement of sequences was greatly to be welcomed.

Velghe stressed the need for the establishment of photo-electric R and I standards for use in investigating low temperature stars in the Milky Way. He suggested that these standards should be set up in the Selected Areas of the Special Plan and said that it was imperative that the particular R and I system chosen must be such that it could be reproduced photographically.

The relative merits of the R,G,U and U,B,V Systems for separating out various types of stars were briefly discussed. *Willstrop* said that Argue using the Cambridge Schmidt had found that both systems separated out some types of stars but not others. As R,G,U standards were not readily available, Argue had reverted to the use of U,B,V. *Steinlin* agreed that there were cases where the U,B,V System is able to sort out types of stars which the R,G,U could not and *vice versa*. The latter system was particularly useful for sorting out late-type giants and dwarfs. Steinlin thought that it was probable that there was no single three-colour system which fulfils all purposes and it was necessary to select the most suitable for the particular object in view. *Schmidt* said that at Bonn they were trying to compare the relative potentialities of the two systems by investigating in both a large number of stars brighter than magnitude 13 in a Milky Way field for which spectral types and luminosity classes were also being determined. Work on the establishment of R,G,U standards in the North Polar Area had been suspended until the results from this test of the two systems were known.

Walraven described the new five-colour photometric equipment of the Leiden Southern Station and showed some photographs of it. He discussed the properties of the various colour systems and indicated how in the case of the Magellanic Clouds they might be used for sorting out foreground stars from genuine Cloud members.

Rybka reported on the progress at the Cracow Observatory with the reduction of the Harvard and Potsdam visual photometries to the Morgan-Johnson V system. Each combination of observer plus instrument needs its own set of systematic corrections and in some cases the colour corrections required are surprisingly large. Unfortunately, reliable colours are available for relatively few stars in the northern hemisphere but is has been found that in most cases colour indices sufficiently accurate for applying systematic corrections to the visual observations can be deduced from the difference between the photographic and photometric magnitudes given in the Henry Draper Catalogue. The mean error of a colour index so derived appears to be about $\pm 0^{m}\cdot16$.

Stoy spoke briefly on the work at the Cape for the 'General Catalogue of Magnitudes' that had been proposed at Moscow. Apart from the collection of much of the published photo-electric data on to cards, the principal progress had been the consolidation into a single list and on to a single system of the various series of photo-electric observations that had been made at the Cape since 1948. This list, which is available as *Cape Mimeogram* No. 12 or as *Royal Observatory Bulletin* No. 64, gives V magnitudes and $(B - V)$ colours for 4950 stars. $(U - B)_c$ colours are given for 3940 of these stars. Many of the stars have been observed in more than one series of observations and for these the results from the individual series are given separately except for the E-Region stars.

Hall said that Serkowski is preparing a short catalogue of stars for which the polarisation has been reasonably well determined. This will extend the list he gave in *Lowell Observatory Bulletin* No. 105 of 'Suggested Standards of Polarisation'.

Discussing extinction, *Rybka* stressed its variability with time and direction. In general it is not sufficient to determine it for a given night and then assume that it is constant throughout the night all over the sky. For accurate work the extinction has to be determined at the time and for the part of the sky in which the observations are being made. This can be done if there are stars in that vicinity for which accurate magnitudes and colours are known. It is to meet this need that the Crimean and Cracow Observatories are determining accurate magnitudes and colours for pairs of stars near each of the Kapteyn Selected Areas. The stars are about the sixth visual magnitude and one of each pair is of spectral type B5 – A5 and the other G5 – K5. Observations on the U,B,V System for 230 stars have been completed at the Crimean Observatory by Nekrasowa and will shortly be published. There is a need to extend this work to the southern Kapteyn Areas and also, possibly, to fainter pairs of stars in each Area.

Speaking on behalf of the Pulkovo astronomers *Rybka* appealed for photometric help in connection with their programme for determining absolute proper motions in 300 areas containing galaxies. Magnitudes are required for about 10 stars in each area. The areas are mostly $2^{\circ} \times 2^{\circ}$ and the range of magnitude to be covered is from 10 to 14. The accuracy desired for the individual magnitudes is not large ($\pm 0^{m}\cdot1$) but it is essential that these magnitudes should be on a homogeneous system with systematic errors well below this limit. Observatories willing to help should contact Professor A. N. Deutsch at the Pulkovo Observatory.

Joint meeting of Commissions 25 and 37

The chief speakers at the joint meeting of Commissions 25 and 37 were *Walker* and *Haffner* who both discussed the problem of the most suitable photometric system for work on clusters. *Walker* reviewed the desiderata for the ideal system and concluded that the *U,B,V* photometry satisfied these more closely than do other three-colour systems now available. He thought that in theory some narrowing of all three colours might be desirable in order to avoid band-width effects when reducing observations to the standard system. In practice, however, this was unlikely to be worth the trouble involved, especially as the effects in question are small and can be fully evaluated by using sufficient standard stars. Walker, therefore, advocated that the present definition of the *U,B,V* System be retained but that the existing standards should be checked carefully for variability and that, in addition, there should be set up a number of accurate faint standards suitable for use with large telescopes.

Haffner said that although spectro-photometry was to be regarded as the only precise approach to an understanding of stellar radiation, it was not always practicable and that for some problems one had to be content with integrated light methods. This was particularly the case for cluster work, especially when the faintest stars were involved. For such work, he strongly recommended the use of the *U,B,V* photometry both for reasons of continuity and of its practicability. The instrumental system should be kept as close to the standard system as possible and its relation to the standard system frequently checked. A satisfactory control needs a five-dimensional system of standard stars—spectral type, luminosity class, reddening, right ascension and declination. Much has still to be done to establish a convenient system of standards, though the number available is steadily increasing in both hemispheres, particularly as a result of the photo-electric sequences that have been set up near clusters. Photographic observations should be made as closely as possible on the system of the photo-electric standards being used to calibrate them. For the brighter stars ($6^m - 12^m$) work in colours *additional* to *U*, *B* and *V* is to be welcomed.

Tifft emphasized the fact that the width of the *U,B,V* bands made it necessary, when making accurate transformations, to take into account terms depending on the band-width squared and that these terms had to be carefully calibrated. He also pointed out that the poorly defined ultra-violet limit of the *U* band might lead to trouble when the time came to compare existing results with observations made outside the atmosphere. He thought, therefore, that it would be worth while to experiment with a system involving slightly narrower and more precisely defined band-widths than the present *U,B,V* System, even though the present system was very satisfactory and would, undoubtedly, continue to be used for many purposes.

King, referring to a remark made by Walker, said that the fact that narrow-band measurements might be hard to reproduce photographically was not a valid criticism against their use. The information contained in a number of narrow bands is intrinsically more than that contained in a single band. It should, therefore, be possible to synthesize from photo-electric measures made in several narrow bands magnitudes suitable for use in calibrating photographic observations.

26. COMMISSION DES ETOILES DOUBLES

Report of Meeting, 19 August 1961

PRESIDENT: Peter van de Kamp.
SECRETARY: Sarah Lee Lippincott.

The Executive Committee's proposal to appoint R. van der Riet Woolley as Vice-President was approved. Following the instructions of the Executive Committee an Organizing Committee was suggested and approved as follows:

O. J. Eggen, P. Muller, K. A. Strand and W. H. van den Bos.

IAU SYMPOSIUM NO. 17

IAU Symposium No. 17 on Visual Double Stars, held on 11–12 August 1961 in Berkeley was briefly summarized by the President and Chairman of the symposium. Salient features included: (*a*) the feeling that double-star observers do not get their share of observing time with large telescopes; (*b*) the need for liaison with other phases of astronomy; (*c*) a critical review of techniques and programs; (*d*) the need to inspire and encourage young people to take up visual double-star astronomy.

The following recommendations were adopted at the symposium:

1. IAU Symposium No. 17 (Visual Double Stars), considering the fundamental importance of double-star observations to our science and recognizing the growing scarcity of qualified observers, stresses the necessity of encouraging young astronomers to take up double-star astronomy.

The symposium expresses the wish that the IAU facilitate by all means at its disposal the sending of young observers to those observatories where this research is actively pursued. (Unanimously adopted.)

Le Symposium No. 17 de l'UAI, considérant l'importance fondamentale des observations d'étoiles doubles pour toutes les branches de l'astronomie et la pénurie actuellement croissante d'observateurs qualifiés, insiste sur la nécessité d'encourager les jeunes astronomes à s'orienter vers l'étude des étoiles doubles.

Exprime le souhait que l'Union Astronomique Internationale facilite par tous les moyens en son pouvoir l'envoi des jeunes observateurs dans les Observatoires où cette étude est poursuivie activement. (Unanimité.)

2. The Symposium recommends that experienced double-star observers be given increased opportunity to use reflectors of large aperture. (Unanimously adopted.)

Le Symposium recommande que les observateurs d'étoiles doubles confirmés se voient offrir davantage d'occasions d'utiliser les grands réflecteurs. (Unanimité.)

3. The Symposium notes with satisfaction that it is the wish of the Republic Observatory, South Africa, to continue its traditional specialization in the field of visual double stars and expresses the hope that the acquisition of a large reflector for this purpose will not be long delayed. (Adopted with one abstention.)

Le Symposium enregistre avec satisfaction l'intention de l'Observatoire de la République d'Afrique du Sud de maintenir sa spécialisation traditionnelle dans le domaine des étoiles doubles visuelles, et exprime l'espoir que l'acquisition d'un grand réflecteur pour ces travaux puisse intervenir prochainement. (Adopté avec une abstention.)

4. The Symposium expresses its gratitude to Dr Jeffers and Dr van den Bos for their monumental work in creating the Card Catalogue on double-star observations and the index catalogue of double stars.

To insure the preservation of these catalogues, now available only at the Lick Observatory, the Symposium recommends that copies be deposited at a few selected observatories. (Adopted by Acclamation.)

Le Symposium exprime sa gratitude à MM. H. M. Jeffers et W. H. van den Bos pour l'oeuvre considérable qu'ils ont accomplie en créant le Card Catalogue d'observations et l'Index Catalogue d'étoiles doubles.

Pour assurer la conservation de ces catalogues, qui n'existent actuellement qu'à l'Observatoire Lick, le Symposium recommande que des copies soit déposées dans un petit nombre d'Observatoires choisis. (Par Acclamation.)

The proceedings of the symposium will appear in the *Publications of the Astronomical Society of the Pacific;* (added in proof: Vol. **74,** No. 436, 5-34, February 1962.)

REPORTS AND DISCUSSIONS

Jeffers discussed the catalogues covering both the northern and southern hemispheres which he and van den Bos are completing.

Barrato reported that 500 micrometer measurements have been made on 150 stars with the 18-inch refractor at the National Observatory in Brazil.

Hertzsprung called attention to several double stars with variable components. 44*i* Boo contains a W UMa star which could yield a parallax from the light-time across the orbit. The same situation holds for the eclipsing binary component system YY Gem. Attention was also called to QS Aql and BD + 10°2234.

Van Biesbroeck expressed concern over the dearth of young people entering positional double-star astronomy; we have a moral obligation to continue this work.

The desirability of increased liaison between double-star observers and spectroscopists and astrophysicists was brought up. *Petrie* reminded those present that there was much wealth of material awaiting spectroscopic and astrometric observation. A sporadic approach is not as valuable as a well-planned program. *Strand* expressed the hope that Petrie's intensive spectroscopic program would continue. Miss *Roemer* recalled the Lick Observatory Mills Spectrograph program on double stars which was started some years ago. *Finsen* urged that stars of special interest be examined regularly. *Stephenson* suggested that the Warner and Swasey Observatory program in the UV might include a search for duplicity. The organizing committee was requested to consider means for closer liaison with astrophysicists.

Kulikovsky drew attention to the catalogue, in preparation in the U.S.S.R., of double stars in which one of the components is a non-stable star.

Strand expressed concern over the limited double-star work now being carried out with the 36-inch Lick refractor, used with great success in the past for visual, spectroscopic and photographic double-star observations. Visitors' programs only are not sufficiently effective—there must be some long-term continuity. Both Muller and van de Kamp acclaimed the visitors' program, but urged more permanent programs and long-range planning.

Couteau stated that during the coming year he and van Biesbroeck will use the interferometer with the 40-inch Yerkes refractor and could look at some stars specified by the spectroscopists.

Luyten called attention to pairs with large proper motion and white-dwarf components for the purpose of obtaining masses. Few doubles with a white-dwarf component have short periods. Masses must be obtained through statistics. There is need for close cooperation between double-star astronomers and those working in other fields of astronomy.

Couteau's proposal for a table of true anomalies will be considered by Muller and Strand.

van de Kamp said that double stars are the first step to multiple stars and perhaps we should start thinking of a symposium on multiple stars.

At the recommendation of van Biesbroeck the *Draft Report* was approved and accepted by those present.

27. COMMISSION DES ETOILES VARIABLES

Report of Meetings

PRESIDENT: P. Th. Oosterhoff.
SECRETARIES: R. Canavaggia, M. F. Walker.

Administrative meetings, 18 and 21 August 1961

According to the new rules the Commission had to propose names for an organizing committee. Following suggestions made by the President the meeting agreed to the proposal of the following names:

President: P. Th. Oosterhoff
Vice-President: G. H. Herbig
Members of the Organizing Committee: Mlle R. Canavaggia, L. Detre, C. Hoffmeister, P. N. Kholopov and M. F. Walker

Later the Nominating Committee and the Executive Committee approved these proposals.

At the time of the Berkeley meeting the Commission had 58 members, after the meeting this number has increased to 80.

It was decided at Berkeley to discontinue nearly all the Sub-Commissions and consequently the three Sub-Commissions of Commission 27 have been dissolved. As some of the work must be continued the meeting decided to set up two committees. They are:

Committee on Variable Stars in Clusters
President, Mrs Sawyer Hogg; Arp, Rosino and Wesselink

Committee on the Spectra of Variable Stars
President, Herbig; Bidelman and Kukarkin

Then the *Draft Report* was discussed and accepted. Shapley stressed the importance of investigating whether stars, thought to be constant such as photometric standards, are really constant. Van Hoof reported that α Lupi is definitely a β Canis Majoris variable.

The President made a financial recommendation, namely that $400 be granted for the publication of an English version of the remarks in the first supplement to the second edition of the General Catalogue of Variable Stars. The meeting approved. [This recommendation was approved by the Finance Committee, and incorporated in its report.]

Then followed the discussion of the recommendations and suggestions made by members. They were:

1. With the available Durchmusterung maps the positions for equinox 1900·0 in the *General Catalogue of Variable Stars* are not practical. The old equinoxes of 1855·0 and 1875·0 are to be preferred (Hoffmeister).

2. Galactic co-ordinates in the new IAU system (See *Information Bulletin No.* 1, June 1959) should be computed and published for all variables. (Mavridis).

3. The system of denomination and classification.

(*a*) Sometimes variable stars are denominated, for which only the mere fact of variability is known. On the other hand many old variables of which the variability is well established are still without final designation. It is suggested that we return to the old standards established by Prager, according to which a variable may be denominated only after some details

about type and other properties are known. (Hoffmeister). Hoffmeister also suggests that the old variables mentioned above be observed systematically to decide whether they may be named or not.

(*b*) It is proposed that a sub-committee of three or four persons reconsider the present system of classification (Plaut). As an example of some unsatisfactory aspects of the present classification Plaut mentions: that some variables classified as δ Sct-type probably are RR Lyrae-type variables; that no clear criteria exist for a distinction between δ Cep and W Vir stars; and that many variables, classified as semi-regular, belong to the long-period or *Mira*-type stars. (This last statement was independently made by Miss Harwood.) Further it has been suggested that systematic checks be made, on existing plate collections, of cataclysmic variables, the assignment of which depends on few and scattered observations. (Hoffleit).

(*c*) It is suggested that the Commission should study the question of denomination of variables in the Magellanic Clouds. (Wesselink). This question has been provisionally discussed by Sub-Commission 28*a* at its meeting in the Argentine in December 1960. Many of these variables carry a Harvard number, but in recent years many new variables have been discovered and it is to be expected that many more will be found in the next years to come. Some of the new variables have been denominated and are now given in the *General Catalogue*. It has been suggested that a special system for denomination or numbering be adopted for all the variables within certain regions around the two Clouds and that a special catalogue be prepared, similar to the list of variables in globular clusters, as prepared by Mrs Sawyer Hogg. Any positive decision on this problem will require a great deal of work for one or more persons.

4. Hertzsprung recommends that the coefficients of the rectangular co-ordinates of the Sun, X and Y, in the expression:

$$-X \cos \alpha \cos \delta - Y(\sin \alpha \cos \delta + 0{\cdot}4337 \sin \delta)$$

be given for all the variables for which the reduction to the Sun is significant.

5. The need for a photographic map of the sky north of $-20°$, from which fairly accurate co-ordinates can be derived quickly, has been expressed by Hoffmeister. As an example he mentions the Johannesburg maps for the southern sky.

6. It is recommended that a list be prepared of all the intrinsic variables which have been observed photo-electrically (Plaut).

7. Strohmeier would like to see quicker ways of communicating data on newly-discovered bright variables and of special phenomena. He suggests that the IAU *Circulars* be used for this purpose. Detre has similar complaints and suggests the establishment of a special publication of Commission 27 in the form of an international journal on variable stars, to be issued twice a year or so. If published in Hungary, the Konkoly Observatory could bear the cost of printing and a term of printing of 2-3 months could be guaranteed.

8. It is suggested that Commission 27 should indicate to the various Associations and Sections of Variable Star observers the most useful form in which observations should be published. (Bateson).

9. To further observation of variables for which sequences are not yet available, it is suggested that the amateur Associations have their most experienced observers select suitable stars for a sequence in each field and prepare charts from which they can be readily identified. (Bateson).

10. Miss Hoffleit re-iterates the need for evaluating the completeness of discovery of variable stars of the various types to specific limiting magnitudes for different parts of the

sky. This type of information is important in discussions of the galactic distributions of these stars.

11. Miss Hoffleit also stresses the importance of 'normal colour indices' which would be of considerable value in parallax problems and for studying the relationship between some classes of variables and their association with gas and dust.

12. Bertaud recommends photo-electric observations of the stars with composite spectra: HD 4174 = BD + 39° 167 and BD + 67° 922 and also of the A-type stars with abnormal spectra: HD 43246, HD 30353 and HD 50169.

Recommendation 1 was dropped. The Yale and Naval Observatories are putting different catalogues, including the *General Catalogue of Variable Stars*, on IBM cards. Supplements will also be put on the cards. Other equinoxes could easily be computed and copies of cards made available at nominal cost.

Recommendation 2 was accepted. Kukarkin stated that the new l and b values will be given to one decimal in the third edition of the *General Catalogue of Variable Stars*.

Concerning recommendation 3, Kukarkin remarked that variables are named only when the type is known. Stars which are certainly variable, *e.g.* with a large amplitude, but of unknown type are not named, but they will be published in the *Catalogue of Stars Suspected of Variability*. The Commission strongly recommends that the stars in this catalogue be divided in two groups: (*a*) variability certain, but type unknown; and (*b*) suspected variables. The meeting also stressed the importance of an early supplement to the catalogue of suspected variables.

The problems connected with recommendation 3(*b*) are complicated. The meeting nominated a working group, consisting of Kukarkin, Oosterhoff, Payne Gaposchkin and Harlan Smith, which should report to the Commission in one or two years.

The meeting decided that recommendation 3(*c*) should also be studied by a working group. The following members were nominated: Arp, Buscombe, Payne Gaposchkin and Wesselink.

Recommendation 4. The meeting agreed that it would not be practicable to publish the co-efficients of X and Y for the individual variables in the *General Catalogue*, but that it would be better to produce a table of the coefficients as a function of α and δ. Walker, Irwin and some others were in favour of new and more accurate tables of the actual solar corrections. As Kukarkin was willing to publish tables of the coefficients to six decimals, the meeting gratefully accepted this.

Recommendation 5 was dropped. Transparent grids for the Palomar Sky Atlas can be obtained for $85 from the National Radio Astronomy Observatory, P.O. Box 2, Greenbank, West Virginia, U.S.A.

Recommendation 6. Hoffleit and Walker suggested that such information be included in the next edition of the *General Catalogue*. As Kukarkin remarked that it probably will be possible to follow this suggestion, although many complications are involved, the meeting strongly supported this idea.

Recommendation 7. After some discussion the meeting decided to establish an *Information Bulletin on Variable Stars*. This has become possible through the initiative of Professor Detre and the generosity of the Konkoly Observatory. The bulletin will *not* be a new journal for articles on variable stars, but its main purpose will be the rapid communication of discoveries, interesting observations, requests for photometric or spectroscopic observations, etc. Therefore speed will be essential. Texts in English or French should be forwarded direct to:

Professor L. Detre, Budapest XII, Postoffice 114, Box 67

One sheet of the bulletin (not more than two typewritten pages double-spaced) can probably be printed and mailed in about a week. Longer communications may take a month or six weeks after the typescript has been received. Drawings should be avoided, although it may be necessary to include finding charts. The bulletins will be air-mailed to all members of Commissions 27 and 42 and also to the observatories and institutes on the mailing list of the Konkoly Observatory.

Hoffmeister drew attention to the fact that longer articles or series of observations which do not need a very rapid publication can usually be published in the MVS (*Mitteilungen über veränderliche Sterne*). Such typescripts should be forwarded to his address.

The meeting agreed on the importance of the recommendations 8, 9, 10, 11 and 12, but decided not to take action in these matters.

At the request of the authors the President announced that: (*a*) Tsesevich has prepared finding charts for all the RR Lyrae type stars of the *General Catalogue*; these charts will be distributed to all observatories; and (*b*) van Herk has made a list of RR Lyrae variables to a certain limiting magnitude with indications of proper motion, radial velocity, magnitudes and colour, mean magnitudes and mean colour and Preston's value ΔS. This list makes it quite clear that our information on these stars is still very incomplete. Copies can be obtained from the author.

Scientific meeting, 16 August 1961

The topic of this meeting was:

Secondary Periods and Beat-Phenomena in Pulsating Variables

The first speaker was *A. van Hoof* on

THE MULTI-PERIODICITY OF THE β CMa STARS

Abstract. About half the number of variables in the β CMa group are known to have a secondary period. The speaker has suggested (*PASP*, 1957) that one of the periods is the free pulsation period in the fundamental mode while the other is a resonance period between the fundamental mode and an as yet undetected overtone whose period is about one half the fundamental period. Photo-electric observations of ν Eri, β Cru and θ Oph have proved that the idea is correct. The numerous light curves have indeed revealed the existence in each of these stars of *several* pulsations, which could be identified as the fundamental one, the successive overtones and those resonance (difference-) oscillations between them whose periods are close to the free periods. These oscillations have been traced in the radial velocity data, each showing maximum light at the descent of the velocity through the γ-value. In the case of ν Eri Walraven's S and M deformations are also present.

From the run in the ratios, yellow/ultra-violet amplitudes, we can infer that the amplitudes of the oscillations increase faster and faster towards the stellar surface with increasing order of the overtone, as predicted by theory. We can further conclude that there exists a difference in spatial behaviour inside the star between the free oscillations and the resonance oscillations of comparable period.

From the ratios P_i/P_0 of the various overtone periods and their comparison with Schwarzschild's computations (*Ap. J.*, **94**, 245, 1941) it follows that these stars are built up as polytropes of index 3 and $\Gamma_1 = 1{\cdot}52$. When this model is admitted, Schwarzschild's computations can be used for the computation of the stellar radius. This yields plausible and consistent values for the different oscillations. Also the predicted temperature changes agree with the observations. Under certain assumptions the age of these stars is found to be of the order of 10^7 years.

We advance the following working hypothesis to explain the genesis of the oscillations: the fundamental pulsation is exicted by a central disturbance, and the overtones are excited far from the centre; if a reversible reaction, involving temperature changes, takes place in a thin shell that contains the nodal surface of a particular overtone, then that overtone will be excited and if more overtones are excited this way, they will in turn excite those difference oscillations that are sufficiently near resonance with a frcc lower mode. This hypothesis leaves open the possibility of a star pulsating only in one or more overtones. The *c*-type RR Lyrae stars and the δ Sct variables are believed to belong to this category.

The second speaker was *L. Detre* on

THE BLAZHKO-EFFECT IN RR LYRAE VARIABLES

Abstract. At the present time there are 20 RR Lyr variables with known secondary period, but the number of those which show light-curve variations is much greater. Photo-electric work disclosed some RR Lyrae stars with secondary variations of quite small amplitude, *e.g.* the RRc star TV Boo and the RRa star ST Leo. It is possible that secondary variations are a general phenomenon for RR Lyr stars.

RR Lyrae-stars with secondary periods

Star	P_o d	P' d	P'/P_o	ΔS	R. V. km/sec	Reference
*TV Boo	0·3126	31·2	100	8	− 85	Budapest, unpub.
RS Boo	0·3773	537	1424	2	− 10	Oosterhoff, *B.A.N.* **10,** 101.
*SW And	0·4423	36·8	83	0	− 22	*Budapest Mitt,* 36.
*RW Dra	0·4429	41·7	94	3	−125	*Budapest Mitt,* 27.
RV Cap	0·4478	221·9:	494:	6	−110	*Sternb. Inst. Tru.* 23.
XZ Cyg	0·4666	57·3	123	6	−160	Muller, *B.A.N.* **12,** 11.
*RV UMa	0·4681	91·1	195	8:	−180	*Budapest Mitt,* 34.
*AR Her	0·4700	31·6†	67	6	−335	*Budapest Mitt,* 8.
*XZ Dra	0·4765	75·5	159	3	− 25	Bud. unp., *A.N.* **271.** 231.
*ST Leo	0·4780	30:	63:	7	+170	Budapest unpub.
X Ret	0·4920	45:	91:	—	—	Hoffmeister, *Sonn.* **5,** 3, 1.
V674 Cen	0·4939	29·5	60	—	—	Hoffmeister, *Sonn.* **5,** 3, 1.
*RZ Lyr	0·5112	122·1	239	9	−230	Budapest, unpub.
Y LMi	0·5245	33·4	64	—	—	*Budapest Mitt.* 39.
*AC And	0·5251	2·04	3·9	pec	− 70	Budapest unpub.
UV Oct	0·5426	80:	147:	—	—	Hoffmeister, *Sonn.* **5,** 3, 1.
*RW Cnc	0·5472	29·7†	55	—	—	*Budapest Mitt.* 23.
*RR Lyr	0·5668	40·8†	72	6	− 70	Walraven, *B.A.N.* **11,** 17.
DL Her	0·5916	49·2	83	—	—	Tsesevich, *Odessa Izv.* LII
150·1936 Her	0·6131	40·6	66	—	—	Tsesevich, *A.Zh.* **38,** 293.

The stars are arranged according to the length of the fundamental period, P_o. Stars preceded by an asterisk (*) are those observed photo-electrically at the Budapest observatory. P' denotes the length of the secondary period; a dagger (†) refers to variations of P' with a longer cycle. ΔS is Preston's spectral-index.

There are two different types of this Blazhko effect: (*a*) When P' is relatively short (*e.g.* RR Lyr, RW Cnc; see Fig. 1), the lower portions of the rising branch of the light-curve appear to be substantially constant in time and phase at different phases of P'. The light-curves

figure 1

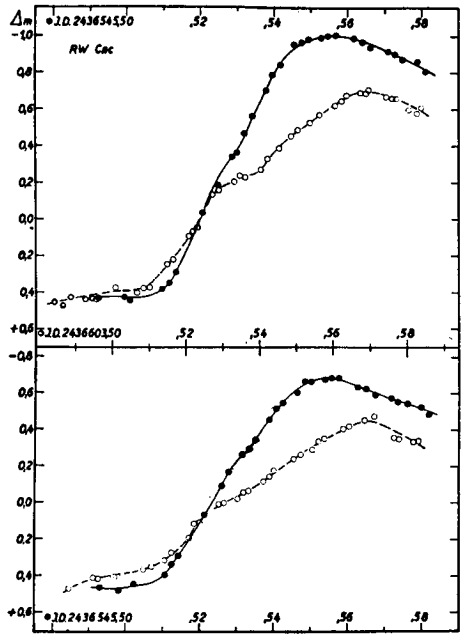

figure 2

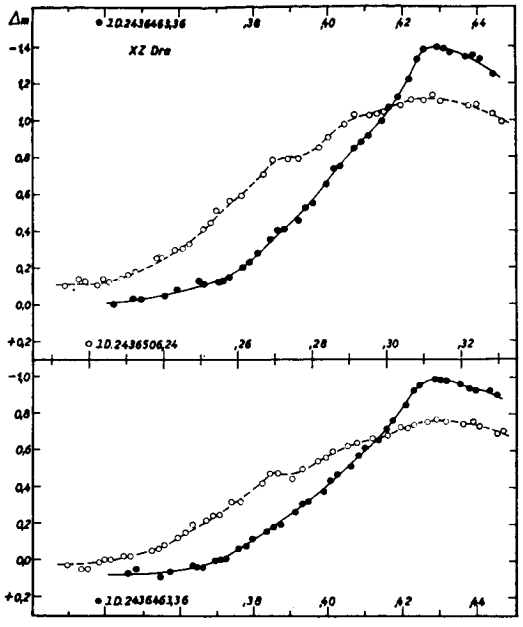

figure 3

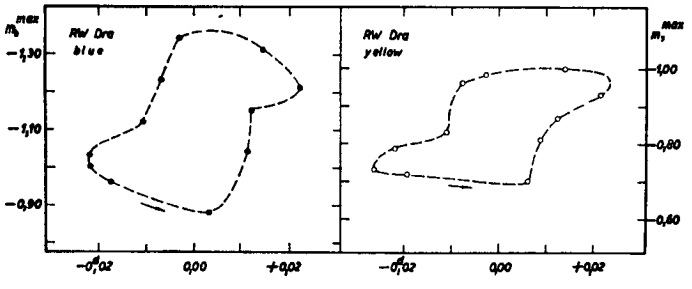

figure 4

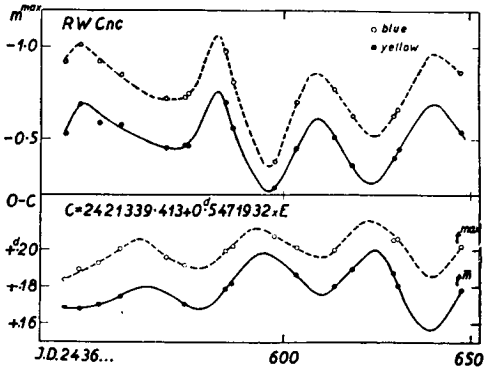

figure 5

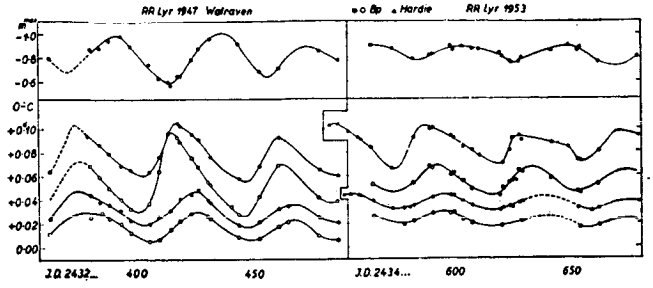

figure 6

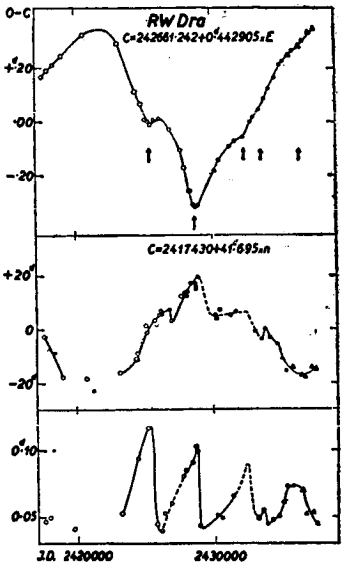

figure 7

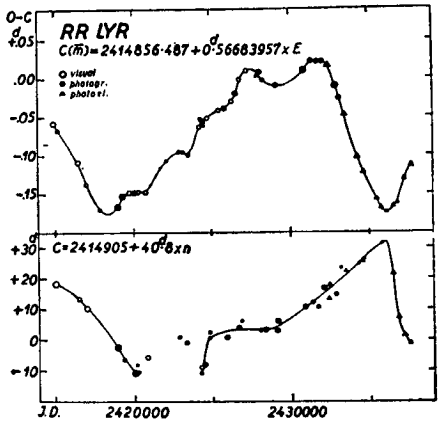

figure 8

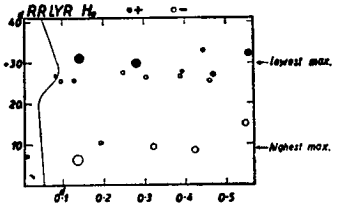

Fig. 1. Two extreme maxima of RW Cnc. Photo-electric observations at Budapest. Above in blue, below in yellow light.

Fig. 2. Two extreme maxima of XZ Dra. Photo-electric observations at Budapest. Above in blue, below in yellow light.

Fig. 3. Variations of brightness and phase of maximum light of RW Dra. Photo-electric observations Budapest, 1958.

Fig. 4. Successive cycles of the Blazhko effect for RW Dra. Photo-electric observations Budapest. Above, variations of maximum in blue and yellow; below, phase variations of maximum and of median brightness on the rising branch of light-curve.

Fig. 5. The Blazhko effect of RR Lyr in 1947 and 1953. Above, variations of maximum brightness; below, black dots and triangles denote phase variations of maximum and median brightness, circles the phase variations of the upper and lower parts of the ascending branch.

Fig. 6. RW Dra. Above, O − C diagram for P_0; in the middle, O − C diagram for P'; below, total amplitude of phase-variation of maximum brightness.

Fig. 7. RR Lyr. Above, O − C diagram for P_0; below, O − C diagram for P'.

Fig. 8. Effective magnetic field intensity of RR Lyr arranged according to phases of P_0 and P'.

depart then from a common rising branch at the phase of P_0 where the UV-excess has its greatest value (1). It is at this same phase that the remarkable changes occur in the hydrogen-line structure, observed by Sanford (2) and Struve (3). The phase-variation is greatest at maximum light, and diminishes towards minimum. The lowest maximum comes latest. (*b*) When P' is long (*e.g.* XZ Dra; Fig. 2; RV UMa, RS Boo), the phase-variation of maximum light is small, but the phase-variation of the lower part of the rising branch has a great amplitude. When the rising branch begins early, its slope is small and the range of the light-variation is a minimum. When on the other hand the rising branch comes late, it is steep and the light-range is largest. The highest maximum comes latest.

Fig. 3 shows for RW Dra that the amplitude of the variation of m_{max} is greater in blue than in yellow light, but the reverse is true for the amplitude of the phase-variation.

Different cycles of the Blazhko effect may differ in length and amplitude as was first shown by Walraven for RR Lyr (4). Especially large are the differences between successive cycles for RW Cnc (Fig. 4). To represent these variations by longer periods may be successful for a short time-interval, but long series of observations show that the variations are not periodic. Sometimes the Blazhko effect may undergo considerable changes: *e.g.* for RR Lyr its amplitude was much smaller than in 1947 (see Fig. 5). For some RR Lyr stars, like RR Gem and SW And, the effect can temporarily cease to exist.

The changes of the Blazhko effect seem to be connected with the variations of the fundamental period P_0. This is evident for RW Dra, (Fig. 6) where every sudden increase in P_0 is accompanied by a drop of the amplitude effect, sometimes to a third of its previous value. For this star the O−C diagram for the secondary period, P', has a trend opposite to that for P_0. This is only partly valid for RR Lyr (Fig. 7). But it is a general rule that the amplitude of the Blazhko effect is small while the run of the O−C diagram is smooth. RRc stars showing light-curve changes have generally very complicated O−C diagrams.

In Fig. 8 we have arranged Babcock's measures of the magnetic field intensity of RR Lyr (5) according to the phases of P_0 and P'. There is no correlation with P_0, but a separation of positive and negative values is apparent in the course of the 41^d secondary period. Brightest maxima coincide with largest negative, lowest maxima with largest positive values of the field intensity. As the number of the magnetic observations is small, the correlation is not yet definitive. But if real, it may be of fundamental importance in understanding the nature of the Blazhko effect (6).

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The third speaker was *Th. Walraven* on "The short-period variables of the AI Vel type and on multicolour observations of V 703 Sco and other similar variables." No report.

Finally *P. Th. Oosterhoff* reported on work by Jansen on the Cepheid U TrA, which proved to be very similar to TU Cas, the ratio P_1/P_0 being identical for both Cepheids and equal to 0·710.

Scientific meeting, 22 August 1961

The topic of this meeting was:

Atmospheres of RR Lyrae variables

The first speaker was *J. B. Oke* (also on behalf of *L. T. Searle*) on:

ATMOSPHERIC CONDITIONS IN RR LYRAE STARS

Abstract. The observation of RR Lyrae stars with photo-electric spectrum scanners has now made it possible to study the atmospheres of these stars in considerable detail. From these scans the absolute energy in the spectrum is obtained at each phase. A comparison of this with model atmospheres determines the effective temperature T_e and the effective gravity g_{eff}. An analysis of SU Dra ($P = 0^{d}{\cdot}66$) yields effective temperatures ranging from 6000 to 7500 °K. The effective gravity varies from 20 to 100 cm/sec² except during the phases of rising light when it reaches a value of 2000 cm/sec². These very large gravities on the ascending branch of the light-curve make the Balmer discontinuities abnormally small and consequently produce the well-known loop in the usual 2-colour diagram. Using the monochromatic light-curves and model atmospheres one can solve for the relative radius R/R_{min} at each phase. The amplitude of the radius variation is 10%. This photometric displacement curve represents the motion of a layer which is always near $\tau = 0{\cdot}6$.

Spectra with a dispersion of 18 Å/mm have also been obtained for SU Dra. The metal lines give a velocity-curve which is continuous and nearly identical with that of RR Lyrae (Sanford, 1949). The Hα curve has a larger amplitude and is discontinuous, the hydrogen lines being double near maximum light. Since these velocity-curves are different, each layer in the atmosphere must be moving with its own characteristic velocity. Since the opacity is changing with phase the metal velocity-curve does not represent the motion of a particular layer of the star, and integration of this curve does not give a displacement-curve which can be compared with that from the photometric data. Fortunately between phases 0·4 and 0·8, the temperature, the pressure, and consequently the opacity remain effectively constant. Hence one can integrate this portion of the velocity-curve and compare the resulting displacement which refers to a fixed layer in the atmosphere with the photometric displacement-curve. This comparison yields an absolute radius for SU Dra which varies from 34×10^5 to 37×10^5 km.

The layer where the metal lines form moves $3{\cdot}2 \times 10^5$ km while the layer where the hydrogen cores are formed moves $6{\cdot}4 \times 10^5$ km. This implies that the scale-height of the atmosphere changes by a factor 17 between minimum and maximum distention. The scale-heights computed from the model-atmosphere data are in approximate agreement with this.

From the absolute radius and temperature at maximum radius, one finds an absolute visual magnitude at phase 0·40 of + 0·8. The total range in magnitude is from + 0·2 to + 1·2. This agrees with the recent determinations made by fitting colour-magnitude diagrams of globular clusters to the main sequence.

The period-density relation gives a pulsation constant of 0·06 if the mass in solar units of SU Dra is 1·0. Masses of 0·5 and 0·25 yield pulsation constants of 0·04 and 0·03 respectively. Since theoretical values are approximately in the range 0·03 to 0·04 days, it appears likely that the mass is considerably smaller than one solar mass. Using a mass of 0·5 and the radius obtained above one obtains an acceleration of gravity of 500 cm/sec². Combining this with the mechanical accelerations derivable from the radial-velocity curve suggests an effective gravity of about 300 cm/sec². This is considerably larger than that observed. It should be pointed out that the effective gravities inferred from the Balmer discontinuities may be in considerable

error because, (*a*) the absolute calibration of α Lyrae is uncertain in this wave-length region and, (*b*) the constant involved in the negative-hydrogen ion is somewhat uncertain.

One must be very cautious in applying static models to moving atmospheres as has been done in the above work. It can be shown readily that radiative equilibrium is always established. It can also be shown that unless accelerations are very large, even in a moving atmosphere static models are satisfactory approximations. It should be recalled that Babcock has observed a large magnetic field in RR Lyrae on several occasions. Such fields, if they exist generally, must play an important role in the interpretation of atmospheres of RR Lyrae stars.

The second speaker was *Hazelhurst* on: Shock wave phenomena in the atmospheres of RR Lyrae stars. An abstract follows.

SHOCK WAVES IN RR LYRAE VARIABLES

The good overall agreement found by Oke and Bonsack (*Ap.J.*, **132**, 417, 1961) in RR Lyrae and by Oke (see above) in SU Draconis between the kinematic and model-atmosphere effective gravities is here ascribed to the existence of radiative equilibrium in the atmosphere at almost all phases. The sharp increase in g_{eff} just after light minimum and the doubling of the hydrogen lines are attributed to the formation of a collision layer generated by the meeting of the infalling and rising gases.

It is suggested that there is a temporary breakdown of radiative equilibrium along the path of this collision layer and that the subsequent diffusion of the excess radiation is responsible for the observed temperature variation. The decay time of the temperature curve indicates the presence of Mach 2 shock within the collision layer. It is emphasized that line doubling could occur even in the absence of a shock within the layer.

The incorporation of the observed value of the temperature peak within the shock propagation calculations permits an estimate of the atmospheric density. This is in good agreement with that obtained by the usual (indirect) methods.

Combined scientific meeting of Commissions 27, 27*b* and 37, 19 August 1961

Variable Stars in Clusters

First speaker, *R. P. Kraft* on

CLASSICAL CEPHEIDS IN GALACTIC CLUSTERS

Abstract. The most reliable data on Cepheids in galactic clusters have been collected in the following table:

Star	log P	$E(B-V)$	$\langle(B-V)^\circ\rangle$	$\langle M_V^\circ\rangle$
EV Sct	0·490	0·58	+0·57	−2·62
CF Cas	0·687	0·555	+0·655	−3·45
U Sgr	0·628	0·55	+0·605	−3·92
DL Cas	0·908	0·50	+0·72	−3·84
S Nor	0·989	0·205	+0·78	−3·96

From these data we find the relation between intrinsic colour and period:

$$\langle(B-V)^\circ\rangle = -0{\cdot}101\,(\log P)^2 + 0{\cdot}538\,(\log P) + 0{\cdot}264$$

and the zero-point of the period – luminosity relation:

$$\langle B^\circ\rangle = -1{\cdot}33 - 2{\cdot}25\log P$$

in which the coefficient of log P follows from a study of the Small Magellanic Cloud. On the basis of these relations one can find

(*a*) spiral structure from Cepheids brighter than $\langle M^\circ\rangle = -4{\cdot}5$;

(*b*) Oort's constant $A = 15$ km/sec/kpc.

It seems that there may be classical Cepheids at large distance in the northern Milky Way having low metal abundance.

Second speaker, *A. D. Thackeray* on

RR LYRAE VARIABLES IN CLUSTERS IN THE MAGELLANIC CLOUDS

Abstract. Searches for RR Lyr variables in the following globular clusters have been successful: NGC 121 (SMC), and NGC 1466, 2257 (LMC), probably also in NGC 1978. Three-day Cepheids have been found in NGC 1866, confirming Shapley's findings.

A few pairs of Radcliffe plates of a number of other clusters in both Clouds have also been searched for variables without success. Details will be communicated on request. The difficulty of finding variables at 19th magnitude naturally increases greatly for clusters in rich regions. For this reason it is not surprising that searches were quickly successful in outlying clusters like NGC 121, 1466 and 2257; the latter is so far out that it lies outside Kerr's 21 cm isophotes. These regional successes do *not* prove that Cloud clusters containing RR Lyrae variables are only to be found in the outer regions, although this possibility cannot be excluded.

Third speaker, *G. H. Herbig* on

IRREGULAR VARIABLES IN YOUNG CLUSTERS AND ASSOCIATIONS

Abstract: There are a number of questions concerning the irregular variables in young clusters and associations that are particularly pertinent at the present time, and that should be brought to the attention of members of these Commissions.

1. A very thorough study of the light-curves of a representative group of T Tauri stars, extending over several seasons and including a search for new variables, is long overdue. The region of the Tau-Aur dark clouds ($3^h\,40^m < \alpha < 5^h\,00^m$, $+\,15° < \delta < +\,30°$) is recommended. There are about 55 known T Tauri stars in this area brighter than $m_{pg} = 17{\cdot}5$, and probably many more variables remain undiscovered. The plates should be inspected not long after exposure in order that interesting changes can be promptly brought to the attention of spectroscopists.

2. An especially careful watch, by either photographic or visual observers, should be kept on "nova-like" T Tauri stars such as UZ Tau, VY Tau, and EX Lup, so that quick announcement can be made of any flare-up.

3. It is very desirable that a photo-electric check be made of the bright B- and A-type variables in the Orion Nebula, to see if they are truly variable, or whether their apparent changes were simply the result of background difficulties. No such variables have been found in other similar associations, and few modern photo-electric observations have not shown any variation.

4. Photometric study of the bright variables of later type found in nebulae is desirable; here, however, the variation is unquestioned. Examples are FU Ori, BF Ori, and VY CMa.

5. A search is recommended of a number of nearer clusters and associations for the flash-variable population that has been found in Orion, NGC 2264, and the Tau-Aur clouds by Haro and Rosino.

Fourth speaker, *J. Sahade on*

W UMa VARIABLES IN GALACTIC CLUSTERS

Abstract: Sahade and Frieboes published the results of a preliminary search for these variables in galactic clusters. Three or four are now known to be certain cluster members,

including TX Cnc in Praesepe, RZ Com in the Coma Berenice cluster and IR Car in NGC 3532. Sahade and Frieboes also noted that these variables appeared in clusters with ages near 10^8 years. This fact was further discussed by Eggen for the three stars mentioned above, all of which have periods near $0^d{\cdot}36$ and lie approximately one magnitude above the main sequences of the clusters concerned. It is very important to attempt the discovery of additional variables of this type in other clusters to ascertain whether or not (*a*) they occur in clusters of all ages and (*b*) a correlation exists between the period of the variable and the age of the cluster.

Sahade and Béron Dávila are now completing a more extensive catalogue of eclipsing variables of all types in galactic clusters which will greatly extend and revise previous catalogues of this kind by Kholopov and by Kraft and Landholt. Accurate photometry is obviously desirable for all these variables.

Fifth speaker, *B. V. Kukarkin* on

VARIABLE STARS IN WIDE AREAS AROUND GLOBULAR CLUSTERS

Abstract: Kurochkin and Kukarkin started a search for variable stars in very wide areas around globular clusters. Preliminary conclusions are: (*a*) RR Lyrae type variables exist at very great distances from the globular clusters, up to 2 kpc. According to the values of $(m - M)$ the majority of them belong to the clusters. The estimated number of field RR Lyrae variables is several times smaller than the number of variables actually discovered. (*b*) One can estimate that one third of all RR Lyrae stars, not connected now with globular clusters, have originated from such clusters.

With more material we may be able to evaluate: the number of stars leaving a cluster, the velocity of escape, the masses of the clusters, the time during which a star remains in the RR Lyrae stage and the direction of evolution for these variables.

Two recommendations: (*a*) Some W UMa stars are sub-dwarfs and quite a few could be expected in globular clusters. Therefore it is important to search for new variables which are 3 - 5 magnitudes fainter than the RR Lyrae stars. (*b*) Many of the red giants, 2 - 4 magnitudes brighter than the RR Lyrae stars, may be variable. Plates with long time-intervals should be used for their discovery.

Sixth speaker, *Tifft* on

THE CLUSTER NGC 121 IN THE SMALL MAGELLANIC CLOUD

Abstract. NGC 121 appears to have a colour-magnitude diagram fairly closely like galactic globular clusters. The red-giant variables lie on the extension of the giant branch, and the cluster-type variables lie at the blue end of a red-populated horizontal branch. For the red variables $\langle V\rangle = 16{\cdot}4$ and $\langle B\rangle - \langle V\rangle = 1{\cdot}9$. Cluster-type variables in the field have $\langle V\rangle = 19{\cdot}6$ and $\langle B\rangle - \langle V\rangle = 0{\cdot}25$. These variables are slightly brighter in the cluster than in the field, but this is possibly due to background enhancement.

Last speaker, *L. Rosino* on

WORK BEING CARRIED OUT AT THE ASIAGO OBSERVATORY

Abstract: A systematic survey has been made in 1959–61 in the regions of the Trapezium and the Horsehead Nebula (ζ Orionis) with the 50–40 cm Schmidt and with the 122 cm reflector. Light-curves of many irregular variables have been derived and 97 new variable stars were discovered around the Trapezium, NGC 1977 and NGC 1999. Many new variables were also discovered near ζ Orionis. Some of the new variables show flares. Variables have been found in NGC 7023 (Rosino and Romano); M 8 (Rosino); M 17 and M 20 (Maffei).

Photographs of some loose and distant clusters have been taken with the Asiago reflector and with the Lick 120-inch, by Kinman and Rosino. In particular the following clusters are now under investigation for variables as well as for distance and colour-magnitude diagram: Abell 1, 2, 4, 5, 10, 11, 12, 13, IC 1276 (Abell 7) and the Shakhbazian cluster. The last is probably not a physical association of stars, but simply an assembly of some extremely distant galaxies and some foreground stars. Clusters Nos. 2 and 10 are deeply reddened, they are scarcely seen on the blue Asiago plates, but they appear fairly rich in yellow and deep red. Nos. 4, 5 and 13 have been the object of preliminary study by Rosino; work is continued on the luminosity function, the HR diagram and the periods of variables. No variable stars have been found in Abell 11, but this search is not complete. Five were found in Abell 7, one of which has a large amplitude and a period greater than 30 days. Several suspected variables are present in Abell 12. Finally Zwicky's cluster at $16^h\ 57^m$, $-0°\ 28'$ (1950) has been observed and several suspected variables identified.

27*b*. SOUS-COMMISSION DES ETOILES VARIABLES DANS LES AMAS

Report of Meeting, 22 August 1961

PRESIDENT: Mrs H. Sawyer Hogg.
SECRETARY: L. Rosino.

DRAFT REPORT AND BUSINESS

The meeting opened at 11^h. The *Draft Report* was approved and discussion proceeded on the proposals in Section 4 of the report.

1. Detre emphasized the importance of having photographs of globular clusters taken at different observatories made available to interested observers for the study of variable stars. It was noted that Sandage is preparing to publish a detailed study of the U,B,V light-curves of the variables in Messier 15, a cluster for which periods have been published without observations. Oosterhoff supported the request of Detre. The Sub-Commission was in favour of the proposal.

2. Detre proposed further that new plates be made in order to study the secondary changes of periods of variable stars in ω Centauri. Schwarzschild stressed the importance of such a search in this important cluster. Oosterhoff noted that, with the period already known with high accuracy, only a small number of plates is sufficient for the study of secular variations. The Sub-Commission was in favour of the proposal.

3. The President noted that, at the meeting of Commission 27, the Sub-Commission had been transformed to a Committee consisting of H. Arp, L. Rosino, A. J. Wesselink, with H. Sawyer Hogg as chairman.

4. With the business of the Sub-Commission thus concluded, the President invited scientific discussion on results of researches obtained since the *Draft Report* went to press.

SCIENTIFIC REPORTS AND DISCUSSION

Rosino spoke of the recent photographic researches made with the 120-inch telescope of the Lick Observatory by Kinman and himself, on some loose inter-galactic clusters, like Abell 1, 5, 11 and 13, the Shakhbazian cluster, and IC 1276. An RR Lyrae star and two variables with periods greater than 100 days and large amplitude have been found in IC 1276 (No. 1 by H. Sawyer Hogg, Nos. 2 and 3 by Rosino and Kinman).

Kinman reported on a study of NGC 2419. The periods of the variable stars in this cluster will be derived from material taken with the 120-inch telescope. Of two RR Lyrae variables already studied, one has a period of 0·37 and one of 0·63 days.

P. Hodge told of his search, with Miss F. W. Wright, for variable stars of the W Vir type in red globular clusters of the Large Magellanic Cloud. They have found 13 variables in, or superimposed on, 10 clusters. Periods and magnitudes are being determined to see how these stars compare with Cepheids in the general field of the Cloud.

Van Hoff announced his discovery, from Boyden Station plates, of 15 RR Lyrae variables in the globular cluster NGC 6362, 7 of sub-class *a* and 8 of sub-class *c*. He remarked that while the frequency distribution of the periods is that of the Oosterhoff group I, the ratio *a*/*c* is typical of the other group.

Arp mentioned his work on the position of some irregular variables in the H-R diagram of 47 Tucanae. Wesselink is following photo-electrically the RR Lyrae stars recently found in this cluster. Feast told of the spectra that he and Thackeray have obtained of the three long-period variables. Although the mean radial velocity is in agreement with the velocity of the cluster, the individual values show a considerable spread.

The President noted that since the joint meeting of Commissions 27, 37 and Sub-Commission 27 *b* had dealt very fully with variables in galactic clusters, this meeting had been concerned with variables in globular clusters. She mentioned, however, the work of F. Spite of Lille, who is trying to ascertain if any of the RR Lyrae stars tabulated by Kholopov in the regions of galactic clusters are actual members.

Hoffmeister, at the end, gave interesting data on the probability of discovery of RR Lyrae variables, taking into consideration such factors as number of pairs of plates searched and magnitude above the plate limit.

28. COMMISSION DES NEBULEUSES EXTRAGALACTIQUES

Report of Meetings

PRESIDENT: N. U. Mayall.
SECRETARY: G. C. McVittie.

Meetings were held on 16 August, $11^h - 12^h$, 19 August, $10^h - 12^h$, 21 August, $9^h - 11^h$, and 22 August, $15^h - 17^h$. A joint discussion with Commission 40 was held on 21 August, $14^h - 17^h$.

Business meetings

At the business sessions, the following matters were dealt with:

(*a*) The *Draft Report* was approved subject to typographical corrections.

(*b*) It was announced that J. B. Sykes had prepared an English translation of G. Ogorodnikoff's 'Dynamics of Stellar Systems', which was being published by the Pergamon Press.

(*c*) The group of astronomers carrying out the International Super-nova Search should become a Committee of the Commission, with the following membership: C. B. Bertaud, E. F. Carpenter, G. Haro, B. V. Kukarkin, G. Mulders, L. Rosino, J. L. Sérsic, P. Wild, with F. Zwicky as Chairman.

(*d*) A list of eight names was drawn up by the Commission of persons who might be members of the Organizing Committee. The President was asked to decide on four persons from this list who would form the Organizing Committee. He selected the following: E. Margaret Burbidge, B. Y. Mills, A. R. Sandage and A. D. Thackeray. As proposed by the Executive Committee, the new President would be B. Lindblad, and the Vice-President, R. L. Minkowski.

(*e*) The Commission sent forward to the Executive Committee of the Union a resolution that the name of the Commission be changed to 'Commission on Galaxies' (Commission des Galaxies). [This was approved by the Executive Committee and the General Assembly.]

(*f*) Oort proposed that the word 'inclination' in extra-galactic research should be used only for the angle between the equatorial plane of a galaxy and the plane of the sky, at the position of the galaxy. The Commission endorsed the proposal and recommended it to all astronomers working on galaxies.

(*g*) The President proposed, and the Commission approved, that G. C. McVittie should continue as Secretary of the Commission for the next General Assembly.

(*h*) Sub-Commission 28*a* on the Magellanic Clouds was reconstituted as a Committee of the Commission, with the following membership: S. C. B. Gascoigne (Chairman), F. J. Kerr, J. L. Dessy, E. M. Lindsay, A. D. Thackeray, W. G. Tifft and T. Walraven. The Committee held a special meeting and agreed to the following recommendation regarding co-ordinate systems in the Magellanic Clouds: where the use of a rectangular co-ordinate system is desirable, the Committee recommends that the (ξ, η) system of Wesselink be preferred to the Harvard (X, Y) system.

(*i*) An *ad hoc* group on Galaxy Photometry met under the chairmanship of G. de Vaucouleurs. It was agreed that an informal liaison group should be established: G. de Vaucouleurs (Dept. of Astronomy, Univ. of Texas, Austin 12, Texas) will centralize informa-

tion on programs, equipment, etc., and circularize interested astronomers. A list of a dozen or less 'Reference Objects' in the equatorial belt of the sky will be set up. A preliminary list includes NGC 3379, 4486, 3115, 4111, 4594, with others to be selected after further exchange of views. Observers undertaking extensive programs of surface photometry (iso-photometry) will be encouraged to observe these objects in order to check techniques and to provide theorists with the best possible data on some typical systems. Recent and current observing programs were reviewed: a detailed tabulation will be circularized later after observers have communicated more detailed information. This will include both detailed surface photometry and integrated magnitudes and colors. The new iso-photometer of the University of Texas was described and tracings shown: this instrument will be commercially available in 1962. Koelbloed indicated that an iso-photometer will be tested shortly at the Sterrekundig Instituut in Amsterdam.

(*j*) Considerable attention was devoted to the question of the contamination of space in the neighbourhood of the Earth and, in particular, to Project West Ford. This was described by Liller on the general lines of his article in *A. J.*, **66**, 105, 1961. At the last session of the Commission, Oosterhoff described the two resolutions on space contamination that were to be presented to the General Assembly by the Executive Committee of the Union. The Commission passed a resolution supporting the action of the Executive Committee.

(*k*) The President asked Holmberg to report on the work of the *ad hoc* Committee on catalogues of galaxies of which he was Chairman. Holmberg stated that his Committee would prefer to leave the question open until the 1964 General Assembly. Zwicky, Vorontsov-Velyaminov and de Vaucouleurs had issued, or were issuing, their own catalogues outside the purview of the committee. By 1964, these catalogues would be available and, at that time, it would be easier to decide whether any further catalogues of galaxies would be needed and, if so, what their form should be.

The President asked Zwicky, de Vaucouleurs and Vorontsov-Velyaminov to describe their catalogues briefly.

Scientific meetings

At the sessions devoted to reports of scientific work, the first speaker was *J. L. Sérsic* who described the work at Córdoba on the Shapley-Ames galaxies brighter than the eleventh magnitude and lying south of $-25°$. Photographic isophotes have been traced and a set of maps will be ready by the end of 1961. A search for variable stars in NGC 55 and 300 is being conducted. Standardized plates for photometric purposes for the NGC 1566 group have been obtained. Peculiar objects such as NGC 1487 and 3256 have been studied photometrically and particular attention is being devoted to NGC 6438. The total photographic magnitude of NGC 5128 has been determined to be 8·0 and the distance of the galaxy has been found to be 4 Mpc.

The next speaker was *W. A. Baum*, who gave the following report on his work:

"The most powerful test of world models is the relationship between the redshifts and the bolometric magnitudes of galaxies belonging to clusters, but redshifts well beyond the usual spectrographic limit at $z \sim 0{\cdot}2$ are needed to make this test decisive. In the present program, the redshifts of three clusters beyond $z \sim 0{\cdot}2$, as well as those of five nearer clusters, have been observed by a completely photo-electric method undertaken in 1955. These redshifts are obtained by measuring each galaxy photo-electrically in six or eight colors ranging from ultra-voilet to infra-red. The observations are translated into a spectral-energy distribution-curve in terms of energy per unit wave-length as a function of wave-length. When plotted on log-log scales, the $E(\lambda)$ curve for a distant, redshifted galaxy is similar in shape to

the $E(\lambda)$ curve for a nearby galaxy having no appreciable redshift, but the two curves are displaced from one another. The horizontal (log λ) displacement yields the redshift, while the vertical displacement yields the difference in bolometric magnitude. There are no K-corrections except for a geometric one due to the logarithmic abscissa.

"The uncertainties in the magnitudes are greater than those in the redshifts but are not believed to be serious enough to upset the general nature of the results. The magnitudes require normalization to a standard intrinsic diameter, they require the relating of the luminosity functions of the various clusters to one another, and they are more vulnerable than the redshift to any evolutionary effect. For the normalization of magnitudes to a standard diameter, the intensity profiles of some representative galaxies have been measured photo-electrically. The relating of luminosity functions can be improved by further photometry. The dependence on evolution can be estimated from a population model for elliptical galaxies that has been derived in connection with the present program.

"The largest redshift thus observed is $z = 0{\cdot}44 \pm 0{\cdot}03$ for the cluster found by Minkowski in the position of Cambridge Radio Source 3C 295. On the assumption that the emission line found by Minkowski at 5448 Å is [O II] 3727, the validity of the photo-electric method is well confirmed out to the distance of that cluster. The two main observational problems ahead are to find more clusters in this range or beyond, and to construct a multi-channel instrument for accelerating the observations.

"It is difficult to judge the probability of finding additional clusters through the identification of radio sources, but it would be over-optimistic to hope for an adequate sample from that method alone. We shall probably have to depend mainly upon optical discovery. Photographic searching with the 48-inch Schmidt telescope has already been explored with the help of techniques for slightly extending its threshold beyond the limit of the Sky Survey plates, and some further work of that kind will probably be worth pursuing. Searching with the 200-inch telescope may also be practicable when large-field image converters become available.

"The photo-electric redshift-magnitude observations themselves should be greatly accelerated by measuring all colors at once instead of one color at a time. A multi-channel photometer is now being prepared for permanent installation in the east side-arm of the 200-inch telescope. In its initial design the instrument consists of an $F/16$ zero-deviation liquid-prism spectrograph and eight pulse-counting channels. It is a rotatable structure about 6 meters long with provision for co-ordinate offsets, for guiding, and for automatic commutation between object and sky. We contemplate the eventual addition of channels for simultaneous observation of object and sky."

de Vaucouleurs described the work that is being done on the photographic photometry of bright galaxies at a number of observatories. He mentioned the Harvard College Observatory–University of Texas project in some detail, describing the iso-photometer he was using and the isophotes of galaxies that had been obtained. He then proceeded to review the work on photo-electric photometry being carried out by a number of workers. de Vaucouleurs emphasized the need for co-ordination and co-operation in studies of this kind, in order to prevent duplication of effort and also to secure an agreed method of presenting the results. He thought that standard objects should be selected, such as NGC 4486, 3115, 4595, etc., to serve the same purpose as the standard reference stars in stellar photometry. It was agreed that a group of interested astronomers should meet on August 23 to discuss these problems of co-operation in the work on the photometry of galaxies.

Contopoulos described theoretical work being carried out at Thessaloniki. It concerns the events that occur during a collision between two galaxies. The perturbations produced in

stellar orbits during the collision, and which arise from the ellipticity of the galaxies, are insignificant if the orbits lie close to the planes of symmetry. It is, however, possible that, under certain conditions, ejection of stars from the galaxies can take place. Further work is planned on this aspect of the problem in order to find the order of magnitude of the ejected mass, the relationship to the observed tails of galaxies, etc.

Hoffmeister spoke of the observations he had made at the Boyden Observatory in 1959. He had taken plates with the 250 mm Metcalf camera in order to investigate in 13 fields the RR Lyrae stars of the galactic halo. The plates were checked for transparency of the areas by marking and counting extra-galactic objects. About 2 to 3 degrees north of ι Mic a region of 15 to 20 square degrees was found to be practically free of extra-galactic objects. Only 5 faint and small objects were found, where statistically 20 to 30 from 12^m to 16^m might have been expected. This region shows a rather sharp limit. The surprising fact is that both normal galactic stars and RR Lyrae variables of the galactic halo are present in the expected number. Thus, if there is an absorption effect, the absorbing cloud must lie beyond the galactic halo. For several reasons such a cloud is expected to merge gradually into the unobscured surroundings. So there must be an increase of mean brightness of the galaxies and an increased number of elongated forms, when one procedes from the centre of the obscured region to the undisturbed area, the latter effect being caused by the fact that any absorption depresses first the fainter outer parts of a galaxy, independent of its distance. Thus five different areas were investigated: 1, the region of strongest obscuration; 2, 3, and 4, three concentric zones surrounding this region, of 30′ breadth each; 5, the undisturbed area outside the 4th zone. Here are the results:

	Mean Magnitude $\bar{m}$	Number n	Number n	Percentage of elongated forms
Area 1	15·75	5	5	0·0
,, 2	14·97	36	25	24·0
,, 3	14·85	36	19	31·6
,, 4	14·69	34	22	36·4
,, 5	14·58	106	46	47·8

The effect on the left side might eventually be due to the tendency toward grouping. On the right side, to avoid the grouping effect, only the galaxies of 15^m and fainter have been included. Thus strong evidence is given that there really exists a distant absorbing cloud in this region of the sky. The absorption might be estimated to be at least 2 or 3 magnitudes, probably more. As to the size and shape of the cloud, the most probable hypothesis might be that it is of similar size to the Magellanic Clouds, and that it is a member of the Local Group.

E. Margaret Burbidge then gave an account of the work done at Yerkes and McDonald Observatories on the measurement of rotation curves of spiral and irregular galaxies, and of the determination of mass distributions and total masses from these measurements. The Table contains the presently available masses and mass-to-light ratios for spiral and irregular galaxies, not only from work by Prendergast and the Burbidges at Yerkes, but also from work by Mayall, de Vaucouleurs, Volders, Münch, and Raimond *et al.* In the Yerkes work, a long slit (5′) was used so that one or two spectra usually covered most of the major axes of suitably oriented galaxies. The Hα and [N II] emission lines were then measured at points along the length of the slit, and absorption lines were measured in the central regions. The night-sky lines of [O I] and the Ca II absorption lines H and K on twilight or moonlight spectra, all extending the full 5′, provided a check on the accuracy of the spectrographic curvature correction and on systematic errors in the measurement of both emission and absorption lines.

The table shows a general increase in $\mathfrak{M}/L$ in the progression of types Irr-Sc-Sb-Sa, but the correlation is only loose, partly because of the effect of internal absorption within the galaxies (*e.g.* M 82, in which L was not corrected for the undoubtedly large internal absorption).

Galaxy	Type	$\mathfrak{M}/\mathfrak{M}_\odot \times 10^{-10}$	$\mathfrak{M}/L_{pg}$ (solar units)
M 82	Irr.	1·5	7·4
NGC 55	Irr.	~4	~6
NGC 3556	Irr.-Sc	1·4	1·4
LMC	Irr.-Sm	1·3	4
NGC 3646	Sb-Sc(p)	>20−30	>2·5−4
NGC 2146	Scp	1·8	3
M 33	Sc	1·8	11
NGC 157	Sc	6·0	1·9
NGC 3504	SBb	0·3-0·9	≲1
NGC 5055	Sb-Sc	5·5	2·8
NGC 2903	Sb	4·9	>4·2
M 101	Sc	1·4	13
NGC 5005	Sb	9	6
M 81	Sb	15	20
M 31	Sb	34	23-10
NGC 3623	Sa-Sb	20-30	10-20

Problems arising in the Yerkes-McDonald work were mentioned, such as: (*a*) whether non-circular motions might occur in some cases; (*b*) whether a galaxy might have more than one system with non-coplanar principal planes; (*c*) the difficulty, related to (*a*) and (*b*), arising in some cases, of determining the equatorial plane. NGC 3646, a very large Sbc galaxy with an outer structure apparently not in dynamical equilibrium, was cited as an example of (*a*). NGC 4736 was cited as an example of (*c*). A mass for the latter galaxy is not yet available.

Richard Miller followed with a report on the detailed photometric study of the EO galaxy NGC 3379. A point-by-point scan with a photo-electric photometer has been carried out. About 400 points were measured, distributed over the galaxy image, to determine the position dependence and to check the symmetry. The colour is nearly constant but becomes slightly redder within half a minute of arc from the centre. A preliminary account of the reductions was given.

In the discussion following the papers by Dr Burbidge and by Miller, the President was urged to publish his results on the rotations of some 80 galaxies that he has observed.

Zwicky spoke on the International Super-nova Search. He pointed out that the division of super-novae into two classes only, Type I and Type II, is likely to be inadequate. He thinks that there is already an indication that five types may be needed. He cited the super-nova in NGC 4303, whose light-curve fluctuated about the maximum for 60 days, and whose sprectrum looked somewhat like that of an O-type star. He also referred to the super-nova in NGC 3003, whose spectrum was very difficult to understand. Since the year 1885, 100 super-novae have been found. It was to be expected that the Super-nova Search should produce about 40 super-novae per year from now onwards. Zwicky thanked the National Science Foundation of the United States, and the governments of all the countries in which the observatories taking part in the Search lay, for their financial support of the program.

Vandekerhove described his ideas on the spectro-photometric gradients of galaxies and *Oosterhoff* drew the attention of the Commission to the work, which was proceeding under

his direction, on the Sculptor dwarf system in Ursa Minor. A complete analysis of Baade's 200-inch plates of this object was in progress. Over ninety variables had been found and these were probably all that existed.

The work done at the Burakan Observatory, since 1958, on the colorimetry of galaxies was discussed by *Markarian*. A photographic image of a galaxy, made with a Schmidt telescope, is measured by a fast-acting microphotometer that has a square diaphragm. Each square section of the galaxy image is measured and there is no overlap of squares. A map of the distribution of brightness and colour over the galaxy image is thus produced.

These maps can be used to find the integrated brightness and colour of the galaxy as a whole, and also of its various regions. The change of brightness and colour between centre and outer parts was thus determined, as were these quantities for the disk alone, for the spiral arms, for the bar of barred spirals and for stellar associations. The relative blueness of the outer parts of spirals was noted, in agreement with de Vaucouleurs' results. The effect is due to the change in composition of the disk population and only partially to the increasing amount of radiation from the spiral arms as the outer parts of the spiral are attained. Asymmetry in the distribution of brightness and colour was observed in many galaxies. In the case of M 51 the asymmetry is explained by the assumption that there is a large quantity of dark matter in the region between the two components of the galaxy.

28*a*. SOUS-COMMISSION DES NUAGES DE MAGELLAN

Report of Meeting, 23 August 1961

PRESIDENT: S. C. B. Gascoigne.
SECRETARY: M. W. Feast.

The *Draft Report* was approved without a discussion. The President drew attention to the fact that there had been a meeting of the Sub-Commission in Cordoba in December, 1960.

The President initiated a discussion on nomenclature for variable stars in the Magellanic Clouds. At present the majority of variables in the Clouds were discovered at Harvard and have HV numbers. However, there are considerable doubts as to whether many of the variable stars can now be recovered as the positions are not generally very accurate and no maps are available for many. Furthermore, extensive work is already in progress which will produce many more variables (*e.g.* the work of the Greenwich astronomers, Dessy, etc.). Dr Eggen stated that all Greenwich variables would be given a Greenwich number irrespective of whether or not they had already an HV designation. This was necessary since it was difficult to be certain in many cases of the identification with an HV star. Dr Gascoigne spoke of the help he had received from Dr Shapley and the Harvard Observatory in finding HV stars. Much of the unpublished Harvard material is now in Dr Gascoigne's keeping at Mount Stromlo in card-catalogue form. The best way to make use of this material was discussed, but no final decision was reached. An attempt to map all the variables had been begun at Mount Stromlo, but not completed. Dr Tifft offered help in the construction of charts of Harvard variables. Dr Thackeray proposed a motion that all observers be strongly urged to publish finding charts for all new variables. This motion was passed unanimously. It was also agreed that observers should be urged to print both the scale and orientation on each map. The normal practice (North at top, West to the right) should be followed, and Dr Bok suggested

29. COMMISSION DES SPECTRES STELLAIRES

Report of Meetings

PRESIDENT: L. H. Aller.
VICE-PRESIDENT: Anne B. Underhill.
SECRETARY: Margherita Hack.

Business meeting, 17 August 1961

The President, L. H. Aller, announced the names of the Commission executives. These are: Vice-President, A. B. Underhill; Secretary, M. Hack; Organizing Committee, M. W. Feast, Y. Fujita, H. Kienle, A. Melnikov and J. Sahade. It was suggested that V. Bappu, W. Iwanowska, and A. Slettebak act as alternates should any of the above be unable to serve.

The *Draft Report* was adopted with minor corrections.

Following this the question of reprinting the Henry Draper Catalogue was discussed. A motion, moved by A. B. Underhill and seconded by J. Sahade, that a working group be established to evaluate the need for reprinting the Henry Draper Catalogue, to estimate the cost of such a project, and to investigate the possible methods of proceeding was passed. C. H. Gaposchkin was appointed chairman of this working group.

Greenstein reported on a proposal by R. Griffen to produce an intensity-tracing atlas of the spectrum of α Bootis from Mount Palomar spectrograms. The spectrograms have a resolution of at least 100 000 and the linear dispersion is 1·1 Å/mm in the range λ3600 to λ5500 and 1·6 Å/mm in the range λ5300 to λ6800. Samples were shown of the intensity tracings that it is proposed to reproduce. The scale is closely similar to that of the Utrecht Solar Atlas. Greenstein requested that comments regarding the desirability of the undertaking be addressed to him. It appears that such an Atlas would be a valuable teaching aid as well as a source of useful information for research purposes.

The future organization of Commission 29 was discussed and it was decided to make no major change at present. There will be three Committees and one Working Group.

1. Committee on Line Intensity Standards—Chairman, K. O. Wright.
2. Committee on Spectral Classification—Chairman, W. P. Bidelman.
3. Committee on Spectrophotometry—Chairman, J. B. Oke.
4. Working Group on Question of Reprinting H. D. Catalogue—Chairman, C. H. Gaposchkin.

Slettebak reported that he and Iwanowska had concluded that the best way to effect the exchange and loan of high-disperson spectroscopic material was through personal contact between the interested parties and that attempts to establish a central clearing office were undesirable at present.

The value of and need for concentrated, high-dispersion observing of selected objects with spectra that may vary rapidly, for example, W. Serpentis, was emphasized by M. Hack. Observations of W Serpentis are urgently needed at phases between 13·2 and 13·7 days at a dispersion close to 10 Å/mm.

Working group on Be stars

After the formal business meeting had adjourned, a working group on Be stars was organized with Mme R. Herman as chairman and D. B. McLaughlin and A. A. Bojartchuk to represent

that any plate reproduced should be photo-visual. The President of Commission 27 (Dr Oosterhoff) announced that his commission had set up a small sub-committee to look into the problem of variable star nomenclature in the Magellanic Clouds. This is to consist of Wesselink, Payne-Gaposhkin, Arp and Buscombe.

The meeting then discussed the system of co-ordinates to be adopted in the Magellanic Clouds. Positions of many of the objects in the Clouds are published in the Harvard x, y system. Dr Gascoigne drew attention to the fact that at its Cordoba meeting the Sub-Commission had decided that, where a rectangular co-ordinate system was desired, then the standard co-ordinates ξ, η, as discussed by Wesselink (*M.N.* **119,** 576, 1959) should be used in preference to x, y. The Radcliffe Observatory had prepared tables giving x, y, ξ, η, and α, δ for a considerable number of objects. Dr Stoy stated that the section of the 1950·0 Cape Catalogue covering the Magellanic Clouds had now been finished and could be supplied to interested observatories in microfilm form. This catalogue gives about 10 stars per square degree to $10^m - 11^m$ with an accuracy better than $0''{\cdot}1$. He also reported on a Cape-Greenwich programme to measure 144 stars per square degree, going down if necessary to $13^m - 14^m$. He felt that these stars will provide a sufficiently fine grid that the position of any object could be measured accurately in α and δ with respect to them. This would probably obviate the need for a rectangular co-ordinate system. Dr Gascoigne said that the Uppsala-Stromlo maps of the Clouds would be ruled in both α, δ and ξ, η. Dr Lindsay noted that whatever system of co-ordinates was used maps were essential in crowded regions.

A number of scientific contributions were then presented. Dr Tifft spoke of his work on NGC 121 and the surrounding field of the SMC, and Dr Walraven of the multi-colour photometry carried out on Cloud B-type stars by himself and his wife. Dr Fehrenbach reported that the telescope to observe radial velocities in the Clouds by his objective prism technique had now been set up in South Africa. Dr Lindsay announced that he and Dr Shapley were preparing a new catalogue of some 900 clusters (mainly open) in the LMC. A Cape-Herstmonceux programme will determine proper motions for foreground stars in the LMC to $15^m - 16^m$ by comparison of new and old (40 to 60 years) astrograph plates. Current work at Mount Stromlo, Sydney (radio), Cordoba and Pretoria (Radcliffe) was reported. There was also a discussion of the frequency of foreground stars to be expected in colour-magnitude diagrams of regions of the Clouds.

the Northern Hemisphere and J. Sahade and A. D. Thackeray to represent the Southern Hemisphere.

Joint meeting with Commission 25, 18 *August* 1961

A joint session of Commission 29 was held with Commission 25 at 7 p.m. on Friday, 18 August, to discuss the setting up of color and energy-distribution standards in a zone between declinations $+15^\circ$ and -15° so these stars could be used as standards by observers in both hemispheres. A committee consisting of G. E. Kron and J. B. Oke was appointed to co-ordinate activities of observers interested in this problem.

Joint meeting with Commission 9, 21 *August* 1961

A joint session was held at 9 a.m. on Monday, 21 August, with Commission 9, to discuss practical problems that arise in coudé spectroscopy.

Scientific meeting, 18 August 1961

The scientific program consisted of the following papers:

Summarizing Reports—

H. Kienle, Absolute Stellar Energy Distributions

J. L. Greenstein, Spectra of Faint Stars

H. W. Babcock, Properties of Magnetic Stars

Short Papers—

C. and M. Jaschek, Spectroscopic Work at La Plata

L. Frederick, Some Image Tube Results of Spectroscopic Interest

N. Roman, Rocket Observations of Stellar Spectra

A. Thackeray, Comments on η Carinae

ABSOLUTE STELLAR ENERGY DISTRIBUTIONS

H. Kienle

H. Kienle briefly summarized some of the calibration work described in the *Draft Report* and mentioned recent results on carbon arcs and ultra-violet standards that are suitable down to 2000 Å. Bahner's very preliminary results of work done at the McDonald Observatory with photo-electric scanning seems to show that: (1) the spectrum of α Lyrae may be represented precisely by a Planckian curve for 14 000 °K. from λ4000 to λ6800 to within 0·01 in the logarithm of the flux; (2) there is no discontinuity larger than 0·01 in log F near λ4800 in the spectra of the B stars; (3) the apparent excess of radiation near λ4800 found when B stars are compared with F stars disappears if the measurements are corrected for unresolved lines; it seems to be caused by a minimum of line concentration in this part of the F spectrum.

Discussion of Kienle's paper. Greenstein remarks that the lines are very important in the determination of stellar gradients. It would be desirable to derive gradients both with and without lines.

Kienle replied that his group is doing this, in fact. They use both a wide slit (35 Å resolution) and a narrow slit (0·5 Å) in their spectrum scans.

SPECTRA OF FAINT STARS

J. L. Greenstein

Spectroscopic studies of faint blue stars to about magnitude 16·5 have become attractive both because of the instrumental possibilities of the 200-inch prime-focus spectrograph and

the discovery of large numbers of faint blue stars at the galactic poles. From a survey carried out mostly at 180Å/mm, Greenstein finds that approximately one third of the stars bluer than $-0{\cdot}1$ $(B-V)$, are white dwarfs, and one third are very hot sub-dwarfs with He II strong in the sdO type and He I surprisingly weak, but pressure-broadened. In another group, the so-called 'horizontal branch' stars, the hydrogen lines are surprisingly sharp (lines up to $n = 15$ are visible) as if the stars were super-giants. These stars probably have shells as a result of their evolutionary development.

Among 15th magnitude stars thus selected by their colors, about one third have a mean luminosity fainter than $+9$, one third about $+3$, and the balance near zero.

The nuclei of faint planetary nebulae range in luminosity from about -1 to about $+8$, i.e., the fainter ones are nearly as dim as the white dwarfs. Four of these are extremely hot (possibly they are among the hottest stars known) and show OVI emission as the strongest emission lines. Several of these old novae are white dwarfs, and at least two (possible recurrent novae) are probable binaries like DQ Herculis.

Parallaxes should be measurable for the white dwarfs. Accurate absolute proper motions are badly needed for the hot sub-dwarfs, and first-epoch plates should be obtained. A fifteenth magnitude star of the solar luminosity should have a parallax of only $0''{\cdot}00$ but if it has a space velocity appropriate to that of a halo star, the annual proper motion should be $0''{\cdot}030$.

In the following discussion the importance of the 60-inch astrometric telescope projected by Strand was emphasized. Aller (*Ap. J.*, **108**, 462, 1948) remarked that the nucleus of the planetary nebula NGC 246 was a relatively bright star of the high-excitation type here described.

PROPERTIES OF MAGNETIC STARS

H. W. Babcock

H. W. Babcock, using a dispersion of 4·5 Å/mm and a magnetic analyzer, has recently studied the three magnetic stars 53 Camelopardalis, HD 187 474 and HD 215 441.

53 Cam is the best example of a magnetic star with periodical changes; the magnetic field varies from $+3400$ to -5000 gauss in a period of eight days. The spectrum is variable; the Mg II λ 4481 line has a peculiar behavior; it is faint and becomes unusually wide when the field is zero.

HD 187 474 is remarkable for the slowness of the magnetic change. It appears to have a regular variation from about -2000 to about $+2000$ gauss in a period of about seven years, which is by far the slowest rate of change among magnetic stars. Up until now the slowest known magnetic variable was HD 188 041 which had a period of 226 days. The spectrum of HD 187 474 is variable and the lines are sharp.

HD 215 441 always seems to show the same polarity. Its field, 35 600 gauss, is so strong that the three Zeeman components of a line are completely resolved. The magnetic fluctuations are irregular. The spectrum of this star is peculiar but the intensities of its lines are not particularly unusual.

SHORT REPORTS

C. Jaschek reported on his observations of the Si- λ4200 stars; HR 3413, HR 5619, α Dor, τ Eri, and HR 5627. Many unclassified lines are present; lines of Fe III are also observed. Several of these stars have large magnetic fields.

Nancy Roman described studies made of stellar spectra from rockets fired above the Earth's atmosphere. The continuous spectrum of an FoIb star in the far ultra-violet agreed within one per cent with the theoretically predicted curve. At wave-lengths shorter than λ2400

the observed intensity distribution in the B star fell below that predicted by theory, while the Wolf-Rayet star, γ Velorum, showed even greater discrepancies (if one can accept any theoretical model as appropriate for a Wolf-Rayet star). The NASA group also studied the B-stars β Canis Majoris and ϵ Canis Majoris. In the visual and photographic regions of the spectrum these two stars are very similar but below $\lambda 2900$ they have completely different spectra.

A. B. Underhill remarked that recent theoretical calculations indicated a decline in intensity below $\lambda 2400$ as compared with earlier theoretical work and in harmony with the observations, although quantitative agreement had not yet been achieved. Greenstein remarked that the strong absorption wings of Lyman alpha would serve to depress the continuum and might account for this discordance. At the present time, however, no fully satisfactory theoretical treatment of the influence of the pressure-broadened lines upon the continuous spectrum has yet been given.

L. Frederick reported on developments of the image tube as applied to stellar spectroscopy in the infra-red. Spectrograms with a dispersion of 60 Å/mm covering the region near 10 000Å – 11 000Å were displayed. These technological improvements promise to revolutionize studies of this spectral region in stars and nebulae.

A. D. Thackeray (*Observatory*, **81**, 99, 1961) discussed the polarized halo around η Carinae. Then the meeting adjourned.

APPENDIX—ADDITIONS TO THE DRAFT REPORT

We append herewith two summaries of scientific programs which were not included in the *Draft Report*, because they were not received in time.

O. A. Melnikov has summarized further Soviet stellar spectroscopic studies.

Crimean Astrophysical Observatory. M. E. Bojartchuk and E. R. Mustel (**1**) studied spectra obtained by G. A. Shajn of DQ Herculis at its maximum in 1934 to assess the physical conditions in its atmosphere. They found a small turbulent velocity which they attributed to presence of a magnetic field. Although the metals appeared to have about the same abundance as in a normal star, C, N, O seemed to be more abundant and hydrogen less abundant. They regard it as unlikely that these effects can be produced by deviations from local thermodynamic equilibrium. They also discuss the possibility that the chemical composition of the star may vary with depth.

M. E. Bojartchuk (**2**) studied line intensities in 30 F-type stars (dispersion = 23·4 Å mm^{-1} at $H\gamma$) to make a spectroscopic study of their atmospheres. He used a curve-of-growth method to compare stars of small and large velocities, finding carbon and iron contents eight times greater for the high-velocity stars than for low-velocity ones. The hydrogen/metal ratio is about twice as great in the high-velocity stars as in the low-velocity stars. In comparing metal contents of the two groups, Bojartchuk finds no appreciable difference, except Ba and Sr are possibly less abundant in the high-velocity stars than in the low-velocity ones.

The Crimean astrophysicists are also studying the physical parameters of atmospheres of the δ Scuti variables to see whether they represent a physical continuation of magnetic or metallic A stars or are type II stars.

A. A. Bojartchuk (**3**) has studied characteristics of the γ Cassiopeia envelope on 1940 spectrograms secured by V. F. Haze. This envelope was transparent in the continuum but opaque in the centers of the first lines of the Balmer series. He estimated a mass of about 10^{-10} that of the Sun and studied dilution effects and variations of the numbers of absorbing atoms in the envelope. The envelope did not change appreciably in 1940 and 1941; he concluded that

the line profiles cannot be explained by hypothesis of a rotating and pulsating envelope and he suggests a circulation of matter in the envelope. A. A. Bojartchuk (4) has also studied the spectrum of the super-giant star χ Cass with the 122-cm reflector. The composition differs but slightly from that of the other B stars, although a small deficiency of nitrogen and carbon is probable.

From a study of effects of magnetic fields upon the intensification of spectral lines Stepanov, Bojartchuk, and Efimov (5) concluded that neglect of magnetic intensification cannot affect estimation of abundance by more than a factor of 3. Hence the chemical abundance anomalies found in the peculiar A stars must be regarded as real. A study of the influence of a magnetic field upon the curve of growth for spots was made by Melnikov and Zhuravlev (6).

Kopylov (7) at the Crimea studied equivalent widths of the Balmer lines, the Balmer discontinuity and the numbers of the last observable lines of the Balmer series for about 300 stars in classes O to F. He obtained the logarithm of the electron density by both the Unsöld method and the Inglis-Teller formula. He has also investigated atmospheres of 26 supergiants by means of the curve-of-growth method, and changes in spectral line intensities in several super-giants, particularly ϕ Cass, 89 Her and ν Cep.

The Crimean workers have also studied the accuracy attainable in absolute-magnitude determinations from equivalent widths of the hydrogen lines, and concluded that there exists a "cosmical" probable error of $\pm 0^{m}{\cdot}30$ due to variations in relative H abundance and other factors that influence the intensity of the H lines.

R. N. Kumalgorodskaya of the Crimean Astrophysical Observatory measured profiles of emission lines λ4686 He II and $\lambda\lambda$4631-34 N III in 8 Of stars including 9 Sge, 68 Cyg, HD 19 322, ξ Persei, S Mon, HD 206 267, and λ Cephei and established a variability of the equivalent widths with time.

A spectrophotometric study of AG Draconis carried out at *Burakan Observatory* by N. L. Ivanova and M. A. Arakelian (8) shows a steady increase in intensity from the Balmer limit to λ 3100 Å. N. Z. Ivanova found variations of about 0·5 magnitudes in the short-wave region of the spectrum of X Persei in 1955–7. I. D. Kupo (9) at Alma Ata carried out an extensive spectrophotometric study of χ Ophiuchi.

The "spectroscopy" group of the *Paris Observatory*, astrophysical department located at Meudon (R. Herman, V. Doazan, M. Lacoarret, S. Weniger, M. Duval) regularly obtained low-dispersion spectra of Be stars north of $-20°$, and brighter than the seventh magnitude. In addition, particular Be stars are observed with the coudé spectrograph of the 193-cm telescope at Haute Provence Observatory.

In some stars, the line profiles show rapid, large variations, *e.g.*,

(*a*) HD 37 202 ($=\zeta$ Tauri), the Balmer line profile variations seem to be related to phase (10).

(*b*) The main absorption of the Fe II lines in HD 50 138 agrees with a period of about 70 days with an amplitude of about 20 km/sec, whereas the secondary absorption has a much greater velocity (amplitude about 170 km/sec). Similar effects are found for H and Ca II (V. Doazan).

(*c*) V. Doazan also finds that the shell lines in HD 45 910 are very complex and the components may have quite different velocities. The He I line velocities (which are difficult to measure) seem to be in opposite phase to the shell lines.

Numerous spectra obtained of the shell of HD 217 050 indicate that the present shell is stable. (11)

M. Lacoarret finds that a large number of low-dispersion spectra of HD 174 237 indicates

two periods. One of 2·5 years applies as far as the emission of Hα is concerned, the other involving profile variations of the Hα line is a little more than a day.

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29*a*. SOUS-COMMISSION POUR LA THEORIE DES ATMOSPHERES STELLAIRES

Report of Meetings

PRESIDENT: C. de Jager.
SECRETARY: Anne B. Underhill.

Business meeting, 18 August 1961

The President, C. de Jager, announced that the Secretary would be A. B. Underhill. Names of the Vice-President and members of the organizing Committee for Commission 36 (which is the new form of the Sub-Commission) have been submitted to the Executive Committee for confirmation. The following were later appointed:

Vice-President: K. H. Böhm

Organizing Committee: E. R. Mustel, R. N. Thomas, A. B. Underhill, H. van Regemorter, M. H. Wrubel

After the *Draft Report* had been adopted with minor corrections, the President reviewed the colloquia which were organized in 1959 and in 1960 under the auspices of Sub-Commission 29*a*.

A. B. Underhill reported on the Progress of the Working Group on Nomenclature which is under the chairmanship of M. Rudkjøbing. Attention was directed towards the need for a single, clear system of notation for the mass absorption and scattering coefficients and for related quantities such as the optical depth. It was decided that the work of this Group should continue and that attempts be made to clarify further the notation used in transfer theory. It was recommended that roman or italic letters be used so far as is possible rather than greek letters.

M. H. Wrubel, chairman of the Working Group on Co-operation in the Exchange of Computer Information relating to Stellar Atmospheres, gave a brief report. The problem

of exchange is made difficult by the rapid change in computing facilities at many institutions, by the rather short life-time of most programs, and by the unfortunate fact that programs are usually created by one person who frequently does not describe the program adequately in a report. The result is that if the key person is not available, the program cannot be used. Nevertheless, it was decided that it would be profitable to compile and distribute a list of persons working on the problems of stellar atmospheres with electronic computers, and to give in this list information about the type of equipment available at each institution and the chief areas of interest. Wrubel will prepare this list.

Seaton remarked that much basic data on absorption coefficients have been computed, but that such information is not generally available. He suggested that the problem of making such fundamental data available be explored. Ueno reported work being done by himself and others at the Rand Corporation, Santa Monica, on obtaining numerical solutions of the time-dependent, integro-differential equations for diffuse reflection. Some of this material will appear in a book on radiative transfer that is being prepared by this group.

Scientific meetings

Two scientific sessions were held: one on solar problems and one on stellar problems. Abstracts of the invited introductory talks follow together with a summary of the discussion.

THE RELATIVE VALUE OF THE VARIOUS PHOTOSPHERIC MODELS

A. K. Pierce

Homogeneous models of the solar atmosphere represent the observed limb-darkening and energy distribution within the errors of observation, that is within about one per cent for limb darkening and within about five per cent for the energy distribution, for all wave-lengths between 3200 Å and 26000 Å. Conversely, the observations determine the mean temperature distribution to limits of $\pm 50°$ between optical depths 0·1 to 2·0. The uncertainties rise to $\pm 500°$ at the boundary and at optical depths greater than $\tau = 3·0$.

Several non-homogeneous models have been set forth. These represent solar granulation and limb darkening satisfactorily, but are subject to further refinement in the light of our present knowledge of granulation.

Solar models can only be improved by further observations of energy distribution, of limb darkening at the extreme limb, and of granulation. Theoretical studies of convection processes are needed.

The high photosphere can only be determined from the analysis of eclipse observations or from balloon work. Pagel's work indicates a temperature minimum at $\tau = 0·01$ with a value of 4300 °K. ± 100°.

Unsöld gave a schematic diagram to show that a model based on the solar continuum is not sufficiently well-defined to be of use for interpreting medium and strong lines. He also remarked that the accuracy necessary in the constancy of the flux varied with depth in the model. The desirable accuracy for a spectral feature formed above the layer τ is of the order of τ.

De Jager, *Rösch*, *Suemoto*, and *Gaustad* reported observations showing that the curve of limb darkening becomes irregular very near the limb. It is difficult to correct for scintillation, but it seems that these observations will help to define the upper part of the solar models more accurately and in particular give information on the temperature law in the outermost layers.

EMPIRICAL METHODS IN PHOTOSPHERIC STUDIES

J.-C. Pecker

Three types of data can be used: continuum (to obtain models), line total intensities (to obtain abundances), and line profiles (to obtain data on velocity fields). Line intensities and line profiles must be used in an iterative process to yield both abundances and velocities.

Several methods are available for exploring the physical properties of an atmosphere in depth. They may be summarized as follows:

(*a*) several lines of a given multiplet will give information on the depth dependence of the source function in a line,

(*b*) limb darkening will give information about the source function and on temperature inhomogeneities or optical roughness,

(*c*) profiles will give information about the source function and about velocity fields.

Recent results from the detailed analysis of solar spectra are summarized schematically in Figures 1 and 2 which show temperature T plotted against log τ. The line labelled T_e gives

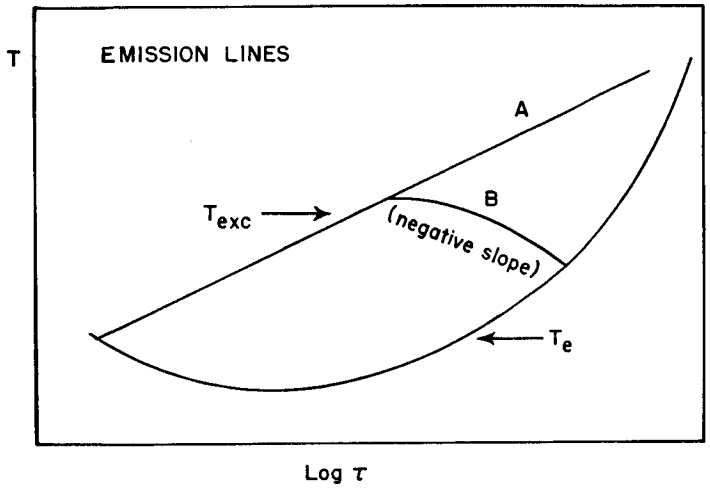

Fig. 1. A schematic diagram of temperature against log τ in the solar atmosphere. See text for description.

the variation of the electron temperature with depth. In each figure line A represents the variation of the excitation temperature with depth which is deduced from the central intensities using several lines of a multiplet; lines B represent the temperature law deduced from profile analysis at different values of μ; line C represents the results from limb darkening. The cores of the lines are formed at higher levels (log τ small) than are the wings. Attention is directed to the negative slope of line B in the case of emission lines.

A lively discussion followed regarding the significance of the so-called departures from LTE. On the observational side, Waddell, Unsöld, Müller, Goldberg and Suemoto reported analyses of certain lines in the solar spectrum indicating that it is very difficult to detect possible departures from LTE. Athay reported observations of Mg 1 lines which suggest that large departures from LTE occur in both directions, *i.e.* $T_{exc} < T_e$ and $T_{exc} > T_e$. It

was concluded that lines from levels of high excitation probably yield good abundances, but that the abundance estimates made from lines of low excitation may be uncertain owing to departures from LTE. The problem of estimating how valid it is to assume that LTE occurs was also discussed from the theoretical side. Seaton observed that one should consider the cross-sections for collision with atoms, ions and molecules as well as the cross-section for collision with electrons when estimating the populations of upper levels, for the first three types of collision may dominate over radiation processes and electron collisions for filling excited levels. It is certain that departures from LTE do occur at some level in an atmosphere since radiation does escape, and theories for strong lines should take account of this.

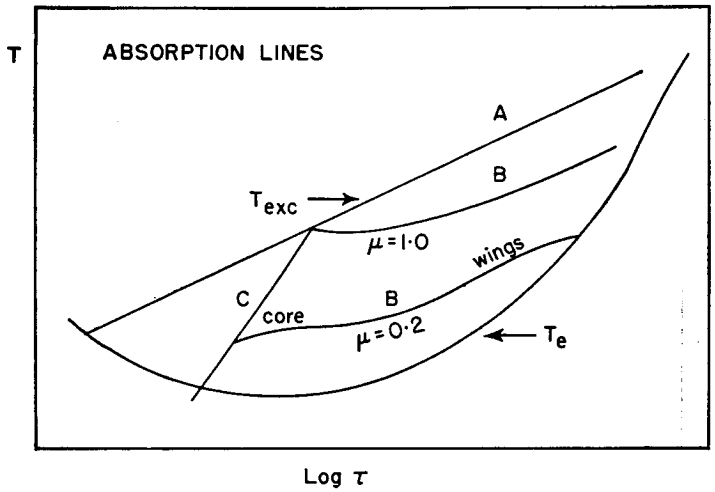

Fig. 2. A schematic diagram of temperature against log τ in the solar atmosphere. See text for description.

COMMENTS ON THE METHODS OF ANALYSING STELLAR ATMOSPHERES

Anne B. Underhill

At this time with fast, large-memory computers becoming readily available, the method of model atmospheres is being developed rapidly. Swihart and Gingerich are developing methods useful for solar-type stars. Underhill is developing methods suitable for O and B type stars.

Two problems exist: (1) to construct an acceptable numerical analogue of a stellar atmosphere, and (2) to predict the theoretical spectrum of the analogue in sufficient detail that the analogue may be identified with a real star. Then abundances of the elements and other physical parameters of the star may be deduced.

The numerical procedures for forming early-type model atmospheres were summarized. Most of the work relates to solving the equation of transfer with adequate rigour yet with a method that is sufficiently flexible for the actual values of the absorption and scattering coefficients to be preserved. The physics of the interaction of radiation with matter is simplified to the case of absorption and emission under local thermodynamic equilibrium and coherent, isotropic scattering.

When a model is identified with a real star it is essential that those levels of the model are identified in which the part of the spectrum under study is formed. It is not easy to identify early-type models because of the paucity of suitable observed line intensities, etc.

THE THEORY OF EXTENDED ATMOSPHERES

L. H. Aller

It is pretentious to speak of a theory of extended stellar envelopes since except in a few limiting cases all one can do is to propose hypotheses that may be helpful in assessing some special set of observations. The principle types of object are: (1) late-type giants and supergiants including objects such as Cepheids, irregular and long-period variables; (2) circumstellar envelopes around binary stars; (3) novae; (4) combination variables; (5) Be, Of, and Wolf-Rayet stars; (6) stars with extremely tenuous outer envelopes such as planetaries; and (7) stars in the process of formation.

Theoretical analyses of extended envelopes are based on some sort of an assumed model. A preliminary geometrical picture is established from qualitative and quantitative data concerning the general level of excitation of the spectrum, line shapes and displacements. The geometrical model is linked with a physical model by adopting mechanisims of energy input and dissipation. In most models the hydrodynamical and kinematical aspects of the problem must be considered. Magnetic fields are almost surely important in orderly expanding envelopes such as planetary nebulae. So far only rather primitive models and theories have been discussed, particularly for the combination variables where departures from thermodynamic equilibrium appear to be large.

29*b*. SOUS-COMMISSION DES ETALONS D'INTENSITE DE RAIES

Report of Meeting, 19 August 1961

PRESIDENT: K. O. Wright.
SECRETARY: J. Houtgast.

The President in his introductory remarks noted that, although this would be the last meeting as a Sub-Commission of Commission 29, the need for inter-observatory comparisons of line intensities seemed to be as great as ever. In the discussion of the *Draft Report*, Miss Underhill thought that some of the lower values of equivalent widths obtained by photo-electric spectral scanning might be the result of the relatively short scan in wave-length and the influence of absorption lines on the continuum.

Several short communications were presented:

1. *J. B. Oke* discussed the Photo-electric Scanning of Stellar Spectra at Mount Wilson Observatory. No results in addition to those listed in the *Draft Report* have yet been obtained, but it is possible that a dispersion of 1·1 Å/mm may be used in the future.

2. *N. J. Woolf* commented on the Fabry-Perot Monochromator that has been described by Geake, Ring and Woolf (*M.N.* **119**, 616, 1959) and that is now being tested at the Lick Observatory. Although no exact quantitative results have yet been obtained, the method appears to be very promising, especially for sharp interstellar lines.

3. *J. Houtgast* described the Photo-electric Scanning of Solar Lines at the Utrecht Observatory. The influence of spectral resolution on the equivalent widths of Hδ and Ca I, λ 4227 were investigated and appeared to be small. It was thought useful to continue this work and to include the effects that dispersion may have on equivalent widths when determined photo-electrically.

4. *K. O. Wright* described results obtained from a Photographic Comparison of the Kienle Step-Filter and the Victoria Rotating Sector. When care is taken to ensure uniform illumination over the field, the calibration curves are found to be identical within the errors of measurement. He also discussed a table of equivalent widths of lines in the spectrum of *Procyon;* pre-1950 observations showed large divergences especially for weak lines, but for later observations obtained with high dispersion the scatter is decreased appreciably.

The President had brought the step-filters of Kienle and Minnaert that had been calibrated by Kienle, and they were on display at the meeting. They have been used to check the calibration procedures at Victoria, Saltsjöbaden and Asiago. Taffara had sent the results of his comparison of the Asiago exponential diaphragm and edge with the Kienle step-filter.

In his concluding remarks the President commented that it seems desirable that there should be some organized group to maintain the interest in co-operative intensity measurements and in calibration problems. He suggested that the Sub-Commission should continue as a Committee of Commission 29. This was approved by all members present (and later by Commission 29).

29*c*. SOUS-COMMISSION DES CLASSIFICATIONS STELLAIRES

Report of Meetings

PRESIDENT: W. P. Bidelman.
ACTING SECRETARY: P. J. Treanor.

First meeting, 17 August 1961

The President's *Report* was adopted in the form in which it appears in Vol. XI A of the *Transactions*, the only significant change from the *Draft Report* occurring in Appendix II, which was slightly modified at the request of the authors.

W. W. Morgan and *H. A. Abt* reported on progress on the new *Spectral Atlas*, for which the plate material, secured on Kitt Peak, is approximately 85% complete. The atlas is being prepared from grating spectrograms of dispersion 125 Å/mm which extend to the neighborhood of $\lambda 3500$ for early-type stars, but its final form is not yet definite. The atlas will not be available for at least another year.

A. Slettebak reported that the funds allocated three years ago to the Perkins Observatory to support a spectroscopic information center there had been returned to the IAU, because the requisite clerical help was not available. The President noted that an information file on all stars for which luminosity determinations (objective-prism or slit) or remarks concerning spectral peculiarities are available (some 15 000 stars) is currently being prepared at the Lick Observatory. Information from this file can be supplied on request; the catalogue uses 1900·0 co-ordinates. C. Jaschek has a similar catalogue for southern objects. The President expressed the opinion that the publication of a complete list of stars that possess two-dimensional classifications is not desirable at the present time, but suggested that any future edition of the Yale *Catalogue of Bright Stars* or other similar catalogue should contain such data.

K. G. Henize discussed his southern-hemisphere objective-prism classification work on carbon and S stars, and his survey of emission-line objects, while N. G. Roman reported on her unpublished slit-spectra classifications of some 600 objects in various Selected Areas. W. W. Morgan announced that he plans to continue work on the classification of OB stars

at Yerkes, using the image-tube equipment now under development there. D. J. K. O'Connell stated that successful objective-prism tests had now been made with the new Vatican Schmidt. This instrument is provided with three objective prisms giving dispersions ranging from 75 to 800 Å/mm. Ch. Fehrenbach discussed his classification (and radial-velocity) programs with his objective-prism equipment. A total of 1500 classifications have now been published, while 2000 more await publication. The older objective prism goes to 10th magnitude, the newer one to 12th. Work is now under way on the south galactic pole region and on the Magellanic Clouds. K. Gyldenkerne spoke briefly on his three-dimensional classification work, with special reference to the G and K stars.

Second meeting, 21 August 1961

At the second meeting of the Sub-Commission, E. K. Kharadze reported on the bright-Hα and general spectral surveys being carried out at Abastumani with the 28-inch objective prism. C. Jaschek spoke of his classification work, carried out at Bosque Alegre, and of the proposed 42 Å/mm spectral atlas of southern stars. D. S. Evans commented briefly on the "fundamental data" program for southern stars. O. C. Wilson discussed his recent work on the relation between spectral type and color for late-type dwarf stars; his new spectral classifications are based on spectrograms of dispersion 10 Å/mm. Recent classification work in terms of the parameters G_{uv}, G_b, and D (ultra-violet and blue gradients and Balmer jump) was summarized by L. Divan: numerous standard stars are being classified between declinations $+15°$ and $-15°$, and stars of special interest are being extensively observed. Work in this field is continuing at the Jungfraujoch.

RECOMMENDATIONS

It was strongly recommended by the Sub-Commission that when the results of objective-prism surveys are published suitable finding charts also be made available, especially for stars near or below the *Durchmusterung* limits, to facilitate slit-spectrographic observations of individual objects. Such charts can easily be made from the existing Palomar or Lick *Sky Atlases*, but the specific requirements depend upon the magnitudes of the stars involved and the complexity of the fields. The President recommended that the blue Palomar prints be used, rather than the red.

A formal resolution, proposed by W. W. Morgan, requesting that Sub-Commission 29c be given Commission status, was seconded and approved unanimously by those members of the Sub-Commission present. This resolution was transmitted to the Executive Committee by the President of the Sub-Commission, but was not accepted. The Sub-Commission becomes a Committee of Commission 29.

30. COMMISSION DES VITESSES RADIALES STELLAIRES

30*a*. SOUS-COMMISSION DES VITESSES RADIALES FONDAMENTALES

Report of joint Meeting, 17 August 1961

PRESIDENT 30: Ch. Fehrenbach.
PRESIDENT 30*a*: J. F. Heard.
SECRETARY: D. S. Evans.

Agenda: Commission 30.

1. Composition of Commission 30
2. Organizing Committee
3. Joint Discussions
4. Re-issue of the Mount Wilson Catalogue
5. Discussion of *Draft Report*
6. Correspondence
7. Remarks by Dr. Martynov

Discussion opened by Dr Evans and Professor Heard.

1. A list of names of additional members was read out by the President, Professor Ch. Fehrenbach.

2. The composition of the Organizing Committee, as follows:
President: Ch. Fehrenbach; Vice-President: R. M. Petrie; Secretary: D. S. Evans; Members: F. K. Edmondson, J. F. Heard and A. D. Thackeray, was agreed to by the Commission.

3. A joint discussion on 'Stellar Motions and Stellar Dynamics' was announced for Friday 18 August at $14^h\ 00^m$.

4. It was noted that the Mount Wilson *General Catalogue of Radial Velocities* was out of print and stated that a reprint could be made by the Carnegie Institution if this was desirable. During the discussion it was noted that Tonantzintla has the data in the form of IBM punched cards and that there is also a card catalogue at La Plata. It was agreed that notes of errors in the Mount Wilson Catalogue and bibliographic notes of work published since its appearance should be sent to the Secretary of the Commission. These could be published on a few additional sheets to be distributed with the new prints of the catalogue so as to avoid the expense entailed in any attempt to revise the general Catalogue. An attempt would be made to distribute these sheets to all holders of copies of the first printing of the Catalogue.

5. Presenting the *Draft Report* the President remarked that there were 15 Observatories engaged in radial velocity work of which 6 or 7 undertook work of this class as a major proportion of their scientific efforts. This excluded the Observatories mainly engaged in extragalactic velocity work. At Haute Provence a new 40-cm objective prism had been produced in place of one for which the glass was not of the highest quality. This gave velocities over the field with probable errors of 5–8 km/s down to limiting magnitude about 12, with an exposure of $2^h\ 40^m$. Longer exposure times gave good access to stars in the Magellanic Clouds, and the new prism had been sent to the station erected under ESO auspices at Zeekoegat about 50 miles south of Beaufort West in South Africa. Results were now coming forward, and particular

acknowledgment should be made of the value of the work of Thackeray and his associates in providing velocity calibrations in this area.

Other important projects now in prospect included the objective prism at Abastumani Observatory by Dr Kharadze and the suggestion for the use of an objective grating by Dr Dewhirst.

At many places projection methods were now being used for the measurement of spectra, and automatic methods were being developed. One development is the registration by cathode ray tube which was especially useful for early-type stars with broad lines and for very late-type spectra of great complexity (Dr Gollnow and Dr Bouigue).

6. A letter was read from Dr van Herk, who reported a project with Dr Oort on RR Lyrae stars and sent a list of 94 such stars in both hemispheres of which 59 were brighter than magnitude 12·5. A discussion ensued in which the difficulties of the work were pointed out. The objective prism is not the correct instrument to use for individual stars. Prestor's spectra of RR Lyrae stars on a dispersion of 80 Å/mm might be useful for radial-velocity studies. Blaauw remarked that a high accuracy for the velocities was not essential but that the cycles must be followed through and single plates were insufficient. Evans remarked that, as in Kinman's work on 22 southern RR Lyrae stars, it was desirable to have photometric observations concurrent with the radial velocity work.

7. Dr Martynov reported the publication of Volume I (0^h to 6^h) of a bibliography of Spectroscopic Binary Stars and distributed copies. This work, undertaken mainly at the Engelhardt (Kazan) Observatory was by Korytnikov, Lavrov and Martynov and would be designated as the KLM Catalogue. The first volume contains 592 stars. Volume II was in press, and Volumes III and IV are in type and will probably be out within 12 months.

About 2 000 pairs would be included covering work published up to 1 January 1960. The President congratulated Dr Martynov on this work and thanked him for distributing copies.

The President asked Dr Petrie to report on a colloquium on radial velocities of visual binaries. Dr Petrie said there would be a full report in *P.A.S.P.* There were many visual binaries which could be observed successfully. The lower limit of separation depended on the observatory and was usually about 2 to 3″. There were questions of the velocity range. Radial velocity observations could often provide useful pieces of information such as establishing the true physical connection in some cases as well as the provision of calibrations of wavelengths and absolute magnitudes.

Sub-Commission 30*a*

Professor Heard then took the chair for what he described as the last meeting of Sub-Commission 30*a* as such. This would now become a Committee of Commission 30.

The *Draft Report* contained some comments by Evans on the accuracy of radial-velocity measures. Evans then spoke as follows:

"Radial Velocities are published with formal probable errors of a few tenths of a kilometre per second but the real accuracy is nowhere as good as this. Increased accuracy is needed for the identification of moving groups and the useful investigation of orbital motions in visual binaries. Investigation of Cape measures of standard stars by Wayman showed that the real errors could be found by postulating an additional random error equivalent to half a micron on the plate at all dispersions. Effects such as this would render nugatory attempts to improve accuracy by measuring more lines. Kinman's studies of the effects of atmospheric dispersion showed that this could be dangerous at low dispersions with wide slits and high zenith distance.

There was some evidence of this in southern stars observed at low altitudes from the North. The Cape controlled results by observing standard stars, one or more of which was observed every night and having all measurers measure all these spectra. Adopting, effectively, Mount Wilson Catalogue values for the velocities of these stars, the results were used to correct programme stars to the Mount Wilson Catalogue system. Over a period of ten years the corrections for two measurers had the following average values:

Mean Systematic corrections

	Dispersion	Dispersion
Measurers	29 Å/mm	49 Å/mm
Evans	+ 0·3 ± 0·2	− 1·5 ± 0·2
Menzies	+ 0·6 ± 0·2	− 1·0 ± 0·3

"It was thought that the personal differences were just significant and that the differences between dispersions were definitely significant. The wave-length standards were those produced by Victoria. Petrie had not claimed universal validity for his system of standards and it was interesting, but unexplained, why these differences with dispersion should have appeared in transferring them to another spectroscope.

"About 700 programme velocities, mainly of late-type stars thought to be non-variable, had now been produced by the Cape (using Radcliffe equipment) of which 122 appeared in the Mount Wilson Catalogue. These provided a wider basis for comparison. Dividing them according to quality and type, the following table results in the sense MWC — Cape.

Quality	A Stars	Solar Stars
a	− 1·2 (4)	− 0·2 ± 0·2 (39)
b	− 0·7 ± 0·9 (13)	− 0·3 ± 0·3 (32)
c	− 0·3 (2)	− 1·3 ± 1·0 (18)
d	+ 0·7 (4)	+ 3·3 ± 2·2 (5)
Weighted mean	− 1·0 ± 0·9 (23)	− 0·2 ± 0·2 (94)

"Bracketed figures show the total numbers of stars involved. There is no tendency for lower quality stars to drift off in one direction, as was thought to be the case at one time. The difference between the A stars and the solar stars might just be significant.

"Segregation of the 71 solar-type stars of *a* and *b* quality into groups according to luminosity class produced the following results:

Class	I	III III − IV	IV IV − V	V
No. of stars	3	19	14	35
Mean, MWC—Cape	+ 0·6 ± 0·2	0·0 ± 0·2	+ 0·3 ± 0·4	− 0·7 ± 0·3

"The difference of measured velocity with luminosity class is known as the Feast effect, first identified by him in a much more pronounced form in a galactic cluster. There seems to be a small but definite effect as between dwarfs and brighter stars for these solar-type field stars near the Sun. Finally segregating these stars into dwarfs and others, a plot of residual against declination shows an apparent reduction with increasing declination. This is unlikely to be real and suggests rather the commission of similar errors."

A co-operative programme of observation of IAU standards from north and south was suggested and Drs Petrie and Heard supported the proposal.

Dr Heard reported measures of standard velocity stars made at the David Dunlap Observatory on 33 and 66 Å/mm, the latter being split into two groups before and after 1960. The mean errors of single observations are distributed normally, but systematic corrections are necessary to bring them to the IAU standards. If we switch to Petrie's wave-lengths on the higher dispersion we find a mean correction of opposite sign. In our case there seems to be a run of the corrections with spectral type, and some signs of a run with hour angle; we have not particularly noted a run with declination.

Jones reported a similar Feast effect at Herstmonceux for Mount Wilson coudé plates of the Hyades; and Edmonson reported a phenomenon of a zero correction alternating between two values. Gollnow said there were no such errors at Mount Stromlo, but the seeing was often poor. A general exchange of experiences by speakers including Deutsch, McLaughlin Thackeray, and Gollnow followed.

31. COMMISSION DE L'HEURE

Report of Meetings

PRESIDENT: W. Markowitz.
SECRETARIES: N. Stoyko, M. Thomson.

First meeting, 17 August 1961

The session was opened by the President, who asked for comments on the *Draft Report*. There being none, the *Report* was approved.

Nominations were made for the Organizing Committee of Commission 31. The Director of the BIH was proposed as a member, but he considered that he was not eligible to be on this Committee. The following were then nominated: L. Essen, W. Markowitz, H. M. Smith, M. M. Thomson, and a member from the U.S.S.R., to be designated later (N. N. Pavlov).

APPARENT PLACES OF FUNDAMENTAL STARS

Dr Fricke reported that corrections to star positions in *Apparent Places of Fundamental Stars* (APFS) to change from FK 3 to FK 4 will be available by January 1962. The FK 4 catalogue will appear first in the APFS for 1964, since the volume for 1963 has already reached the manuscript stage. It was agreed, in keeping with Resolution No. 59 adopted in 1958 at Moscow, that the determination of Universal Time will be based on the FK 4 as of 1 January 1962. Danjon remarked that the change from FK 3 to FK 4 would be straightforward for transit instruments, but would create a problem for PZTs. The President suggested that this question be referred to the Organizing Committee. This was approved.

A proposal concerning the notation of Ephemeris Time had been sent to the Presidents of Commissions 17 and 31 by the President of Commission 4. The President (of Commission 31) remarked that the proposed notation does not change definitions previously adopted by the IAU which define Ephemeris Time. These are contained in *Trans. IAU* **9**, pages 451 and 458 to 462, and **10** page 72. Comments on the proposed Resolution were made by G. Wilkins for Commission 4. The Resolution was discussed, and then approved by Commission 31.

Proposals had been received by the President concerning the method of denoting the epoch of observation. H. M. Smith had proposed that the fraction of the Julian Day be given, and B. Guinot had proposed that the fraction of the Besselian year be used. Members of Commission 31 had been invited to distribute their comments, and other proposals, to members of the Commission in advance of the Berkeley meeting. These proposals were discussed, but no agreement was reached.

The question of adopting a fixed origin for the pole, which is used to compute corrections for variations in longitude, was next discussed. The President pointed out that harmful discontinuities in time-keeping were introduced by shifting the origin. E. Fedorov thought that a fixed origin could not be adopted. Further discussions were postponed, as the meeting ended.

Second meeting, 19 August 1961

The session was devoted to a discussion of changes in speed of rotation of the Earth, in particular, during the year 1959. This is discussed in the *Draft Report*.

The President stated that in reply to his request he had received reports from eight observatories. Summaries of these reports are given in the mimeographed Report to COSPAR by

Wm. Markowitz, of 4 April 1961. The President reviewed additional studies that had been made.

He noted that two different methods were used to correct for polar motion and seasonal variation. In the method adopted by the IAU, U.T. 0 is transformed into U.T. 2 by correcting for observed polar motion and for extrapolated seasonal variation.

Danjon, in his method, uses a mathematical formula to remove the effect of the 14-month term in the polar motion, obtaining T.U.$_{1/4}$. He analyzes several years of observation to determine the seaonal variation for each observatory. This combines corrections for the 12-month term in the polar motion, for the annual variation in speed of rotation, and for systematic corrections to star places. T.C. 1 is obtained when T.U.$_{1/4}$ is corrected for the seasonal variation.

The President stated that U.T. 2 and T.C. 1 are essentially equivalent in that both give the speed of rotation of the Earth, freed of certain periodic effects. He and R. G. Hall had determined, for Washington, U.T. 2, using the corrections of the BIH, and T.C. 1, using the corrections of Danjon; the graphs of U.T. 2 and T.C. 1 for Washington are essentially the same.

The President asked *D. Brouwer* to give an account of his analysis of the fluctuation curve which was published in *A.J.*, **57**, 132, 1952. Brouwer stated that he was led to the attempt to represent the fluctuation curve on the assumption that the second differences of the annual means are random quantities with mean value zero.

If the derivative of the fluctuation curve can be approximated by straight-line segments, then the fluctuation curve itself should be representable by a series of parabolic segments. At a point of the curve where two parabolic segments join, the two arcs have a common tangent. However, the interpretation of the fluctuation phenomenon might require a more complicated hypothesis than that advanced by Brouwer or by B. L. van der Waerden (*A.J.*, **66**, 138, 1961), who introduced a term for friction.

A. Mikhailov reported that at Pulkovo, N. Pavlov had found no sudden change in speed in July 1959, but had found a change in phase of 30° in the seasonal variation of 1959.

J. Bonanomi commented on the formula of B. Guinot and S. Débarbat for the 14-month Chandler motion. For the interval 1956·5 to 1960·1 the Neuchâtel observations and the formula were in close accord. Hence, no error was introduced by Danjon through use of T.U. $_{1/4}$. The Neuchâtel observations were treated according to the method of Danjon, but the annual variation found is different from that found by Danjon for Neuchâtel. T.C. 1 derived at Neuchâtel, Bonanomi stated, shows no irregularity in speed of rotation near 1959·5.

A. Danjon gave a report of his recent work on the study of speed of rotation, described in *C.R.*, **252,** pages 2039, 2343, and 2779, 1961. Danjon exhibited plots of T.C. 1 for the Paris, Greenwich, Washington, and Neuchâtel observatories. The President hoped that Professor Danjon would distribute the numerical details of his studies. Danjon said he planned to do so.

Third meeting, 22 August 1961

This session was concerned chiefly with action on recommendations and resolutions.

Discussions of specifying the mean epoch of observation were continued. No agreement was reached and the President suggested that the Calendar date, Julian date, and Besselian date might all be given on a trial basis. This will be done by the U.S. Naval Observatory, starting 1 January 1962.

Discussion of the proposal for adopting a fixed origin for use in determining corrections to time for polar motion was resumed. The President pointed out that the effect of the discontinuity when a change was made was uncertain. He listed three different sets of values which had

been issued by the BIH for the change in co-ordinates made in the last quarter of 1958. He pointed out that this impeded, in particular, studies in changes in speed of rotation of the Earth. Objections to adopting a fixed origin were made by A. Danjon, N. Stoyko, and B. Guinot. Since agreement could not be reached at this time, the President suggested withdrawing the resolution for adopting a fixed origin, which was done.

A proposal for creating a joint commission of the IAU and IAG to derive new conventional longitudes for time-service stations was discussed. The President remarked that the time-transmissions of several countries were co-ordinated and it was essential that discordances in conventional longitudes should be removed. Empirical corrections were being applied, for example, by the U.S. Naval Observatory to the Washington and Richmond, Florida, observations for time, because of errors in the conventional longitudes, to bring them in accord with those of the Royal Greenwich Observatory. A revision of the longitudes would eliminate the necessity for empirical corrections. According to proposal B.2 of the *Draft Report*, the revised longitudes would be available in 1963.

Professor Danjon stated that the BIH was prepared to issue a revised list shortly, which could be adopted for use on 1 January 1962. Use of the BIH list would save time. The President was in accord with the change proposed by Danjon because it would shortly eliminate the need for empirical corrections. He noted, however, that, while the new longitudes would serve to co-ordinate time transmissions, the various star lists had not been referred to FK 4 and that there were uncertainties due to the change in the origin of the pole in 1958. Hence, a further revision might have to be made at some time in the future.

It was agreed to modify proposal B.2 so that the BIH would derive new longitudes in consultation with the observatories concerned.

A resolution was adopted, recommending that high-altitude artificial satellites be launched which would be useful in the study of time.

It was agreed that each year, in consultation with observatories which determine time, the BIH should recommend a fractional offset from nominal frequency which is to be used in the succeeding year by stations which transmit constant frequency during the year.

Danjon suggested that the use of rhythmic signals should be discontinued. This was agreed.

The question of combining Commissions 19 and 31 was discussed. It was agreed that the two should not be combined at this time, but that the question could be studied again in the future.

Dr J. Bonanomi continued his report, begun at the second meeting. J. De Prins had analyzed the frequency spectrum of T.U.$_{\frac{1}{2}}$ at Neuchâtel. For the interval 1957·5 to 1960·8 there are maxima at frequencies 1 year and $\frac{1}{2}$ year. However, for the 5-year interval, 1956·3 to 1961·6, there is only a pronounced maximum at 1 year. These results are of interest since the existence of a semi-annual term appeared, previously, to have been well established. This question should be studied further, it was agreed.

The President thanked the Secretaries for their services. He expressed his appreciation, upon the conclusion of his term of office, to the Director of the BIH for the co-operation of the Bureau. He thanked the Chef du Bureau for his work in providing promptly the corrections $\Delta\lambda$ for the large number of time-service stations.

RESOLUTIONS ADOPTED BY COMMISSION 31

1. The provisional value of Ephemeris Time that is obtained by comparing the Moon's mean longitude, given by observations, referred to the equinox of FK 4, with the positions tabulated in the Improved Lunar Ephemeris is denoted by E.T. 0. The difference E.T. 0 − U.T. 2 is denoted by ΔT_0.

2. A list of new conventional longitudes of time-determining stations shall be prepared by the BIH in consultation with the observatories concerned. Time-keeping will be based on these new longitudes as of 1 January 1962.

3. It is recommended that high-altitude satellites be launched which can be used for experiments concerning the fundamental nature of time.

4. Each year, after consultation with observatories concerned in the transmission of time pulses and constant frequency, the BIH shall recommend a value of the fractional offset from nominal frequency to be used during the next year in order that the time pulses shall be nearly on the system U.T. 2. The offset is based on an assumed frequency of 9 192 631 770 c/s for caesium.

5. The use of rhythmic time signals should be discontinued.

RÉSOLUTIONS ADOPTÉES PAR COMMISSION 31

1. La valeur provisoire du temps des éphémérides, obtenue en comparant la longitude moyenne de la Lune résultant d'observations rapportées a l'équinoxe du FK 4, avec les positions données par l'Improved Lunar Ephemeris est appelée T.E. 0. La différence T.E. 0 − T.U. 2 est appelée ΔT_0.

2. Une liste des nouvelles longitudes conventionnelles des stations horaires sera préparée par le BIH en consultation avec les observatoires intéressés. La conservation de l'heure sera basée sur ces nouvelles longitudes dès le 1er janvier 1962.

3. On recommande le lancement de satellites artificiels de haute altitude qui puissent être utilisés pour des experiences sur le caractère fondamental du temps.

4. Chaque année, apres avoir consulté les observatoires intéressés par la transmission des signaux horaires et des fréquences constantes, le BIH recommandera une valeur du décalage de la fréquence nominale qui doit être utilisée durant l'année suivante, de sorte que ces signaux horaires restent approximativement dans le système T.U. 2. Le décalage est basé sur la fréquence adoptée de 9 192 631 770 Hz pour le césium.

5. Les signaux horaires rythmiques devront cesser.

33. COMMISSION DE LA STRUCTURE ET DE LA DYNAMIQUE DU SYSTEME GALACTIQUE

Report of Meetings, 16 and 22 August, 1961

PRESIDENT: A. Blaauw.
ACTING SECRETARY: W. P. Bidelman.

Business meetings

The *Draft Report* was adopted, subject to a few minor corrections; the final version is printed in Vol. XIA of the *Transactions*.

After a brief explanation of changes in the structure of IAU Commissions and Sub-Commissions, the President informed the members of the Commission of the nominees for members of the Commission's Organizing Committee: President, B. J. Bok; Vice-President, L. Perek; and members: G. Münch, B. Strömgren, and either W. Becker or A. Blaauw. After some discussion, it was unanimously agreed that both W. Becker and A. Blaauw should be asked to serve as members, along with the others nominated, and the complete slate of nominees was then unanimously elected to the Organizing Committee.

The future of Commission 33's three Sub-Commissions was then considered:

33*a*: The President proposed that the duties of this Sub-Commission on the Co-ordination of Galactic Research be taken over by the Commission's Organizing Committee. Adopted.

33*b*: The task of this Sub-Commission for the Determination of the Galactic Pole and Galactic Longitudes is nearly completed. An extensive report of the Sub-Commission, containing its findings, has appeared in *M.N.R.A.S.*, **121**, 123, 1960, and tables enabling the determination of galactic co-ordinates in the new system have been prepared under the direction of I. Torgård and published as *Annals of the Lund Observatory*, Vols. **15**, **16**, and **17**. Charts permitting the rapid determination of galactic co-ordinates have not yet been prepared, but are planned. The President proposed that this Sub-Commission be made a Working Group of Commission 33. Adopted.

33*c*: It was proposed by the President that this Sub-Commission on Selected Areas remain permanently within Commission 33 as a Committee of that Commission. Adopted.

There was considerable discussion of L. N. Mavridis' proposal that those who have computed galactic co-ordinates for certain objects in the course of their work should publish these for the convenience of others. While this was felt to be useful, several members thought that the computation of galactic co-ordinates for various objects important in galactic research should be undertaken in a more systematic fashion. B. J. Bok suggested that an accuracy of 0°·01 would be desirable, and that modern machines make the labour trivial. G. Abell stated that he already has available a program for such computations. The Chairman passed on a statement by L. Perek (who could not be present) that he has prepared tables facilitating the transformation of radial and tangential velocities to U,V,W components.

The recent English translation by J. B. Sykes of K. F. Ogorodnikov's "Dynamics of Stellar Systems" was appreciatively noted by the President.

Scientific meetings

Scientific communications were presented as follows:

S. Vasilevskis: The Lick Proper Motion Program.

The stars to be measured on the Lick 20-inch astrograph plates range in photographic

magnitude from 6 to 17·5. The second-epoch plates, to be obtained starting in 1967, will be taken both with the original blue lens and with a new yellow lens giving an effective wavelength of about λ5500. Positions, proper motions, magnitudes, and colors will be obtained. It is planned to measure on each plate about 70 galaxies, about 15 AGK2 stars, some 25 stars of about the 12th magnitude, and another 25 stars of the 16th or 17th magnitude, making a total of about 135 objects per plate. It will, however, be a simple task to measure at least 200 objects per plate, since the final measurement of such a plate will take less than two hours. Thus suggestions as to additional stars to be measured will be welcomed.

The limiting galactic latitudes depend, of course, on the nebular counts, but may be estimated to be in the neighbourhood of 20°. This is on the assumption that no more than 20% of the nebulae on the plates will be suitable for measurement. The fields studied will extend to at least declination −23°, but plate material that may be worthy of measurement is available to declination −33°.

J. J. Nassau: Luminous Stars in the Northern Milky Way.

An objective-prism survey of high-luminosity stars in the northern Milky Way is being carried out jointly by the Hamburg and by the Warner and Swasey Observatories. The aim is to catalogue, down to our limiting magnitude, all stars of the following types:

(*a*) OB stars, divided into three luminosity groups;

(*b*) late B, A, and F super-giants;

(*c*) OB stars with Hα in emission;

(*d*) Wolf-Rayet stars.

The limiting photographic magnitude of the survey is about 13·0. The present state of the project is as follows:

Vol. I (Hamburg): l^{II} = 113° to 142°; b^{II} = ± 9°. Published in 1959.

Vol. II (Warner and Swasey): l^{II} = 42° to 80°; b^{II} = ± 10°. Published in 1960. (The plates for this region were taken at Hamburg.)

Vol. III (Hamburg): l^{II} = 80° to 142°; b^{II} = ± 10°. To be published in 1961.

Vol. IV (Warner and Swasey): l^{II} = 14° to 46°; b^{II} = ± 28°. To be published early in 1962.

Vol. V (Hamburg): l^{II} = 142° to 192°; b^{II} = ± 12°. Work in progress.

Vol. VI (Warner and Swasey): l^{II} = 192° to 226°; b^{II} = ± 12°. Only a few plates have been taken in this region.

The above boundaries are approximate; the first two volumes published contain 3 000 stars.

Discussion: The President suggested that plans should be made for photometry of these important objects, and he stressed the importance of obtaining it in a uniform photometric system. If possible, the photometry of this valuable material should not be broken up into a number of limited, small projects with different systems.

P. Pishmish: Outline of a Theory of the Origin and Evolution of Spiral Arms.

In a series of papers published in the last two years in the *Tonantzintla y Tacubaya Bulletins*, the origin and development of the spiral features of our own and other galaxies have been treated. The starting point is the well-known expansion of the neutral hydrogen arm at 3 kpc from the galactic center; a vestige of such an expansion seems to be present in the motions of OB associations.

The basic idea is that spiral features are formed as a result of the ejection of gas from a rotating nucleus. The emergence of arms from the extremities of a diameter of the nucleus (which may be embedded in an older population) is explained by introducing a novel assumption: that the magnetic field in the nucleus of the Galaxy — and similar galaxies — is poloidal, say a dipole, with its axis perpendicular to that of galactic rotation. Excess matter in the amorphous nucleus, in such a circumstance, will be funneled out through the polar regions, thus producing the observed symmetry.

A nucleus, while ejecting matter, will probably suffer a contraction. The matter and momentum that goes into the arms might thus be provided at the expense of the shrinking nucleus, which would leave behind spiral formations.

P. O. Lindblad: Stellar Orbits and Spiral Structure.

The effects of perturbations acting on revolving mass points in a Galaxy-like force field are well demonstrated by motion-picture techniques. A two-dimensional model is assumed, and the calculations have been done on an electronic computer. See *Stockholm Obs. Ann.*, **21**, no. 4, 1960.

H. D. Greyber: Dynamics of Spiral Galaxies.

From the investigations of F. D. Drake and others, it is clear that magneto-hydrodynamic effects must be important in the Galaxy. One may assume that the Galaxy possesses a ring current in the central regions, giving rise to a dipole field. Mass will flow in and out of the nuclear regions, in equal amounts. Small instabilities will exist, and occasionally a long-wavelength disturbance giving rise to a large surge will occur. This idea may be checked by polarization observations.

G. Contopoulos: Stellar Orbit Computations.

Some results found by B. Barbanis (Thessaloniki) in connection with the third integral of motion in an axially symmetric galaxy may be mentioned. Barbanis has applied the third integral in velocity space in order to explain the peculiar form of the orbits in the R, Z plane. In particular, he has introduced the first-order terms of this integral as an argument in the distribution function, in addition to the energy integral.

Concerning the third integral itself one may say:

(*a*) The convergence of this integral has not been established, but it is possible that an isolating integral exists, even if it is not uniform everywhere.

(*b*) There are other cases in which a third integral may exist.

(*c*) A study of periodic orbits would be illuminating.

(*d*) It would be interesting to calculate orbits in various potential fields, especially in those corresponding to actual galaxies.

I. Torgård: Three-Dimensional Galactic Orbits.

This work, done with A. Ollongren, consists of calculations done on the BESK electronic computer of galactic orbits in a potential field similar to that given by M. Schmidt's model of the Galaxy. A high-velocity family of orbits has been studied, defined by fixed energy and fixed areal velocity. Two different types of orbit were found: "box-orbits" (distorted Lissajou orbits) and "tube-orbits", which oscillate around a periodic orbit (a stable periodic orbit is surrounded by an infinite number of concentric tube-orbits together forming a tube). In an

inclination diagram (π/z against $\tilde{\omega}$ for $z = 0$), a box-orbit is represented by a line, a periodic orbit by a finite number of points, and a tube-orbit by a finite number of rings. A tube-orbit corresponds to a rational number, a box-orbit to an irrational number. There appears to be an infinite number of each of the three types of orbit.

Discussion: I. R. King remarked that it would be of great interest to extend these calculations to slightly flattened elliptical systems.

G. Elwert: Theory of the Tilt of the H I Layer.

Analysis shows that the gravitational attraction of the Magellanic Clouds may be responsible for the observed tilt of the neutral hydrogen layer in the outer parts of the Galaxy.

Discussion: It was suggested by I. R. King that if this explanation is correct, we should expect distortions of the local velocity field of the order of 5 to 10 km/sec, which could seriously affect our interpretation of 21-cm data.

F. J. Kerr: The 15-Meter Survey and the H I Distribution in the Galaxy.

The southern hemisphere 21-cm line data and those from various thermal sources all agree well in showing the spiral structure; the 15-meter survey shows H II regions in absorption all along the Milky Way plane.

When attempts are made to combine the 21-cm data from both hemispheres into a consistent and plausible spiral-arm pattern, however, difficulties arise. These can be removed if one assumes that the local standard of rest possesses an outward velocity, relative to the galactic center, of the order of 7 km/sec.

Discussion: It was remarked by several members of the Commission that this rather surprising result does not seem compatible with the observation that stars of different ages in the solar neighborhood do not show differential motions of the sort that this would appear to imply.

33c. SOUS-COMMISSION DES "SELECTED AREAS"

Report of Meeting, 19 August 1961

PRESIDENT: T. Elvius.
SECRETARY: L. Plaut.

Selected Area Committee

Under the new By-laws of the Union the Sub-Commission will continue as a Committee under Commission 33, the members being: Elvius (chairman), Kharadze, Plaut, Weaver.

The *principal function* of the Selected Area Committee has been defined by Bok, the new President of Commission 33, as:

1. to report on work done and to make suggestions for extension and co-ordination of work under way or being planned;

2. to suggest specific new projects for work relating to Selected Areas;

3. to consider ways in which Selected Area programmes may contribute to the advance of our knowledge in galactic structure.

Kharadze drew attention to the possibility of coming outside the boundaries of Kapteyn's Selected Areas. It was felt that in such cases the whole Commission 33 has to consider the matter.

Blaauw stressed the necessity of considering observational programmes as a means to obtain more and new information on the structure of the galactic system rather than as an end in themselves.

The Draft Report

The *Draft Report*, as presented was accepted with some small corrections. The following additions were proposed during the meeting:

Photometry: Photo-electric sequences in *U,B,V* are observed by Purgathofer at Lowell Observatory for many of the Selected Areas of the Basel programme; limiting magnitude 18^m; only *U* for areas measured by Baum for *B* and *V* (Steinlin).

Reference was made to the work on 6th magnitude stars in Areas 1–115 at the Crimean Observatory as quoted by Commission 25, ref. (7) (Rybka) (see Vol. XIA, p. 250).

Proper motions: Reference was made to the 20-in. Astrograph programme at Lick Observatory (*Trans. IAU*, **9**, 466, 1957 and **10**, 503, 1960).

Other investigations: Luyten has searched for faint blue stars in a large number of Selected Areas using several telescopes. Proper motions of some of these have been published in the Minnesota series "A search for faint blue stars".

Discussion of current work

Photometry: Publication of the photo-electric sequences by Baum has been urgently requested again (*Trans. IAU*, **10**, 502, 1960).

Miss Roman reported slow progress on her sequences on account of zero-point difficulties (*Trans IAU*, **10**, 503-4, 1960).

Rybka spoke on his programme of two bright stars in each of the Areas 1 to 115 and suggested extension to the more southern Areas.

An accurate sequence in Area 141 near the southern galactic pole is in preparation (Bok); publication in the near future has been recommended (Luyten).

Bok and Miss Roman stressed that *U* magnitudes should be given preference rather than spectral types, *U-B* colours may give important information on population groups, etc.

Proper motions: A discussion was held (Blaauw, Deutsch, Fehrenbach, Roman, Weaver) on the desirability of a repetition of the Radcliffe proper-motion plates, a programme being initiated by Allen at London (Mill Hill) (see Vol. XIA, p. 393). No decision has been made on the preference to be given either to this programme or to a determination of proper motions of brighter stars, say to about $12^m{\cdot}5$, on larger fields as could possibly be done by means of Carte du Ciel plates (see Helsinki, Vol. XIA, p. 393). This matter will be discussed more thoroughly by the Committee.

Maps: Maps are in preparation or are being planned by Miss Roman and by Bok. In 1957 Brun published an *Atlas des* 139 *Selected Areas du Mount Wilson.*

34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

Report of Meetings, 16, 17 and 22 August 1961

PRESIDENT: Lyman Spitzer, Jr.
SECRETARY: F. D. Kahn.

Business session

At the first meeting, on Wednesday, 16 August, no member commented in reply to the President's request for suggestions on the future organization of the Commission and on the type of programme it should undertake. In reply to a request for comments on the *Draft Report*, Dr L. H. Aller suggested that emission nebulae in external galaxies ought to be discussed by Commission 28; Dr B. Bok felt that Commission 34 could deal with nebulae near enough to be seen in detail, and Dr R. Minkowski thought it ought to study their physics, irrespective of their distance.

The *Draft Report* was then approved, subject to minor corrections and additions.

Scientific sessions

In the subsequent scientific session, Dr B. Bok spoke about recent Australian work, including spectroscopic and photographic studies of the Southern Milky Way and the Magellanic Clouds. He described the recently completed Mount Stromlo Atlas, and discussed the connection between optical and radio studies of the Galaxy.

Next, Dr G. Courtès spoke about recent work done at the 75-inch telescope at Haute Provence with an interference filter 60 Å in width. This combination proved to be most powerful in discerning H II regions, in particular it had revealed a gaseous filament of galactic dimensions in NGC 4258.

He had further studied radial velocities of H II regions; thus he had confirmed the galactic rotation curve deduced by Münch by means of interstellar absorption lines. He had also found, together with Dr S. Pottasch, that the H II regions surrounding elephants' trunks tend to expand at the speed of sound. Dr Pottasch then briefly showed that this result agreed with theory.

Finally Dr L. Woltjer assessed the present evidence on the strength of the galactic magnetic field. A field of some 3×10^{-5} gauss is needed to explain the non-thermal galactic radio noise, to confine cosmic rays and to explain the large-scale motions of the interstellar gas. A much smaller field, of less than 3×10^{-6} gauss, is needed for theories of star formation and to explain why the Zeeman effect is not seen at 21-cm. wave-length. In any case it is hard to explain how the field would have originated. To help settle the problem one ought to try to measure the Faraday rotation of polarized galactic radio noise, and study the gas dynamics of H II regions with magnetic fields. In the discussion which followed Dr R. D. Davies argued that the non-thermal galactic radio noise originates in super-nova remnants, and has nothing to do with the Galaxy at large.

At the second meeting, on Thursday, 17 August, Dr B. Vorontsov-Velyaminov spoke about his catalogue of planetary nebulae, which contains data on their magnitudes, spectra, radial velocities, and internal velocity dispersions. Distances of nebulae are hard to estimate and are therefore not given. He went on to discuss intensity changes in the spectral lines of nebulae and their possible explanation.

Dr R. Minkowski then briefly mentioned his own catalogue of 730 planetary nebulae, and Dr L. H. Aller said that modern photo-electric data would enable distances to be found.

Dr J. M. Greenberg spoke next about the nature of interstellar dust grains. They may be dielectric, metallic, made of graphite, or they may be large free radicals. The choice between these possibilities must be based on measurements of extinction at different wave-lengths and in different planes of polarization, and by considering whether the grains can grow at all and be lined up by a magnetic field. For optical data Dr Greenberg largely used his results on the scattering of electromagnetic waves by model grains (on the scale of $1 : 10^5$). The evidence tended to favour the dielectric grains.

Dr F. D. Kahn then discussed the implications of the density profile deduced by Menon for the Orion Nebula. Its details should be correct to about 0·5%. The electron density decreases by a factor 200 from the centre to the boundary. The implied pressure gradient must noticeably change the density profile within 10 000 years. This limits the time which can have elapsed since the original ionization of the nebula. Dr T. K. Menon then showed a profile for the electron density in the Rosette Nebula, in which the predicted change has already occurred.

Finally Dr E. E. Khatchikyan described his measurements of the polarization of the light of the Omega Nebula. It amounts to 26% in the mean, and 50% at the maximum. In reply to questions he stated that polarization was seen in integrated light and that his instrumental polarization was negligible.

An informal discussion meeting of Commission 34 was held on Tuesday, 22 August, for the purpose of considering observational programs relating to theories of interstallar grains. The discussions were led informally by J. M. Greenberg, who presented a brief outline of some of the observations needed to establish the physical characteristics of the grains.

Short reports on present and future programs of investigation were given by J. S. Hall, W. A. Hiltner, A. Behr, P. J. Treanor, S. J., G. Westerhout, T. Walraven, L. Divan, J. Borgman, C. Schalén, A. S. Meltzer, A. Elvius, and C. J. van Houten. The main subjects discussed were: (*a*) wave-length dependence of polarization; (*b*) wave-length dependence of extinction; (*c*) variation of (*a*) and (*b*) with galactic longitude; (*d*) continuation of surveys of extinction and polarization; and (*e*) extra-galactic studies of scattering by grains.

In addition to the work of the above speakers, reference was made to the recent works of E. J. Wampler and A. Rogers on the wave-length dependence of extinction and of H. L. Johnson on extinction in the far infra-red. Also mentioned were programs for future investigations by A. A. Hoag and B. J. Bok.

The existence of a correlation between variations of the extinction curve with the degree of polarization (galactic longitude) has received a fair degree of confirmation, although there is not yet unanimity on interpretation.

35. COMMISSION DE LA CONSTITUTION DES ETOILES

Report of Meetings 19, 21, and 22 August 1961

PRESIDENT: M. Schwarzschild.
SECRETARIES: M. Wrubel, A. G. Massevitch.

Draft Report

The *Draft Report* was accepted, subject to minor revisions by the President.

Ages of Old Stars

O. Wilson reported on a new Hertzsprung-Russell diagram in which the absolute visual magnitudes are determined from the exterior width of the emission core of the K line. Approximately 400 stars for which colors are available were plotted, and the provisional results indicate that Sandage's curve for NGC 188 fits the lower boundary for the field stars in the solar neighborhood. Thus a line representing the oldest disk population stars appears to be established. Oke, using an independent method, has found similar results.

Hoyle discussed the sensitivity of computed evolution tracks to age. He pointed out that the 'plateau' in population I cluster diagrams was particularly suitable for age determinations. Computed tracks for M 67 yield an age of 10^{10} years; the age of NGC 188 was determined by applying a homology transformation to the M 67 tracks. The greatest uncertainty in recent age determinations is probably due to the revised rate for the $He^3 + He^4$ reaction, which may lead to a reduction in age of perhaps 30%.

Aller pointed out that diffusion may not be negligible over such long times and that spectra may not be a reliable indication of the heavy element abundance in the interior.

Opacity data

A. N. Cox briefly described the parameters of a computer code for calculating opacities and offered to compute tables for specific mixtures if requested.

Pulsation theory

J. P. Cox reported on calculations of the instability produced by He II ionization, as first suggested by Zhevakin. The instability appears to be sensitive to the location of the narrow ionization zone within the star. The numerical results for the classical Cepheids and the RR Lyrae variables appear highly promising.

Kippenhahn described similar work done with Baker in which detailed model atmospheres were included to consider the effect of convection. In general, the results agreed with those of Cox.

Convection during pre-main sequence contraction

Hayashi outlined his work on a possible explanation of the location of faint stars in the HR diagram of very young clusters. His results suggest that convection is much deeper in the pre-main sequence contraction phase than has previously been supposed. The corresponding luminosities and evolution rates of these phases come out much higher than earlier estimates.

Biermann suggested that the observed effect may be due to a combination of convection and mass ejection.

Urey discussed the effect on the evolution of the solar system if the Sun was brighter during its early life.

Numerical techniques

Brownlee briefly described the computing scheme used with A. N. Cox at Los Alamos.

Henyey reported in detail the method now being used at Berkeley. The essential points were the selection of grid points, the choice of variables, the difference scheme used for second-order accuracy and stability, the boundary conditions, and—most importantly—the method for solving the resulting matrix.

37. COMMISSION DES AMAS STELLAIRES ET DES ASSOCIATIONS

Report of Meetings

PRESIDENT: H. Haffner.
SECRETARIES: J. B. Irwin, A. G. Velghe, V. Vanýsek.

Two joint meetings were held, one with Commission 25 (Stellar Photometry) and the other with Commission 27 (Variable Stars); the reports are included with those of Commissions 25 and 27.

Business meeting, 17 August 1961

In opening the first session the President paid tribute to the late W. Baade (died 25 June 1960) who was a member of the Commission for many years and its President from 1948 to 1952.

The President explained to the Meeting the meaning of the new Constitution of the Union. The following Organising Committee was proposed and elected:

President:	H. Haffner.
Vice-President:	M. F. Walker.
Members:	O. J. Eggen, A. R. Hogg, H. L. Johnson, P. N. Kholopov.

Including 21 Astronomers who have recently applied for membership Commission 37 will now comprise 46 members. Their names were read.

The *Draft Report* was adopted after several technical questions had briefly been discussed in connection with it. The President then referred to the Prague Card Catalogue of Clusters and Associations which is currently being supplemented by the co-operative work of G. Alter, J. Ruprecht, Mrs H. Sawyer-Hogg, and V. Vanýsek. To facilitate the continuation of this catalogue authors are urgently requested to send reprints of their papers to the Astronomical Institute, Ondrejov, Czechoslovakia.

In opening the presentation of several minor communications on catalogue and similar work, the President then introduced the new Prague Atlas of Galactic Clusters which is just being published by G. Alter. Unfortunately an advance copy of the Atlas mailed to Berkeley prior to the General Assembly, had been mis-directed by the local Post Office and could not be produced at the meeting. Vanýsek briefly described the Atlas. It consists of a large map covering the whole field of the Milky Way and 36 detailed maps each covering 10° of longitude. The large map has a width of $\pm 45°$, and the small maps $\pm 20°$. The diameters of the circles representing the clusters on the small maps correspond generally with the angular diameters of the clusters. Nine symbols have been selected to represent various properties of the clusters, such as star number, colour index, colour excess, spectrum, photo-electric photometry, proper motion, radial velocity.

Mrs K. A. Barkhatova presented a number of copies of the second part of her Atlas of Colour Magnitude Diagrams (Moscow, 1961). It gives diagrams for 4 associations and 52 clusters, most of which have been published between 1958 and 1960.

A. R. Hogg commented on the new Mount Stromlo Atlas of galactic clusters south of $-50°$. It has been based on blue plates taken with the 74-inch reflector; limiting magnitude 17 to 18. Copies will be supplied by Mount Stromlo on personal request. So far, no extension to red plates and further to the north has been considered, though highly desirable.

H. F. Weaver reported that a second edition of his and F. Setteducati's Atlas of Newly Found Clusters is in progress. He further explained the present position in editing Trumpler's posthumous cluster work. (Charts of 100 clusters; $B-V$ magnitudes, radial velocities, spectral types and rectangular co-ordinates of approximately 5 000 stars.) After considerable difficulties at the printers had been overcome, the work is now going to press. He was glad to show a sample of the first proof sheets.

Mrs H. Sawyer-Hogg spoke on her bibliographic work in globular clusters which is to bring up to date the catalogue given in *Publ. David Dunlap Obs.* Vol.1, No. 20.

P. Th. Oosterhoff said that G. Pels at Leiden has investigated the outer regions of the Pleiades and discovered roughly 50 new physical members.

RECOMMENDATIONS

1. *Nomenclature of associations.* Following A. Blaauw's suggestion to revise the present somewhat confusing system of nomenclature of associations (*e.g.* II Cas and Cas II which mean different things), a small Working Group (Blaauw, Markarian, Morgan, Schmidt, Vanýsek, Haffner (Chairman)) was established and entrusted to make precise proposals for remedying the annoying situation. At the second meeting the Working Group presented the following recommendations:

(*a*) The nomenclature introduced by Markarian in 1952 will be kept as a basic system.

(*b*) Associations subsequently discovered and denominated by other observers will get new designations within the Markarian system.

(*c*) A vocabulary will be worked out within the next months which will give the new designation for all associations contained in the lists of Morgan and Schmidt.

(*d*) This vocabulary will be drafted by Dr Vanýsek and Dr Ruprecht, approved by the Working Group and published in five astronomical periodicals.

These recommendations were unanimously adopted.

2. *Duplication of cluster photometry.* The question had been asked to what extent photometric work in clusters will serve a sensible purpose after so many clusters (at least the brighter ones north of $-25°$) have been studied. In reply, H. L. Johnson commented on the newly published (*Publ. U.S. Naval Obs.* Vol. VII, 19, and *Lowell Obs. Bull.* No. 113) papers on 70 clusters. He emphatically stressed that he does not consider this work of himself and his collaborators to settle the photometric questions in those clusters. Rather would he like to encourage any further work on these and other clusters, both observational and theoretical. As a striking example M 25 was mentioned by the President, which has been investigated by four different astronomers within twelve months (*Ap. J.* **131** and **133**). In spite of that, the results do not agree and the problem still remains unsolved.

3. *Presentation of Cluster data.* A vivid discussion on the publication of cluster work resulted in the following recommendations:

Any paper on photometric cluster work should give:

(*a*) In the introduction, equatorial and new galactic co-ordinates (to $0°{\cdot}1$) of the cluster;

(*b*) a finding chart with orientation and scale indicated;

(*c*) full photometric data on the photo-electric standard sequence stars marked on the finding chart.

This was unanimously adopted.

4. *Symposium.* The suggestion of holding a symposium on clusters in 1962 or 1963 was frankly discussed, but finally the plan had to be dropped since there appeared to be no interest or enthusiasm for it. B. J. Bok commented on the joint Symposium of Commissions 28 and 33 with special emphasis on the southern hemisphere to be held in Mount Stromlo, probably early in 1963.

Scientific meetings, 22 and 23 August 1961

A. A. Hoag and *H. L. Johnson* commented in some detail on the comprehensive photometric work on 70 clusters which has been carried out by A. A. Hoag, H. L. Johnson, B. Iriarte, R. J. Mitchell, K. L. Hallam and S. Sharpless as a joint programme of Lowell Observatory and U.S. Naval Observatory. Ample copies were distributed of these two papers, one dealing with observations, the other with the results pertaining to stellar evolution and galactic structure. Johnson drew special attention to NGC 6940 the only cluster so far known which shows a giant branch sloping downwards to redder stars. That, of course, is of high importance for the theory of stellar evolution. In the discussion L. Mavridis pointed out the need of good proper motions to check the physical membership of those giant-branch stars in NGC 6940. The slope seems to depend on three or four stars only. He, further, referred to his systematic search for M-, S-, and C-type stars in selected galactic clusters (Warner and Swasey Schmidt with infra-red objective-prism plates) and asked for evidence of the existence of such very red stars in the *C-m* diagrams of the new material. There are indeed some cases. No doubt the new material has much bearing on those and similar problems. F. Zwicky mentioned that he had found clusters of stars ("pygmy galaxies") in the nearby inter-galactic space (30 to 100 kpsc). They have from 50 to 10 000 stars. Some of them, but not all, contain red ordinary giants as their brightest stars. Widened spectra recently taken by Zwicky with the 200-inch nebular prime-focus spectrograph show G 5 to K 5 types. But it is expected to find a variety of types. The classification of the spectra of the brightest stars would give powerful means of determining the total absorption through the whole of the galactic system in various directions. The apparent magnitudes of stars which are being investigated in the pygmy galaxies range from 16 to 20.

G. Alter delivered a paper (read by the President) on the galactic structure as deduced from the apparent distribution in galactic longitude of 864 galactic clusters. The shape of the curve confirms the presence of obscuring clouds in the vicinity of the galactic centre. It is further suggested that the cluster system has an elongated shape with its major axis in the direction of the galactic rotation. This is supported by the fact that the number of clusters contained in the sectors enclosing the major axis exceeds by 8:5 the number contained in the sectors enclosing the perpendicular direction, centre to anti-centre.

K. A. Grigorian reported on new photo-electric observations (16-inch at Burakan) of polarisation in 6 clusters: NGC 2422, 7092, IC 4665; NGC 6530, 6514; IC 1590. The clusters of the first group are situated in regions of small and/or smooth interstellar absorption. Correspondingly the planes of vibration of the cluster members are found to be fairly parallel, although the dispersion of θ for NGC 7092 is four times larger than for IC 4665. Further, the amount of polarisation in NGC 7092 increases with increasing m of the cluster members. These two facts are explained by the author by the hypothesis that in NGC 7092 a stellar polarisation contributes to the interstellar component. The second group of clusters shows a rather chaotic distribution of the planes of vibration. It is easily accounted for by the heavily turbulent structure of the clouds of interstellar material in which these clusters are embedded. (See Figs. 1–3 on the following pages.)

A. A. Hoag and *V. Bappu* reported on their independent work on Hγ photometry in associations (*e.g.* Ori 1) carried out at the U.S. Naval Observatory Station at Flagstaff and at Naini Tal, India. It aims at determining very accurate absolute magnitudes.

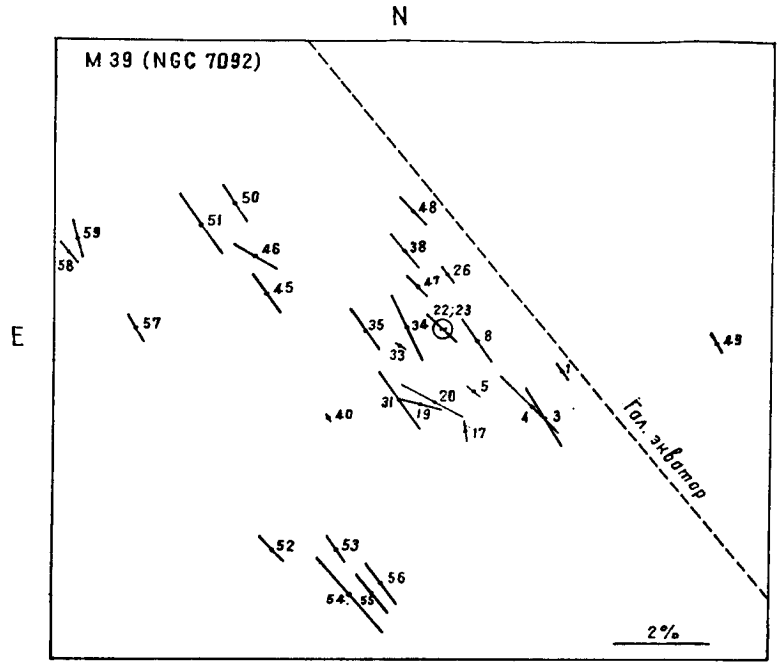

Fig. 1. Polarisation in NGC 7092

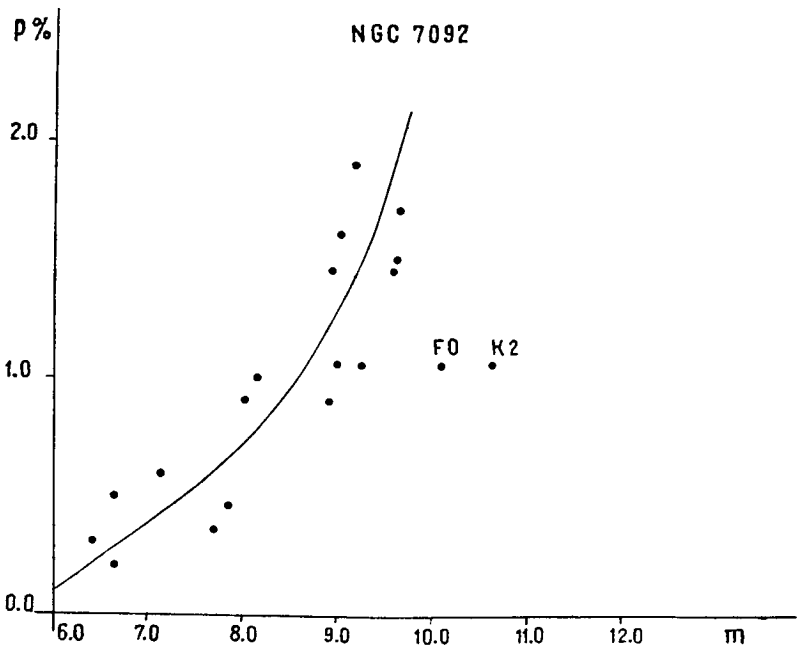

Fig. 2. Polarisation in NGC 7092

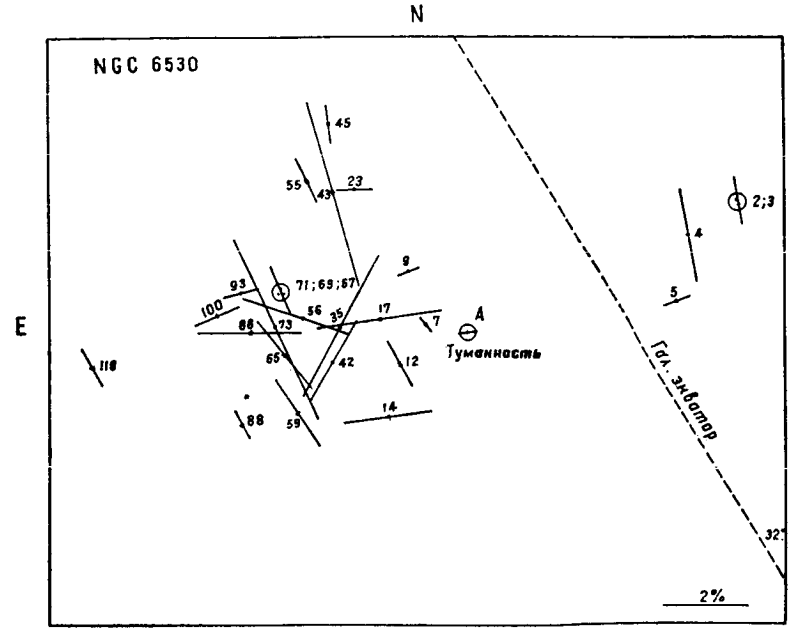

Fig. 3. Polarisation in NGC 6530

V. A. Ambartsumian spoke on a cluster of white dwarfs recently found by him in the vicinity of δ Lyr. He expressed the opinion that clusters of white dwarfs may be a very common feature in our Galaxy and that it is only due to their faintness that they have escaped our attention so far.

A similar, but not identical, object was dealt with by *W. J. Luyten.* He summarized the results of his search for faint blue stars in galactic clusters as follows. In clusters with well-known proper motions many white dwarfs have been established: Hyades (7 to 8, found largely by Zwicky), Pleiades (1 possible), Praesepe (2, and 50 to 100 blue stars down to 21 mag. in the general area). For more distant clusters we can only proceed statistically. M 36, 38, 39, 41, NGC 129 and 6885 have been blinked on Palomar Survey plates together with corresponding control areas. Fewer blue stars were found in the clusters than in the control areas. In NGC 752 and IC 4665 large numbers of blue stars were found, but the same numbers in the control areas. In M 34 and 67 a few possible white dwarfs are indicated at the expected apparent magnitude 19 to 21.

Finally, *I. R. King* gave a report on the results of a programme that aims at determining the density-distributions in about 15 globular clusters. Plates taken with the 48-inch Schmidt camera have made it possible to trace the density out to a low level at the edges of the clusters. In the outer parts of a globular cluster the surface density f is found to follow the law

$$f = c\left(\frac{1}{r} - \frac{1}{r_t}\right)^2 \qquad (1)$$

where r is the projected distance from the centre of the cluster. As observed in several clusters, the limiting radius r_t lies close to the expected cut-off due to the tidal force of the Milky Way.

In the observations of the central parts of globular clusters, the star counts have been supplemented by photo-electric measurements of surface brightness. Near the centre of a cluster the surface density is approximated by

$$f = f_0\{1 + (r/a)^2\}^{-1/2} \qquad (2)$$

This is very similar to Hubble's law (*Ap. J.*, **71**, 131, 1930) for elliptical galaxies. Since Hubble showed that his law closely resembles the projection of the central parts of an isothermal sphere, it appears that the profile of the central parts of a globular cluster is simply a consequence of the resemblance of its velocity distribution to a Gaussian shape.

A possible combination of formulae (1) and (2) is

$$f = f_0[\{1 + (r/a)^2\}^{-1/2} - \{1 + (r_t/a)^2\}^{-1/2}]^2 \qquad (3)$$

This law represents the observed density-distributions in globular clusters and Sculptor-type galaxies. It also approximates to the profiles of elliptical galaxies, provided r_t is taken to be very large. Apart from the inevitable scale factors, the law has only one free parameter, the central concentration r_t/a, which is the accidental result of a combination of external and internal circumstances.

Some tentative dynamical conclusions can be drawn: (1) If the observed density-distribution is to be reconciled with a slowly relaxing velocity-distribution, then the motions in the outer parts of a globular cluster must show a moderate but not an extreme preference for the radial direction. (2) If the resemblance between globular clusters and elliptical galaxies is more than accidental, then some relaxation must have taken place in the elliptical galaxies. A likely source of relaxation is in the initial mixing, at the time when the stars settled down from the primeval gas distribution to the final stellar distribution.

CORRECTIONS AND AMENDMENTS TO THE DRAFT REPORT (VOL. XIA)

With reference to the quotation on page 440, second paragraph, concerning the papers of A. J. Meadows (**40**) and D. H. McNamara (**42**) on rotational velocities of B stars in clusters compared with those of field stars, A. J. Meadows has drawn attention to the fact that for the Orion association he found the Be stars to be distinctly under-abundant, other than in clusters where they had been found over-abundant. Hence there is actually no contradiction with McNamara's results which indicated small values of $v \sin i$ for the Orion association corresponding to under-abundant Be stars.

On page 445, the report on S. von Hoerner's paper (**86**) is to be supplemented by a reference to M. Dirikis, *Publ. Ap. Lab. Acad. Sci. Latvian S.S.R.*, **7**, 5, 1958. This author has made similar computations for some cases of three mass points.

On page 446, first paragraph, a paper of E. A. Dibai, F. A. Tsitsin, A. S. Sharov (*Astr. J. Moscow*, **37**, 659, 1960) should also be mentioned. These authors have considered the problem of determining the mean distance between the stars in a cluster in connection with the application of the virial theorem in the dynamics of clusters.

38. COMMISSION POUR L'ECHANGE DES ASTRONOMES

Report of Meeting, 17 August 1961

PRESIDENT: M. G. J. Minnaert.
SECRETARY: Bart J. Bok.

In his opening remarks, the President paid high tribute to the memory of Professor Stratton, who was the first President of Commission 38 and who for many years guided its work with kindness and with wisdom. He also presented a brief tribute to Dr Dawson, who for the past six years had represented South America on the membership.

The *Report* of the Commission was accepted. The importance of keeping up to date the Addendum—which deals with a listing of 'Facilities for Visiting Astronomers'—was stressed. Dr Page suggested that an additional paragraph be included to describe the Foreign Visitors Program of the American Astronomical Society, sponsored by the United States National Science Foundation.

The Commission agreed to the proposal that its President should from time to time prepare material for inclusion in an IAU *Information Bulletin*—so as to ensure that all astronomers—young and old—shall be constantly aware of the opportunities for exchanges and visits abroad that do exist.

Dr Kourganoff and others drew attention to the problems of an administrative nature that arise, especially in regard to Fulbright Awards, because of the great time-lags between the initiation of an application, the making of the award, and the starting time of the fellowship. The President was requested to write to the Foreign Secretary of the U.S. National Academy of Sciences requesting that this 'lead-time' be shortened appreciably.

More flexibility in fellowship awards was urged for NATO Fellowships, notably in regard to the time interval for which one of these fellowships can be held. The value of short-term fellowships for experienced scientists was stressed during the discussion. It will be brought to the attention of the Ministers of Education of some countries.

In the past it has been the policy of the Commission to support principally requests for small travel grants. Because of the growing need for travel abroad by astronomers from remote countries (Japan, Australia, Latin America), coupled with the desires of European astronomers to work in these countries, the need is recognised for increased future emphasis on a limited number of larger grants. The meeting stressed the great value of the flexible approach to awards that was the traditional policy of the late President Stratton, and Professor Minnaert also favours the following of no set rules.

It was decided that, in the normal course of events, there will be two closing dates for the receipt of applications, 1 January and 1 July. But it was noted that exceptions will and should be made and that applicants should not hesitate to write to the President during the intervening months, especially in cases of urgency.

The meeting voted unanimously to request the Executive Committee to increase the annual budget from its present level of $6,000 to $10,000 annually. This substantial increase seems justified for the following reasons:

(*a*) increases in travel costs alone warrant a substantial increase;

(*b*) there will be more emphasis on travel between distant points in the future than there was in the past;

(*c*) the number of countries involved in astronomical research is growing and so is the number of astronomers in each country;

(*d*) many more competent young astronomers are needed now than was the case ten or more years ago.

[The Finance Committee was able to provide, in its budget, only an increase to $7500.]

The Commission agreed to recommend the following composition of the Organizing Committee: M. G. J. Minnaert, President; P. Swings, Vice-President; B. J. Bok, A. A. Mikhailov, T. L. Page, members. The hope was expressed that the present members of the Commission will continue to serve during the next triennium and that the following will also agree to serve as members of the Commission: Bappu, Kienle, Kourganoff, Miyamoto, Righini, Sahade, Thackeray, Woolley.

40. COMMISSION DE RADIO-ASTRONOMIE

Compte rendu des Séances

PRÉSIDENT: J. F. Denisse.
SECRÉTAIRE: R. N. Bracewell.

A. QUESTIONS ADMINISTRATIVES

La Commission a tenu trois séances. les 18 et 21 août de 9^h à 12^h et le 22 août de 9^h à 11^h. Dans toutes ces séances ont été considérées des questions administratives et dans les deux dernières ont été également traitées certaines questions scientifiques qui ne trouvaient pas leur place dans les trois symposiums (UAI no. 15, "Problems of extra-galactic research"; UAI no. 16, "Solar Corona"; et le Philco Symposium,—"Grands Radio-télescopes") organisés à l'occasion de l'Assemblée de l'UAI et où de nombreux aspects des recherches radio-astronomiques ont pu être évoqués. Enfin une séance commune aux Commissions 40 et 28 a eu lieu le 21 août de 14^h à 17^h, où ont été discutés les problèmes d'intérêt commun aux deux Commissions relatifs aux observations radio-astronomiques de grande sensibilité et résolution.

Séance du 18 août 1961

Les questions à l'ordre du jour considérées au cours de cette séance ont porté sur les points suivants:

1. *Draft Report*

Le *Draft Report* a été approuvé avec l'adjonction d'un rapport communiqué par A. P. Molchanov sur les travaux effectués en U.R.S.S. et reproduit en annexe.

2. *Organisation de la Commission*

Pour satisfaire à la nouvelle organisation de l'Union, la Commission a procédé à la désignation d'un Comité d'Organisation. Le Comité de 5 membres proposé par le Président: R. N. Bracewell, C. H. Mayer, V. V. Vitkevitch, G. Westerhout et J. P. Wild, a été adopté sans modification.

3. *Comité "ad hoc" pour la répartition des responsabilités respectives de l'UAI, de l'URSI et du COSPAR* (H. C. van de Hulst)

Sur l'initiative des Présidents des unions intéressées, un comité avait été formé en 1960 pour considérer la division des intérêts et des responsabilités entre la Commission 40 de l'UAI, la Commission V de l'URSI et le COSPAR. Ce comité, composé de: J. H. Oort, Président de l'UAI, D. H. Sadler, Secrétaire-général de l'UAI, L. V. Berkner, Président de l'URSI, E. Herbays, Secrétaire-général de l'URSI, H. C. van de Hulst, Président du COSPAR (rapporteur), un représentant de l'Académie des Sciences de l'U.R.S.S., L. G. H. Huxley, A. C. B. Lovell (Commission V) et J. F. Denisse (Commission 40), a présenté un rapport à l'Assemblée Générale de l'URSI en Septembre 1960 à Londres. Ce rapport recommandait essentiellement que, si il est nécessaire que tous les résultats d'importance et d'intérêt commun soient présentés aux assemblées de chacune des Unions, il faut cependant que les discussions scientifiques et les responsabilités soient nettement orientées dans le sens de la vocation particulière de chacune des Unions: les matières considérées à l'URSI étant plutôt rattachées aux questions radio-scientifiques et aux problèmes instrumentaux, et les matières considérées à l'UAI tournées vers la discussion des problèmes plus proprement astronomiques.

4. *Allocations de fréquences pour la Radio-astronomie* (J. F. Denisse, C. L. Seeger).

Depuis la dernière assemblée générale de l'UAI à Moscou la question des allocations de fréquences pour la Radio-astronomie a fait l'objet de plusieurs décisions importantes:

Au cours de sa dernière réunion (Los Angeles, 1958) le CCIR (Comité Consultatif International des Radiocommunications) a entériné dans ses grandes lignes les demandes d'allocations de fréquences formulées par l'UAI à Moscou.

Au cours de sa Conférence Administrative tenue à Genève, en 1959, l'UIT (Union Internationale des Télécommunications) a décidé de reconnaître la Radio-astronomie comme un 'service' officiel, donc autorisé à formuler des demandes d'allocations de fréquences pour son fonctionnement. Dans les actes de cette conférence (*Règlement des Télécommunications*, Genève, Décembre 1959) certaines bandes de fréquences ont été explicitement réservées pour la Radio-astronomie. A part l'importante exception de la bande 1400-1427 Mc/s qui a été réservée à l'usage exclusif et mondial des radio-astronomes, conformément à leurs voeux, toutes les autres allocations sont partielles et généralement locales. Ces premiers résultats ne sont cependant pas négligeables et sont dus essentiellement au fait qu'une représentation permanente des intérêts de la Radio-astronomie (et des Recherches Spatiales) a pu être assurée au cours des trois mois des délibérations de la Conférence de Genève par J. H. Oort, van der Pol, H. C. van de Hulst, C. L. Seeger, J. F. Denisse, J. W. Findlay, R. Coutrez et W. J. G. Beynon.

Pour assurer sur une base permanente la défense des intérêts de la Radio-astronomie, un comité groupant des représentants de l'UAI, de l'URSI et du COSPAR a été constitué par l'ICSU. Ce comité interunion: IUCAF (Comité Inter-Union pour les Allocations de Fréquences) comprend J. H. Oort, V. V. Vitkevitch, A. Unsöld, J. F. Denisse (Président), représentant l'UAI; R. L. Smith-Rose (Secrétaire Général), J. A. Ratcliffe, V. Ilyin, H. Sterky, représentant l'URSI; H. C. van de Hulst, J. P. Hagen, A. P. Mitra, L. G. H. Huxley, représentant le COSPAR.

Depuis sa création, l'IUCAF, qui a obtenu de participer officiellement aux travaux du CCIR et de l'UIT, s'est occupé en particulier de coordonner l'activité des radio-astronomes des différents pays pour la préservation de leurs observations, d'amorcer des discussions pour l'observation dans la bande du Deutérium (320-327 Mc/s), d'assister à la Conférence Européenne de la Radiodiffusion à Stockholm où la préservation de la bande 600-614 Mc/s a pu être partiellement maintenue, d'entreprendre les démarches nécessaires pour que les problèmes radio-astronomiques soient inclus dans l'ordre du jour de la prochaine conférence extraordinaire de l'UIT qui doit se réunir en 1963, de formuler les recommandations nécessaires pour le groupe d'étude no. IV du CCIR qui s'occupe en particulier des questions radio-astronomiques.

Il ressort clairement de ces premiers efforts que la reconnaissance et la défense des intérêts vitaux de la Radio-astronomie ne pourront être obtenus que par un effort permanent de tous les radio-astronomes qui doivent prêter leur concours pour assurer dans chaque pays une liaison entre les radio-astronomes et les autorités responsables des allocations de fréquences. Car il est essentiel qu'à l'échelon national ces autorités soient complètement informées des besoins de la Radio-astronomie.

L'ensemble des données techniques concernant ces problèmes ont été rassemblées par le Secrétaire Général de l'IUCAF. La liste de ces documents et ces documents eux-mêmes peuvent être obtenus sur demande à:

Dr R. L. Smith-Rose, Secrétaire Général de l'IUCAF; 21 Tumblewood Road, BANSTEAD, Surrey, England.

5. *Projet West Ford* (J. F. Denisse, A. E. Lilley)

Le but final de cette entreprise est d'assurer un moyen de télécommunication par l'intermédiaire d'une ceinture de dipôles diffusants placés en orbites circulaires à 3000 km d'altitude environ. Pour tester l'intérêt de ce programme, il est prévu de lancer une ceinture de dipôle expérimentale qui constitue le projet West Ford. La description de ce premier projet et ses effets possibles sur les observations optiques et radio-astronomiques ont fait l'objet d'un ensemble de publications parues dans l'*Astronomical Journal*, **66**, 105-118, avril 1961.

Les promoteurs du projet, appartenant au Lincoln Laboratory, ont demandé au "Space Science Board" de l'Académie des Sciences des U.S.A. d'examiner les incidences possibles de ce projet sur les observations radio-astronomiques en particulier. Les conclusions essentielles de cet organisme sont résumées dans une lettre datée du 11 août 1961 et communiquée à la Commission:

"1. The Project West Ford experiment will constitute no interference to optical or radio astronomy. As a matter of fact, the belt will be barely detectable, even by astronomers with advance information and upon the taking of special efforts for detection. It is true that a belt or belts could be erected which could cause serious interference to astronomical observations; however, the United States Government policy provides that no further launches of orbiting dipoles will be planned until the West Ford results have been analyzed and evaluated and further, will be contingent on the development of necessary safeguards.

"2. The Board will continue its studies of this area of experimentation on behalf of the scientific community. In these studies it will depend on objective and quantitative assessments that constitute the foundation for scientific discussions, recommendations and decisions. These assessments can only be achieved through a carefully controlled, harmless test, and Project West Ford provides a clear opportunity for scientists of all nations to cooperate in making observations to form the basis for an objective understanding of the behavior of an orbiting dipole belt, both in terms of its astronomical properties and of its communication capabilities.

"3. The Board will continue to keep the scientific community everywhere informed and it invites the cooperation and assistance of scientists everywhere who have interest and specialized knowledge in this area. The Board acknowledges with gratitude the assistance of many scientists—both at home and abroad—who have already contributed to its studies."

D'autre part, une déclaration du gouvernement américain exposant la politique qu'il entend suivre concernant les suites à donner à ce projet est également communiquée à la commission:

"The United States Government, in conducting the West Ford Project, will be guided as follows:

"1. No further launches of orbiting dipoles will be planned until after the results of the West Ford experiment have been analyzed and evaluated. The findings and conclusions of foreign and domestic scientists (including the liaison committee of astronomers established by the Space Science Board of the National Academy of Sciences) should be carefully considered in such analysis and evaluation.

"2. Any decision to place additional quantities of dipoles in orbit, subsequent to the West Ford experiment, will be contingent upon the results of the analysis and evaluation and the development of necessary safeguards against harmful interference with space activities or with any branch of science.

"3. Optical and radio-astronomers throughout the world should be invited to cooperate in the West Ford experiment to ascertain the effects of the experimental belt in both the optical

and radio parts of the spectrum. To assist in such cooperation, they should be given appropriate information on a timely basis. Scientific data derived from the experiment should be made available to the public as promptly as feasible after the launching."

Afin d'étudier dans quelles conditions pourrait être observée la ceinture de dipôles experimentales par certains observatoires radio-astronomiques, un groupe de travail est formé, composé de Lilley, Seeger, Smith, Haddock (rapporteur), McClain, Molchanov, Gold et Blum.

A la suite de ces informations s'engage une discussion générale qui montre que la grande majorité des membres de la Commission est complètement opposée à ce que le projet West Ford soit tenté dans les conditions actuelles, n'étant pas convaincue en particulier que la ceinture de dipôles puisse avoir une durée de vie limitée. Ce point de vue est exprimé dans une résolution proposée par Bondi, Christiansen et Gold, qui est adoptée à l'unanimité par la Commission.

Séance du 21 août 1961

5. *Projet West Ford (suite)*

Le texte de la résolution finalement adoptée par la Commission après discussion et addition d'un préambule, est indiqué dans l'appendice I (résolution 2).

F. T. Haddock expose les conclusions du groupe de travail constitué au cours de la séance précédente et décrit en détail les différents types d'expériences possibles pour étudier la ceinture expérimentale. Celles-ci consistent soit en observations passives, en observations radar ou en expériences effectuées en coopération avec le Lincoln Laboratory. Drake fait remarquer que ces expériences sont d'autant moins difficiles qu'elles pourront être tentées immédiatement après le lancement.

En conclusion une résolution proposée par Seeger et Pawsey est adoptée par 7 voix contre 4 et indiquée dans l'appendice I (résolution 3).

Enfin une troisième résolution proposée par Christiansen (résolution 1 de l'appendice I) qui s'élève d'une manière générale contre toute contamination inconsidérée de l'environnement terrestre est adoptée à l'unanimité par la Commission qui décide de transmettre les trois résolutions pour considération par le Comité Exécutif.

6. *Recommandation pour les allocations de fréquences*

La recommandation concernant les allocations de fréquences (indiquée dans l'appendice II) et proposée par J. P. Hagen est adoptée à l'unanimité. Elle insiste sur l'importance d'inclure la Radio-astronomie au programme de la prochaine Conférence extraordinaire de l'UIT.

7. *Bibliographie*

J. L. Pawsey expose la situation concernant la bibliographie des publications radio-astronomiques; la Commission est unanime à reconnaître la grande valeur d'une liste de résumés des publications complète et publiée avec un minimum de délai. Un groupe composé de Mme M. S. Carpenter et de J. L. Pawsey, R. Fleisher, F. J. Kerr, et G. Westerhout s'est réuni durant l'Assemblée pour étudier cette question: ces recommandations approuvées par la Commission sont les suivantes:

1. Le groupe de Sydney compléterait la compilation de leur série de courts résumés indicatifs pour la période 1957–60 inclusivement (un précédent volume couvre la période 1954–6 inclus).

2. Le groupe de Cornell, avec le support de la National Science Foundation, commencerait la compilation du volume de leurs résumés, plus longs et plus descriptifs, pour l'année 1961.

Ce volume devrait pouvoir être publié en août 1962. Il serait souhaitable que les volumes suivants puissent être publiés sur une base annuelle avec publication aux environs du milieu de l'année suivante. Cette cadence impliquera sans doute la réduction de certains résumés laissée à la discrétion de l'éditeur, et le report à la publication de l'année suivante des publications que l'on n'aura pas obtenues à temps.

3. Le groupe de Sydney continuera à tenir à la disposition des éditeurs de Cornell leur liste hebdomadaire de résumés.

4. La finition des résumés de Cornell pour les années 1954–60 serait laissée à la discrétion de leur éditeur et de la National Science Foundation.

8. *Catalogue des radio sources*

Le problème de la révision des listes de radio sources antérieurement complétées par le Dr J. L. Pawsey et publiée par l'IAU a été examiné par un groupe de radio-astronomes réunis par le Dr D. W. Dewhirst. Les conclusions de ce groupe sont les suivantes:

"A small number of astronomers interested in the precise determination of radio-source positions, and the search for and examination of objects that may be found in their place, met informally on 19 August.

"Present: R. Minkowski, who was asked to lead the discussion, and E. M. and G. R. Burbidge, D. W. Dewhirst (reporter), T. Matthews, B. Y. Mills, M. Ryle, M. Schmidt, and G. J. Stanley.

"Most of those present had felt for some time that the exchange of information between radio and optical astronomers was not working very efficiently. Publication of the radio data is often slow, so that it is difficult for an optical astronomer to get rapidly the total information available about radio position and intensity distribution, which are guides to the most profitable sources to be studied. On the optical side there is the danger that big telescope time may be used inefficiently by the duplication of effort on one object whilst others remain unstudied. These and other difficulties become more serious as the optical objects for study become fainter and the demands on big telescope time heavier.

"It did not seem that the preparation of a new IAU List of Radio Sources would be of value in this connection, since the radio data are still changing and growing rapidly. The need was for one astronomer familiar with both the radio and optical problems to co-ordinate the data and make it available to those who wanted it: *e.g.*, by advising the radio observers of seemingly discordant positions, and optical observers of objects which required study.

"Dr Minkowski agreed to act in this capacity. We urge that all those concerned communicate relevant radio data to him with the least possible delay, or advise him of their intention to make optical studies.

"It was felt that the need could be met adequately by private exchange of information, and that it was not necessary to constitute a formal sub-committee of Commission 40 for the purpose."

9. *Obtention des données radio-astronomiques sous une forme utilisable par des machines à calculer*

Etant donné le développement des observations radio-astronomiques, le Dr F. J. Kerr désire que l'on envisage dès maintenant la possibilité d'obtenir les données radio-astronomiques sur rubans ou cartes perforées, afin qu'elles puissent être plus facilement échangées entre différents observatoires et utilisées sur machines à calculer. Un groupe de travail réuni par F. J. Kerr et comprenant G. Westerhout, E. J. Blum, A. Hewish, B. S. Yaplee, F. D. Drake, G. J. Stanley et J. G. Davies a considéré cette question au cours de l'Assemblée. Il a conclu

qu'il suffisait pour l'instant d'assurer la représentation de la Radio-astronomie à la Commission 7 qui considère cette même question dans le cadre de la mécanique céleste, et a chargé le Dr F. D. Drake de réunir la liste des informations déjà obtenues dans différents observatoires sous forme de cartes ou de rubans perforés.

10. *Catalogue des évènements solaires*

La Commission approuve le projet exposé par J. P. Wild de publier un catalogue de spectrogrammes dynamiques des évènements solaires les plus caractéristiques. Un tel atlas, comprenant de 20 à 30 planches photographiques de haute qualité, pourrait être publié en 1000 exemplaires par exemple sous le couvert de l'UAI. Pour financer cette publication, la Commission adopte la demande de subvention suivante:

"La Commission 40 (Radio-astronomie) demande que l'Union Astronomique Internationale publie un catalogue d'enregistrements panoramiques d'évènements radio-électriques solaires. Ce catalogue comprendrait une trentaine de planches photographiques, son tirage pourrait être de 1000 exemplaires; la dépense est estimée à 3000 $.

"Ce catalogue serait une publication de l'UAI qui en vendrait les exemplaires; elle serait dirigée, sous la responsabilité de la Commission 40, par l'un des observatoires de radio-astronomie engagé dans ce genre d'observations."

Cette demande a été votée à l'unanimité par la Commission 40, mais elle n'a pas reçu l'approbation de la Commission des Finances. Aussi la Commission 40 décide de confier à son Comité d'Organisation l'étude d'un autre moyen de financement de ce catalogue dont l'intérêt dépasse d'ailleurs le cadre des membres de l'UAI.

Séance du 22 août 1961

11. *Quarterly Bulletin of Solar Activity*

A. D. Fokker a accepté d'assurer la suite de S. F. Smerd comme éditeur du *Quarterly Bulletin* pour les évènements radio solaires. La Commission exprime sa gratitude pour l'énorme travail accompli par le précédent éditeur et pour le soin et la compétence avec lesquels il a mené à bien ce travail depuis le début de ces publications. Mr Fokker décrit quelques modifications qui seront introduites dans l'édition, modifications qui visent essentiellement à tirer le meilleur parti des progrès accomplis dans la compréhension et la classification des évènements radio solaires au cours de ces dernières années.

La Commission 10 responsable au sein de l'UAI de l'édition du *Quarterly Bulletin* a désigné pour assister Mr Fokker un comité consultatif comprenant:

H. Daene, H. W. Dodson-Prince, A. Maxwell, Mme Pick-Gutmann, S. F. Smerd, Tanaka, Troitsky et P. Wild.

Une discussion générale s'est engagée sur l'opportunité de poursuivre les observations actuelles. Il est apparu raisonnable de cesser pendant la période du minimum d'activité solaire certaines observations en particulier les spectrogrammes dynamiques dont le rendement deviendra très faible.

La Commission exprime le voeu que les publications du *Quarterly Bulletin* puissent rattraper le retard qu'elles ont actuellement.

12. *Terminologie*

G. Westerhout porte à la connaissance des membres de la Commission une liste de définitions destinée à normaliser la terminologie utilisée en Radio-astronomie. Cette liste sera publiée en anglais, français, allemand et russe dans les *Zeitschrift für Astrophysik.*

13. *Occultations des radio sources*

D. W. Dewhirst rend compte du travail d'un sous-comité constitué à Paris en 1958 avec lui-même, Ch. L. Seeger, et F. M. McBain Sadler pour étudier la prédiction des occultations des radio sources par la Lune. Le Nautical Almanac Office a envoyé aux observatoires intéressés une liste de prédictions concernant les occultations d'une quarantaine de radio sources au cours de ces dernières années.

14. *Système de référence pour les observations radio-electriques de Jupiter*

Un comité composé de B. F. Burke, H. Smith, A. G. Smith et J. Warwick, qui se chargera de le réunir, est chargé d'étudier le meilleur système de coordonnées à utiliser pour les observations radio-électriques de Jupiter.

15. *Programme d'observations pour le prochain cycle d'activité solaire*

Plusieurs membres de la Commission discutent certains aspects particuliers des observations solaires qu'il serait souhaitable de promouvoir au cours du prochain cycle d'activité solaire.

J. P. Wild traite particulièrement des observations classiques des sursauts solaires; il souligne les difficultés de ces observations et la nécessité d'obtenir simultanément des mesures de distribution de brillance des sursauts en deux dimensions et leur polarisation.

F. T. Haddock expose l'intérêt des observations à partir de véhicules spatiaux qui permettront d'étudier les sursauts radio sur très basses fréquences apportant des indications sur les perturbations de la couronne solaire.

A. Hewish souhaite que les observations de l'occultation de la Nébuleuse du Crabe par la couronne solaire soient poursuivies et si possible accrues.

V. R. Eshleman décrit quelques résultats déjà obtenus par l'étude des échos radar sur le Soleil. Le pouvoir réflecteur de la couronne solaire varie dans de très grandes proportions avec l'activité solaire et ces études qui débutent seulement semblent devoir être du plus haut intérêt.

B. COMMUNICATIONS SCIENTIFIQUES

Observations galactiques

G. Westerhout décrit des observations de polarisation du continuum galactique effectuées en Hollande par lui-même et C. L. Seeger. L'homogénéité des vecteurs polarisation observés conduit à penser que l'effet observé est produit dans des régions relativement voisines du Soleil. Des observations similaires par Pauling-Toth, Baldwin et Shakeshaft dans la région qui s'étend au nord du plan galactique au voisinage de la longitude $l = 30°$ ont donné des résultats négatifs.

R. Davies décrit ses recherches sur l'effet Zeeman dans la raie d'absorption sur 21 cm de Cas A; le résultat négatif de ces observations conduit à admettre une valeur maximum du champ magnétique dans le bras galactique égal à 3.10^{-6} gauss.

J. L. Locke, J. A. Galt et C. H. Costain ont effectué des observations sur la raie 21 cm avec le réflecteur de 84 pieds de Penticton (B.C.). Des cartes de distribution de brillance dans la région d'Auriga ont été obtenues à partir des profils obtenus à vitesse radiale constante.

W. E. Howard a examiné la correspondance qui existe entre les vitesses radiales interstellaires déduites des observations optiques et dans la raie 21 cm. Il trouve une dispersion de 4 Km/s dans les differences de vitesse, dispersion qui peut d'ailleurs être d'origine instrumentale.

Observations planétaires

J. Warwick interpréte certaines particularités des émissions de Jupiter entre 7 et 35 Mc/s en postulant l'existence d'un dipôle magnétique qui produit dans l'atmosphère de la planète une zone aurorale en forme de U.

Les résultats d'observations de Mercure à 8 000 Mc/s avec le miroir de 85 pieds de l'Observatoire de Michigan sont décrits par W. E. Howard. La température d'antenne obtenue égale à 0°·04 K. correspond à une température du point subsolaire égale à 1050° ± 350 °K.

McClain rapporte des observations de Vénus faites par C. Mayer. Sur 3 cm de longueur d'onde la température de Vénus est trouvée égale à 500°. Sur 8 mm et 4 mm de longueur d'onde la température est égale à 400°.

Observations solaires

A. P. Molchanov rapporte des observations de l'éclipse de soleil du 21 février 1961 effectuées sur les longueurs d'onde 2, 3·2, 4·5, 4·9, 9·2 et 21 cm. Ces mesures ont montré qu'une source située sur le limbe solaire présentait un diamètre de 1′ sur toutes les longueurs d'onde sauf sur 21 cm où son diamètre à été trouvé égal à 3′.

S. F. Smerd résume un travail effectué en collaboration avec J. P. Wild et K. V. Sheridan sur les positions relatives et l'origine des harmoniques dans le spectre des sursauts solaires de type II et III. Les observations montrent que l'émission de l'harmonique des types II provient d'une direction qui correspond à une altitude beaucoup plus basse que celle du fondamental. Même tendance pour le type III mais moins concluante. Pour interpréter ce résultat Smerd suppose que l'harmonique est rayonné de préférence vers l'intérieur de la couronne et vu par réflexion sur les couches plus basses. Il montre que l'on peut rendre compte de ce résultat par la théorie de Ginzburg et Zhelezniakov qui suppose que l'harmonique est engendré par diffusion des oscillations de plasma sur les fluctuations de charge thermiques du plasma coronal au cours de laquelle les oscillations de plasma sont couplées au champ de radiation.

P. A. Sturrock propose de reconsidérer la théorie initialement proposée par Smerd et Wild pour la génération du second harmonique dû à la nonlinéarité des oscillations de plasma. Il a montré en effet (*J. Nuclear Energy*, Part C, Plasma Physics, 1961) que les équations auxquelles satisfont les oscillations de plasma non linéaires produisent de préférence le second harmonique (conformément aux observations). Comme on doit s'attendre à ce que le champ E_p de l'onde soit supérieur au champ E_f des fluctuations, on peut penser que l'harmonique produit par non-linéarité, proportionnel à E_p^2, soit plus important que celui qui est dû à la diffusion, proportionnel à E_pE_f.

APPENDICE I. RESOLUTIONS BY COMMISSION 40 FOR THE ATTENTION OF THE EXECUTIVE COMMITTEE

Resolution 1

Commission 40 views with concern the increasing contamination of the space around the Earth by radiating and scattering objects. It feels that no group has the right to change the Earth's environment in any significant way without full international study and agreement.

Resolution 2

Commission 40 expresses its appreciation for the fact that the plans for project West Ford have been publicly announced well ahead of launching and that it has been stated officially that the U.S. Government policy on further launchings will be guided by the principle that

such projects should not be undertaken unless sufficient safeguards have been obtained against *harmful interference with astronomy.*

Nevertheless, Commission 40 views with the utmost concern the possibility that the belt of dipoles proposed in project West Ford might be *permanent*, and is completely opposed to such an experiment until this question is clearly settled in published papers and time has been given for their study. Whatever the limitations of present radio astronomical equipment, the Commission is inflexibly opposed to any steps that might permanently compromise future development in radio and optical astronomy.

Resolution 3

If the objections of Resolution 2 above can be removed and the experiment West Ford is performed, Commission 40 regards it as essential that the fullest observations of, or experiments on, the properties and variations of the belt be made by all possible means.

Such observations should be made and analyzed according to the highest scientific standards and by means of the best equipment available, bearing in mind that barely detectable signals today may be a great source of interference to future scientific research with more sensitive equipment.

These observations or experiments are likely to be difficult to perform and will in many ways parallel those carried out by the bodies responsible for performing the experiment West Ford. Moreover, much specific information such as precise and up to date ephemeris data will be required in any case. Commission 40 therefore urges the establishment of channels in the IAU to obtain fast and full co-operation among the astronomers making such observations and to provide for world-wide dissemination of the results along accepted standards in scientific research.

Viewing the position taken by the U.S. Government that any decision on later experiments of this type would be contingent on the results of the analysis of the presently proposed experiment, Commission 40 appreciates the offer of the U.S. Government to extend co-operation and, in particular, asks that the U.S. Government grant full privileges to a group of astronomers, acceptable to the IAU to co-operate with project West Ford authorities to perform quantitative experiments and observations using West Ford facilities with the purpose of determining the properties of the belt and its variations with time and position and to assess its impact on present and future research in astronomy and radio astronomy.

APPENDICE II. RECOMMENDATION ON FREQUENCY ALLOCATIONS FOR RADIO ASTRONOMY

Considering that the exclusive allocation of channels for radio astronomy is essential for the successful pursuance of this branch of astronomy,

that in order to be effective one such channel, having a width of at least 1%, should be available in every octave consistent with earlier discussion relating to specific frequencies;

that at present only one world-wide allocation of a channel has been agreed upon;

Proposes that all possible steps be taken to include radio astronomy in the agenda of the proposed extraordinary administrative radio conference of ITU in 1963; and that steps be taken to make allocations for radio astronomy approximately in each octave of the spectrum on a world-wide basis.

41. COMMISSION DE L'HISTOIRE DE L'ASTRONOMIE

Report of Meeting, 17 August 1961

PRESIDENT: P. G. Kulikovsky.
SECRETARY: J. Ashbrook.

There were present 30 members and guests.

Business meeting

The agenda for the business session was:

1. Additions to the Draft Report.
2. Discussion of the Draft Report, and Resolutions.
3. Membership of the Commission.

1. *Additions to the Draft Report*

The President communicated the titles of the following works, published after the preparation of the *Draft Report:*

Alexandre Koyré. *La révolution astronomique* [Copernic, Kepler, Borelli] Paris, Hermann, 1961, p. 525.

A. Pannekoek. *A History of Astronomy*, London, Allen & Unwin, 1961, p. 506.

Simon Stevin. *Principal Works* Vol. III, *Astronomy, and Navigation*, Amsterdam, 1961, p. 632.

Historico-astronomical Investigations, Vol. VII, Moscow, 1961, p. 420.

P. Kutitzsch. *Untersuchungen zur Sternnomenklatur der Araben*, 1961, p. 125.

A. Beer & others. "An 8th Century Meridian Line: I-HSING's chain of Gnomons and the Pre-history of the Metric System" in *Vistas in Astronomy*, Vol. IV, 1961.

The President noted the omission from the bibliography of two articles by C. H. Smiley on the astronomy of the Mayas: "The Antiquity and Precision of Mayan Astronomy" (*J.R.A.S. Can.*, **54**, 222-226, 1960); "A New Correlation of the Mayan and Christian Calendars" (*Nature*, **188**, 215-216, 1960).

On this subject the President reported that the decipherment of Mayan texts by means of electronic data processing equipment has been performed at the Novosibirsk branch of the U.S.S.R. Academy of Sciences.

2. *Resolutions*

After discussion of the *Draft Report* and of its propositions, Commission 41 adopts the following *resolutions:*

1. The Commission expresses its desire that the National Committees of Astronomy in countries adhering to the IAU organize wherever possible Commissions on the History of Astronomy, in order to co-ordinate the efforts of scientists in allied fields.

2. The Commission expresses the hope that the extension of its membership to include Presidents of future national commissions on the history of astronomy, as designated by their

National Committees, will be approved by the Executive Committee of the IAU in the few cases when such persons are not members of the IAU.

3. The Commission desires to undertake the preparation and publication of an annual bibliography of studies in the history of astronomy, and its distribution to members of Commission 41, to national commissions, to National Committees, to observatories and interested scientists.

(The President expressed the hope that the U.S.S.R. Academy of Sciences will have the kindness to publish this bibliography for the next three years).

4. The Commission desires to promote the exchange of information by publishing and distributing, under IAU auspices, an *Information Circular*, of which several issues would appear each year. (The President expressed the hope that the U.S.S.R. Academy of Sciences will similarly have the kindness to publish the *Circulars* during the next three years).

5. The Commission accepted all the recommendations made on pages 462-463 of the *Draft Report*, (see Vol. XIA), except the first, which was approved in principle but deferred to a later time.

Two additional suggestions were accepted.

(*a*) The desirability of encouraging individual observatories to compile or bring up to date their histories (D. Alter),

(*b*) The expression of encouragement to Dr T. Przypkowski (Jedrzejow, Poland) to complete and publish an illustrated description of his unique collection of sundials, other gnomonic instruments and books, started by his ancestor in 1738 (P. Kulikovsky).

3. *Membership*

J. Ashbrook (U.S.A.) was named as Vice-President of Commission 41. The Organizing Committee, in addition to the President and Vice-President *ex officio*, contains the following members: H. Dingle (U.K.), A. V. Douglas (Canada), H. Michel (Belgium), K. Yabuuti (Japan), E. Zinner (Germany).

The list of members of Commission 41 for the next three years is given in Part 6.

Scientific meeting

The agenda for the scientific session was:

1. Astronomical texts in Tibet (W. E. Petri).

2. Jan Hevelius (1611–1686) (E. Rybka).

3. Mikhail Lomonosov (1711–1765) (P. G. Kulikovsky).

1. In collaboration with the Professor of Indology in Munich University (Professor Dr H. Hoffmann) W. E. Petri studies Tibetan and Sanskrit texts relevant to the history of astronomy. Their main interest is focussed on the *Kàlacakvalaghütantra*, a Buddhist work of about 1000 A.D.

It is hoped that further discussion will throw some light on the missing links between Greek and Hindu astronomy. A scrutiny of Tibetan xylographs and manuscripts preserved in the U.S.S.R. is highly desirable.

2. E. Rybka reported that the correspondence of Jan Hevelius preserved in the Bibliothéque National, Paris, has been investigated by T. Przypkowski and the results are expected to be soon published, partly in the *History of Astronomy in Poland*, which may be available in 1963. On 24 April 1961 there was celebrated at Gdańsk in Poland the 350th anniversary of Hevelius'

birth. He drew attention to P. G. Kulikovsky's article on the activity of J. Hevelius in Vol. VII of *Historico-Astronomical Investigations* pp. 257-288, Moscow, 1961.

3. On the occasion of the forthcoming 250th anniversary of the birth of M. Lomonosov, P. G. Kulikovsky reported on his researches into the astronomical works of this great Russian scientist. Among others he mentioned that Lomonosov invented an oblique reflecting telescope prior to W. Herschel and from his observations of the 1761 transit of Venus he correctly deduced the existence of a Cytherean atmosphere. Kulikovsky's new book about Lomonosov's astronomical work will be published in Moscow in Setpember, 1961.

The President expresses his gratitude to all persons present at this session and especially to Mrs S. D. Gossner (U.S.A.) for her kind assistance with translation from French to English and *vice-versa*.

42. COMMISSION DES ETOILES DOUBLES PHOTOMETRIQUES

Report of Meetings

Business sessions: 16 and 23 August 1961.
Scientific sessions: 18 and 22 August 1961.

PRESIDENT: D. J. K. O'Connell.
SECRETARY: J. E. Merrill.

One two-hour and two three-hour sessions were held during the Congress, and a two-hour joint scientific session with Commission 27. By agreement between Dr O'Connell and Dr Oosterhoff, Presidents of the Commissions concerned, the report on the joint session is incorporated herein.

Business and Administrative Sessions

On motion of Dr Wood and by unanimous vote, the *Draft Report* was approved for publication, with thanks to the President for the work of preparation. The form and extent of future *Draft Reports* were discussed. It was agreed that the form of the present report was highly satisfactory. It was left to the discretion of future Presidents to modify or extend the Report as seems required.

A committee consisting of Drs Huffer (chairman), Schneller and Piotrowski, was appointed to receive and report on any additional items suggested for the agenda. In fact, only one such item arose; it was placed on the agenda for the second session.

Co-ordinated Programmes

Results of the Co-ordinated Programmes on β Lyrae and VW Cephei are given in the Commission Report in Volume A. To expedite the selection of stars for future co-operative effort, the following committee was appointed: Drs F. B. Wood (chairman), Kron, Kwee, Larsson-Leander and Sahade. Stars proposed were: QS Aql, ζ Aur, BM Cas, Y Cyg, V380 Cyg, 31 Cyg, Z Her, β Lyr, η Ori, AW Peg, β Per, SZ Psc, W Ser, AL Vel. On the basis of the committee's report, the following systems were adopted for co-operative photometric and spectroscopic study during the next triennium:

System	Co-ordinator
ζ Aur	Gyldenkerne
31 Cyg	K. O. Wright
AW Peg	Tsesevich
W Ser	Sahade

Several speakers emphasized the difficulties resulting from the longitude gaps (especially in the southern hemisphere) now existing. The Co-ordinated Programmes Committee was requested to consider ways of improving the situation.

Times of Minima

On motion by Dr Batten, a committee consisting of Drs Kopal (chairman), Plavec, Szafraniec and Whitney, was appointed to prepare a list of eclipsing binaries for which regular observation of times of minima on a continuing basis are particularly needed. This list will be drawn up and distributed in the near future. It was suggested that the committee contact such groups of amateur observers as might contribute effectively to these programmes.

Orbiting Astronomical Observatory

Discussion of the desirability of observations from an Orbiting Astronomical Observatory, led to the appointment of the following committee to consider the problem: Drs Kopal (chairman), Huffer, Kron, Martynov and Merrill.

Bibliography

In accordance with the resolution adopted at the Moscow meeting, a running bibliography of eclipsing binaries has been initiated and three issues have been distributed up to date. The Commission unanimously decided that the Bibliography was of great value and should be continued. After considerable discussion as to the frequency of issue and the most suitable form, the following committee was set up to receive and consider suggestions. Drs Ovenden (chairman), Plaut and Sahade. After the report by this committee and further discussion, the Commission decided to recommend that:

1. entries in the Bibliography be classified under star names whenever possible;

2. multiple references to individual papers be abbreviated by the use of reference numbers;

3. entries include a brief statement of the essential nature of the new material in the listed paper wherever the title of the paper does not make such details explicit;

4. the editors of the principal journals be requested to send a list of papers on eclipsing binaries to a designated bibliography compiler in advance of publication;

5. an attempt be made to issue the bibliography semi-annually.

The following persons have agreed to assist in compiling the bibliography:

Mrs Kron and Dr Sahade	The Americas
Dr Cester and Dr Fresa	Italy
Dr Schneller	Germany
Dr Plavec	Czechoslavakia and Poland
Dr Shulberg	U.S.S.R.
Dr Plaut	other countries

Drs Batten and Popper are willing to assist as needed.

The Commission re-affirmed the resolution passed at the Moscow meeting, requesting authors of articles on eclipsing binaries to inform the President of Commission 42 of the fact and, if feasible, to transmit to him a copy of the manuscript.

Dr Sahade suggested that it would be very helpful if workers in the field could be kept informed of researches in progress or in prospect. It was agreed that the Commission should request that such information should be sent to the bibliographer concerned for inclusion in the bibliography.

Russell Memorial Volume

It was proposed by Dr Sahade that the Commission consider the publication of a volume in memory of Henry Norris Russell. A committee composed of Dr Sahade (chairman), Dr Merrill and Mrs Shapley was appointed to consider the proposal. After consideration of the committee's report, it was agreed that the matter was not within the exclusive competence of this Commission and the committee was requested to discuss it with other interested persons and organizations.

Proposal for a Single Commission for Binary Stars

Dr Plaut proposed the creation of a single commission for visual, spectroscopic, and photometric binaries. Since this is a matter that obviously cannot be decided by Commission 42 alone, it was recommended that the Organizing Committee refer it to the appropriate Com-

missions. The proposal emphasized, in the opinion of those present, the importance of closer co-operation between workers in these related fields, although the majority felt that a single commission would prove too unwieldy in dealing with the diverse problems and techniques involved.

Interim Organization

It was decided that the Organizing Committee should study the future organization of the Commission, including possible by-laws. It was agreed that the following should be regarded, for the time being, as standing committees of the Commission, with the membership as listed above:

1. Co-ordinated Programmes
2. Times of Minima
3. Orbiting Astronomical Observatory
4. Russell Memorial Volume.

Resolutions

The Commission formally expressed its thanks for important services rendered:

(*a*) To the Co-ordinators of Programmes: Dr Huffer, Dr Kwee and Dr Larsson-Leander.

(*b*) To those who prepared the Running Bibliography: Dr Fresa, Mrs Kron, Dr Merrill, Dr O'Connell, Dr Sahade, Dr Schneller and Dr Shulberg.

(*c*) To Dr Batten for his lists of eclipsing binaries in need of spectroscopic observations and to Dr McLaughlin for his lists of spectroscopic binaries under observation.

(*d*) To the Cracow Observatory for the publication of the ephemerides of eclipsing binaries.

(*e*) To Dr Kordylewski for the Eclipsing Variable Circulars which he is editing at Cracow.

(*f*) To Dr Korytnikov, Dr Lavrov and Dr Martynov for the first volume of their Bibliography of Spectroscopic Binaries.

(*g*) To Dr O'Connell and Dr Merrill for their unremitting work during the past six years as President and Secretary of Commission 42.

Scientific Sessions

The contributions in the scientific session of Commission 42 and the joint session of Commissions 27 and 42 can be grouped under three general headings.

INVESTIGATIONS ON SPECIFIC STARS

M. F. Walker, "DQ Herculis"

The photo-electric observations of this system show that reliable orbital elements probably cannot be obtained. There is fairly convincing evidence that the orbital period of the system is increasing. The one-minute (more exactly 71-second) variations have been found to be strictly periodic and the period of this phenomenon shows no change; the variations disappear for about 20 minutes during primary eclipse. The spectrographic observations by Kraft and Greenstein have revealed a velocity variation for the He II and higher Balmer emission lines, and a Rossiter effect before and after eclipse.

On the basis of all the existing observations, our present picture of the system is the following. The ex-nova is extremely small and dense and the one-minute variations represent its fundamental period of pulsation. Being very small, it is totally eclipsed by the companion star during the 20 minutes when the one-minute variations are absent. The ex-nova is surrounded by a rotating disk of material ejected by the companion, which fills the inner Lagrangian surface of the system; it is the eclipse of this disk which produces the observed primary

minimum. The variable opacity of this material in different directions around the ex-nova causes the amplitude of the one-minute variations to fluctuate in phase with the orbital period. The mass lost during the nova outburst is estimated by Ahnert from the change in orbital period before and after the explosion to be 0·43%.

M. F. Walker, "AE Aquarii"

Simultaneous photo-electric and spectroscopic observations have been obtained in order to investigate the spectroscopic changes occurring during the "explosions" characteristic of this short-period binary system. The photo-electric observations were obtained with the Crossley reflector, while the spectroscopic observations were obtained using the Lallemand Electronic Camera at the focus of the 20-inch camera of the Coudé spectrograph of the 120-inch reflector. With this equipment and a photo-cathode of only mediocre sensitivity, exposures at a dispersion of 48 Å/mm (on the cathode) could be obtained in about 20-30 minutes at minimum ($m_{uv} \approx 12^m{\cdot}5$) and 12-15 minutes at maximum ($m_{uv} \approx 11^m{\cdot}0$).

The behaviour of the system is complex; in general, a new "event" begins before the preceding one ends and it is difficult to isolate the changes occurring between undisturbed minimum and a single uncomplicated maximum. Preliminary analysis of these observations reveals that during an "explosion".

1. The emission lines of H and Ca II become stronger and broader.

2. The emission lines may broaden either symmetrically or asymmetrically to the red or to the violet, indicating that the "explosion" occurs in a restricted area in the system on or near the surface of one of the stars.

3. A hot continuum appears which fills in the late-type absorption spectrum of the companion.

It is noted that high time-resolution spectroscopy of this type could not be obtained in any other way than through the use of an image tube.

R. P. Kraft, "U Geminorum Stars as Binaries"

Several U Geminorum variables were tested spectroscopically for binary motion. Five stars are shown to be binaries with periods less than 9 hours (SS Cyg, U Gem, RX And, RU Peg, SS Aur), one spectrum is composite (EY Cyg), and one other (Z Cam) shows evidence of binary motion with an, as yet, undetermined period. There is no evidence contradicting the hypothesis that all members of this group are spectroscopic binaries of short period.

The peculiar radial velocities are small and the corresponding statistical parallax leads to $\langle M_v \rangle = +9^m{\cdot}5 \pm 1^m$; the blue stars in these systems are probably white dwarfs. The masses of the red components and their spectra (when photographed) seem consistent with those of a star of mass $\sim$ 1 solar mass. Thus the red components of U Gem variables are seriously underluminous for their masses. Evidence is presented which indicates that the red stars overflow their lobes of the inner Lagrangian surfaces; the ejected material forms, in part, a ring, or disk, surrounding the blue star. Several lines of argument suggest that the U Gem variables are descendants of the W UMa stars.

AUTOMATIC REDUCTION OF PHOTO-ELECTRIC OBSERVATIONS

H. Arp

The purpose of photometric reduction is to go from observed deflections at the telescope, to magnitudes and colours outside the atmosphere on some standard system. For example, if we have u, b, y raw deflections we will want to derive U, B, V magnitudes.

The standard reduction formulae are:

$$2{\cdot}5 \log d = \text{Gain}_y - 2{\cdot}5 \log y - k_{34} \sec z \quad (1)$$

$$C_y = \text{Gain}_b - \text{Gain}_y + 2{\cdot}5 \log y/b - k_{12} \sec z \quad (2)$$

$$C_u = \text{Gain}_u - \text{Gain}_b + 2{\cdot}5 \log b/u - k_{56} \sec z \quad (3)$$

$$k_{34} = k_3 + k_4 C_y \quad (4)$$

$$k_{12} = k_1 + k_2 C_y \quad (5)$$

$$k_{56} = k_5 + k_6 C_u \quad (6)$$

$$V = 2{\cdot}5 \log d + a C_y + b \quad (7)$$

$$B - V = c C_y + d \quad (8)$$

$$U - B = e C_u + f \quad (9)$$

By using equations (4), (5), (6) we neglect second-order terms in extinction but the error introduced is very small and it is standard procedure to make this approximation. If the telescope-photometer system is very close to the U, B, V system then the linear transformation (7), (8), (9) may be used. If the natural system of the telescope-photometer is not similar to the U, B, V response then extensive empirical calibrations are required.

Advantages of Computer Reduction are:

1. The entire computation process will take about 5 minutes on a moderate-sized computer; a run of photo-electric data which would ordinarily have taken two working weeks to reduce can be finished by computer techniques in a day.

2. It can be assumed that the results are free of computational errors; any errors present in the result will reflect errors in the input data. An important practical feature of a program is the ability to locate input errors and to re-run computation immediately.

3. Most machines give permanent, condensed final results which may be annotated and filed conveniently.

There are two main desiderata in photometry: (*a*) maximum systematic identity with U, B, V system; (*b*) maximum accuracy of individual measures. In order to attain these goals I reduce from 1 to 7 nights simultaneously as one night. This is possible because the telescope-photometer system changes only slowly, and experience shows that all good nights are about the same, so the nightly differences can better be handled after this first reduction by means of small corrections. One can inspect or analyze the results for deviation of individual nights in extinction. Experience has shown that if any night is good enough to yield (after considerable special measurement) a value of the extinction coefficient, then this extinction coefficient is very close to the mean extinction coefficient. The mean extinction coefficient in turn is very close (except for a grey term) to the extinction computed from Rayleigh scattering at the altitude of the observatory. Therefore it seems reasonable to use the mean extinction coefficient.

G. O. Abell

It is assumed that many standard stars are observed during the run, and that large ranges of secant z and colour are represented among them. Then object stars, scattered widely over the sky, can be reduced by comparison to the standards. This method is not especially well suited for continuous measures of one object (say an eclipsing star) for which only differential extinction between that star and a nearby standard is applied. Even for the latter type of photometry, however, the present program provides information that makes the remaining reduction trivial.

There are two parts of the program, which operate in succession.

1. *Extinction determined from data.* Assumes following transformation equations to go from instrumental magnitude, V_z, and colours C_{yz}, C_{uz}, as measured *inside* the atmosphere, to standard values of V, $B - V$, $U - B$, on, say, the Johnson system:

$$V = V_z + A + B \sec z + C\,C_y \tag{1}$$

$$B - V = D + (E\,C_{yz} - F \sec z)\,(1 - 0{\cdot}03 \sec z)^{-1} \tag{2}$$

$$U - B = G + H\,C_{uz} - I \sec z \tag{3}$$

B, F and I are extinction constants, assumed constant (or at least that mean values are sufficient) over the period of observations included in the program.

A, C, D, E, G and H are constants in the colour equations. All nine constants are found by least squares by fitting observed standards to the Johnson system.

2. *Use of given extinction constants.* It may be that extinction is not well determined from the data, in which case it is of interest to reduce the observations with standard extinction constants, and compare the reduced values of V, $B - V$ and $U - B$.

In part 2, 8 sets of extinction data are read in:

A_1, A_2,.....A_8; $K1_1$, $K1_2$,.....$K1_8$; $K2_1$, $K2_2$,.....$K2_8$

For each set, instrumental colours and magnitudes are computed:

$$V_o = V_z - A \sec z$$

$$C_y = (C_{yz} - K1 \sec z) / (1 - 0{\cdot}03 \sec z)$$

$$C_u = C_{uz} - K2 \sec z$$

Then, for each set, the constants in the colour equations are computed:

$$V = V_o + B + C\,C_y$$

where

$$C'_y = (C_{yz} - 0{\cdot}12 \sec z) / (1 - 0{\cdot}03 \sec z)$$

$$B - V = D + E\,C_y$$

$$U - B = G + H\,C_u$$

Finally, V, $B - V$, and $U - B$ are found for each object.

In each least-squares solution for constants, the values of V, $B - V$, $U - B$, computed from the derived constants, for each standard, are compared with the standard values. If V differs by as much as $0^m{\cdot}2$ or if the colours differ by as much as $0^m{\cdot}15$, that standard is set aside and a new solution is made. The process is repeated until the same standards are rejected twice in succession. In this way, the bad standards are eliminated from the solution. The program is written in FORTRAN, and copies can be provided on request by G. O. Abell.

R. H. Hardie

The Dyer Observatory is currently modifying the photo-electric photometer to permit measuring three colours simultaneously and recording all data automatically.

Dichroic filters are being tested for efficient separation of the desired bands; conventional filters will be used in each beam as necessary to match the bands to the U, B, V system of Morgan and Johnson. Three photo-multipliers, suitably cooled, will receive the beams, and the measured current and gain settings of the three compact amplifier units will be automatically recorded by an IBM card-punch unit. It is anticipated that the increased efficiency of this type of photometer over a conventional single-channel unit will result in obtaining up to 100 measures per hour in each of 3 colours.

D. L. Crawford

Dr Crawford described the program for reduction of photometric measures, in use by staff astronomers and visitors at Kitt Peak National Observatory. Details are available from the Observatory and are published in *Contributions from Kitt Peak Nat. Obs.* No. 10.

H. L. Johnson

A new nine-colour photometer has been developed at the University of Texas and the McDonald Observatory. The nine wave-length bands are as follows:

Band	Wave-length, microns	Band	Wave-length, microns
U	0·35	*J*	1·3
B	0·45	*K*	2·2
V	0·55	*L*	3·6
R	0·62	*M*	5·0
I	0·85		

The *U*, *B* and *V* bands are measured by a 1P21; the *R* and *I*, by a Farnsworth FW-118; *J* and *K* by a PbS cell and *J*, *K*, *L* and *M* by an InSb cell.

The photometer is completely digitized. The three different amplifiers needed for the above cells can be fed into an integrator and digital voltmeter, and then to a tape-punch for recording on paper tape. In addition to the measured photometric deflections, all other data that are needed for the reduction of the observations are also automatically punched on the tape; this includes the date and time from a digital calendar and clock, the amplifier gain settings, the filter being used, etc. The name of the object and its right ascension and declination are read from a punched observing card which is inserted into a card-reader after the object is found.

All of these data are punched in the proper form so that the resulting tape can be fed directly into the CDC 1604 of the University of Texas. The reduction program computes extinction coefficients by one of several methods, whichever is most efficient for the data obtained on a particular night, reduces the observations, collects the several observations on an individual object, and, finally, prints a table suitable for publication. Intermediate stages in this computation use punched cards and sorting operations, as well as the computer. The program also makes an analysis of the observational precision.

This photometer is now in operation at the McDonald Observatory; the digitized portions were first used on 2 August, 1961.

W. Blitzstein

The nature of the methods used is largely dictated by the dual, pulse-counting operation of the Pierce Photometer, by the availablility of a UNIVAC I computer and by the use of a card-to-magnetic tape converter. For our purposes, then, it is planned to punch IBM cards at or near the Pierce Photometer using an IBM 024 or 206 programmed card punch. However, the output of the storage counters is parallel in nature and the card-punch must be operated serially, so suitable converters utilizing rotary stepping switches or cross-bar switches have been designed.

It is desirable to punch more data than can be fitted on one IBM card and some of the data will be the same for all observations of a given set of measurements. Therefore data which do not change during a run will be punched manually on a master card, while data which change from measure to measure will be punched automatically.

The program for the UNIVAC will contain all the usual features for reducing the original measurements to magnitude-differences and light-ratios, making light-time corrections, cor-

recting for differential extinction, etc. Two sub-routines peculiar to the Pierce Photometer will be included: (1) Coincidence corrections must be applied to the indicated counts since the system has a finite resolving time. This time has been measured experimentally by the two-source method which is commonly used in nuclear physics. (2) Since the operation is dual the ratio of the sensitivities of the two channels must be measured and computed for the spectral bands used. The observing sequence will provide the proper measurements for this purpose.

The card punching and the programming will be made sufficiently flexible so that data from photometers using chart recorders can be processed. Also special sub-routines will be provided for data from the lead-sulphide infra-red photometer.

F. C. Bertiau

The program developed for the reduction of photo-electric measures at the Vatican Observatory, is essentially the same as the FORTRAN program at Mount Wilson. Three interesting points should however be mentioned. (1) No constants in the reduction are assumed to be zero. (2) The observations are weighted automatically according to zenith distance, length of deflection, and quality of night. Observations at large zenith distances should have lower weight. (3) The four constants necessary to correct the yellow magnitude for extinction and reduce it to the U, B, V system should be computed simultaneously and not in two steps. This procedure makes it possible to compute the mean errors of the four constants easily and gives the best fit. The same remark applies to the colours $B - V$ and $U - B$.

MACHINE COMPUTATION OF LIGHT AND ORBITAL ELEMENTS OF ECLIPSING BINARIES

I. Jurkevich, Application of High-Speed Data-Processing Techniques to 1959 VW Cephei Observations.

The 1959 co-ordinated VW Cephei program resulted in approximately 8 000 observations, and another 5 000 data points had been obtained by Kwee prior to the campaign. The variability of the light-curve demands that each cycle be treated separately whenever observations are sufficiently accurate and numerous. Under these conditions treatment of the data by conventional means is deemed impracticable. Since much of the preparatory work, such as plotting of light-curves, conversion of magnitude differences to intensity ratios, determination of the times of minima, etc., is routine, it is felt that conventional techniques are not only wasteful of time, but unjustified in view of other methods available. It is these types of problems to which modern high-speed digital and analog machines are so admirably suited. It was decided to program for the IBM 7090, not only all preliminary steps but also the computation of elements and a perturbation analysis.

So far the entire set of observations has been punched on cards and transcribed to magnetic tape. This tape, with suitable instructions for supplying scale factors along both axes, was used to activate the digital-to-analog converters of automatic Moseley plotters. Following this an extremely simple program was employed to convert magnitudes to intensities. The operating times were as follows:

(*a*) Keypunching,	17 hours.
(*b*) Verification,	17 hours.
(*c*) Plotting,	50 pts/minute; total $\simeq$ 5·5 hours.
(*d*) Δm to intensity,	3 minutes.

A program has been written for the determination of the times of minima, based on a method which requires no assumption concerning symmetry of minima or equality of spacing between

data points. Dispensing with these assumptions leads, however, to considerably greater complexity in the computations. The machine program in question is currently being tested; first indications are that, for a set of observations consisting of 200 points, simultaneous solution for both the period and the time of minimum requires somewhat less than 0·1 second of machine time. Plans for further work include the preparation of programs for computation of orbital elements and for perturbation analysis as developed by Kopal.

C. M. Huffer, Automatic Computation of Elements of S Cancri and AR Cassiopeiae

Light-curves of S Cnc and AR Cas on the *U*, *B*, *V*, system, were shown. The observations were made at Madison, Flagstaff, and Kitt Peak.

The rectified and reflected magnitudes, arranged in order of phase, were fed into a CDC 1604 computer. Values of k, the ratio of the radii, and of the darkening coefficient, u' or u'', were pre-selected. The machine solved Kopal's equation in six unknowns by the method of least squares, using individual observations. The resulting value of k was tested and, if Δk was less than one-half the probable error, the solution terminated; otherwise the process continued for up to 20 iterations.

After k was accepted, the machine computed the light-curve with residuals in both light and magnitudes. The process of solving between 250 and 600 equations for 6 unknowns took less than two minutes.

The results were as follows:

S Cancri

	U	*B*	*V*
	$u' = 0{\cdot}4$	$u' = 0{\cdot}4$	$u' = 0{\cdot}4$
k	0·3827	0·4344	0·3979
	±·0245	±·0106	±·0295
i	83°·39	84°·37	83°·91
	±0°·23	±0°·11	±0°·30
number of observations	328	477	566

AR Cassiopeiae

	U		*B*	*V*
	$u'' = 0{\cdot}4$	$u'' = 0{\cdot}6$	$u'' = 0{\cdot}4$	$u'' = 0{\cdot}4$
k	0·5147	0·4742	0·3483	0·4067
	±·0540	±·0514	±·0469	±·0875
i	90°·00	90°·00	88°·41	90°·00
	±0°·11	±0°·37	±1°·27	±1°·13
number of observations	298		302	258

The large probable errors are due to the shallow eclipses, which are about $0^{m}{\cdot}12$ in depth.

It is planned to publish a paper, including tables of observations, in the *Supplement* of the *Astrophysical Journal*.

A flow diagram of the process of computation was shown. The programming was by Mr George W. Collins, II, a graduate student at the University of Wisconsin Department of Astronomy.

D. B. Wood, Machine Method for Calculation of Orbital Parameters

Traditional approach to the solution of eclipsing binary light-curves involves the mathematical and computational simplicity of rectification and tabulated values for the "spherical" model. Since high-speed digital computers are not worried about simplicity of calculation a whole new approach to the problem is possible, that is, the direct solution of all orbital parameters simultaneously by means of a least-squares iterative procedure. A program has been coded for the IBM 704 which will predict a light-curve for 11 assumed parameters. Thus by means of a first approximation at the solution, the light intensity can be predicted at each observed time and the difference in observed and computed intensities used to calculate differential corrections to the orbital elements by least squares. The problem is simplified by the following 5 assumptions: (1) the figures of the stars are similar tri-axial ellipsoids; (2) the major axes point toward each other; (3) the minor axes are perpendicular to the orbital plane; (4) limb darkening follows the usual one-parameter law; (5) brightness is independent of latitude or longitude on the star's surface. These assumptions serve a twofold purpose: (*a*) they restrict the parameters of the system, and (*b*) they simplify the geometry of the figures projected on the plane of the sky. The reflection effect is currently being investigated separately and its inclusion is being planned.

The actual calculation of observed light is done by numerical (Gauss 4- or 10-point) integration over the eclipsed area. The geometry is simplified by the use of a transformation to the eccentric projection.

Two slides were shown, one on the nature of isophotes on an ellipsoidal star, and one a parameter study showing the effect of changing the line of apsides. Many such parameter studies could be undertaken.

When solution of an actual light-curve is attempted, it is found that limb darkening gives rise to convergence problems, so that it may be possible to obtain solutions only as a function of given limb darkening. The best solution could then be found by looking for the minimum R.M.S. error of this family of solutions. Much work still remains to be done in the investigation of convergence problems and their circumvention.

P. Wellmann, Programming for the IBM 650

At Hamburg, a set of programs for the computation of orbital elements of eclipsing binaries with an IBM 650 electronic data processing machine has been in use since 1958.

The computation is done in three steps:

(*a*) harmonic analysis of the light curve outside of eclipse;

(*b*) rectification;

(*c*) computation of the elements α_0, k, $\sigma = \sin^2\theta_{n=1/2}$ for any one of the cases occultation, transit, total or annular eclipse.

The coefficients of the sine and cosine terms, determined for arguments up to 3θ if desirable, are used to obtain the constants for the rectification.

The rectified eclipse observations are used in program (*c*). The basic process in this program is: assuming α_0, compute k from the depth equation, then solve $\sin^2\theta\ (n) = \sigma \cdot \chi(n, \alpha_0, k)$ for σ by a least-square method, compute a theoretical light curve and $S = \Sigma(l_o - l_c)^2$. The cycle is repeated with a new assumption for α_0, with the aim to minimize S. A part of the program predicts the most probable value of α_0 by comparing the values of S in the three preceding hypotheses. The iteration is stopped when the accuracy of α_0 matches a pre-set value. One cycle is accomplished in about 8 sec. Finally the mean errors of the elements are computed. The contribution of the uncertainty of the depths of minima is included.

The time necessary in a typical case is: 1 hour for punching and checking of IBM data cards; 3 minutes for computation with program (*a*); 10 minutes for preparing the input card with constants for the rectification; 3 minutes for computing with programme (*b*); about 1 hour for derivation of weights and depths of minima, and punching of four data cards; 5 - 8 minutes for computation of final elements and their mean errors.

A wrong assumption as to the type of eclipse is recognized from the results $S(\alpha_0)$. In the course of the computation the limb darkening coefficients u_p and u_s are supposed to be known; if necessary, the program is started again with altered values.

Z. Kopal, Interpretation of Light-Curves of Eclipsing Variables in the Frequency-Domain.

Transient phenomena like stellar eclipses should properly be analyzed not in the time-domain, but in the frequency-domain, that is, it is not the light-curve which should be subject to analysis, but rather its Fourier transform.

In the time-domain the light changes of a close eclipsing binary system consist of a superposition of the photometric proximity effects, which are continuous in time, upon discontinuous effects of the eclipses. Moreover, the mutual distortion of figure of both components gives rise to photometric effects which are multiplicative (*i.e.*, are multiplied by the fractional luminosity of the respective component), those of the reflection are additive to the total light of the system. In the frequency-domain these distinctions largely disappear, for the Fourier transform of a discontinuous time-function (such as the light-changes due to eclipse) becomes continuous in the frequency parameter, and, more important still, the frequency spectrum of all proximity effects becomes discrete and its distribution known in advance. Thus a separation of the proximity effects and the eclipse effects becomes automatic in the frequency-domain, and no rectification is necessary.

The students of eclipsing variables have much to learn from the existing theory and practice of information and communication engineering. Many similar operations in the field of communication engineering have been successfully automatized, and it is perhaps not too much to expect that the same will eventually prove to be true in the analysis of the light-curves of eclipsing variables.

43. COMMISSION DE LA MAGNETO-HYDRODYNAMIQUE ET DE LA PHYSIQUE DES GAZ IONISES

Report of Meeting, 17 August 1961

PRESIDENT: H. Alfvén.
SECRETARY: C.-G. Fälthammar.

Business meeting

The Executive Committee had made proposals for President and Vice-President and for members of the Organizing Committee, as follows:

President: H. Alfvén

Vice-President: L. Spitzer

Organizing Committee: L. Biermann, T. G. Cowling, and A. B. Severny.

The meeting had no objections to these proposals.

Commission 43, which was formally established at the General Assembly in Moscow, 1958, was meeting for the first time, and the President emphasised that the present *Draft Report* represented his personal view of what should be the scope of the Commission. He asked for comments on the report and suggestions for future changes in the scope. After a brief discussion whether or not ionospheric phenomena should be included, it was agreed not to make any recommendations for changes at present. Due to the rapid progress in the various fields of research involved, the possibility should be left open for future changes that might become desirable by forthcoming developments in any of these fields of research. S. Chapman suggested some minor changes in the *Draft Report*.

Scientific meeting

A second session of the meeting was devoted to a discussion on "Electro-magnetic Conditions in Interplanetary Space". Invited contributions were given by E. R. Mustel on "Scientific Results of U.S.S.R. Space-Probe Measurements" and by C. P. Sonett on "Scientific Results of U.S. Space-Probe Measurements".

Short communications were also presented by T. Gold on the escape of particles from the Earth's radiation belts and by L. Mestel on the equatorial acceleration in the Sun.

EXPERIMENTS ON PLASMA AND MAGNETIC FIELD INVESTIGATIONS BY MEANS OF SOVIET SPACE PROBES

E. R. Mustel

The purpose of this paper is to give a brief review of some results of experiments, carried out by Soviet space probes, aimed at investigating plasma and magnetic fields.

1. In 1958 a group of specialists in radiophysics under the leadership of Dr K. I. Gringauz used spherical probes screened by spherical grids, the so called ion traps (**1, 2**), to investigate the concentration of positive ions in the ionosphere with Sputnik III. Later, traps of charged particles were placed on all containers with scientific instruments jettisoned from Soviet cosmic rockets (starting from the first artificial planet launched on 2 January 1959 and including the automatic interplanetary station launched to Venus on 12 February 1961). The third electrode—an internal grid—has been introduced in these traps to suppress photo-

emissions from the collector, which are produced by ultra-violet radiation from the Sun, and limit sensitivity of the device to the stream of charged particles coming into the trap from the surrounding medium (Fig. 1).

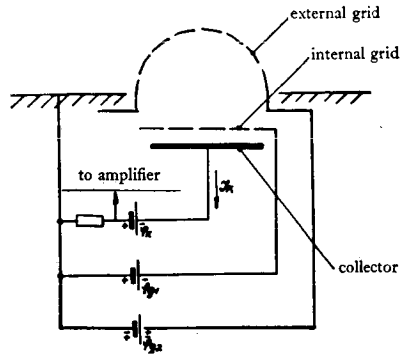

Fig. 1. Schematic diagram of ion trap, showing the internal grid.

There is no possibility in this communication of describing the details of the methods of measurement by the traps of charged particles on each space probe (changed after each experiment); nor to describe the theoretical considerations on the basis of which measured currents in the collector circuits of the traps were reduced to concentrations of charged particles. This material has been published in Soviet scientific periodicals (3, 4, 5) and was presented by Gringauz in April 1961 in Florence at the Second International Space Science Symposium (6). Below are given the principal conclusions, made on the basis of experimental data obtained by those scientists who carried out the experiments. A group of specialists in astrophysics, under the leadership of I. S. Shklovsky, took part in the interpretation of some results obtained within the geomagnetic field at distances less than 100 000 km from the Earth.

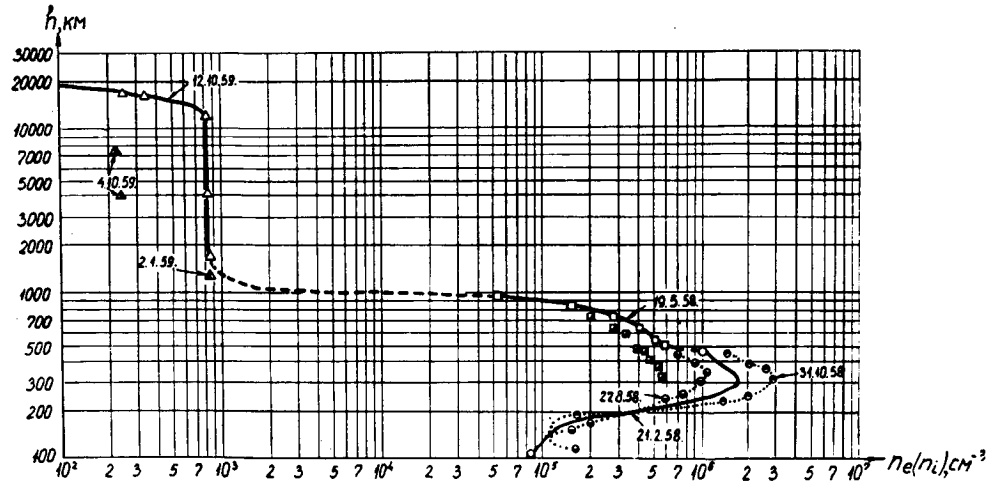

Fig. 2. Showing the variation of concentration of charged particles near the Earth—see text.

Fig. 2 shows the tentative variation of the concentration of charged particles near the Earth for the daylight period of time close to the maximum of solar activity (based on Soviet experiments in 1958–9 made with geophysical rockets, on Sputnik III and space probes). Corresponding dates are indicated near experimental points; a dotted part of the curve indicates an area in which there are no experimental data.

Treatment of the results in measuring collector currents in traps of charged particles, placed on the first cosmic rockets, showed that at altitudes of about 50 000 to 75 000 km above the Earth, beyond the limits of the radiation belt, there have been registered electron fluxes of about 10^8 per cm^2 per sec and with energies exceeding 200 ev (3). At the same time the energies of these electrons are insufficient to be registered with the help of counters of cosmic rays which had registered electrons of the outer radiation belt with the same rockets.

These results gave reasons to draw conclusions about the existence, beyond the limits of two radiation belts, of a third outermost belt of charged particles, the streams of which are larger than those in the second radiation belt, but the energy of which is less (4, 5). It was supposed, as had been done in the case of radiation belts, that the boundaries of that outermost belt of charged particles are situated along geomagnetic lines of force. The location of radiation belts (1 and 2) and the outermost belt of charged particles (3) is shown in Fig 3.

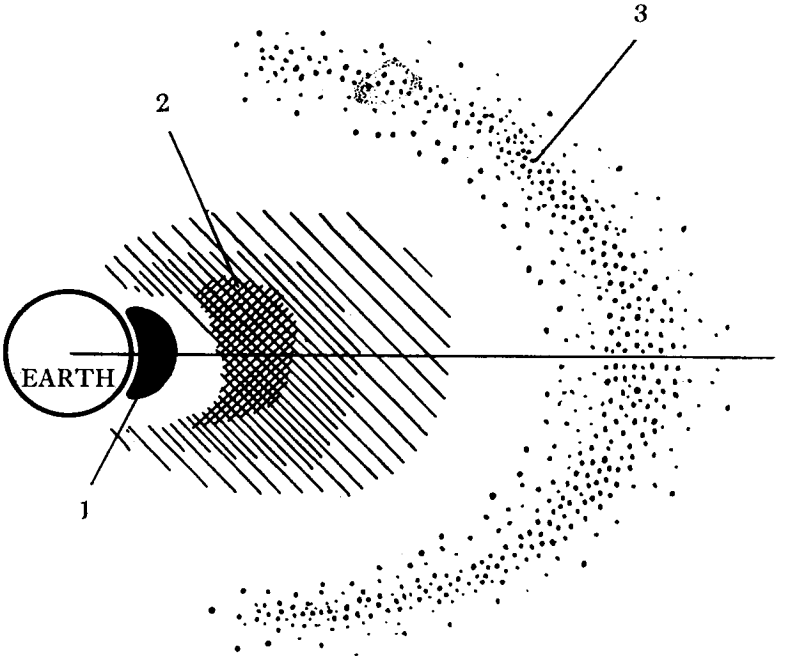

Fig. 3. Radiation belts (1 and 2) and belts of charged particles (3) round the Earth.

After launching the American space probe Pioneer V in March, 1960, there were published the results of measurements of the geomagnetic field carried out with it by Dr C. P. Sonett and other scientists (7). Deviations of the measured magnitudes of the geomagnetic field from the theoretical magnitudes of the dipole field, led American scientists to conclude the existence of a current-ring surrounding the Earth. A comparison of Sonett's data (8) with those published earlier by Gringauz and others (3, 4) showed that the current-ring, computed according to

magnetic measurements, and the streams of electrons, revealed in Soviet experiments with three-electrode traps, are placed in the same region of space (8).

Thus, the above-mentioned experiments mutually confirm and supplement each other.

Data on the concentration of an interplanetary ionized gas (particles possessing thermal energies) obtained from Lunik III at distances from the Earth of the order of 150 000 km showed that, for such distances, the concentration of ions does not exceed a few particles per cm^3 (6).

Before the beginning of flights of cosmic rockets it was impossible to make direct observations of solar corpuscular streams in interplanetary space because, when entering the geomagnetic field and upper atmosphere of the Earth, they become essentially changed.

At first, currents created by positive ions of solar corpuscular emission were registered in 1959 outside the Earth's magnetic field (at a distance of the order of 100 000 km. from the Earth) by means of three-electrode traps of charged particles placed on Soviet space probes. To the outer grids of the traps there were applied positive potentials (relative to the body of the rocket) retarding positive ions. Magnitudes of these potentials excluded the possibility of trapping ions with thermal velocities; that is why registered positive currents could be created only by ions of corpuscular streams (3, 6). A good correlation between values of registered currents and K-indices of geomagnetic variation, observed on the Earth, was found (6).

Three-electrode traps of charged particles orientated to the Sun were placed in the automatic interplanetary station launched on 12 February, towards Venus; one of those traps was specially designed for registration of the ionic component of solar corpuscular radiation. On 17 February 1961 during a period of communication with the automatic interplanetary station a passage of the station was registered through a noticeable flux of corpuscles (of order 10^9 cm^{-2} sec^{-1}). Simultaneously a geomagnetic storm was observed (6).

In future such experiments will permit to fix quantitative relations between intensities of geomagnetic storms and intensities of solar corpuscular streams creating them.

Devices, so far applied in Soviet experiments, have only permitted a statement that registered streams of ions did not include ions with thermal velocities, and measuring density of a stream but not permitting the determination of energies of registered corpuscles. At present, devices have been prepared which will permit the determination of the energy spectrum of corpuscles coming into the traps.

2. The results of magnetic field measurements from the Venus Probe Automatic Interplanetary Station

On the Venus Probe three-component magnetometers, for measuring the field near the planet, and magnetic variometers, for in-flight measurements of relative variations of the field, were installed. The magnetic measurements were carried out by Sh. Dolginov, E. Eroshenko, L. Zhuzgov, N. Pushkov.

The magnetic variometer in use was a two-channel instrument with independent electronic elements and pick-ups. The pick-ups of the variometers were oriented in parallel, and thus measured the same component of the field.

To minimize the influence of the container on the instrumental readings, the pick-ups were fixed on an antenna at a distance of about 2 metres from the container.

The antenna was directed at an angle of the order of 43° with respect to the normal to the solar cells. The sensitivity threshold of the variometers was 2 gammas, and the range of measurement was 50 gammas.

The variometer information was obtained during radio contacts on 12 February and 17 February 1961. Though the information obtained is comparatively limited (the time of information was 52 minutes), it is of undoubted interest since it throws light upon the multifarious features of a magnetic disturbance formation.

On 12 February the day was magnetically quiet according to data from magnetic observatories. Moderate magnetic disturbances took place on 13 February, 16 February and 17 February; the last was most intense.

Fig. 4 presents the indications of the variometers when the Venus probe was in the vicinity of the Earth, but beyond its magnetic field, at a distance of 165 000 – 175 000 km. Lower curves illustrate the field-variations on the Earth, according to data from a middle-latitude

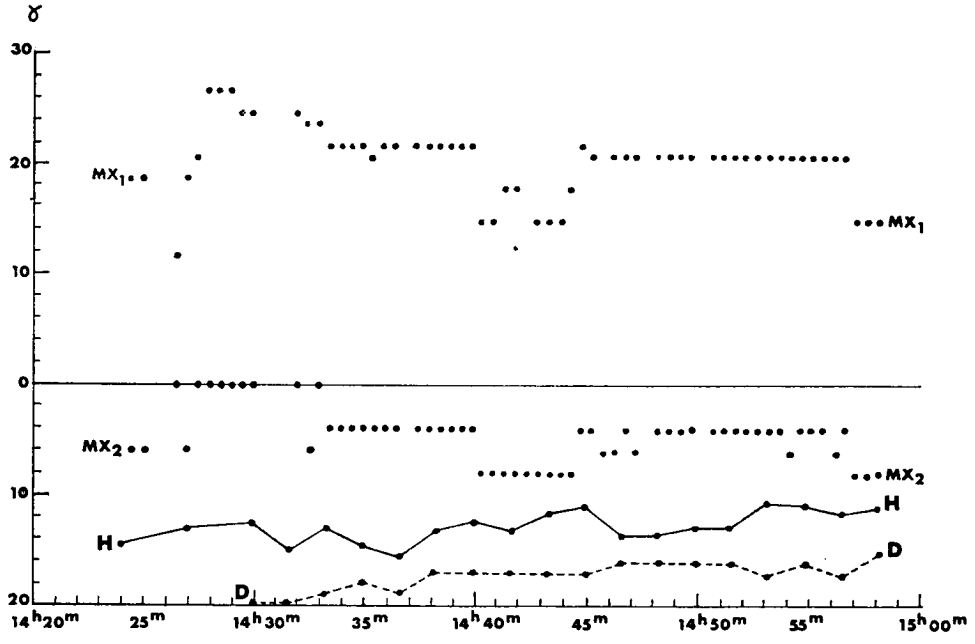

Fig. 4. Magnetometer indications of the Venus probe on 12 February 1961; the dotted lines MX_1 and MX_2 indicate distances of about 170 000 km.

magnetic observatory. Both channels of the variometers revealed, in the main, co-ordinated changes about the average level within ± 4 gammas. Characteristic changes, of 4-minute duration, had the form of steps due to character of the information transmissions. The curve H plotted in the lower part of Fig. 4 shows changes within the same limits, but not synchronous.

Analysis of telemetry data of a number of instruments carried by the probe makes it possible to believe that these changes of the field are not connected with interferences from the probe, but reflect actual pictures of the fluctuations of the field in the closest vicinity of the Earth.

The next radio contact took place on 17 February at a distance of 1 900 000 km from the Earth. Fig. 5 shows the variometer indications and the field variations on the Earth at this time. The variometers during a 22-minute radio contact show almost invariable readings. The Earth's magnetic field at this time revealed considerable changes which, according to data from the middle-latitude station, reached 20-25 gammas. Time-intervals before and after

the time of observation on the Venus probe were also disturbed. It is impossible to expect similarity of the field-variations curves, but in this case the absence of synchronism in activity is revealed for the next time-intervals during the radio contact.

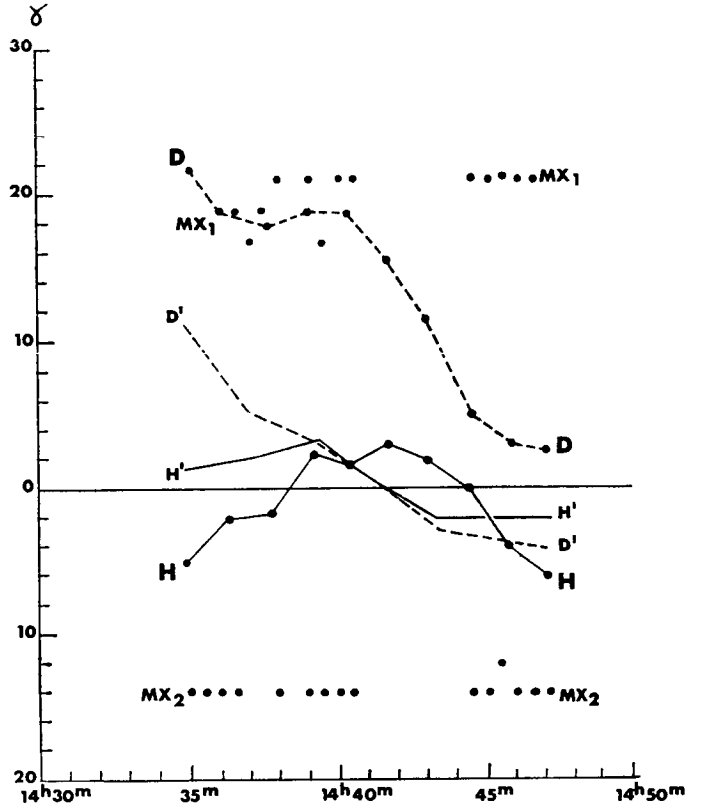

Fig. 5. Magnetometer indications of the Venus probe on 17 February 1961; the dotted lines MX_1 and MX_2 indicate distances of 1 900 000 km.

The next important feature which should be mentioned in discussing the magnetic-measurement results is that other instruments of the probe, namely, detectors of charged particles, which also gave information during these radio contacts measuring low-energy corpuscular radiation, also revealed changes during the 17 February contact as compared to the 12 February contact. These changes can be explained if we suppose that on 17 February the probe was within a corpuscular stream. During the whole radio contact on 17 February the indications of the charged particle detectors did not change, as was the case with variometers.

The comparison of the average levels of the indications of the variometer channels on 12 and 17 February provide an indication of the magnitude of the magnetic field of the corpuscular stream revealed by the detectors. The average levels of counting by the MX_1 variometer (see Figs. 4 and 5) were the same on 12 and 17 February. The level of the indications of the variometer (MX_2) on 12 and 17 February differs by 9 gammas. This indicates that the MX_1 or the MX_2 variometer experienced a drift of 9 gammas for five days. It is most likely that the MX_1 variometer had no drift, and in this case the component of the stream field along the

sensor axis was $\leqslant$ 2 gammas. In another case it should be assumed that the component of the stream field was 9 gammas.

According to the theory of the Forbush effect the intensity of the stream magnetic field in the closest vicinity of the Earth can be obtained from the cosmic-rays variations. The ground data on the cosmic-ray neutron component variations are presented in Fig. 6. As evident from Fig. 6 a Forbush decrease at the Earth began six hours later and reached its maximum nine

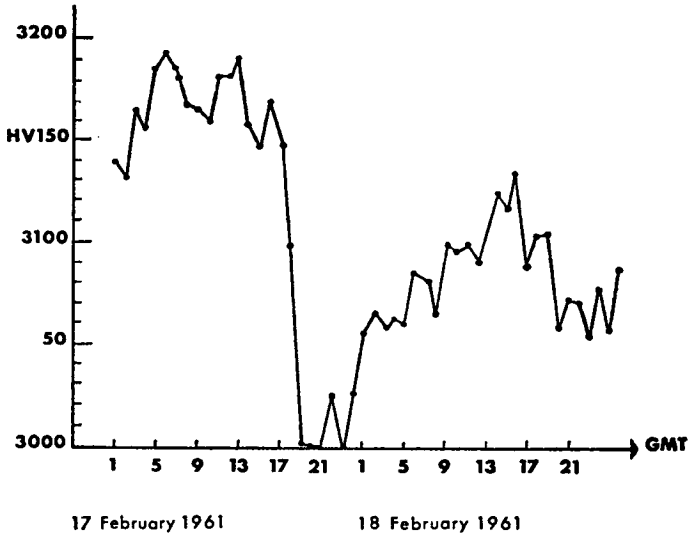

Fig. 6. Ground data (Jungfraujoch, Switzerland) on the variations of the cosmic ray neutron component. (Courtesy, Professor Dr H. F. Houtermans).

hours later than the observation made on the probe on 17 February 1961. On the basis of the data presented the conclusion can be drawn that, at the moments of the observations of the Venus probe, the field of the stream was low, not only near the space probe but also in the vicinity of the Earth. Consequently the cause of geomagnetic disturbances at the Earth during radio contact with the Venus probe on 17 February was not frozen magnetic fields of the stream, but the other kind of transformations of the stream energy into magnetic energy within the Earth's magnetic field.

Comparing terrestrial data and the Venus probe data it is possible to conclude that in this experiment (unlike the Pioneer V experiment) no conditions existed when the disturbance of the magnetic field on the Earth is correlated with the disturbance of the field in interplanetary space.

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SCIENTIFIC RESULTS OF U.S. SPACE PROBE MEASUREMENTS

C. P. Sonett

The survey nature of rocket study of cosmic hydromagnetics suggests that space-probe data be considered chronologically. In short, the experiments consist primarily of verification or denial of hitherto postulated models, substantiation of surface observations, and findings in some cases implying so great a deviation from current ideas that repetition of the experiment is suggested.

This summary dwells primarily upon magnetic field and plasma probe data with some attendant comments on cosmic ray results. To begin, we summarize the Pioneer I findings (**1**). These suggest (for 11 October 1958) a dipolar field from 3·7 to 7 R_e (R_e = geocentric radii) and a magnetostatic compression at 12·4 – 14 R_e to twice nominal value. At 14 R_e the field gradient steepens and the implication of a boundary suggests an interplanetary field less than 6γ. An elastic collisional process between a plasma wind and magnetosphere implied further an interplanetary proton density $\sim 10^2$ cm^{-3} in qualitative agreement with later results. On the other hand, the finite amplitude waves noted at 12·3 – 14 R_e, presumably transported into the magnetosphere, might be expected to modify the momentum balance at the boundary (**2**), suggesting for this day a solar wind of 10^{-9} dynes/cm^2 pressure. These large waves, seen also on Pioneer V (**3**) and having an electron analogue on Pioneer IV (**4**), seem to fit the category of almost collisionless magnetic pulses propagating normal to the ambient field direction. The term "hyperwave" is suggested (**5**). Front thickness and downstream oscillations seem to satisfy the hypothesis of local acceleration in the magnetosphere (**6**). Such waves may be characteristic of colliding astrophysical plasmas.

The interior of the magnetosphere showed hydromagnetic wave activity having an energy-density 10^{-13} – 10^{-12} ergs/cm^3 over 0–1 cps. The total magnetospheric hydromagnetic energy to 7 R_e would then be $\sim 10^{10}$ ergs over 0–1 cps. Details of the spectra and partial separation of modes is now being made (**7**).

Explorer VI primary experiments were a triple coincidence 2π cosmic-ray telescope (Simpson), an ion chamber-Geiger tube experiment (Winckler), and a search-coil magnetometer (Sonett). Useful life-time of the satellite was almost 2 months and allowed traversal of the Van Allen belts through two magnetic storms. Many results of Simpson's experiments have recently been published (**8**). We shall not consider the particle experiments here because of lack of space. A primary finding of the magnetometer was a storm-type disturbance field which implied a current source exterior to the peak of the second Van Allen belt (**9**). Another result was a persistent deviation in both the magnitude and direction of the geomagnetic field from dipolar on the anti-solar or night side at distances beyond 5 R_e (**10**). The gross configuration of currents associated with these disturbances has not been established. Presently, the two primary models appear to be a geomagnetic tail (**11**) or an annular current about the Earth. These data qualitatively fit either model though the former leaves unexplained the findings of Pioneer V, the variable latitude cosmic-ray knee, or the Soviet plasma probe results.

Wave phenomena observed by the Explorer VI magnetometer are presently being studied in conjunction with variations in scintillation counter rate (**12**).

Simultaneity of magnetic storm events, Forbush decreases, and propagation of solar cosmic rays was studied during the lifetime of Pioneer V, launched 11 March 1960. Instrumentation included a 2π triple coincidence telescope operating sub-proportionally (Simpson); an ion chamber-Geiger tube combination utilizing a Neher-type integrating chamber (Winckler) and a search-coil magnetometer (Sonett). Five Forbush decreases at the position of the spacecraft correlated with magnetometer disturbances (**13**). The large storm sequence of 31 March–1 April 1960 provided conclusive evidence of the interplanetary origin of galactic cosmic ray obscuration and of its magnetic nature. Fields of at least 20–50γ were noted during this time, having a radial extent estimated at 0·7 A.U. (**14**). There is now adequate experimental substance to support the mechanism of plasma-field ejection from the Sun with solar cosmic-ray trapping. Field-energy density, $E_H \geqslant 10^{-8}$ ergs/cm^3 required an ordered plasma-energy density $E_P > 10^{-8}$ ergs/cm^3 and the transit time from the Sun to vehicle implied a plasma density, $\rho > 10$ cm^{-3} but not necessarily much higher. If so, the flux of E_H is comparable to the gas-energy flux; the magnetic-energy flux is ~ 1 erg/cm^2 sec. During quiet times ($\sim 50\%$ of the time of observation) a steady field of $\sim 2\gamma$, making a large angle to the ecliptic, was observed. (**15**) A field of this configuration is most in accord with the interplanetary gas model of Chamberlain and Brandt and is incompatible with a wind of energy density comparable to or greater than 10^{-11} ergs/cm^3. From Simpson's experiment the galactic cosmic-ray gradient in the radial direction was found to be $-15 \pm 20\%$ (A.U.)$^{-1}$ near Earth (**13**). At 6 Earth radii an anomaly consistent with Explorer VI was noted. (**3**) From 10–14 Earth radii fluctuations consistent with Pioneer I hyperwaves were noted.

Explorer X carried an Rb magnetometer, flux gates, a Sun scanner (Heppner), and a plasma probe (Bridge) into the anti-solar hemisphere to 37 R_e. A negative anomaly of 200–400 γ appeared at ~ 2 R_e qualitatively consistent with Soviet data (**16**). No explanation is given. At 4·5 R_e the field began to rotate in the same manner as Explorer VI. At 7 R_e, $|H|$ began to exceed nominal dipolar and by 21·5 R_e was still 32 γ. Heppner *et al.* suggest a geomagnetic tail. Qualitative inconsistency with an annular current is not conclusive. Cosmic-ray latitude knee is, for example, explained by a ring current.

At 21·5 R_e penetration into a highly disturbed plasma occurred. Magnetic activity had been mild and continued to 37·2 R_e when a sudden commencement at both vehicle and Earth surface occurred. The sudden commencement caused a spike in $|H|$ followed by a gradual rise in $|H|$. Field direction was highly variable outward from 21·5 R_e and did not seem to be influenced by the sudden commencement. In general, the field was highly agitated, suggesting waves and vortical motion. The appearance of boundary penetration at 21·5 R_e is strongly suggested and fits the ~ 14 R_e boundary on the solar side established by Pioneers I and V.

Plasma activity close to the Earth consisted of passage through a cold medium (1·3 – 2·9 R_e) (**17**). From 2·9 – 21·5 R_e plasma signal was not received, confirming proper photo-electric suppression in the equipment. This also bounds the plasma current to below 5×10^6 cm^{-2} sec^{-1}. (The instrument was biased to accept only protons with energy between vehicle potential and 2300 volts.) Beyond 21·5 R_e plasma was seen most of the time (4×10^8 cm^{-2} sec^{-1} at mean $E = 500$ volts). The flux varied from threshold to 10^9 cm^{-2} sec^{-1}, high values coinciding with weak field. Strong field in the anti-solar direction resulted in low plasma flux. Consideration of energy measurements yielded ion densities varying from 6 – 20 cm^{-3}. Analysis of spacecraft spin-plasma intensity showed plasma-directed velocity to be away from the Sun. The sudden commencement observed on the magnetometer showed a proton-energy spectral shift to higher values.

A typical burst of data showed a region, perhaps $10^{10} - 10^{11}$ cm where the magnetic field-energy density was ~ 250 ev/cm^3, the ordered gas kinetic-energy density ~ 5 kv/cm^3, followed by a region perhaps 10^{11} cm in extent where $H \sim 20\gamma (E_H \sim 2$ kv/cm$^3)$ and

$E_P \sim 1$ kv/cm^3. The former region implies a thermal energy component not exceeding 250 ev/cm^3 or that E disorder $\sim 0{\cdot}1E$ order (**18**).

Detailed analysis of spin modulation of the plasma signal allowed extension of the energy spectrum accessible to higher values. The sudden commencement transit time from the Sun implied 10 kv particles. There was no strong evidence for these and the hypothesis is raised of a wave propagation mechanism from Sun to Earth with attendant local acceleration (**18**). The estimated particle volume densities for the two regions cited above are $n \sim 10$ cm^{-3} and $n < 0{\cdot}2$ cm^{-3} respectively. Basically, the plasma flux values are consistent with Soviet data. (**19**) The complexity of the magneto-hydrodynamics of the processes at play require further study of these data.

This summary is necessarily incomplete. Consideration of much of the data discussed is current and definitive interpretations are pending. The omission of Vanguard III is due to lack of adequate information by this author. Both spherical harmonic analysis and whistler data are being presently evaluated. We also have not included the discussion of the results of the Ionospheric Satellite, Explorer VIII.

Some accomplishments of this programme are:

1. establishment of the scale of Forbush decrease mechanisms;
2. discovery of a quiet interplanetary field;
3. determination of the interplanetary storm field magnitude;
4. simultaneous observation of solar cosmic rays in transit and on Earth;
5. discovery of large current systems in the exosphere;
6. observation of collisionless shocks *in situ*; and
7. determination of distances of the geomagnetic boundary.

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44. COMMISSION DES OBSERVATIONS ASTRONOMIQUES EN DEHORS DE L'ATMOSPHERE TERRESTRE

Compte rendu de la Séance, 23 août 1961

PRÉSIDENT: P. Swings.
SECRÉTAIRE: J.-C. Pecker.

1. La Commission discute de la composition du comité d'organisation. Il sera composé comme suit:

Président: L. Goldberg;
Vice-Président: A. G. Massevitch.

Membres du comité d'organisation: MM. J. E. Blamont, H. E. Butler, H. Kienle, P. Swings, H. C. van de Hulst.

2. Le *Draft Report* est ensuite approuvé. Le Président s'excuse de ne pas avoir exposé avec assez de détails, les travaux effectués au Jet Propulsion Laboratory (JPL) du California Institute of Technology; il n'avait guère reçu d'information à leur sujet.

JPL handles the American program for lunar and planetary exploration. It has taken an essential part in the launching of the U.S.A.'s first successful satellite (Explorer I, 31 January 1958), of several other satellites and of probes. It is now actively engaged in the preparation of the lunar program (rough-landing missions, 1962, and soft landings, 1963 to 1970) and of the planetary program (Venus, 1962–1971; Mars, 1964–1971; Mercury, 1968; Jupiter, 1970).

3. Le Professeur van de Hulst fait un exposé sur les activités du COSPAR. Il s'agit d'un comité inter-unions qui s'occupe de tous les problèmes associés à l'espace. En sont membres dix-huit nations (par leurs Académies des Sciences) et dix Unions Scientifiques. Son secrétariat permanent est à La Haye. Le COSPAR essaie d'éviter les responsabilités déjà assumées par d'autres organismes: les problèmes clairement astronomiques restent du domaine de l'UAI; au contraire les problèmes relatifs à la législation de l'espace sont du ressort du COSPAR. L'une des tâches du COSPAR est l'organisation de symposia.

Rapports scientifiques

L. Goldberg: The U.S. Space Program

Dr Leo Goldberg described some of the developments that have taken place in the U.S. Space Program since the publication of the *Draft Report.*

Rocket Experiments. A. Boggess* (NASA) has obtained absolute fluxes for a number of stars in wave-length bands centered at 2600Å and 2200Å with an accuracy of about 20 per cent. T. P. Stecher and J. E. Milligan* (NASA) have scanned the spectra of ten stars in the wave-length region 4000Å – 1600Å, including five stars of spectral classes O and B, one of class Fo and one of class WC7. The observed energy distribution for the Fo star (α Carinae) is in good agreement with theory. For the early spectral types, the observations agree with theory down to λ 2600, after which the observed curve becomes depressed and then declines steeply from 2400Å to 2000Å, where the discrepancy between theory and observation amounts to an order of magnitude.

* Paper reported at 108th meeting of American Astronomical Society, Nantucket, Massachusetts, 18-21 June 1961.

Excellent new photographs of the far ultra-violet solar spectrum in the spectral region 175Å – 600Å have been obtained with a grazing incidence spectrograph by R. Tousey of the Naval Research Laboratory. The emission lines below λ350 are largely unidentified.

F. T. Haddock (Michigan) is planning a Journeyman-rocket shot late this year, which will carry three receivers at frequencies 0·7, 1·2 and 2·2 Mc. connected to a 40-foot dipole. The altitude of apogee should be 2 500 kilometers, or well above the critical level of the outer ionosphere.

Satellite Experiments. On 27 April 1961, NASA successfully launched its Gamma-ray astronomy satellite (S-15), the experiment being carried out under the direction of W. L. Kraushaar and G. W. Clark of Massachusetts Institute of Technology.

The *Draft Report* lists the experiments to be carried aboard the S-16, the first vehicle in the NASA program of orbiting solar observatories. This vehicle is scheduled for launching later in 1961. The second in the series, called the S-17, is planned for flight late in 1962 or early 1963.

The following experiments have been scheduled for inclusion in the stabilized section:

1. Scans of the solar spectrum in the range 1600Å-75Å, by Goldberg and Liller (Harvard).

2. A series of six experiments by Tousey and collaborators (NRL) including observation of the white light corona, scans of the disk in Lα, scans of the disk in 8-20Å and 44-60Å X-rays, measurement of X-ray emission in connection with surge prominences and with types III and IV radio emission.

3. Measurement of the solar constant by the Goddard Space Flight Center.

Equipment has been developed by Haddock (Michigan) for a sweep-frequency receiver in the band 2-4 MHz. for solar burst observations from a satellite in an eccentric orbit in a flight planned for 1963.

The Goddard Space Flight Center is working on the design of an artificial comet to be launched in a high Earth orbit for the study of the effects of solar radiation on an icy conglomerate of known constitution.

H. Friedmann. Results with X-rays

Le Dr H. Friedmann rend compte des résultats obtenus dans le domaine des rayons X: image du soleil dans ce domaine, et enregistrement, pendant une éruption, du flux X très fortement affecté par l'éruption, au contraire du flux en Ly α, observé simultanément. Le Dr Friedmann expose quelques-uns des projets de son équipe.

A. G. Massevitch. Research in U.S.S.R.

Le Dr A. G. Massevitch expose certaines des recherches effectuées en U.R.S.S.

1. *Plasma investigations.* Ion traps for measuring positive ion concentrations in the ionosphere and interplanetary space were mounted on Sputnik III, several geophysical rockets and Soviet space probes. Most of the details are published in the Russian issue *Iskussvennie Sputniki Zemli*, 1958–1961. I shall only give a short survey of the results obtained.

Data on concentration of interplanetary ionized gas (particles with thermal energy), obtained by K. Gringauz and others during the flight of Lunik III (November 1959) at distances of about 150 000 km from the Earth, showed that the concentration does not exceed a few particles per cc. Positive ion currents of solar origin were registered in 1959 outside the magnetic

field of the Earth (at distances of about 100 000 km) by means of three electrode traps placed on space probes. Possibility of thermal energy particles interfering was excluded by applying high potentials on the outer grids. A rather good correlation between the intensity of the registered currents and the K-indices of geomagnetic variation was established. Similar traps oriented toward the Sun were mounted on the Venus probe launched 12 February 1961. One of these traps was specially designed for measuring the ionic component of the solar corpuscular radiation. During the last communication with the probe (17 February) a noticeable stream of corpuscules (of the order 10^9 particles/cm^3) was noted. That corresponds to an ionic concentration of the order of 20 cm^{-3}. Simultaneously, a geomagnetic storm was observed. At distances of about 50 000 to 75 000 km beyond the limits of the radiation belts streams of electrons with densities about 10^8 particles/cm^2 sec and energies exceeding 200 Ev have been detected (with the first cosmic rockets, January and October 1959). The energies of these electrons are too low to be measured by cosmic ray counters mounted on the same rockets which registered electrons of the outer radiation belt. These results lead K. Gringauz, J. Shklovsky and others to suspect the existence of an outer belt of electrons. Those conclusions are in agreement with Pioneer V measurements of the geomagnetic field obtained in March 1960 by Sonett and others.

So far all the devices applied in Soviet experiments allowed the detection of streams of ions in space and the confirmation that they did not consist of thermal-velocity ions. It has not yet been possible to measure the energy of the registered corpuscules. New devices, permitting measurements of the energy spectra of those streams, are now in preparation.

2. *Micro-meteorites.* Acoustical detection of small meteorites in space by geophysical rockets, satellites, and space probes has been carried out by J. N. Nazarova and others. The minimal mass of the micro-meteors measured was about 3×10^{-9} g to 3×10^{-8} g (for a velocity of about 15 km/s). For heights of about 100-300 km the impact rate is about $0{\cdot}1 - 1$ particle/m^2 sec; for 400 km up to an Earth's radius, of the order of 10^{-3} particles/m^2 sec.; for 10^5 km, 10^{-3} to 10^{-4} particles/m^2 sec.

3. *Heavy nuclei in cosmic rays.* On the three spaceships (1–2 December 1960) with an integral Tsherenkov counter (measuring nuclei $Z \geqslant 5$; $Z \geqslant 13 - 14$; $Z \geqslant 31 - 32$ and $Z \geqslant 34 - 37$) an increase of the intensity of heavy nuclei was noted (1 December 1960, at 11^h20^m U.T., lasting about 12 min.). The intensity of the nuclei with $Z \geqslant 13 - 14$ increased $2{\cdot}8 \pm 1{\cdot}4$ times (as compared to the mean intensity for geomagnetic latitudes $50° - 70°$, where the spaceship at that time was travelling). No definite increase was noted for $Z \geqslant 5$. Simultaneously, only one nucleus (during the whole experiment) with $Z \geqslant 31 - 34$ was observed. The differential Tsherenkov counters noted at the same time an increase of α-particles (from 11^h20^m to 11^h26^m) ($2{\cdot}7 \pm 1{\cdot}3$ times) and no increase for $Z \geqslant 5$. The energy of the measured particles exceeded $1{\cdot}4$ to $1{\cdot}5$ Bev/nucleus. This increase can be correlated with a chromospheric flare (1+) that started at 11^h24^m and had its maximum at 11^h35^m. A simultaneous radio-burst at 208 MHz. was observed. L. V. Kurnosova, L. A. Razorenov, M. J. Fradkin (*Iskusstvennie Sputniki Zemli*, in press, Moscow 1961) conclude that the observed heavy nuclei are of solar origin.

4. *Magnetic field measurements.* Magnetic field measurements in interplanetary space were carried out by Dolgintsov, Pushkov and others on Sputnik III (1958), Luniks I and II (1959) and the Venus probe (1961). Most of these results have been presented by E. Mustel at the meeting of Commission 43 and I would rather not repeat them. Perhaps a few words should be said about the new results obtained with the Venus probe. Though the information obtained is rather limited (as measurements could be made only during 57 minutes), they confirm the fact established by Sonett and others, namely that in some cases magnetic fields frozen in corpuscular streams may be not very high, of the order of 10^{-5} gauss.

A. Severny. X-Ray and Lα experiments

Le Professeur A. Severny complète l'exposé précédent par les considérations suivantes, relatives à:

X-Ray and Lα experiments carried out at Korabl-Sputniks II and III. Efremov used the rotating disk with the set of filters transmitting the spectral regions 1·4 – 3 Å (lead), 1 – 12 Å (Ber.), 8 – 20 Å (Al), and 44 – 100 Å (CH), and Lα (LiF-CaF). For quiet Sun, he found $\lambda_{max} = 32$ Å, and $T = 0{\cdot}9 \times 10^6$ degrees, but at the onset of a flare 2+, 19 August 1960, the flux in Be-filter increased 7 times and in Al-filter 3·3 times, which leads to a temperature $T = 6{\cdot}5 \times 10^6$ degrees and $\lambda_{max} = 6$ Å. The Lα-flux remained essentially unchanged (or decreased a little) during this flare event. Mandelstam and others obtained nearly the same values for the quiet Sun during the same flight. Prokoviev and Bruns who use a grazing incidence spectrometer with a photo-multiplier for scanning the He II line $\lambda = 304$ Å, obtained the total flux in this line $\approx 0{\cdot}5$ ergs/cm². sec at the mean height 210 km, from Korabl-Sputnik III, December 1959.

Une discussion s'engage au cours de laquelle le Dr Friedmann attire l'attention sur le danger que courent les fenêtres métalliques (Al par exemple), en raison du flux de météorites; il faut remarquer que la durée de vie de ces fenêtres a été plus grande que prévue, le flux de météorites ayant été surestimé.

H. A. Brück. British Space Experiments

Le Professeur H. A. Brück présente ensuite les expériences astronomiques effectuées, ou devant être effectuées en Grande-Bretagne:

In this brief report I want to confine myself to mentioning a few astronomical experiments which have either been successfully carried out, or are about to be carried out, or are definitely planned for the reasonably near future.

All the work so far has been based on the use of vertical sounding rockets, in particular of "Skylark", a rocket which had been developed for the IGY and with which payloads of the order of a hundredweight can be carried up to altitudes of the order of 200 kilometres. Some recent experiments have also made use of the high-altitude rocket "Black Knight".

There does not exist yet a British satellite, but in view of the fact that in due course Britain is likely either alone, or more probably in collaboration with other countries, to launch satellites, a fair amount of work has been done on a detailed design study for a satellite to be used for astronomical spectroscopy.

Plans are far advanced for the launching of some U.S.-U.K. satellites in the case of which the vehicle, its launching, and the telemetry will be the responsibility of NASA, whereas the actual experiments and the design of the necessary instrumentation will be the responsibility of British scientists. Definite programmes exist at present for the launching of two such "Scout" satellites.

Most of the British space research has been carried on under the guidance of Professor Sir Harrie Massey of University College, London. In London Dr Boyd has either carried through or planned the following experiments:

1. Measurements of the solar X-ray emission between 8 Å and 16 Å. A figure of 2 to 3 $\times 10^{-2}$ erg cm^{-2} sec^{-1} has been determined for the total energy.

2. Measurements of the intensity distribution within the same range of wave-lengths. This experiment is about to be flown.

3. Study of the Sun with an X-ray scanning spectroheliograph. This experiment is now being prepared.

4. Measurement of the Lyman-alpha flux of the Sun. A figure of 4 erg cm^{-2} sec^{-1} has been found.

5. A sky scan at 1700Å with a set of photo-multipliers with peak sensitivity at 1700Å. This experiment was flown on 1 May of this year, and preliminary analysis seems to show traces of certain O- and B-stars of the southern sky. (Like other rockets, this one was flown from Woomera, Australia).

6. Sky photography at 1700Å with a camera containing a fused quartz lens focussed for 1700Å.

Mention might also be made of plans which are to be undertaken in due course by a group at Harwell under Dr Wilson. This group which studies, in the laboratory, the physics of plasmas through spectroscopy in the vacuum ultra-violet, intends—in collaboration with Professor Allen of London—to study the spectrum of the solar chromosphere and corona between 400Å and 3000Å.

As regards satellites, I should like to mention the design study for an astronomical satellite carried out at Farnborough under Dr Lines. The satellite is to carry a Cassegrain telescope of about 20 inches in diameter and a spectrograph with which spectra of individual stars are to be obtained within the range from about 1000Å to 3000Å with a resolution of about 1Å.

Finally I should like to mention the two Scout satellites for which the necessary instrumentation has been agreed on between NASA and the British Space Research Committee. Scout I, which is to be flown in 6 months' time, will contain two astronomical experiments, both due to Dr Boyd, and both extensions of his rocket work, namely measurement of solar X-rays between 3 and 20Å, and determination of the Lyman-alpha flux.

Scout II, which will only be flown in two years' time, contains two experiments of direct astronomical interest. The first of these, due to Dr Graham Smith of the Mullard Radio Observatory, Cambridge, aims at extending ground measurements of galactic radio noise to the lowest possible frequency, and in particular to the range between 0·75 and 3 MHz. A test launch of the equipment has been made with Black Knight.

The second astronomical experiment in Scout II is due to Dr Jennison of the Nuffield Radio Laboratory at Jodrell Bank. Dr Jennison intends to measure numbers and sizes of micrometeorites encountered by the satellite during its flight. The sensitivity of the relatively simple equipment is such that it should be possible to detect meteorites down to a diameter of one micron.

There are other groups in Britain just about to start work in this field, and there is, of course, a fair amount of both optical and radio/tracking work carried out, but it is too early to talk about the first, and not quite the place here to talk about the second.

Z. Suemoto. Space Research in Japan

Le Dr Z. Suemoto expose ensuite les réalisations japonaises. Elles comportent les principaux points suivants:

1. *Observations made so far by means of rockets.*
   - (*a*) Cosmic rays: thin walled Geiger-Müller counter.
   - (*b*) Positive ions: spherical probe coated by gold. Photo-emission.
   - (*c*) Electron density and electron temperature. Resonance probe.
   - (*d*) Solar spectrography (gratings, 600 lines/mm) has been a failure due to recovery problems.

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2. *Observations in preparation.*

(*a*) Night Airglow: photo-multipliers, used with filters (red, green, IR).
(*b*) Geomagnetism: fluxgate magnetometer.
(*c*) Energy spectrum of electrons and ions.
(*d*) Soft X-ray: gas-filled GM counter; photo-multiplier.
(*e*) Video Frequency Wave.

3. The *rockets* developed in Japan are as follows:

Name	Length	Diameter of section	Weight	Obtainable altitude	Payload
	m	cm	tons	km	kg
Kappa-8	10·95	42	1·5	200-220	35
Kappa-9L	12·50	42	1·5	350	35

A new series of rockets, the Lambda's, will then be developed. Their characteristics would enable them to carry 30 kg to 600 km or 3 kg to 1000 km.

4. The *launching sites* are Akita (West Coast, facing the Japan Sea, in Northern Japan) and Kajoshima (Southern Coast, facing the Pacific Ocean, in the Southern part of Kyûshû-Osami Peninsula).

Japan is taking an active part in international satellite collaboration, through the Baker-Nunn camera at the Tokyo Astronomical Observatory, and through the telemetering of satellite data, at Radio Research Laboratories.

Recherche française et italienne

Les chercheurs français et italiens, estimant que rien n'a été fait, en matière de recherche astronomique spatiale, en plus des recherches déjà mentionnées dans le *Draft Report*, renoncent à leur intervention.

R. Lüst. European collaboration

Le Dr R. Lüst fait ensuite l'exposé suivant sur la collaboration européenne en recherche spatiale:

I would like to report very briefly on plans for European collaboration in space research. These plans go back to some unofficial preparations and planning during the past year. At the end of last year eleven European countries (Norway, Sweden, Denmark, The Netherlands, Belgium, United Kingdom, France, Germany, Switzerland, Italy and Spain) signed an agreement for establishing a preparatory commission. This preparatory commission (COPERS) has the task of proposing the plans and drafting a convention for a European Space Research Organization (ESRO). The President of this preparatory commission is Sir Harrie Massey and one of the Vice-Presidents is Professor van de Hulst. Its Executive Secretary is Professor Auger. The plans for this organization have been worked out by a scientific and technical working group, and quite a number of astronomers actively participated in this planning stage.

In general terms, the purpose of the planned organization shall be to provide for and promote collaboration among European states in space research and technology. In doing this, the organization may operate facilities to design and construct payloads for sounding rockets, satellites and space probes. Furthermore, this organization shall provide launching vehicles, including their launching, and provide means for the reception, collection, reduction and analysis of data.

This scientific programme should start with research by making use of sounding rockets. The upper atmosphere will be studied, particularly in the auroral zone, and also astronomical investigations will be carried out. In the fourth year after establishing the organization the first small satellites and space probes shall be launched, carrying payloads of about 200 kg. A number of astronomical studies have been proposed, including those for studying the interplanetary medium and the comets. In the sixth year a first astronomical satellite with a stabilized platform should be launched, carrying a telescope of about 20 inches. The following is an indication of how large the effort may finally become when the ESRO is running at full activity: about 65 sounding rockets, 6 small satellites and space probes, and one large satellite should be launched each year.

The scientific instruments for the different payloads shall in general be developed and built by the universities and research units of the member states, as far as the launching vehicles, the small satellites and the space probes are concerned. The design and the construction of the payloads as a whole and of the whole satellites will be done by a European space technology centre. In this centre also applied research in the field of space technology will be done. Locally connected with this centre will be a smaller research laboratory to provide opportunities for original research in space science beyond those which exist in the individual countries.

Furthermore, it is intended that a number of radio tracking and telemetry stations be set up and also optical tracking stations. Our hope is to have close co-operation with all existing networks, and that these planned stations should complement the existing world-wide networks.

The data received from these stations will be collected together with data from solar and geophysical observatories by a European space data centre. At this centre there will be facilities to reduce and analyze the data. Also, it is intended that at this place research will be done on the analysis of solar and geophysical events. To fulfill this task effectively, it is sought to set up a fast communications system, not only with tracking and telemetry stations with launching ranges, but also with European geophysical and astronomical observatories and other organizations.

Finally, I should say that it is our hope to establish a launching range for sounding rockets in the auroral zone, very probably in the northern part of Sweden at Kiruna. A number of other launching ranges for sounding rockets exist already in some European countries. The kind of vehicles to be used is still under discussion. The United Kingdom made the proposal to finish development of the so-called "Blue Streak", a vehicle comparable in performance to the Atlas vehicle. The outcome of these discussions might be that there will be a second European organization for the development, construction and building of launching vehicles.

These are the plans at the moment. The governments have not, as yet, come to an agreement, but I think that there is good hope that the convention might soon be signed, and that the planned organization will start its activity in the near future.

L. Biermann. Space Research in Germany

Le Professeur Biermann expose l'état de la recherche spatiale astronomique en Allemagne, dans les termes suivants:

Space Research is being planned or pursued in Germany, first of all at several University Observatories, such as those at Bonn, Heidelberg, Tübingen, and at the Schaunsland Observatory. Since Dr Siedentopf is among us, I presume that he will be willing to say a few words about the activities at these places, and particularly his own. I, myself, will describe in some detail the work which is being done in the framework of the Astrophysics Institute of the Max Planck Institut für Physik und Astrophysik. There will probably soon be a special division

for space research in the Astrophysics Institute, the responsibility for which lies, at this stage, with Dr Lüst. The group will consist of a number of scientists and engineers and a somewhat larger number of technicians. It will be established at Garching, about seven miles north of the Max Planck Institut on the same site as the Institute for Plasma Physics.

The experiments to be prepared first will aim at producing artificial plasma clouds at a distance of some 100 000 km from the Earth, outside the reach of the Earth's magnetic field. Work, which is in course of publication in the *Zeit. f. Astrophysik*, has shown that quantities of the order of 1 kg of the earth-alkali metals calcium, strontium, or barium are sufficient to produce clouds which should be visible without difficulty. The matter can be emitted as a neutral gas, since the ionization by solar light is fast enough. The comparison between the behaviour of these different elements should give information about the mechanism which couples such plasma clouds with the solar corpuscular radiation; also the direction of the velocity of the solar corpuscular radiation could be directly observed. In case of the higher particle flux from the Sun which presumably is characteristic for magnetic storms, it appears that also carbon monoxide could be used, which then should become ionized by charge transfer with a cross section known from laboratory experiments. In this way a direct measurement of the solar particle flux could be obtained which might be of interest in view of the very great experimental difficulties of all existing methods of measurements usable from space probes.

Other experiments which are planned or at least discussed among our group are related to the measurement of cosmic radiation, specifically the component which originates in the Sun, of high-energy electrons and of the magnetic fields in interplanetary space and their relations to the ordinary solar corpuscular radiation.

In conclusion, I would like to mention that the Max Planck-Garching group co-operates closely with space research going on in the Max Planck Institutes for Ionospheric Research and for Physics of the Stratosphere and for Nuclear Physics in Lindau/Northeim and in Heidelberg.

H. Siedentopf. Work at Tübingen

Le Professeur Siedentopf complète cet exposé par quelques précisions sur les travaux poursuivis sous sa direction à Tübingen, relatifs au suivage et à la télémétrie des satellites, d'une part, et, d'autre part, à l'étude de la partie intérieure de la lumière zodiacale (5-25° du soleil).

G. Newkirk. Observations from balloons

L'exposé suivant dû au Dr G. Newkirk, traite des observations en ballon:

Results of some astronomical observations from a balloon. In the fall of 1960, the High Altitude Observatory flew an externally occulted coronagraph to an altitude of 22 km to observe:

1. the angular distribution of skylight at scattering angles from 2° to 60° from the Sun;

2. the spectral energy distribution at a scattering angle of 2°·4 over the wave-length range $\lambda \sim 3650$–8000 Å. The coronagraph used was originally designed by J. W. Evans and was found to introduce instrumentally scattered light of a brightness less than 10^{-8} of the brightness of the solar disk into the field.

The instrument was oriented toward the Sun with an accuracy ± 1 minute of arc by means of the pointing control which was developed for M. Schwarzschild for project Stratoscope I.

From the measurements and the theory of scattering of light in the atmosphere it is possible to determine the size distribution of aerosols suspended in the atmosphere above the point of observations. A preliminary estimate of the *upper limit* of micro-meteoritic influx of 100 particles per m^2 per second in the radius range $0{\cdot}1\mu$ to 1μ is obtained.

Cet exposé est suivi, en fin de séance, de la projection d'un beau film de Gordon Newkirk relatif aux expériences en ballon ci-dessus décrites.

H. Friedmann. UV stellar radiation

Enfin, le Dr H. Friedmann présente quelques remarques sur le rayonnement UV des étoiles et discute l'origine du rayonnement observé sous forme de nébulosité autour des étoiles très chaudes.

RESOLUTION

La fin de la séance est consacrée à la discussion d'une résolution relative à l'étude des comètes par engins extraterrestres. La discussion, à laquelle participent MM. Davis, Gold, Goldberg, Muller, Swings, Whipple et Miss Roman, aboutit à la rédaction de la recommandation ci-après:

Commission 44 recommends that, in addition to the plans for astronomical space experiments of high scientific interest which have been already planned, consideration be given to the launching of a space probe into the close vicinity of a comet.

Le Président lève la séance à $12^{h}00^{m}$.

PART 5

JOINT DISCUSSIONS

A. Stellar Motions and Stellar Dynamics

B. Solar Magnetic Fields

C. The Demands made on Celestial Mechanics by the Preparation of Ephemerides

D. Problems requiring Radio-Astronomical Observations of High Sensitivity and Resolution

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REPORT OF MEETING OF THE INTER-UNION COMMISSION ON SOLAR AND TERRESTRIAL RELATIONSHIPS

A. JOINT DISCUSSION

ON

STELLAR MOTIONS AND STELLAR DYNAMICS

Friday 18 August 1961 at 14^h00^m

ORGANIZING COMMITTEE: A. Blaauw (Chairman), Ch. Fehrenbach, F. P. Scott and K. Aa. Strand.

MEETING CHAIRMEN: A. Blaauw, K. Aa. Strand, B. J. Bok.

RECORDERS: S. Sharpless and O. G. Franz.

Introductory note

The texts of the twelve prepared contributions, often in abbreviated form, are given first; they are followed by a summary of the discussion on all the contributions considered together.

CONTENTS

1. *W. Gliese.* The Study of the Nearest Stars
2. *F. K. Edmondson.* The Solar Motion for Different Types of Stars
3. *J. H. Oort.* The Constants of Differential Galactic Rotation
4. *A. Blaauw.* The Establishment of the Distance Scale in the Galaxy
5. *W. Fricke.* The Proposed Revision of the Albany General Catalogue
6. *W. Dieckvoss.* What Data will be Provided by the AGK3?
7. *A. N. Deutsch.* The International Programme of Absolute Proper Motions with respect to Extragalactic Nebulae from Astrographic Plates
8. *S. Vasilevskis.* The Lick Program of Absolute Proper Motions
9. *D. Brouwer.* The Southern Program of Absolute Proper Motions
10. *W. J. Luyten.* Proper Motions with respect to Faint Blue Stars
11. *R. M. Petrie.* Current Radial-Velocity Programs for Stars Brighter than Ninth Magnitude
12. *Ch. Fehrenbach.* Programmes de Mesure de Vitesses Radiales Plus Faibles que $m=9$
13. Discussion

1. THE STUDY OF THE NEAREST STARS

Wilhelm Gliese

The significance of the study of the nearest stars lies in the fact that only in the immediate neighbourhood of the Sun do we know individual data for a sizeable fraction of all the stars in a space volume. Only among the nearest stars do we know individual space velocities with sufficient accuracy. Trigonometric measures of parallax become unreliable already beyond 25 pc. Spectroscopic measurements are possible to much larger distances, but to date we know spectroscopic data only for some distinct groups of stars.

The compilation of the catalogue of stars nearer than 20 pc (**1**) in 1957 included 915 single and double stars with nearly 1100 components. Space velocities were available for 600 of these stars. No radial velocities were known for the rest. Most of the nearest stars are main-sequence stars from A 0 to the faintest M-dwarfs. Moreover there are a few giants, some sub-giants, sub-dwarfs, and white dwarfs. It is well known that the entirety of these stars form no homogeneous group of stellar motions. But subdividing these stars into several groups, we ask the question: which data will be characteristic for a group of common velocity distribution?

Woolley in his paper 'The Dynamics of Stars in the Neighbourhood of the Sun' (**2**) stresses that the time of relaxation of stellar motions, through stellar encounters, may be about a hundred times greater than the supposed age of the Galaxy. It is for this reason that the present motions of the stars are by no means random motions, but are no doubt still very markedly influenced by initial conditions. Therefore we may suppose that present motions still show a limited number of star streams or extended open clusters. A subdivision into spectral classes alone cannot show us all existing features.

Woolley groups the stars according to the eccentricities of their galactic orbits. This grouping requires the knowledge of individual space velocities, and so it is limited to nearby stars. Comparing the colour-luminosity diagrams for groups of different eccentricities Woolley and Eggen (**3**) show that the array of the group having nearly circular orbits resembles that of the Pleiades, and there is a gradual change of the array to the class with the largest eccentricity. This last array resembles that of the open cluster M 67. In terms of the current evolutionary theory the Pleiades is a new cluster, while M 67 is an old cluster.

A special group seems to be the A-type stars with a strong vertex deviation in their velocity distribution. Another group consists of the M-dwarfs with emission lines, which seem to compose a very young group of low-velocity dispersion.

Among stars with reliable space-velocity data Eggen (**4**) searched for groups of common motions. The colour-luminosity array of such a group shows which stars may really belong together. Among the groups investigated by Eggen are the Hyades, the Sirius group, and the groups of ζ Her, ϵ Ind, 61 Cyg, γ Leo, and Groombridge 1830. Some of these are groups consisting of high-velocity stars.

Obviously the velocity distribution of the stars is correlated with their age. This question was investigated in more detail by v. Hoerner. In the chapter 'Velocity and Spectral Type' of the book 'The Formation of Stars by Condensation of Diffuse Matter' he states: "For the problem of the formation of stars the dispersion of space velocities is of special interest, and further so is the dispersion of the z-components allowing us to conclude about the layer in which we may find stars of this group." He also made use of the data for the nearest stars especially because he needed the estimation and elimination of selection effects caused by favouring stars of large proper motion. The grouping according to the spectral types shows that the velocity dispersion grows from B to G, but remains constant from G to M.

In another paper 'Correlation between Chemical Composition, Age and Velocity Dispersion of the Stars Nearer than 20 pc' (**6**) v. Hoerner subdivides the HR-diagram in some fields for the determination of stellar ages. His results, which are based only on a small number of nearby stars, are

1. The velocity dispersion is a function of age only.
2. The older the stars, the higher the velocities.
3. The slow increase of space velocities of younger stars with age is explained by the Spitzer-Schwarzschild mechanism.
4. The oldest stars show the original galactic turbulence.

These investigations should be continued—but there is an urgent need for additional observational information. Of the data necessary for computing space velocities, normally the parallax measures are the most uncertain. The main problem is the discovery of additional nearby stars.

More than 80% of the known stars nearer than 5 pc have annual proper motions larger than 1″; the smallest value is 0″·49. Within 10 pc 86% of the known stars have proper motions larger than 0″·5, and the smallest proper motion is 0″·17. If we choose the stars for a parallax programme according to their proper motions, the influence of selection effects would be low for distances up to 10 pc. But for distances larger than 10 pc selection effects by proper motions will become noticeable among the faint stars.

Selection effects were avoided by the spectroscopic search for early M-dwarfs carried out by Vyssotsky and his colleagues at the McCormick Observatory. A programme of tracing faint, late M-stars by objective-prism plates separating giants and dwarfs by proper motion measurements has recently been started at Heidelberg by Schaifers. And we should not forget the searches for white dwarfs by Luyten.

Certainly such programmes need considerable time and should be combined with supplementary radial-velocity measurements of the faint nearby stars. But new data will allow new answers to the problems mentioned above.

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2. THE SOLAR MOTION FOR DIFFERENT TYPES OF STARS

Frank K. Edmondson

A. INTRODUCTION

It has been known for many years that the solar motion is a function of spectral type and absolute magnitude, and is widely different for objects with large velocity dispersion such as globular clusters, certain types of variable stars, etc. Table I is adapted from Vyssotsky (*P.A.S.P.* **69,** 109, 1957) and Edmondson (*A.J.* **61,** 176, 1956 or *Handbuch der Physik* **53,** 16, 1959). X_0 is positive toward the galactic center, Y_0 in the direction of galactic rotation, and Z_0 toward the galactic pole.

Table 1

	X_0	Y_0	Z_0	Dispersion
B	+ 11·3:	+ 16·8:	+ 5·4:	± 8
A	10·3	10·7	6·0	11
F	10·3	12·2	5·8	15
G	10·4	13·4	5·9	19
G 5	10·3	14·7	5·9	21
K	10·3	16·1	5·9	22
M	10·5	20·8	5·8	25
dM	6·9:	17·1:	7·8:	28
Irregular variables	19·7:	27·4:	16·4:	30
Long-period variables	10·0:	52·3:	9·4:	45
Cluster-type variables	10·6: :	126·7: :	27·0: :	86:
Globular clusters	27·8: :	180·0: :	32·1: :	119:
BASIC SOLAR MOTION	+ 10·2	+ 10·1	+ 5·9	
Ca^+ (Blaauw)	11·6	14·4	7·6	
Cepheids (Weaver)	12·5	14·6	(6·8)	
STANDARD SOLAR MOTION	+ 10·5	+ 15·4	+ 7·3	
O 5–B 7 (Blaauw)	10·6	17·3	(6·6)	
Distant Cepheids (Raimond)	8·4	18·9	(7·3)	

11th magnitude K giants (Edmondson, unpublished) give a solar motion in agreement with the value in Table I.

K dwarfs within 20 parsecs of the Sun (Pillans, 1952) have solar motion elements:

$$L = 21°·7,\ B = +25°·0,\ V_0 = 20·3 \text{ km/sec.}$$

K dwarfs at a distance of 100 ± 15 parsecs (Edmondson, unpublished) give a lower solar velocity:

$$V_0 = 12·7,\ K \text{ assumed} = 0,$$

$$\text{or } V_0 = 14·9,\ K = +4·0$$

The co-ordinates of the apex are not well determined, and the disagreement with Pillans' velocity may not be significant.

The velocity dispersions along the three axes obtained by Pillans are ± 30·0, ± 18·6, ± 11·9, and by Edmondson are ± 29·8, ± 20·9, ± 17·6.

(*a*) *The Standard Solar Motion.* The solar motion elements

$$A = 18^{h} = 270°,\ D = +30°,\ V_0 = 20\ \text{km/sec}$$

have been widely used to perform the reduction to the 'local standard of rest'.

(*b*) *The Basic Solar Motion.* Vyssotsky and Janssen (*A.J.* **56,** 58, 1951) have given arguments suggesting that the elements

$$A = 265°{\cdot}0 \pm 1°{\cdot}2,\ D = +20°{\cdot}7 \pm 1°{\cdot}4,\ V_0 = 15{\cdot}5 \pm 0{\cdot}4\ \text{km/sec}$$

are the correct reduction to the 'local standard of rest'.

B. DISCUSSION

It should be noted that only the changes in the Y-component in Table I are systematic. These are related to the two major factors of (*a*) velocity dispersion and (*b*) distance.

The velocity-dispersion effect may be explained in principle by reference to the well-known Haas-Bottlinger diagram. A large velocity dispersion means large deviations from circular motion with a resulting average rotational velocity that is smaller than the circular velocity. Stromberg (*Ap.J.* **61,** 363, 1925) found a quadratic relation between the Y-component and the dispersion along the same axis:

$$y' = -0{\cdot}0192\ \sigma^2(y') - 10{\cdot}0\ \text{km/sec}$$

This effect will explain the K-star solar motion, but not the B-star solar motion.

The B-star solar motion can be explained by another effect, a second-order galactic rotation term in the Y-component which varies as the square of the distance from the Sun (Edmondson, *Handbuch der Physik* **53,** 14, 1959). This statement is only qualitative, owing to the distance-scale uncertainties.

The conclusion of Vyssotsky and Janssen regarding the reduction to the 'local standard of rest' seems to be justified.

3. THE CONSTANTS OF DIFFERENTIAL GALACTIC ROTATION

J. H. Oort

These constants were originally defined as follows

$$A = \frac{1}{2}\left(\frac{\Theta_c}{R_0} - \frac{\partial \Theta_c}{\partial R}\right),\quad B = -\frac{1}{2}\left(\frac{\Theta_c}{R_0} + \frac{\partial \Theta_c}{\partial R}\right),$$

or, alternatively by

$$A = -\tfrac{1}{2} R_0 \frac{\partial \omega_c}{\partial R},\quad A - B = \omega_c$$

R_0, Θ_c, ω_c referring to the region near the Sun.

For $|R - R_0| << R_0$, we have

$$V = -2A(R - R_0)\sin l^{II}$$

For $r << R_0$ we get

$$V = r\,A \sin 2l^{II}$$

$$4{\cdot}74\,\mu_l = B + A\cos 2l^{II}$$

In these expressions, which are for objects in the galactic plane, r is the distance from the

Sun, V the radial velocity corrected for solar motion, and μ_l the proper motion in galactic longitude, also corrected for solar motion.

From the beginning it appeared that there was considerable regularity in the differential motions, and it looked as though A and B could be derived with considerable accuracy, once the distance scale was known. It is noteworthy, in this connection, that there is not only great regularity but also the line perpendicular to the differential motions points almost exactly to the centre. It came out as about 325°, old longitude, while the direction to the centre is 327°·7. There is a difference between the two directions but it is small.

The 21-cm data, however, show that there may be local deviations from circular motion up to 10 km/sec, or so. These might well influence the determination of A based on a relatively small region.

For this reason we prefer to define A as $\frac{1}{2}R_0$ times the derivative of $\omega_c(R)$, ω_c being *smoothed* over as large an interval as practicable.

There remains the uncertainty in the distance scale, which Blaauw estimates as about 20% (p.e.).

The following table lists some of the principal determinations of A from radial velocities.

Authors	Ref.	Type of stars	Region	A
Petrie, Cuttle and Andrews	(1)	B	north	17·7
Feast and Thackeray	(2)	B	whole sky	17·5 ± 1·5
Blaauw	(3)	B 2–5	north	20·0 ± 1·8
Stibbs	(4)	Cepheids	whole sky	19·5 ± 1·9
Gascoigne and Eggen	(5)	Cepheids	whole sky	18·4
Walraven, Muller and Oosterhoff	(6)	Cepheids	south	17·4 ± 2·1
H. L. Johnson and Svolopoulos	(7)	clusters	north	15

References:

(1) *A.J.* **61**, 289, 1956.
(2) *M.N.* **118**, 125, 1958.
(3) *Trans. IAU* **8**, 505, 1952.
(4) *M.N.* **116**, 453, 1956.
(5) *A.J.* **63**, 199, 1958 (abstract only).
(6) *B.A.N.* **14**, 81, 1958.
(7) *Ap.J.* **134**, 868, 1961.

The errors indicated in the table are mean errors. The last determination is to be noted particularly, as the distance calibration in this case should be much more direct and more reliable than in the other cases.

Determinations of A and B have also been made from proper motions. These are independent of the distance scale, but refer to only a small region of space and a small number of stars. The most recent result (Morgan and Oort, *B.A.N.* **11**, 379, 1951) is

$$A = 20 \pm 2, B = -7 \pm 1{\cdot}5$$

As a compromise value we might take $A = 17{\cdot}5$. It should be stressed, however, that this value is still quite uncertain, much more so than might be inferred from the fair agreement between most values in the table. In their recent exhaustive discussion of Cepheids based on Kraft's new distance scale, Schmidt and Kraft arrive at values which are very considerably lower, of the same order as that found by Johnson (still unfinished). (See the reported discussion.)

Information that is very important, because it refers to a large region of space and is independent of the distance scale, can be derived from 21-cm observations. These give the product AR_0. As an average between northern- and southern-hemisphere observations I adopt

$$AR_0 = 150 \pm 10 \text{ (m.e.)}$$

Another entirely independent result comes from the ellipsoidal distribution of stellar motions. The most informative result which refers to regions at about 1 kpc distance in all directions north of $-20°$ declination is that derived by Hins and Blaauw (*B.A.N.* **10**, 365, 1948), who find for the ratio of the squares of the average velocities along the two galactic axes

$$h^2/k^2 = -B/(A-B) = 0{\cdot}24.$$

However, it should be noted that all determinations referring to brighter stars give a considerably higher value for this ratio. A representative result for these is about 0·40.

With $A = 17{\cdot}5$ the two results for h^2/k^2 give $B = -5{\cdot}5$ and $-11{\cdot}7$ respectively. As an average, including the direct determination of B from proper motions, we might adopt $B = -8{\cdot}5$. With $A = 15$, we would get $B = -7{\cdot}5$.

From the constants A and B and the above value of AR_0 we can derive R_0 and Θ_c, the circular velocity near the Sun. The latter is equal to $AR_0 - BR_0$. With $AR_0 = 150$ we obtain the following values:

For $A = 17{\cdot}5$ and $B = -5{\cdot}5$ or $-11{\cdot}7$: $R_0 = 8{\cdot}6$ kpc, $\Theta_c = 197$ or 251 km/sec, respectively.

For $A = 15{\cdot}0$ and $B = -7{\cdot}5$: $R_0 = 10{\cdot}0$ kpc, $\Theta_c = 150 + 75 = 225$ km/sec.

The standard values which up to the present have been used in the reductions of 21-cm observations are

$$A = 19{\cdot}5,\ B = -6{\cdot}9,\ R_0 = 8{\cdot}2 \text{ kpc},\ \Theta_c = 216 \text{ km/sec}.$$

Several astronomers have argued that Θ_c must be higher. The maximum value admissible in view of the 21-cm data and the ellipsoidal distribution of velocities would seem to be about 260 km/sec; the true value is likely to be rather lower.

SOME DESIDERATA FOR IMPROVING THE CONSTANTS

1. Most important is the direct determination of R_0 from RR Lyrae variables in the central region.

2. The value of AR_0 can be improved by a better determination of line profiles in the Southern Milky Way.

3. Measurement of proper motions of stars of 14th and 15th magnitude relative to faint galaxies in the Lick survey may yield $\omega_c = A-B$ with a probable error of about $0''{\cdot}0002$. A similar accuracy can be obtained for A. These determinations will be independent of the distance scale.

4. The Lick survey will similarly yield values of h^2/k^2 which are much superior in accuracy to what is known at present.

4. THE ESTABLISHMENT OF THE DISTANCE SCALE IN THE GALAXY

A. Blaauw

1. The present distance scale in the Galaxy depends to a large extent on cluster work. Even for the calibration of the luminosities of Cepheids, considerable weight is now attached to the information found for Cepheids occurring in clusters. Also, the calibration of early-type super-giants is referred to cluster distances as, for instance, in the case of the double cluster *h* and χ Persei, which contains most of the super-giants available for calibration purposes.

2. Current distances of clusters are based almost exclusively on the distance of the Hyades, which can be geometrically determined by means of the stream elements derived from the proper motions and radial velocities. A second basic piece of information is provided by the Scorpio-Centaurus association, the distance of which is also derived from geometric considerations.

3. For the Hyades, the present uncertainty in the distance arises mainly from the uncertainty in the stream motion expressed in km/sec. The direction of this motion, that is the position of the convergent point of the proper motions, can be determined with high accuracy, but the stream velocity, derived from the radial velocities may well be in error by 1 or 2 km/sec. This error corresponds to a possible error in the distance of 3%. This error systematically affects all the distances based on the Hyades. The possibility of an error in the stream velocity used in current investigations is apparent from the fact that the stream velocity is different when derived from the various spectral types (see J. A. Pearce, *P.A.S.P.* **67**, 23, 1955). Thus, the values derived from the A-type stars and from G-type stars differ by 2 km/sec. We should like to draw the attention of the radial-velocity observers to this point.

4. The present uncertainty in the distance of the Scorpio-Centaurus association is considerably larger than that in the distance of the Hyades. One may therefore wonder why this association should be considered at all in the establishment of the distance scale. The reason is that, if for instance one wants to determine the distance of *h* and χ Persei by means of the Hyades, one has to do this via a few other clusters of intermediate stages of evolution. In this process, (see, for instance, H. L. Johnson, *Ap.J.* **126**, 121, 1957, and A. Sandage, *Ap.J.* **125**, 422, 1957) each step introduces additional errors in the distance found for *h* and χ Persei. On the other hand, it appears possible to connect the luminosities of the *h* and χ Persei stars directly with the Scorpio-Centaurus association by means of B-type stars of common characteristics.

Therefore a strong effort to improve also the distance determination of the Scorpio-Centaurus stars appears justified. This will require both better radial velocities and better proper motions. The stars might be selected from the most recent list of members as given by Bertiau (*Ap.J.* **128**, 533, 1958) which contains about 80 stars brighter than 7th magnitude. At present errors in the distances of the Scorpio-Centaurus stars can be ascribed as follows:

due to errors in the proper motions: ± 10%;
due to errors in the radial velocities: ± 7%.

In addition to this, one wants to check the correctness of the interpretation of the state of motion of the Scorpio-Centaurus stars which is used in the determination of the distances. The precision of the available observational data is not yet sufficient to recognize the relative motions of the stars in the association, not even reliably to estimate the internal velocity dispersion. Observations should be pushed far enough as to allow us to determine the nature of these internal velocities.

5. THE PROPOSED REVISION OF THE ALBANY GENERAL CATALOGUE

W. Fricke

At the Astrometric Conference, held in May 1959 in Cincinnati, a resolution was adopted which urges that the Albany General Catalogue be revised, with the omission of certain stars for special reasons and the addition of supplementary stars. This resolution was the result of a discussion after D. Brouwer (*A.J.* **65,** 186, 1960) had presented an interesting paper on a method of constructing a revised General Catalogue. Before entering such a great undertaking it seems necessary to estimate whether an essential improvement of positions and proper motions of the GC, systematically and individually, can be reached at the present time.

As G. van Herk and A. J. J. van Woerkom (*A.J.* **66,** 87, 1961) pointed out recently, there are modern meridian catalogues which show systematic differences against each other of the same order of magnitude as catalogues based on old observations. In view of the large number of catalogues incorporated in the GC, one might conclude that no appreciable systematic improvement can be expected by addition of the available modern observations. However, after the completion of the fourth Fundamental Catalogue at the Astronomisches Rechen-Institut (FK 4), it turned out that appreciable systematic corrections could be derived for the right ascension system, which is based on absolute observations after 1900, and that also the corrections to the declination system, which is based on observations from about 1840 onwards, are by no means negligible. The individual corrections, which are based on all observations included in FK 3 and in modern catalogues, have already proved to give an effective improvement of the accuracy. From recent observations with Danjon's impersonal astrolabe, Guinot was able to show that suspected systematic errors in FK 3 are no longer present in FK 4. The reason for the individual and systematic improvement is (1) a more critical weighting of older catalogues, and (2) the quality of modern observations which are essentially free from well-known deficiencies of catalogues prior to 1900.

It can thus be stated that, from the experience with the revision of FK 3, a revision of the GC should result in a very effective improvement of positions and proper motions. It must be doubted, however, whether a more reliable system than that of FK 4 can be constructed at the present time. Therefore, a revision of the GC should start with a reduction of positions and proper motions of GC stars into the system of FK 4, a procedure which demands special investigations of the magnitude effects for fainter stars. From then on an individual revision of the data of all stars should be carried out.

For the northern hemisphere quite a number of more recent meridian catalogues and the AGK 3 will make an important contribution to higher accuracy. Also, in the southern hemisphere, modern meridian observations of GC stars carried out at the Cape, as well as photographic positions, are available. In view of the planned southern meridian programme similar to the AGK 3R, however, the last steps of the southern part of a revised GC should be postponed until the star positions of this programme become available. The great importance of the southern meridian programme is generally recognized. For the improvement of the positions of brighter stars the recommendation of IAU Commission 8 should not be forgotten. This urges the use of astrolabes in a chain of conveniently distributed stations down to latitudes as close as possible to $-60°$.

As to the techniques of revision of GC our experience with the formation of the FK 4 warns us against a premature formulation of a fixed procedure. For example, the extent to which older observations have to be omitted is one of the questions which have to be investigated in the course of the work. From the very beginning, however, it is clear that the analysis of such a vast body of data makes imperative the most efficient use of modern documentation

and computation facilities. All observational data are needed in machine-readable form, preferably on punched cards, and all steps of the revision programme are to be carried out on an electronic computer. The first step is therefore the key-punching of those old and new star catalogues which have to be incorporated into the General Catalogue. (For future publications of observational and other catalogues the publishing institutions themselves should make their catalogues available on punched cards.) The Astronomisches Rechen-Institut will distribute a list of star catalogues which are needed with highest priority on punched cards, and an enquiry shall determine whether assistance in key-punching can be expected.

The existence of star catalogues in machine-readable form (e.g. on punched cards) is a necessary condition not only for the formation of a General Catalogue but also for any kind of future analysis of observed star positions. In the past it was only in rare cases that all the star positions in observational catalogues were analysed. In the future, however, it will be easily possible to make use of the full amount of information contained in the observations. The key-punching of the old and new star catalogues—if shared by various institutions—can be expected to be completed within a few years. After all necessary data are on punched cards, the formation of the revised General Catalogue when carried out on an electronic computer will be feasible in well-controlled steps in a reasonable time. The programming of the various steps for the electronic computer is under way at the Astronomisches Rechen-Institut.

6. WHAT DATA WILL BE PROVIDED BY THE AGK3?

W. Dieckvoss

For the region of declination $-2°{\cdot}5$ to the northern celestial pole the plates of the AGK 2, comprising the zones Bonn, Bergedorf and Pulkovo, have been repeated at Bergedorf. All stars contained in the photographic part are measured and proper motions have been derived.

The final AGK 3 catalogue will thus give proper motions of 180 000 stars with mean errors of $\pm 0''{\cdot}008$/year. Those stars belonging to the meridian circle work of the AGK 2 (printed in the relevant volumes under the headings 'Babelsberger Meridianbeobachtungen') will be omitted. Also other double stars with uncertain co-ordinates will be omitted.

The system of the AGK 3 will be the FK 4. Spectral types and photographic magnitudes will be included and, in a belt of 20° width around the galactic equator, colour equivalents also.

Extensive tables in the introduction will provide means of correcting the positions of the AGK 2 for errors depending on magnitude and colour.

With these 180 000 absolute proper motions in a unified system a basic material will be available to bring other catalogue work to a unified system, especially the immense Yale-zone work.

7. THE INTERNATIONAL PROGRAMME OF ABSOLUTE PROPER MOTIONS WITH RESPECT TO EXTRAGALACTIC NEBULAE FROM ASTROGRAPHIC PLATES

A. N. Deutsch

Systematic observations of galaxies in selected areas within the declination zone + 90° to − 5° were commenced with the Carte-du-Ciel astrograph at Pulkovo before World War II. The zone from − 5° to − 25° was studied at the Tashkent Observatory, and that from − 25° to − 68° at the Santiago (Chile) Observatory. Seven areas of the southern circumpolar region were photographed at the Cape Observatory.

The data on the number of areas and galaxies are given in Table I.

Table 1

Declination zones	Number of Areas	Number of Galaxies	New	Suitable for use	Type of Plates
+ 90° to − 5° (Pulkovo)	157	1508	231	610	Agfa-Astro
− 5° to − 25° (Tashkent)	48	226	6	133	Agfa-Astro
− 25° to − 68° (Santiago)	94	1198	829	459	Kodak 103a-o
− 68° to − 90° (Cape)	7	41	13	25	Kodak IIa-o
Totals	300	3000	1000	1200	

In the first two zones the co-ordinates of the centres of the areas were finally adopted, and the estimates of the galaxies checked, by means of repeated photography. The corresponding catalogues have been published in 'Izvestia' of the Pulkovo and Tashkent observatories. The data for the rest of the regions are not as yet final; the centres of the areas and estimates of the suitability of galaxies will be determined after repeated photography.

In the totals, approximate numbers are given. One-hour exposures were used, and as a result images of galaxies to the 14-15th magnitudes and stars to the 16-17th magnitudes were obtained.

According to the Pulkovo plan, three observatories with Carte-du-Ciel astrographs participate in the observations. The data on the state of the work at these observatories are given in Table 2.

Table 2. Observations of the first epochs

The zone + 90° to − 5°

Pulkovo	*Tashkent*	*Toulouse*
Entirely completed.	Considerably advanced.	Commenced.

The zone − 5° to − 25°

Tashkent	*San Fernando*
Considerably advanced.	Commenced.

The zone − 25° to − 90°

Santiago	*Perth*	*Cordoba*
Advanced.	Commenced.	Intended.

It will also probably be necessary to ask the Cape Observatory to repeat the photographs of the areas of the southern circumpolar region after a final adoption of their centres.

In addition to Carte-du-Ciel instruments, astrographs with a longer focal length in Moscow, Kiev, Bucharest and Shanghai (Zô–Sè) and also with a wide-angle camera (focal length 2·3m, focal-ratio 1/10, field 36 square degrees) in Moscow were used for photographing the galaxies. The observations with these instruments are considerably advanced, but the number of galaxies suitable for observation and the number of areas is naturally smaller. At the other observatories the estimates of galaxies in the adopted system of units are lower by unity than at Pulkovo. The estimates made for the Moscow wide-angle astrograph are lower by 0·5 units as compared with the Pulkovo Carte-du-Ciel astrograph. Nevertheless, with the addition of these observations it can be considered that the zone $+90°$ to $-25°$ is well provided for.

However, it is desirable that one more southern observatory with a Carte-du-Ciel astrograph participate in observations in the zone $-5°$ to $-25°$. According to our plan the main task of astrographs of longer focal length is to photograph the fundamental KSZ stars for the reference of the KSZ catalogue to galaxies using background stars of the 13-14th magnitudes. The list of 240 fundamental stars in the zone $+90°$ to $-5°$ and 71 stars for the zone $-5°$ to $-25°$ has been completed and published. The observations of these stars have either been completed or are nearing completion. The stars are selected so that they are located close to the centres of the areas with galaxies and also fill up the "zone of avoidance" with about the same density, so as to make possible the connection of the galactic belt with regions where absolute proper motions are obtained by reference to galaxies. The astrographs in Bucharest and especially in Shanghai (the latitude $+31°$ permitting photography to $-35°$) are of great value in this respect.

The list of the FKSZ stars in the zone $-25°$ to $-90°$ will be compiled as soon as the final co-ordinates of the centres of the areas with galaxies are adopted. I should like to request that observatories with Carte-du-Ciel astrographs and astrographs of long focal-length participate in the photography of areas with fundamental stars. It is necessary to take two plates of each area with an exposure of 20 minutes. An objective grating which gives diffraction companions fainter by four magnitudes than the central image, is required. At present it is possible to commence observations in the zone $-5°$ to $-25°$, as so far only the Shanghai Observatory can photograph this zone completely.

8. THE LICK PROGRAM OF ABSOLUTE PROPER MOTIONS

S. Vasilevskis

The determination of stellar proper motions with reference to galaxies was proposed by Wright (**1, 2, 3, 4**). The first-epoch plates were taken with the 20-inch Carnegie Astrograph by C. D. Shane and C. A. Wirtanen between 1947 and 1954. There are 1246 fields north of declination $-23°$; each $6° \times 6°$ field is covered by a 17-inch square plate. Plates are centered $5°$ apart in declination and $5°$ or less in right ascension. An additional series of photographs down to $-33°$ has been taken for counts of galaxies; these plates may also be considered for proper-motion purposes. Two exposures, of lengths two hours and one minute, through a coarse diffraction grating have been used for reference of bright stars to the frame of faint galaxies.

An automatic measuring engine (5) is under construction by the Gaertner Scientific Corporation, the project being sponsored by the National Science Foundation. It is expected that the machine will be installed in 1962. It is also expected that the Carnegie Astrograph will be equipped with a second, yellow-corrected, lens in 1962; this lens has been ordered from the Perkin-Elmer Corporation.

It is being planned to start the second-epoch photographs of the main (Wright's) program in 1967; the epoch-difference will be 20 years. Plates both in blue and yellow will be taken simultaneously. Since the measuring engine will contain a photometer, it is being planned to determine proper motions, magnitudes and colors of stars measured. Stars within a range of magnitudes 6 to 18 can be selected for measurement. If only first-order spectra of grating images are measured, the range is not continuous because of overlaps between the spectrum and the central image (6). Investigations of the accuracy to be expected have shown, however, that the second-order spectra can be measured without any appreciable loss of precision (7), and that any star can be measured within the magnitude range mentioned. The expected probable error of a proper motion is of the order of $\pm 0''{\cdot}005$ (7, 8).

Selection of stars to be measured is the most important topic to be considered before the start of the second epoch. At least 50 galaxies per plate will be chosen for reference outside the zone of avoidance; this number may be increased if necessary. Stars to be selected can be grouped as follows:

1. AG stars for comparison with proper motions based on a fundamental system, for determination of correction to the precession constant and for investigation of the systematic errors of star catalogues.

2. A certain number of stars, two or more per square degree, with a nearly uniform distribution in positions, magnitudes, and colors for general statistical investigations. An additional number of stars will be selected in areas of particular significance, *e.g.* in low galactic latitudes, faint stars in vicinity of galactic poles, etc.

3. Reference stars for other Lick programs.

4. Special types of stars (variables and others), selection of which needs careful consideration and has to be done in co-operation with representatives of various fields of astronomy. Therefore an invitation is hereby extended to submit suggestions, proposals and lists of stars in this group. It is intended to prepare a detailed list of stars for inclusion in the program for the time of the 12th General Assembly of IAU in 1964, when the selection can be discussed.

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9. THE SOUTHERN PROGRAM OF ABSOLUTE PROPER MOTIONS

Dirk Brouwer

The Southern Astrograph is designed especially for the purpose of extending to the south celestial pole the program of the Lick Observatory of referring stellar proper motions to a background of distant galaxies.

Funds for building the instrument were received from the Ford Foundation in the summer of 1960. Since then, the optics have been ordered from the Perkin-Elmer Corporation. The mounting, according to a fork-type design by Engineer B. G. Hooghoudt of Leiden, the Netherlands, will be constructed by the firm of Rademakers in Rotterdam, the Netherlands.

A site survey in Western Argentina has been in progress, and we hope soon to be able to make a definite choice of site.

The program will be carried out as a joint project by the observatories of Yale and Columbia Universities. It is hoped that observing can begin in the course of the year 1963.

10. PROPER MOTIONS WITH RESPECT TO FAINT BLUE STARS

W. J. Luyten

We now know that faint blue stars exist in very large numbers in high galactic latitudes—at least 25 to 50 per square degree down to $m = 21$ pg on the Palomar 48-inch Schmidt plates. We do not yet know what the distribution of absolute magnitudes is, but among the brighter representatives there are a number with luminosities around $M = -1$ to $M = +4$. If—but this is a pretty big if—it turns out to be possible to distinguish these more luminous ones from the UBV colors alone, then we would have here objects at distances of the order of 25 000 parsecs or more. These may then be expected to have proper motions of the order of only $0''.001$ annually. And, let us remember that if we speak of 'absolute' proper motions we really mean only 'relatively absolute' for they are referred to the Sun and we have just been told that there is still an uncertainty of almost 25% in the value of the Sun's velocity around the galactic center.

Since these faint blue objects are *stars* they are more accurately measurable than galaxies. Since they are more numerous we can measure small areas—with a concomitant simplification in the reductions and increase in accuracy. Hence these stars may well present, if not an improvement, at least a separate and independent mode of attacking the problem of absolute proper motions.

I do not say—and of course no one could guarantee—that this will work, but at the very least it seems to be worth trying out. At any rate I would strongly urge—in taking up Vasilevskis' offer—that several hundred of these faint blue stars in high galactic latitudes be included among the objects to be measured in the Lick program.

11. CURRENT RADIAL-VELOCITY PROGRAMS FOR STARS BRIGHTER THAN NINTH MAGNITUDE

R. M. Petrie

This report is prepared from information communicated by a number of astronomers and from data published in the Draft Reports (see volume XIA). Limitations of space and time demand such condensed accounts of programs that they can only be mentioned with a minimum of description.

The report is summarized very briefly in the accompanying tabulation. The numbers of stars, spectral types, magnitudes, instrumentation, etc., were included where available. An effort was made to include programs which might be of interest, even indirectly, to the subject of the Joint Discussion; possibly this aspect of the tabulation has been overdone. Excluded from the summary are: programs recently completed which have been published; programs of binary stars and variable stars as such; programs of stars of special interest unless such programs are extensive. This report is restricted to stars brighter than ninth magnitude but some fainter stars are included if they are part of a program containing bright stars. Objective prism programs are not included.

Twelve institutions, at least, are carrying out radial-velocity programs on the brighter stars. There are only a few long-term programs that include large numbers of stars distributed generally over the sky, the emphasis being placed on shorter programs having specific objectives. It is noted that several observatories are making spectroscopic observations of galactic clusters and associations; several programs are directed at improving our knowledge of stellar velocities perpendicular to the galactic plane. The former poverty of radial-velocity data of stars in the southern sky has vanished under the energetic attack of the Radcliffe, Cape, and Mount Stromlo observatories.

It is estimated that about 5000 stars, mostly brighter than ninth magnitude, are included in current radial-velocity programs. Approximately three-quarters of these are in general programs which will add substantially to the material now available for the study of stellar dynamics.

The tabulation "Summary of Radial-Velocity Programs" is given on the following two pages, 408 and 409.

Summary of Radial-Velocity Programs

Stars Brighter than 9th Magnitude

Ref. No.	Institution	Program	Details
		(1) *General Programs*	
1	Berkeley Astr. Dept.	N. Gal. Polar Cap	
2	David Dunlap	(A) Kapteyn 6° × 6° zones	90 stars; A 0 and later; 7·5 to 8·0; 0^h to 6^h; north of 15°
3	,,	(B) Kapteyn 8° × 8° zones	106 stars; A0 and later; 7·6 and brighter; 9^h to 18^h; north of 15°
4	Dominion Astrophysical	(A) Faint O-B stars	550 stars; O8 to B5; 7·6 to 8·6; north of 20°
5	,,	(B) N. Gal. Polar Cap	120 stars; A0 to F5; 9·0 and brighter; within 10° of pole
6	Kitt Peak	A stars in N. Gal. Polar Cap	
7	Perkins	*Mira* stars with new p.m.	18 stars 7·5; to 9 at max.
8	Radcliffe	(A) Distant B stars	150 stars; OB
9	,,	(B) Long-period variables	106 stars; Me
10	Royal Greenwich	Bright northern A stars	450 stars; B9 to A5; 6·4 and brighter; north of equator
11	Royal Observatory, Cape	(A) Stars with large π, large p.m., high velocity	1850 stars; F to M; 6·0 to 9·0
12	,,	(B) S. Gal. Polar Cap	120 stars; A type; 6·0 to 9·0
13	Mount Stromlo	Fundamental southern stars	—
14	Mt. Wilson—Palomar	(A) F to K sub-dwarfs	—
15	,,	(B) Faint OB stars	25 stars; longitude 345° to 35°
		(2) *Special Programs*	
1	Kitt Peak	Orion Trapezium stars	
2	Marseilles and Haute Provence	(A) Standard velocity stars	
3	,,	(B) High-velocity stars	
4	,,	(C) Interstellar Lines	
5	Mt. Stromlo	(A) Stars in S.A. 193	50 stars; B and A
6	,,	(B) High-velocity stars	155 stars
7	,,	(C) Suspected sub-dwarfs	30 stars
8	Royal Greenwich	Stars of special interest. Stars of interest for group motion	
		(3) *Clusters and Associations*	
1	Dominion Astrophysical	Clusters and Associations	5 clusters; 60 O to A stars 3 Associations; 60 O to B stars; fainter limit 11 mag.
2	Kitt Peak	Clusters and Associations	2 clusters; 50 stars; I Cephei; 20 stars
3	Mt. Stromlo	Clusters and Associations	2 clusters; 65 stars; I Scorpio
4	Mt. Wilson and Palomar	Clusters and Associations	NGC 6633; 45 stars; II Puppis
5	,,	Cepheids in clusters	NGC 7790; 3 Cepheids

Summary of Radial-Velocity Programs

Stars Brighter than 9th Magnitude

Ref. No.	Telescope Dispersion	Status	Application
		(1) *General Programs*	
1	36-in. refl. 125 Å/mm.	—	Accel. perp. to Gal. Plane
2	74-in. refl. 33 and 66 Å/mm.	Two-thirds complete	To supply r.v. of faint stars near zones.
3	74-in. refl. 66 Å/mm.	Observing and measuring complete	To supply r.v. of faint stars near zones.
4	73-in. refl. 51 Å/mm.	Observing and measuring complete	Gal. rotation, peculiar motions, interstellar calcium
5	,,	90% complete	Accel. perp. to Gal. Plane
6	36-in. refl. 125 Å/mm.		Accel. perp. to Gal. Plane
7	200- and 100-in. refl. 13 to 30 Å/mm.	Complete, 1962	To give reliable space motions
8	74-in. 49 and 84 Å/mm.	Complete, 1962	Gal. rotation; dynamics of Galaxy
9	,,	Complete, 1961	Motions of L.P.V.
10	36-in. refl. 120 Å/mm.	Observing 80% complete; measuring 20% complete	To improve r.v. of northern A stars
11	74-in. refl. 21 to 84 Å/mm.	55% complete	Motions of near stars and high-velocity stars
12	,,	Completed	Accel. perp. to Gal. Plane
13			
14			
15			
		(2) *Special Programs*	
1	36-in. refl. 125 Å/mm.	Partially complete	Motions of faint stars
2	47-in. refl., 76-in. refl.		Improvement of wave-length tables
3	,,		
4	,,		
5			
6		20% complete	r.v., spectral class
7			r.v. and luminosities
8	74-in. refl., 100-in. refl. 6·8, 10, 15 Å/mm.	Kept up to date; continuing	Accurate determination of r.v.
		(3) *Clusters and Associations*	
1	73-in. refl. 51 Å/mm; 90 Å/mm.	30% complete	r.v.; spectral type; absolute mag.; membership; internal motions
2	36-in. refl.; 125 Å/mm.	About 50% complete	r.v.; motions; membership; galactic rotation
3			r.v.; spectral class; absolute mag.; motions
4			r.v.; membership; rot. vel. r.v.
5			r.v.; membership

12. PROGRAMMES DE MESURE DE VITESSES RADIALES PLUS FAIBLES QUE $m = 9$

Ch. Fehrenbach

La proportion des étoiles dont la vitesse radiale est mesurée diminue très rapidement lorsqu'on dépasse la magnitude 7. Elle devient pratiquement négligeable lorsqu'on atteint la magnitude 9.

A. SÉLECTION OBSERVATIONNELLE

L'examen du catalogue de vitesses radiales donne d'ailleurs une image fausse sur notre connaissance des vitesses radiales stellaires des étoiles faibles. En effet le nombre des étoiles qui ont été effectivement mesurées sont, en général, des étoiles très particulières, Céphéides, étoiles à grand mouvement propre, étoiles variables, membres d'amas etc.

L'utilisation de ces données pour des recherches statistiques est par conséquent hasardeuse. Nous pouvons donner comme exemple d'un résultat très discutable la proportion élevée pour les étoiles à grande vitesse. Elle n'est pas confirmée par les astronomes de Marseille qui travaillent à l'Observatoire de Haute Provence, ni par les astronomes du Cap.

On peut dire que notre connaissance des vitesses radiales des étoiles quelconques plus faibles que la 9ème grandeur, est pratiquement nulle.

Naturellement il faut continuer à mesurer les vitesses radiales d'étoiles particulières. Les résultats obtenus dans certains programmes (Céphéides, étoiles O et B), montrent les importants résultats qu'on peut obtenir.

B. PRÉCISION DES MESURES

Il est certain que la précision des vitesses radiales d'étoiles indiquée dans les catalogues est en général surestimée et la répétition de nombreuses mesures est indispensable.

Enfin il ne faut pas exagérer l'importance de ces erreurs de mesures pour un matériel d'étoiles très faibles. Il est certain que de nombreuses vitesses radiales connues à 5 ou 10 km/s près seraient utiles pourvu que ce matériel soit exempt d'erreurs systématiques.

Dans ces conditions on peut prévoir actuellement les programmes suivants:

1. *Programmes avec le spectrographe à fente*

Les mesures par le spectrographe à fente s'imposent dans les cas suivants:

(*a*) Mesures d'étoiles particulières isolées;

(*b*) Etude d'amas très serrés.

Ces mesures sont en général précises mais elles nécessitent particulièrement l'usage de grand télescopes pendant des temps très longs. Elles ne sont donc pas susceptibles d'une généralisation.

Plusieurs observatoires sont engagés dans les travaux de ce genre, particulièrement dans les mesures de vitesses d'étoiles O et B qui sont indispensables pour une étude de la dynamique de notre galaxie. Je pense notamment aux travaux des observatoires suivants: Victoria, Capetown, Mount Stromlo.

2. *Programmes avec les prismes objectifs*

Cet instrument est surtout utile pour l'étude systématique de champs stellaires galactiques, ainsi que pour l'étude des Nuages de Magellan.

Nous avons continué ces travaux à la fois à l'Observatoire de Haute Provence et, depuis le début de cette année, en Afrique du Sud. Je désire donner très rapidement un résumé de l'état actuel de nos travaux.

Petit prisme objectif. L'équipement de l'Observatoire de Haute Provence comprend actuellement un prisme objectif de 15 cm de diamètre, qui permet d'atteindre très facilement des étoiles de 9ème grandeur et, avec un peu plus de difficulté, des étoiles de 10ème grandeur. La précision des mesures s'est révélée très bonne et peut être estimée à l'ordre de 3 km/sec pour les étoiles du type G et K, et de l'ordre de 5 km/sec pour les étoiles O, B et A. Cette précision correspond à une moyenne d'au moins trois clichés et quelquefois jusquà 7 clichés.

Cet instrument a permis d'étudier de très nombreux champs du plan galactique et quelques champs situés près du pôle de la galaxie. De nombreuses Selected Areas ont aussi été mesurées. Actuellement les résultats pour 1600 étoiles ont été publiés et un nombre équivalent est prêt à la publication, mais celle-ci est retardée par l'absence de vitesses radiales de base qui, comme on le sait, sont nécessaires pour étalonner nos champs. Ces résultats ont d'ailleurs été complétés par des classifications spectrales dans le système MK ainsi que par des mesures de l'intensité totale $H\gamma$ et $H\delta$, ainsi que par la photométrie dans le système $U\,B\,V$. Ces résultats sont actuellement utilisés par divers astronomes de l'Observatoire, notamment par M. J. Boulon, Mme M. Barbier et Mlle N. Martin. En principe nous avons mesuré systématiquement toutes les étoiles des champs et les seules étoiles éliminées étaient les étoiles superposées.

On peut dire que le matériel obtenu est exempt de la plupart des effets de sélection d'observation et se prête bien à des discussions statistiques.

Naturellement, suivant les champs stellaires, la proportion des étoiles supergéantes, géantes, et naines est très variable et l'étude des résultats permet d'aborder divers problèmes comme la recherche des bras éloignés de la galaxie. Les supergéantes permettent d'atteindre des distances de l'ordre de 2000 – 3000 pc; les géantes des distances de 800 à 1000 pc et les naines seulement des distances de l'ordre de 100 pc (étoiles de type G).

Grands prismes objectifs. Le prisme objectif de 40 cm de l'Observatoire de Haute Provence a été mis en service en 1957. Malheureusement le verre de l'un des prismes était défectueux. Nous l'avions néanmoins mis en service dans l'espoir de pouvoir en tirer des résultats. Malheureusement ceci n'a pas été le cas et les mesures obtenues avec ces spectres de qualité insuffisante ne sont pas utilisables.

Le prisme a été remplacé en 1959 par un nouveau prisme d'excellente qualité et ceci a complètement changé la situation. Les spectres sont excellents et la précision des mesures permet d'espérer des vitesses radiales avec une précision de l'ordre de 5 km/sec pour des étoiles jusqu'à la 12ème grandeur.

Haute Provence. Le prisme objectif de l'Observatoire de Haute Provence a servi à étudier quelques champs galactiques dont les résultats ont été publiés par Mme Duflot (sous presse), et de nombreux autres champs sont mesurés notamment des champs situés près du pôle de la galaxie (Ch. Fehrenbach).

Le matériel actuellement insuffisant en quantité semble indiquer deux résultats intéressants pour le pôle galactique:

(*a*) une dispersion assez grande des vitesses radiales;

(*b*) un nombre de vitesses radiales négatives relativement important.

Nous nous proposons de compléter ces résultats en étendant considérablement en 1962 et 1963 la zone polaire étudiée.

Afrique du Sud. Un deuxième instrument analogue a été construit pour être utilisé en Afrique du Sud. Malheureusement l'optique de cet instrument n'était pas prête en mars 1961; nous avons dans ces conditions monté l'excellent optique de Saint-Michel sur l'instrument austral.

En août 1961, Mme Duflot doit obtenir les premiers clichés de l'hémisphère austral. L'instrument fonctionne dans le cadre de l'Observatoire Européen. Cet instrument est spécialement destiné à l'étude des Nuages de Magellan. La vitesse radiale permettra très facilement de trier les étoiles des Nuages de celles de notre galaxie.

Le programme de mesures comprend la recherche des étoiles les plus brillantes appartenant aux deux Nuages. L'étude même des Nuages posera le problème de la superposition des étoiles, la grande distance focale de 4 m permettant de réduire celles-ci au minimum. Le programme de recherche sera étendu à la région intermédiaire entre les Nuages, ainsi qu'à la recherche d'un éventuel pont avec la Galaxie.

Nous atteindrons aisément la 12ème grandeur; mais les grandes vitesses radiales des deux Nuages nous permettront de reconnaître l'appartenance pour des étoiles de 13ème grandeur.

Nous avons aussi l'intention d'étudier des champs galactiques austraux pour compléter nos recherches faites en France.

Actuellement, (août 1961), l'optique initialement destinée à l'Afrique du Sud et qui sera utilisée en Haute Provence, est pratiquement terminée et permettra de reprendre les travaux à Saint-Michel, en octobre 1961.

13. DISCUSSION

B. J. Bok. I would now like to invite discussion on the papers that we have heard this afternoon.

W. J. Luyten. There now appears to be a possibility that the Bruce telescope may be mounted again in its old mounting at the Boyden Station. If this should materialize I would like to suggest that it be used to repeat some of the best old long-exposure plates. Conservatively we should be able to find at least 50 of these, showing stars and galaxies down to $m = 18$ pg. These plates are now sixty years old and by repeating them and measuring motions on them relative to galaxies we would have an excellent chance to learn what some of the difficulties are that we are going to encounter in the Lick program. The old plates were taken without a grating, hence we can only measure stars of roughly the same magnitude as the faint galaxies. Moreover, because the scale of the Bruce plates is that of the Carte-du-Ciel (1 mm = 1′) such a program would bridge the gap between the Pulkovo and the Lick programs. Also, the star images on the old Bruce plates are rather fuzzy and therefore resemble more closely the images of the galaxies, which may be of advantage.

S. Vasilevskis. I disagree that fuzzy images help.

W. Fricke. At Heidelberg we have the 40 cm Bruce telescope and we have plates dating from 1900, whose images are also not of the best quality. These plates are usable to determine proper motions of nearby stars, also many red stars can be found. However, I agree with Dr Vasilevskis that one cannot expect the same accuracy as one does from modern astrographs. But I also agree that the tests suggested by Dr Luyten would be valuable.

S. Vasilevskis. In principle I am in favor of Dr Luyten's proposals. I still maintain, however, that fuzzy star images will not be of advantage. The images of galaxies on the Lick plates are measured with errors 1·5 times larger than those for star images. But since there are about 70 galaxies in the reference frame on a plate, the fuzziness of the images of galaxies has virtually no effect upon the accuracy with which the position of a star can be obtained. On the other hand, there is only one single image of each star to be measured, and the error resulting from the fuzziness of a star image will therefore in its full amount affect the determined position of the star.

W. J. Luyten. Images near the center of a good Bruce plate are of better quality than those I have seen near the edge of a Lick plate, yet still within the limits to which measures will be made. What about changes in the lens system and in the emulsion between epochs? The Bruce plates would be valuable for investigating these problems, because such studies carried out now might disclose difficulties which could arise later in the Lick program.

D. Brouwer. The Bruce telescope also may not be the same now as it was sixty years ago. The lens has been dismounted and may therefore not perform in the same way as it originally did. I do not necessarily think it important to have the Bruce restored.

K. Aa. Strand. I would not discourage anyone from carrying out any such program. The sixty-year old Bruce plates should be useful. In 1970, we can meet together again and review the results of all these programs and then decide which one gave the best results. At present all these programs should be considered important and valuable.

J. L. Greenstein. The following remarks refer to Dr Luyten's presentation concerning faint blue stars. Spectroscopic surveys of stars selected in the galactic polar regions only for blueness of color have shown that at a mean apparent magnitude of 15, approximately one-third of the 90 stars observed are white dwarfs. A total of 30 white dwarfs of unknown parallax have recently been found. Only 5 stars out of a total of 180 faint blue and white dwarf stars have been 'normal' B or A stars: these mainly lie between magnitude 11 and 13. The balance

of the stars are (1) 'horizontal-branch' B and A stars of mean spectroscopic absolute magnitude 0 to +3, and (2) hot sub-dwarfs from −1 to +5. Other old stars like nuclei of planetary nebulae range from −1 to +7, and old novae from +3 to +8. In no case is a single direct parallax determination available. Consideration of luminosity of these faint blue stars suggests that, except for the white dwarfs, the mean annual proper motions will be small. But unfortunately no absolute proper motions of the blue stars exist; the majority of the proper motions of even known white dwarfs are still determined from blink methods only. On the assumption that the tangential motions are 60 km/sec, proper motions of the halo and hot sub-dwarfs are only 0″·001 to 0″·010. Even if galactic rotation is the source of dispersion of tangential motion, the proper motions are only 0″·005 to 0″·060; thus the blue stars of magnitude 20 at the galactic pole, if they are in the range $M_v = 0$ to +5, will have $\mu < 0''{\cdot}006$. Thus, the very faint blue stars (near 20 mag.), if they are not all white dwarfs, may provide a slow-moving reference frame. However, decisions as to their nature, which is completely unknown, since spectra stop at 17 mag., will depend on absolute motions, probably with respect to the extragalactic nebulae.

B. J. Bok. In the papers presented this afternoon we have heard from Professor Oort and others about the related problems of A, Oort's constant, and R_0, the distance to the galactic center. It is most important that A should be firmly fixed for the regions near the Sun, for the quantity AR_0 is reasonably well established (approximate value 150 when R_0 is measured in kiloparsecs).

Today we heard that the trend is toward smaller values of A than were suggested a few years ago. Professor Oort seems to support a reduction from $A = 20$ to $A = 17{\cdot}5$. We should, however, bear in mind that during the past decade there have been various suggestions of much smaller values of A. I am thinking here in terms of the OB studies by Whitford and associates at the Washburn Observatory, of Weaver's results, and of the recent value of A found by H. L. Johnson and Svolopoulos from studies of galactic clusters. Over the years I have personally rather favored the Victoria value of the 1930s, $A = 15{\cdot}5$, and the trend seems to be in this direction. An important consequence of a smaller value of A would be that the distance from the Sun to the galactic center might be as great as 10 000 parsecs, certainly larger than Baade's often-quoted value. It would be interesting to hear Professor Oort's comments on the values of A of the order of 15 and less that have been suggested—and also those of Dr Weaver and Dr Whitford, who are both present today. We shall first hear from Dr Schmidt.

M. Schmidt. In trying to reach a decision on the most likely values of A, B and R_0, the following considerations may be mentioned in addition to those given by Professor Oort.

1. The ratio $-B/A$ over the range $R_0 = 6$ to 14 kpc in M 31 is 0·6 or larger.

2. The value of AR_0 as determined from distant stars, is given by Münch as around 200 km/sec. From the OB star material discussed by Thackeray one gets a value around 135 km/sec.

3. The value of R_0 as determined by Thackeray from the same material is 8·9 kpc. Two stars in Münch and Münch's list lead to 9·2 kpc.

4. Fricke has shown that if the rate of escape of stars from the Galaxy is low, the local circular velocity has to be 276 km/sec or more.

5. The relation between A, B, R_0 and the density gradient in the plane of the Galaxy can be studied through the construction of trial models of the distribution of mass. The model I published in 1956 had a large local density gradient. The escape velocity was found to be about equal to the sum of the local circular velocity and the cut-off at 63 km/sec for high-velocity stars moving in the direction of rotation. I now feel that the local density gradient

found in that model is too large. As a consequence, stars near the 63 km/sec limit do not have the escape velocity.

H. F. Weaver. We are preparing a large volume of data on about 100 clusters, and on OB stars and Cepheids, from which we hope to make a determination of the constants A and B from stellar data.

With regard to Professor Oort's presentation, I wish to point out that his values for A and B are local values, inferred from the ω versus R curve. The ratio h^2/k^2, which can be related to the A and B constants, can be determined by various methods, as, for example, the method employing space motions or that employing proper motions. There is a significant discrepancy in the numerical values of h^2/k^2 resulting from these two methods. A value of 0·40 is found from the space motions. Space motions can be determined only for nearby stars; this value is therefore a 'local' value as it should be in keeping with the definition of the velocity ellipsoid. On the other hand, by investigating proper-motion dispersions in different directions, we find a value of 0·24. The average distance of the stars involved in this determination is greater than one kpc. For such distant stars, there are three effects contributing to the proper motions: solar motion; random motions of the stars; and differential galactic rotation. The theory utilized in the usual proper-motion method of deriving the value of h^2/k^2 involves only the first two of these. When a 'two-effect' theory is used to discuss 'three-effect' motions, an erroneous value of h^2/k^2 will result. Thus the larger value of h^2/k^2, obtained from space motions, is likely to be the more nearly correct one. The larger value of h^2/k^2 implies the smaller value of A.

J. H. Oort. We can estimate what improvement in the galactic rotation constants one might hope to obtain from absolute proper motion surveys, such as the Lick program: from a sufficient number of plates taken in the right directions, ω_c should be obtainable with an accuracy of $\pm 0''{\cdot}0002$ or $\pm 0{\cdot}9$ km/sec/kpc. Therefore this would be a significant new determination.

B. J. Bok. Would Dr Whitford comment on his work concerning galactic rotation?

A. E. Whitford. I believe that the Wisconsin results concerning galactic rotation should be viewed with reserve on account of doubts regarding the velocities in various parts of Wilson's catalog.

B. Lindblad. The formula for h^2/k^2 implies a vertex deviation equal to zero, which is generally not the case. One can, however, use a more general theory which includes the vertex deviation, and such recent revisions favor a value of B closer to 10.

I. R. King. I have considered the effects of deviations from a Gaussian curve in the velocity distribution and of irregularities in the shape of the velocity ellipsoid. No comprehensive investigation has yet been made, but preliminary studies show that effects of this kind appear to be significant.

R. P. Kraft. Analysis of Cepheids in galactic clusters leads to a value of A of approximately 15 under the assumption that the slope of the period luminosity relation in our Galaxy is the same as that in the SMC. This result agrees with that of Johnson and Svolopoulos; but the two results are not independent, because the Cepheids used here have been calibrated by means of photometric distances of galactic clusters.

H. F. Weaver. But if one uses a zero point derived from proper motions and not from clusters, one still gets a value of A between 14 and 15, which constitutes a confirmation independent of galactic clusters.

B. J. Bok. Dr Blaauw has drawn attention to the key position that the h and χ Persei cluster and the Scorpio-Centaurus moving cluster hold in the calibration of absolute magnitudes of

super-giants and of blue giants. Recent work at Radcliffe Observatory (Thackeray and Feast) and at Stromlo (H. M. Johnson, Aller and Faulkner, Buscombe) shows that the super-giants in the Magellanic Clouds have normal spectra and that the emission nebulae in the Clouds show the same sorts of relative abundances of the chemical elements as do those of our Galaxy. Would it not be desirable to use the blue super-giants in the Clouds (especially those of the Large Cloud) for calibration purposes? The extreme permissible range of distance modulus for the Large Magellanic Cloud seems to be 18·7 to 19·2 and, if, as seems likely, this range can be halved in the next few years, we should have by far the most reliable absolute magnitudes for super-giants from the data of the Large Magellanic Cloud.

A. Blaauw. This method would be very good indeed, but it will still require an accurate independent determination of the distance moduli of the Magellanic Clouds.

B. J. Bok. We hope to have a determination good to ±0·2 mag. within a few years.

A. Blaauw. We should nevertheless continue to improve calibrations based on moving clusters.

M. W. Feast. We are engaged in a study concerning the use of the Magellanic Clouds for absolute magnitude calibrations. This work can be continued only after a thorough investigation has been made of the possibility of basic differences between stars in the Magellanic Clouds and in our Galaxy.

F. J. Kerr. A major problem in all 21-cm studies is the lack of an independent distance scale. It has been necessary to introduce certain assumptions regarding galactic rotation and overall symmetry of the Galaxy. The higher resolution now obtainable will enable us to measure the width of the hydrogen layer in any particular direction or region. And although it will still be necessary to make certain assumptions, this will give some independence to the 21-cm distance scale. We can try to study the circle of zero radial velocity through the Sun and see how far we can trace it through the Galaxy.

A. Blaauw. If we want to have proper motions in the Scorpio-Centaurus region with the necessary precision, how accurately can we hope to obtain such absolute proper motions, considering the large area covered by the association which makes it necessary to combine meridian observations made from the northern and from the southern hemispheres? In such a procedure, systematic errors and possible discontinuities in the various series of meridian observations may cause a serious problem.

We can, of course, hope to obtain proper motions with respect to extragalactic nebulae for these stars as a result of the Lick program. But how and with what precision will it be possible to extend within the Lick system a reliable tie-in to these stars in low galactic latitudes?

S. Vasilevskis. There are two ways to accomplish this, both requiring proper-motion determinations on each side of the zone of avoidance.

1. By means of overlapping plates the Lick proper-motion system can be extended across the zone of avoidance. Such a procedure, if properly carried out, should result in negligible closing errors where the systems for the two hemispheres are joined.

2. By including a sufficient number of AGK stars in the Lick program one can establish and extend across the zone of avoidance the relation between the proper motion systems of the AGK and of the Lick program.

Galaxies in 'windows' of the zone of avoidance can provide additional reference and check.

H. K. Eichhorn. Programs such as the Lick proper-motion survey will provide absolute proper motions of lesser quality of a large number of stars which can then be used as reference

stars for determinations of accurate absolute proper motions of important individual stars by means of long-focus refractors.

M. W. Ovenden. I would like to comment on the use of the moving cluster method of distance determinations. Without a knowledge of the distances of the stars, it cannot be proved that the motions of a given selected group of stars do fulfill the criteria for a moving cluster. The method therefore makes the hypothesis that, if the observed motions of the selected stars show (approximately) the features that would be exhibited by a moving cluster, then the selection of stars does fulfill exactly the criteria for moving clusterhood, the discrepancies being due to errors of observation. This would be a reasonable hypothesis only if there were some special property in a set of stars having a common space motion—some large *a priori* probability of a group of stars forming a moving cluster. There seems no good reason for believing this to be so, *in general.* Hence I believe that the moving cluster method of distance determination should be used only with the greatest caution, especially for widely-dispersed groups of stars.

R. M. Petrie. I wish to make the following remarks concerning the calibration of the absolute magnitudes of B stars:

1. The study by Bertiau of the Scorpio-Centaurus group makes possible a direct comparison between the MK and the DAO absolute magnitude systems. From 16 stars such a comparison gives:

$$\text{MK} - \text{DAO} = -0^{m}\cdot41 \pm 0\cdot13$$

2. New radial-velocity determinations show many stars to have variable radial velocity. Of 36 stars observed by Buscombe and Morris, 20 have variable radial velocity. Of a total of 77 stars, radial-velocity values cannot be adopted for more than 51 stars. The average residual without sign is 8 km/sec.

3. The new determinations of proper motions and of radial velocities suggest that the conventional moving cluster treatment may not be legitimate: (*a*) if it *were* legitimate, then the new radial velocities would give a correction of about $-0\cdot2$ to the MK absolute magnitudes as deduced by Bertiau; (*b*) if it *is not* legitimate, then the standard solution for the mean parallax results in a correction of $+0\cdot4$ to the MK values.

4. Additional radial-velocity observations are essential to clarify the nature of the motions and to give a reliable space motion, if one is at all meaningful. The great sensitivity of the method to the adopted value of the space motion is not a very good feature, particularly since addition or removal of a few stars makes a significant difference in the resulting space motion. Addition of 16 stars, for instance, changes S from 25·9 km/sec to 21·9 km/sec.

A. Blaauw. For the Hyades and for Scorpio-Centaurus it can be shown that any irregularities can be explained on the basis of errors in the observed proper motions and radial velocities. Such discrepancies therefore do not provide a basis for an objection against the use of the moving cluster method, but merely demonstrate the need for more and better quality observations.

B. J. Bok. Dr Kerr has recently made the suggestion that the interstellar hydrogen in the Galaxy near the Sun has an outward motion from the center of the Galaxy of the order of 7 kilometers per second relative to the older stars—which should on the average show no such outward motion. Small residual effects might be shown by the very youngest stars and associations (O to B) and Dr Pismish has actually pointed to the possible existence of such an effect. I see no evidence of any such effect in Edmondson's tabulations. Would Dr Kerr and Dr Edmondson care to comment on this?

F. J. Kerr. Are the motions of Edmondson's groups of stars really representative of large-scale motions or could they be due to local streaming?

F. K. Edmondson. My table shows that the X_0 - component of solar motion is practically constant.

W. Fricke. There is an angle of about 5° between the directions of the centroids of motion of the high-velocity and of the low-velocity stars, respectively. If the centroid of the high-velocity stars coincides with the direction of circular velocity, then the low-velocity stars move on the average in an orbit which is directed inwards by 5° from the tangential direction.

K. L. Franklin. I plan to convert the Wilson catalog to galactic co-ordinates and to the local standard of rest and I invite comments concerning the catalog material. It is my intention to compare the motions of OB stars with the 21-cm observations of the motions of neutral hydrogen.

V. Osvalds. The results from a recent investigation of *Mira* variables suggest that:

1. For all known *Mira* variables with periods from the shortest up to 225 days, radial velocities and proper motions should be determined in order to see whether the still persisting bump in the absolute magnitude-period curve is real.

2. Spectra of *Mira* variables with periods from about 275 days to 325 days should be examined to see whether there is a more definite division between the shorter- and longer-period *Mira* variables. The velocities and their dispersions are different for these two groups, but the division cannot be established very accurately from these data alone.

B. J. Bok. Thank you very much for having been present.

B. JOINT DISCUSSION
ON
SOLAR MAGNETIC FIELDS

Friday 18 August 1961 at $14^{h}00^{m}$

ORGANIZING COMMITTEE: Dr Leo Goldberg, Dr H. Alfvén, Dr A. Severny, Dr M. Waldmeier

MEETING CHAIRMAN: Dr M. Minnaert

SECRETARIES: Dr Edith A. Müller and Dr K. O. Kiepenheuer

PROGRAM

1. The Solar Magnetic Cycle: *H. W. Babcock*
2. Magnetically Active Regions on the Sun: *A. B. Severny*
3. Sunspot Magnetic Fields and Loop Prominences: *V. Bumba* and *J. Kleczek*
4. Configuration of Magnetic Fields in Sunspot Umbrae: *V. Bumba*
5. The Sun's Magnetic Field from Radio Observations: *A. Hewish*
6. Variations of the Sun's Poloidal Magnetic Field: *M. Waldmeier*
7. Filamentary Currents and the Magnetic Conditions on the Sun: *H. Alfvén*
8. Cosmic Ray Flares: *M. A. Ellison*
9. The Solar Magnetic Field in Plage Regions: *R. B. Leighton*
10. Un Magnétomètre Mesurant les Champs Magnétiques Perpendiculaires au Rayon Visuel. Applications a l'Etude des Champs Radiaux Autour des Taches: *A. Dollfus* et *J.-L. Leroy*
11. Magnetic Fields in Prominences at the Limb: *H. Zirin*

1. THE SOLAR MAGNETIC CYCLE

H. W. Babcock

First I should like to refer briefly to the observations that make this development possible. Records obtained with the improved solar magnetograph, showing the pattern of weak magnetic fields distributed over the Sun, and the changes in these fields, now enable us to specify many features of the topology of the lines of force, both above and below the surface. These observations depend on the Zeeman effect, which is fundamental and quantitative.

The magnetograph has been developed for automatically scanning the entire disk of the Sun with a resolution of 23″ in a period of one hour. Seven distinct electronically-calibrated levels of field intensity are recorded, along with the magnetic polarity of each point. The short recording line is made to slant to right or left to indicate magnetic polarity, while it is made to undergo abrupt changes in brightness or form at calibrated levels of 1 gauss, 2, 6, 10, 15, 25, and 60 gauss.

As was shown some years ago, optical activity occurs wherever the magnetic field is sufficiently strong. Generally, a BMR (bipolar magnetic region) emerges in a small and compact form. It grows rather rapidly until the magnetic field lines, looping through the surface, reach a maximum, after which the total flux seems to remain nearly constant. As the field intensity grows in a young BMR, calcium plages, faculae, and sunspots appear in that order. Later, the BMR expands, and gradually the various kinds of optical activity subside in reverse order

as the field intensity weakens due to the expansion of the area. Finally, only the large, low-intensity field is identifiable, and gradually it merges into the background of other weak fields. The magnetic field is evidently fundamental to various kinds of solar activity.

I now wish to turn to a model showing the topology of the lines of force of the Sun's field and their variations. In addition to making use of some of the elementary ideas of magneto-hydrodynamics, it is essential to consider two of the primary observational findings. These distinctly limit the possible models. They are:

(1) Bipolar magnetic regions (BMRs) disappear by expanding, *not* by contracting and sub-submerging. This finding cannot be ignored.

(2) The Sun has a poloidal or main dipolar field, limited to high latitudes, which has been under observation since 1953. This dipolar field reversed its polarity near the peak of the current sunspot cycle. We assume that this is the usual course of events.

In brief outline, the model proposed here begins with a poloidal field whose lines of force lie in meridian planes. The submerged lines of force are shallow and are distorted by the differential rotation of the Sun, so that kinetic energy of rotation is converted to magnetic energy at an increasing rate as the lines of force are drawn out in longitude to form rather tight spirals—essentially toroidal fields—on opposite sides of the equator. This continues until the magnetic energy of the submerged toroidal fields attains locally a critical limit where instability sets in, forming concentrated flux loops that are brought to the surface by magnetic buoyancy. Each such loop produces a BMR on the surface, with related sunspots. Thus we see that the poloidal and toroidal components are simply parts of the same general magnetic field. By following the development of the lines of force, one finds that, as the BMRs expand and migrate, the initial poloidal field is neutralized and then supplanted by another of reversed polarity. Of perhaps fully as much interest, most of the magnetic flux that is created in the formation of the toroidal fields eventually finds its way through the photosphere and is liberated in the form of large, detached loops, high in the corona.

Consider as Stage 1 of our model the field as measured in 1953–56, which had a mean intensity of the order of one gauss. It was limited to latitudes above 55° and the total flux was estimated to be 8×10^{21} maxwells. In our model, the lines of force are taken to lie in a sheath of thickness $0{\cdot}05\ R$ below latitude 30°. At higher latitudes, the sheath thickens as it merges into the polar cap. The flux is sufficient to give a field, H_0, of 5 gauss in the sheath at the equator.

The differential rotation causes the lines of force in low latitudes to move ahead. Here the dashed lines represent surfaces of constant angular velocity, or 'isotachial surfaces.' The isotachs cut more deeply into the Sun than do the magnetic lines.

After the winding of the submerged lines of force has proceeded for about 3 years, the equator will have gained about 5·6 turns compared to the latitude circle at 55°. Because the angular velocity varies as $\sin^2 \phi$, the spiral winding is tighter in moderate latitudes than it is near the equator. Therefore, as the field grows, it will first become critically unstable at moderate latitudes. If we choose for the epoch of Stage 1 a time midway between sunspot maxima—that is midway between field reversals—this allows about 3 years of toroidal winding to occur before the onset of a new sunspot cycle.

Let us consider how the magnetic energy in a plasma is increased by drawing out the lines of force. Imagine a shallow cylinder with its axis in the meridian plane of the Sun. It contains a plasma with a magnetic field parallel to the axis of the cylinder. As a result of differential rotation, the cylinder will have become elongated, say to twice its original length. Because the plasma cannot cross the lines of force, the cross-section of the cylinder will be diminished to

one-half, with doubling of the field intensity. Since the magnetic energy content varies as $H^2/8\pi$, the energy will be quadrupled by the elongation.

In the model, ψ is the angle of the toroidal lines with the meridian. We have seen that H_0, at the equator, is 5 gauss. At any latitude less than about $\phi = 30°$, the field in the sheath will be $H_0 \sec \phi \sec \psi$.

We wish to develop an expression showing how the critical latitude for the emergence of BMRs and sunspots decreases with the time, n, in years, since the onset of a sunspot cycle.

The angular velocity of the Sun as derived by Newton and Nunn from sunspots is

$$\omega = 14°{\cdot}4 - 2°{\cdot}8 \sin^2 \phi.$$

This is converted to differential advance in longitude as a function of n:

$$\theta - \theta_0 = 17°{\cdot}6\,(n + 3) \sin^2 \phi$$

It is easy to write down an expression for tan ψ, which we have defined:

$$\tan \psi = \mathrm{d}\theta/\mathrm{d}\phi = 35{\cdot}2(n + 3) \sin \phi \cos \phi.$$

The expression for H as a function of latitude and ψ has already been derived. For $H_0 = 5$ gauss and $n = 0$, we have

$$H = 528 \sin \phi.$$

Therefore at $\phi = 30°$, where evidences of instability first occur, the field intensity in our (fictitious) sheath is about 260 gauss when sunspots begin to form. But at lower latitudes the field has not yet reached this intensity. As magnetic amplification continues, however, the critical value of the field intensity will be reached at progressively lower latitudes. After several spot groups have been formed at any given latitude, amplification at that latitude will be terminated by fragmentation of the submerged magnetic flux strands. It may be noted that amplification of the initial poloidal field by a factor of about 50 is attained by the time the critical value is reached for the emergence of flux loops at the surface, with the formation of BMRs and related sunspots.

By substitution we arrive at the following parametric equation which relates the interval n in years since the onset of a given sunspot cycle to the latitude, ϕ_c, at which the critical value of the magnetic field is being attained, with consequent formation of spots:

$$\sin \phi_c = \pm 1{\cdot}5/(n + 3).$$

Note that for $n = 0$, the latitude is 30°, while for $n = 10$ the latitude is about 7°. This equation represents Spörer's law of sunspot latitudes. The graph of the equation (Figure 1) may be compared with the familiar 'butterfly diagram' of Maunder. The line of instability represented by the equation corresponds roughly to the 'leading edge' of the butterfly wing.

We may anticipate later developments by pointing out that the expanding lines of force above merging BMRs will largely be liberated in the corona, but some of them will neutralize and then replace the initial poloidal field of Stage 1 with another poloidal field of reversed polarity. Thus, 11 years after Stage 1, the situation will be the same except for reversed magnetic polarity of the poloidal field. A new cycle of amplification will then commence.

The concept of a uniform sheath that was assumed for calculation is too simple. Actually, owing to turbulence and to the effects of magnetic viscosity, the flux lines will develop irregular groupings and strands. Due to the greater forward velocity of the shallower layers, a twisting or vorticity will be induced in the strands and they will be rolled into so-called 'ropes'. These may be visualized as roller bearings. The field intensity in the ropes will be several times greater than in the uniform sheath, and it will be of the right order of magnitude for the formation of typical BMRs or sunspot groups, wherein the total flux is known to be roughly

10^{21} maxwells. Analysis shows that during each sunspot cycle of 11 years' duration, the total length of such flux rope produced by drawing out will be of the order of 10^3 solar radii. This is ample for the development of 1000 to 3000 BMRs, which is the number observed. The vorticity of the flux ropes will be propagated along their submerged sections to the BMRs where they break the surface. This can explain the characteristic pattern of the 'chromospheric whirls' first described by Hale.

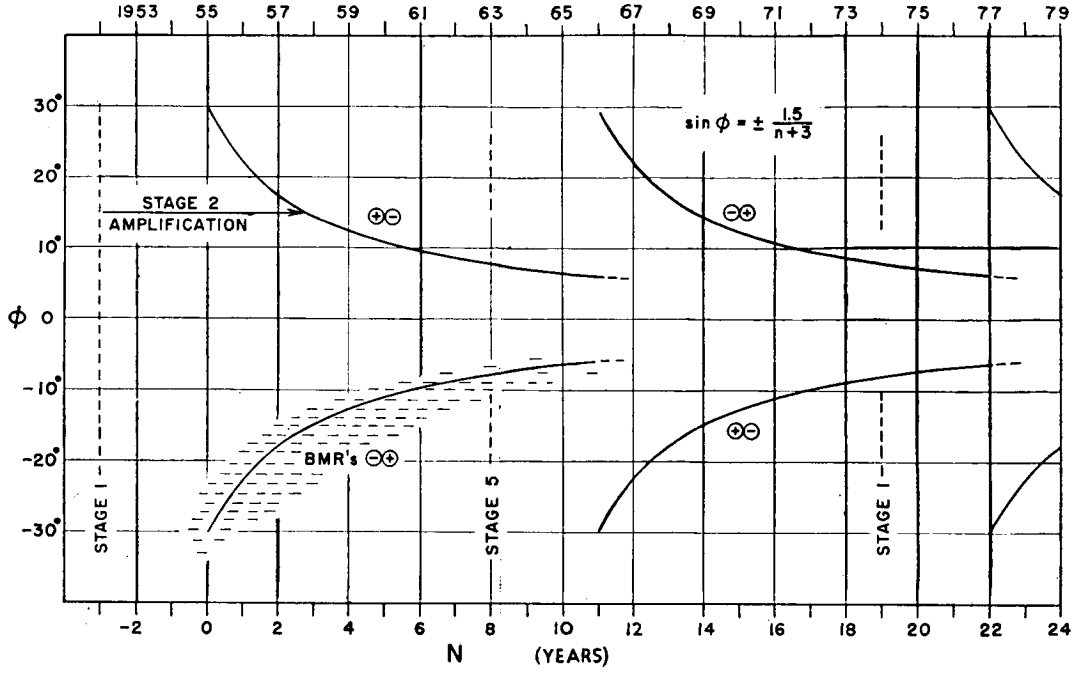

FIG. 1. The repetitive stages in the solar magnetic cycle are indicated as a function of time. In Stage 1 the lines of force lie in meridional planes. After amplification in Stage 2 the submerged fields become unstable and are brought to the surface. The curving lines in the graph represent the zones of appearance of BMRs according to the derived relationship between latitude and time; they may be compared with the Maunder 'butterfly diagram'. As the cycle declines, Stage 5 is reached, which is similar to Stage 1 but with reversed polarity.

This model properly accounts for Hale's laws of sunspot polarity and it is capable of giving a qualitative account of the predominance of preceding spots as well as of the recurrence of activity in limited zone of longitude.

As a BMR grows, there is a general expansion of the magnetic flux loops into the high atmosphere; this is consistent with the expansion of the observed magnetic areas on the Sun's surface and with the expansion reported for coronal features. This expansion is irreversible and is an essential part of the varying topology of the Sun's field.

We come now to the active stages of development of the model when many BMRs are forming and then disappearing by expansion. There is a slight tendency for the preceding parts of BMRs to expand toward the equator, while the following parts tend to expand or migrate poleward. Related to this is a drawing out in long, slanted configurations, seen in calcium plages as well as in the BMRs themselves. The polarity of the following part of a

BMR is opposite to the magnetic polarity of the polar cap toward which it expands. Figure 2, which is a meridian section, indicates schematically how a part of the initial dipolar field is neutralized by the expanding loops above a BMR. The stages of development are in the order *a*, *b*, *c*. Severing and reconnection must occur when the BMR interacts with the main field; thus, the parts labelled *b* are eliminated and a large loop of flux is detached in the corona.

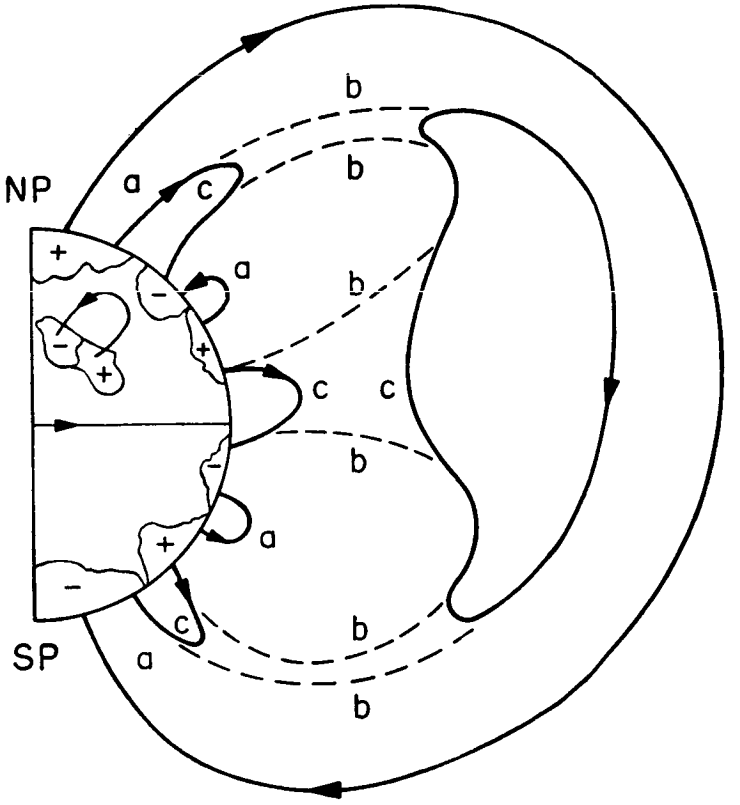

FIG. 2. Far-reaching external field lines of the poloidal field are shown, together with the meridional component of the coronal field loops above expanding BMRs. Severing and reconnection of the approaching field lines account for reversal of the poloidal field, with liberation of detached loops in the corona.

Also, loops are left both in high latitudes and over the equator. These link the photosphere to a shallow depth, and presumably are able to slip free owing to the enormous reduction in conductivity that occurs in the photospheric layers because of turbulence. The theoretical work of Sweet bears on this point.

There is about 100 times as much magnetic flux available from the numerous loops over BMRs as is required to neutralize and then supplant the initial poloidal field of Stage 1 with one of opposite polarity. This not only provides an ample factor of safety, but some further interesting consequences. Many of the flux loops above BMRs may become radially extended to great distances before they are detached as indicated below.

By far the greater part of the field lines are disposed of as indicated in Figure 3. This is a section parallel to the equator. Numerous BMRs formed in various longitudes around the Sun tend to merge into each other as they expand. Thus the preceding part of one BMR merges with the following part of the next BMR to the west, and so on around the Sun. As indicated in the diagram, the approaching flux loops as at $c-c$, which are anti-parallel, neutralize each other with reconnection as in part *d*. This occurs repeatedly, and results again in the liberation of detached field loops in the corona.

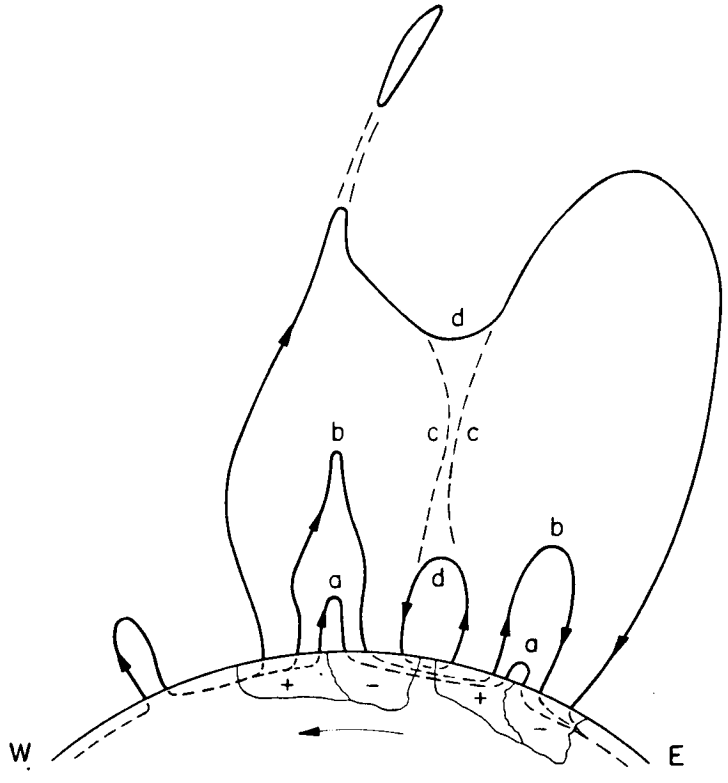

FIG. 3. The field loops above expanding BMRs may become extended radially to great distances, but eventual merging of BMRs to east and west, as shown in this section parallel to the Sun's equator, results in liberation of loops and belts of magnetic flux in the corona. The cumulative effect of the merging of hundreds of BMRs is the liberation of most of the field lines that were generated in Stage 2 as submerged toroidal fields by the action of the Sun's differential rotation.

Such detached field loops or 'magnetic bubbles' are capable of entrapping charged particles having a wide range of energy. Thus, the bubbles, moving outward into interplanetary space at relatively slow speed, may carry within themselves a collection of very energetic particles.

As the terminal stages of the sunspot cycle are approached, the residual activity at low latitudes will diminish. The toroidal fields formed earlier will largely have escaped into the corona. The situation will be similar to that of Stage 1, except that the poloidal field will have reversed polarity. Because the equatorial acceleration continues in the same sense, the

analogues of the preceding stages will occur, thus constituting the second half of the 22-year magnetic cycle. This will be repeated indefinitely, as long as the driving energy is available.

Finally, let us consider the effect of the magnetic fields on the energy balance of the corona. A recent discussion by Osterbrock leads to the result that the loss of energy by the corona is about 1×10^5 ergs/cm^2 sec. Extended over one 11-year cycle, this amounts to 2×10^{36} ergs. Now we have just seen that about 99 per cent of the magnetic field lines generated when the submerged toroidal field is formed eventually pass through the photosphere into the corona. There the magnetic energy must be dissipated by Joule heating in either of two ways: when anti-parallel field lines merge and neutralize one another; or when detached loops and magnetic bubbles immersed in plasma drift outward. When the detached magnetic loops are carried sufficiently far from the Sun they must reach eventually a region where the density is so low that the lowered conductivity will permit their collapse, with consequent conversion of the magnetic energy to thermal energy of the medium. An estimate of the magnetic energy going into the toroidal fields during the amplification process is readily made, and turns out to be 10^{36} ergs in each sunspot cycle. Additional energy must be supplied by the expanding gas above BMRs when the flux loops are inflated during their expansion. Therefore it seems that Joule heating of the corona by conversion of magnetic energy may be of the correct order of magnitude to match the calculated heat losses. Much of this energy conversion would occur at rather high levels in the corona.

DISCUSSION

H. Zirin. As I understand it, your model derives the magnetic field energy from the solar differential rotation. Have you calculated the resulting rate of decay of the differential rotation?

H. W. Babcock. The model proposed here calls on the kinetic energy of the Sun's differential rotation to provide the magnetic energy going into the toroidal fields. If it were not replenished, this would be adequate for only a few thousand years, as Alfvén has shown. Therefore the problem of the maintenance of the differential rotation assumes a greater importance. The differential rotation is, however, an observed fact, and magnetic amplification is a direct consequence.

V. C. A. Ferraro. Does your theory predict the period of the solar cycle?

H. W. Babcock. Given the initial poloidal field and the observed differential rotation, the period follows provided that the critical value of the amplified toroidal field, necessary for formation of BMRs through instability, can be predicted. Here we have obtained the critical value empirically at latitude 30° and have used it to predict the rate of appearance of sunspots at lower latitudes.

T. Gold. I comment on the solar cosmic ray evidence of the cutting off of lines of force of magnetized clouds from the Sun. The connection might be maintained for several days but not for several weeks, because then the field on the solar surface would increase unduly. From the separation of two different geomagnetic storms a disconnection time of a few days can be inferred.

F. Hoyle. Calculations, about which I shall report at Cloudcroft, indicate that the disconnection time scale mentioned by Gold is of the order of several weeks. The precise value depends on the strength of the magnetic field, and on the dimensions of the disconnected region.

R. Lüst. With respect to the time scale of several weeks for the dissipation of the magnetic fields, as stated by Hoyle, it seems to me difficult to explain the heating of the solar corona in this way.

2. MAGNETICALLY ACTIVE REGIONS ON THE SUN*

A. B. Severny

The most pronounced magnetic activity is observed in sunspot groups of complex polarity which are the seats of solar flares. The very appearance of flares may be considered as a manifestation of magnetic activity.

We should like to summarise briefly our present observational data relating to magnetic fields connected with such violent processes as flares (1).

1. The first appearance of a flare practically coincides with a neutral point of crossed magnetic fields of a spot group ($H = 0$, $\nabla H \neq 0$). Flares appear when the gradient of the longitudinal field at this point is sufficiently high (greater than about 5×10^{-2} gauss/km). This was observed in 54 cases of 61; in the 7 cases the discrepancy is larger than possible errors, but can be ascribed to the uncertainty of the data about the onset of a flare and especially to the uncertainty in the localization of neutral points near the *limb*.

2. The comparison of fields *before* and *after* a flare showed in 7 cases out of 8 the simplification of the fields—the reduction of ∇H, the vanishing of nearby magnetic hills, the disappearance of neutral points. I mean that at least one of these effects is observed.

Gapasuk of the Crimean Observatory has recently found an appreciable re-arrangement of magnetic hills connected with flares (2). In 9 cases he found well pronounced shifts of these magnetic hills (of a given field strength) when comparing their location *before* and *after* a flare. At the same time the magnetic configuration remains steady in groups undisturbed by flares. There is also some evidence found by Gapasuk (2), Antalova (3) and Gnevishev (4) that some small spots are shifted in connection with flares. Michard, from spectrographic observations, found considerable decrease in total energy of the field integrated over the active region and diminution of field gradients and of the strength of magnetic fields, when comparing the fields *before* with that *during* and immediately *after* the flare of 1960 April 23 (5). He also observed that two magnetic hills were moved a little after this flare. Leroy, who used a polarimetric technique, reported a 'destruction' of the field in the vicinity of a flare, whereas the field in the regions of the flare itself remains practically unchanged (6). The Crimean observations, as those of the French astronomers, do not as yet permit the determination of when these changes occur, before or during a flare. This circumstance is obviously connected with the low time-resolving power of the technique used. We can only record with a time resolution of 15^m the rapid changes of the field in a small region near a neutral point where moustaches appeared (7). Babcock and Howard were fortunate to get successive records of magnetic fields *after* the onset of a 3^+ flare 1959 July 16 with a time resolution of 15^m, and they found no appreciable changes in the process of the flare development (8). But our examination of the prints of their records show the disappearance of a magnetic hill at C and the reversal of polarity in the vicinity of a neutral point (Figure 1).

Zirin and Severny have recently found that fields of considerable strength (200-300 gauss) can be transferred by limb flares to a considerable height into the chromosphere (9).

Of special interest are the magnetic fields connected with great flares and especially those of proton flares. The magnetic fields in these cases are very peculiar—we sometimes observe the conjunction of several very strong magnetic poles of different polarities in a narrow region. The penetration of the strong field of one magnetic polarity into the very depth of the field of opposite polarity is also observed. These complex configurations are probably extremely unstable and undergo appreciable changes over the period of several hours.

* This paper was illustrated by many magnetograms (not here reproduced), showing the changes in the magnetic fields after a flare and other phenomena. Most of them can be found in *Publ. Crim. astrophys. Obs.*

The disappearance of the striation pattern during some great flares observed by Ellison (**10**) is also very suggestive, being considered as a rapid re-arrangement or destruction of the field surrounding the flare region. This effect is confirmed by the careful inspection of the Hα films for these flares obtained with the Crimean coronograph.

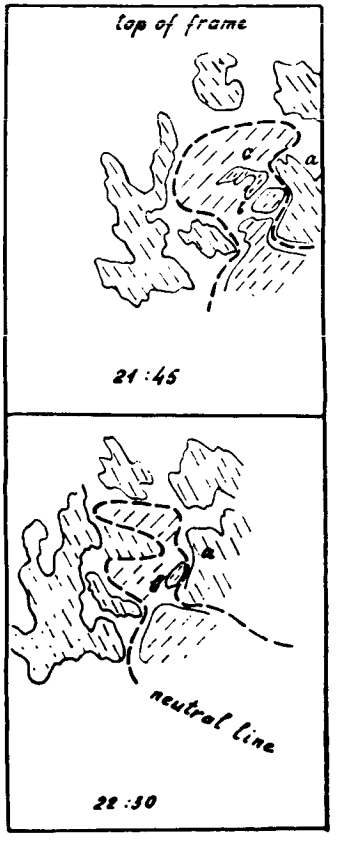

Fig. 1

The instability of the plasma near neutral points (being interpreted as a kind of pinch-effect) is also revealed on records of line-of-sight velocities which can be obtained simultaneously with the records of magnetic fields. These records show that neutral points of H are practically always (in 30 cases out of 37) found on the neutral lines of velocity maps—in places where two motions have opposite velocities. This fact can easily be explained if we assume that contraction or expansion of plasma exists in two predominantly opposite directions with some velocity gradient along these directions. This can be confirmed also by examination of Hα films and spectrograms of flares; Hα films of limb flares show the appearance of cumulative jets out of flares with some velocity gradient along the jet (**11**). Moreover, the observed run of hydrogen emission in the far wings of Balmer lines is in good agreement with the theoretical run of emission in a jet broadened by the velocity gradient along the jet (**12**). But sometimes the mechanism of Stark broadening describes quite adequately the observed broadening. Our recent experiments with laboratory pinch in hydrogen showed clearly that hydrogen emission is mainly broadened by Stark-effect when observing *across* the axis of the discharge tube and by velocity gradients when observing *along* the axis (**13**). (These gradients are obviously con-

nected with the "sausage instability" of pinch and with the ejection of plasma through the hole in electrodes at the phase of maximal contraction.) Therefore, the character of broadening of hydrogen emission in flares being interpreted as pinch-effect can depend on the directions of the line of sight and the neutral line. In this way we can probably explain the striking discrepancy between different spectral observations of flares.

The formation of cone-like tops in most limb flares and the ejection of plasma out of flares implies the idea that the heated flare plasma is trapped in a kind of magnetic bottle possessing a rather cusped field geometry (Figure 2). This assumption is in good agreement with the

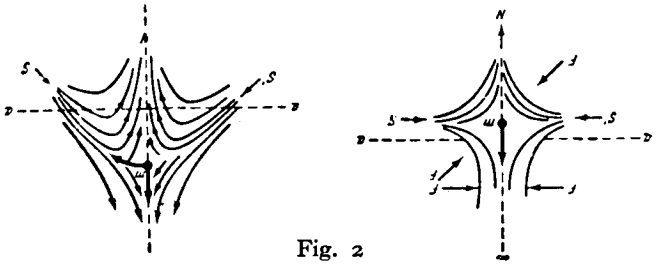

Fig. 2

magnetic field maps over flares in active groups, showing in the majority of the cases the conjunction of three polarities of considerable strength.

In conclusion we should like to say a few words on the fields of sunspots themselves. The vortex structure around some sunspots discovered by Hale (**14**), the spiral-like motions in some prominences (Roberts *et al.* (**15**)), the fine structure of magnetic fields inside *umbrae* of sunspots (**16**) and some considerations on the instability of pure longitudinal fields (**17**), lead to the

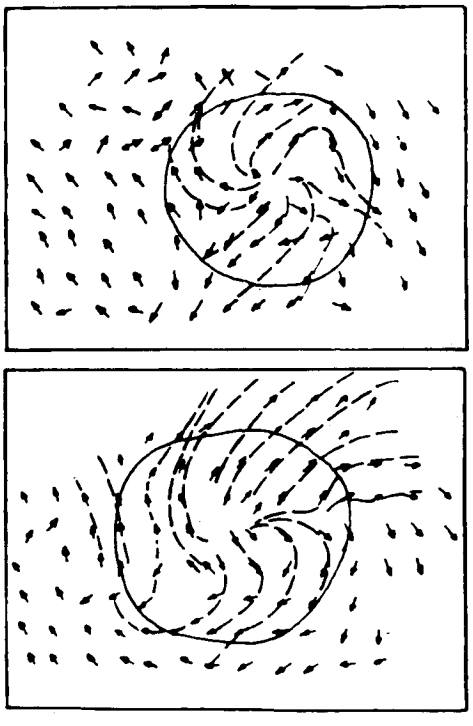

Fig. 3

conclusion that magnetic fields in active regions and especially the fields of sunspots may possess an *azimuthal* component, or that they have the character of a force-free field. To solve this question, Stepanov and myself made an attempt to record the *transverse* component of the magnetic fields in some spot-groups by using the modulating magnetograph (o, $\frac{1}{2}\lambda$). The reduction of these records together with the usual records for the longitudinal component is quite an elaborate process. As an example, Figure 3 shows the field of directions of the transverse component in a sunspot. In some active regions the azimuthal component is a well pronounced feature. The same conclusions have been recently obtained by Bumba, who found that the lines of force are arranged in the tubes coming out from the umbra in a form of spirals. The existence of the azimuthal component can explain the more or less permanent existence of such magnetic tubes of force as sunspots. At the same time, the rapid close approach of two tubes of force with opposite direction of the azimuthal field can eliminate the protection against instability and can lead to the pinch-effect as suggested by Gold and Hoyle (**18**) and Severny and Shabansky (**19**).

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DISCUSSION

H. W. Babcock. Dr. Severny's measurements of transverse magnetic fields are extremely important. The small field changes we observed three years ago may not necessarily be real, but may be due to seeing and instrumental effects. The present equipment has still to be improved. For this reason, perhaps no discrepancy at all exists between your and our measurements.

L. Biermann. How large is the observational error in the localization of the neutral points?

A. B. Severny. At the disk's center the error is about 10-20 seconds of arc. It becomes large near the limb.

G. Wallerstein. Could the depth distribution of the magnetic fields be determined by measuring the Zeeman effect in lines formed at different optical depths?

A. B. Severny. An effort is planned for determining the depth dependence of the fields by using the sodium D lines.

H. Alfvén. It certainly would be extremely important to measure the Zeeman effect in lines originating in different atmospheric levels.

3. SUNSPOT MAGNETIC FIELDS AND LOOP PROMINENCES

V. Bumba and *J. Kleczek*

A large active sunspot group was on the Sun during the summer of 1957. It lasted for five rotations and about 146 flares were observed in it. During its limb passages it was accompanied by a conspicuous loop activity.

One of the authors obtained magnetic maps of the group with the Crimean magnetograph. The loop activity is demonstrated by many photographs from different observatories.

We compared the loop configuration with the magnetic maps and with Hα filtergrams. Using daily photographs of the group, we could find any large changes in the group. One of several pictures we used for comparison is reproduced in Figure 1. It represents: *right part*—the loops and corona of 1957 June 28 (the ordinates of the green curve, dashed, are to be multiplied by two relatively to those of the red curve, dotted); *middle right*—plage area and spot group on June 29, that is one day later, since the active region was not well visible on June 28; *left part*—chromosphere (upper), magnetic map (middle) and spot group (bottom). A good agreement of a quiescent filament stretching across the spot group (upper left) with the line dividing both polarities (dashed in middle left) is obvious. Drifts of individual spots in the group are marked by dashed lines with arrows (bottom left).

It is evident from Figure 1, that the loops are anchored in the peaks of the photospheric magnetic field. The evidence is further stressed by the Hα filtergrams, in which the loops continue against the chromosphere like hazy streamers directly into the umbrae. The peaks for both main loop systems coincide with umbrae of the group. The loops studied by us should therefore represent magnetic tubes of force. It is worth noticing the twisting in the northern arm (denoted by C in Figure 1). It is in agreement with the model of the configuration of a spot magnetic field, proposed by one of the authors (V. Bumba, in the following paper).

A detailed discussion of the association of loops with the underlying photospheric field will be published in the *Bulletin of the Astronomical Institutes of Czechoslovakia.* See also *Observatory* **81**, 141, 1961.

4. CONFIGURATION OF MAGNETIC FIELDS IN SUNSPOT UMBRAE

V. Bumba

We have studied the behaviour of some Fraunhofer lines in umbra spectra, obtained at the Crimean Astrophysical Observatory. By measurement of the intensities of the individual components of the split line Fe I (6302·508Å) we came to the following conclusion: The enhancement of the π component in the Zeeman pattern could be simply explained by the configuration of the magnetic field in the umbra. We came to this idea after elaboration of a few tens of spectra for 19 umbrae in 31 different heliographic positions. We used the measured intensities of σ components for evaluation of γ, which is the angle between the line of sight and the magnetic field direction (Sears, 1913). The angle depends on the distance α of the spot from the centre of the solar disk (see Figure 1), according to the following empirical formula:

$$\gamma_s = \frac{90^\circ + \alpha \sin \alpha}{1 + \sin \alpha} \qquad (\alpha \text{ in degrees}) \qquad \text{(a)}$$

This is in good agreement with the following simple model: The lines of force are arranged in the tubes of force, coming from the umbra in form of spirals, the pitch of which rapidly increases with height. This means, that in the lower layers the lines of force form practically

a horizontal ring, while in the higher levels their arms are nearly perpendicular to the solar surface.

This model also explains some other effects observed in the spectra of sunspot umbrae, for example the 'disappearence of the characteristic serpent-like fringes' (obtained with the aid of polaroid strips and a quarter-wave plate, see Figure 2) in some lines (D_1, D_2, Na I, Ni I 5892·885 Å, etc.). This effect occurs in those regions of the umbra where the faint lines of Ti I and V I (with the large factor $(mg - m'g')$ split in a Zeeman triplet, have a strong π component. This effect is generally observed in large and dark P-spots ($H > 2500$ gauss) of those spot groups where the F-spot is replaced by a few small spots. The effect shows dependence on the orientation of the slit. At the same time the lines $H\alpha$ of H I, H_2 and K_2 of Ca II show a distinct splitting into the 'characteristic serpent-like fringes'.

After a detailed discussion of about 50 spectral lines in three spectral regions (D_1, D_2; 6302 Å; $H\alpha$) for a few spots we came to the following conclusion: The effect is dependent upon the configuration of the splitting pattern and the equivalent width of the spectral line, the components σ and π of which can blend with each other. All the lines therefore show that, in the given region of the spot, the field is nearly transverse with the angle determined by the formula (a) and that the proposed model of the field can therefore explain the 'disappearance of characteristic serpent-like fringes'. Also the distinct splitting of the $H\alpha$ and emission lines H_2, K_2 over the umbrae of the studied spots corroborates our model. These lines are formed only in the longitudinal field, that is in the region where the arms of spiral force lines are nearly perpendicular to the solar surface. Upon the umbral system, in which the lines of force in a tube of force are twisted in spirals with a pitch increasing with height, the penumbral lines of force are wound up. They stretch partially in the surrounding photosphere. The lines of force of this penumbral system have practically the form of a fan. The projected lines of force of the penumbral system are practically radial in relation to the centre of the spot. Their curvature however strongly increases at the boundary between umbra and penumbra (as proposed by Severny, 1959) and the lines wind up on the horizontal ring of the umbral system. It may be shown that the proposed model is in agreement with the classical results of the Mount Wilson observers.

A detailed discussion will be published in the *Bulletin of the Astronomical Institutes of Czechoslovakia.*

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5. THE SUN'S MAGNETIC FIELD FROM RADIO OBSERVATIONS

A. Hewish

Introduction. Magnetograph observations give a detailed picture of magnetic fields in the vicinity of the solar surface, but little is known about magnetic conditions at higher levels in the chromosphere and the corona. Some evidence about these regions may be obtained from radio measurements.

Local Fields. Two methods, based on observations of radio emission, have been used to estimate the field strength in the vicinity of active regions from measurements of the gyro-frequency. Eclipse data were used by observers at Pulkovo to isolate the radiation from a coronal condensation at wave-lengths ranging from 2 cm to 5 cm. The radio spectrum, combined with observations of the degree of circular polarization, gave a gyro-frequency consistent with a field strength of 360 gauss at a height of 50 000 km. A somewhat different

method, in which a particular emission spectrum was explained in terms of enhanced radiation at harmonics of the gyro-frequency, led Kakinuma to a value of 600 gauss at 20 000 – 30 000 km.

It has been suggested by Denisse and others that certain features of the spectrum of enhanced radio emission from active regions are most readily accounted for as synchrotron radiation from relativistic electrons spiralling in a magnetic field. The spectrum of this radiation has a broad maximum at a frequency proportional to HE^2 where E is the electron energy. Takakura has recently accounted for the radio spectrum in this way and with an assumed electron energy of the order of 0·1 MeV he obtains field strengths of 1000–2000 gauss in the chromosphere and 20-40 gauss in the corona.

It should be emphasized that the above estimates are tentative, since the spectrum of the radio emission cannot yet be understood with certainty.

The Polar Field. In the presence of a general bipolar magnetic field, thermal radio emission from the undisturbed solar corona will contain circularly polarized components whose sense is different in the northern and southern hemisphere. Smerd utilized a partial eclipse to isolate the component from one hemisphere and hence showed that the general field in the vicinity of the pole was less than 8 gauss.

More recently the method was refined by Conway who used an interferometer to separate components from the two hemispheres and showed that the field was smaller than 2·5 gauss — a value consistent with Babcock's measurements.

The Far-Out Field. The scattering of radio waves from the Crab nebula during their passage through the outer portion of the corona can now be detected to distances of the order of 100 solar radii. Measurements by Högbom and by Gorgolewski and Hewish have indicated that the ray scattering which occurs is due to a filamentary structure in which the filaments are aligned approximately radially. This result strongly suggests that the general magnetic field is radial to very great distances.

No evidence has been detected for the presence of looped lines of force, as in the common dipole field, but the radial alignment appears to be more disordered towards sunspot minimum. Such a magnetic field might be maintained by a general outflow of material from the corona, the outflow becoming less pronounced and hence more easily disorganized at sunspot minimum.

DISCUSSION

P. A. Sturroch. One may also infer the strength of the magnetic field in the corona from observations of Type II bursts. Each of the spectral lines of these bursts is often split into two, the splitting amounting to a few per cent. This may be ascribed to the excitation of the two resonance frequencies w_p and $(w_p^2 + w_g^2)^{1/2}$, where w_p and w_g are the plasma and gyro-frequencies, respectively. For a given model of density variation with height, one may infer the variation of the magnetic field strength with height. Field strengths of up to 30 gauss are indicated for the heights at which Type II bursts are first observed.

6. VARIATIONS OF THE SUN'S POLOIDAL MAGNETIC FIELD

M. Waldmeier

The polar streamers of the corona have generally been interpreted as magnetic field lines. These streamers are inclined to the radial direction at an angle β. The inclination β is proportional to the angular distance α from the Sun's axis: $\beta = c \times \alpha$. This law holds up to $\alpha = 25°$ or even up to $\alpha = 30°$. The constant c depends on the distance from the Sun's limb at which the inclination is measured. In addition, c may be different for the northern and the southern

polar region and depends also on the phase of the sunspot cycle. The measurements of the inclination have been obtained from large-scale photographs of the corona at the eclipses of 1952, 1954, 1955 and 1961. The following mean values of c have been observed:

Year	1952	1954	1955	1961
c	0·69	1·23	0·90	0·90

The measurements refer to the distances $r = 1{\cdot}1$ and $1{\cdot}3$ from the Sun's centre, and to both the northern as well as to the southern hemisphere, except for the 1961 corona which has shown the polar streamers in the northern polar region only. From the figures given, one may conclude that the inclination of the polar streamers increases as the sunspot minimum (1954) is approached and decreases again after sunspot minimum.

DISCUSSION

V. V. Vitkevitch: I wish to call attention to the Russian eclipse expedition back in 1936. Detailed description of the polar rays have been published in 1939 by E. J. Bugoslavskaya (Sternberg Dissertation). In Kiev further studies have been made of the polar and the equatorial rays and their connection with the Sun's magnetic field. I shall report about them at the Cloudcroft symposium.

7. FILAMENTARY CURRENTS AND THE MAGNETIC CONDITIONS ON THE SUN

H. Alfvén

It is an observed fact that cosmical plasmas often exhibit filamentary structures. Examples of such structures are prominences, polar plumes, coronal rays, supercorona (**1**, **2**, **3**) and filaments in interstellar clouds. Structures of these kinds have been studied recently by Kippenhahn and Schlüter (**4**), Jensen (**5**), Lüst and Zirin (**6**) and others.

Filamentary structure may be an essential and general property of low-density cosmical plasmas. This view can be supported by theoretical arguments. From analysis of a simple model, it has recently been concluded (**7**) that currents in a low-density plasma tend to approach

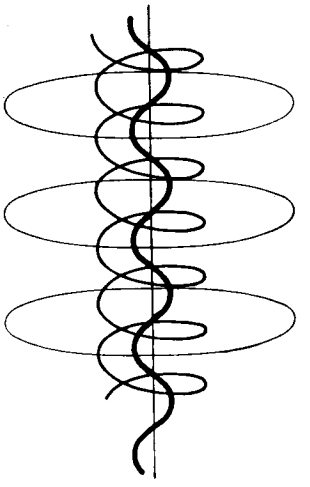


FIG. 1. Magnetic lines of force in a 'magnetic rope'.

a special configuration called 'filamentary current'. By the action of the filamentary current magnetic field lines are bunched into what may be called 'magnetic ropes', a term which is meant to draw attention to the twisted structure of the bunches.

A simple axially symmetric model is discussed in order to show what happens if in the presence of a magnetic flux ϕ_0 in the z-direction there is an electric current parallel to the z-axis. It is shown that the steady state is characterized by the presence of azimuthal currents

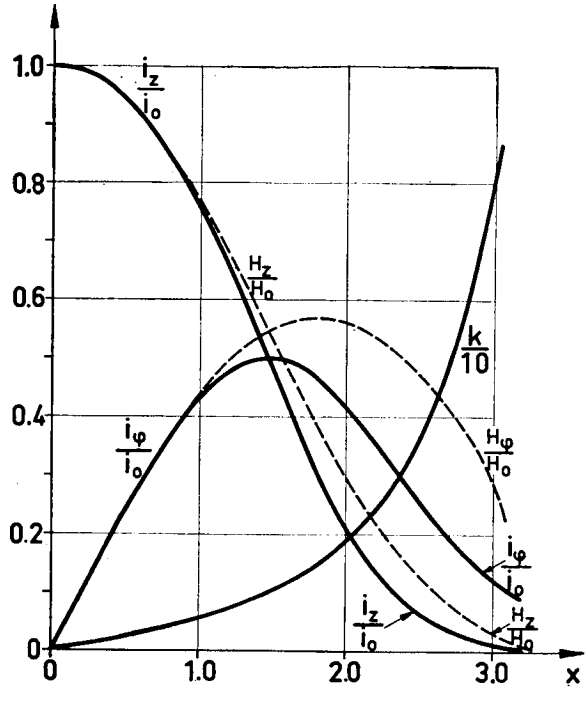
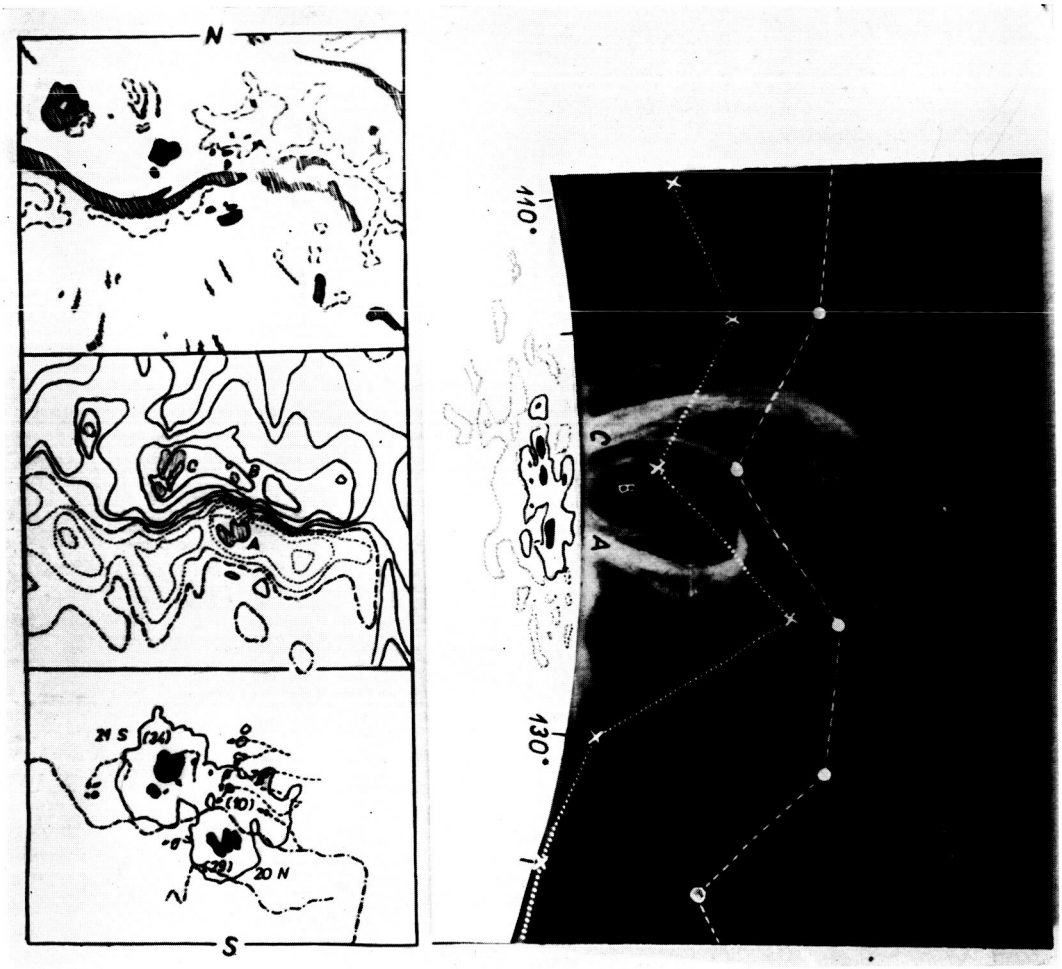


FIG. 2. Axial and azimuthal components of the magnetic field, H_z, H_ϕ, of the currents, i_z, i_ϕ, and the ratio $k = H_\phi/H_z$ as functions of the normalized radius $x = r/b$.

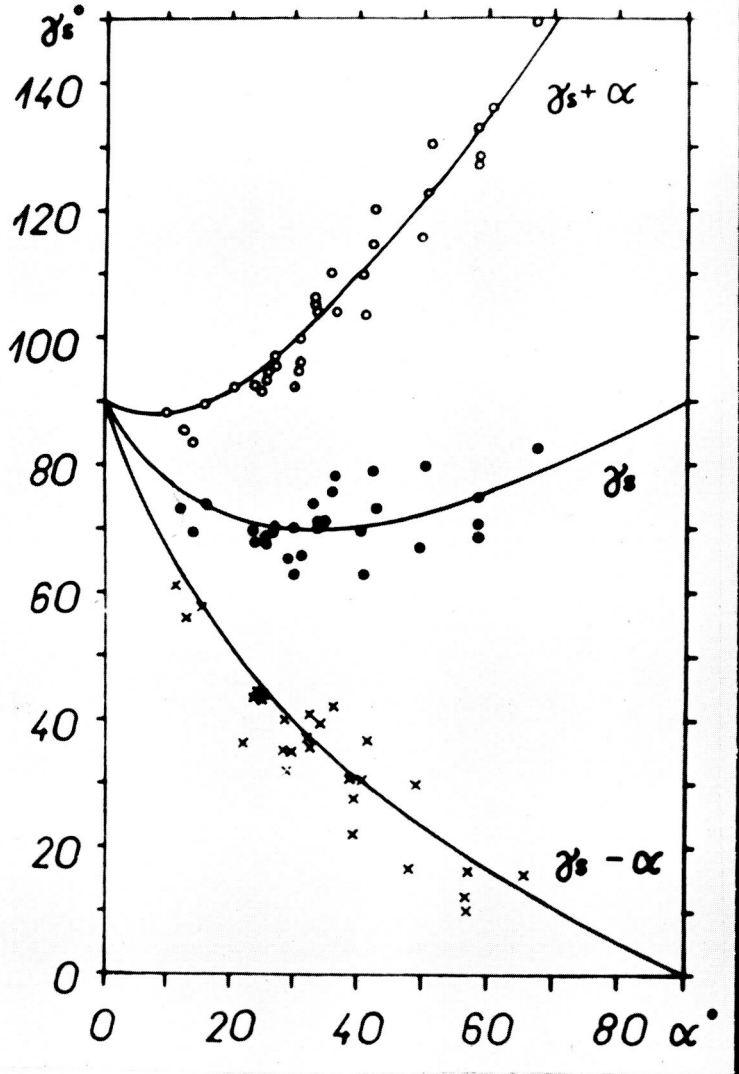
by which the whole flux is confined to a region around the axis. The pressure is assumed to be negligible so that only currents along the magnetic field need to be considered (force-free magnetic field). It is then found that in the steady state the magnetic lines of force form spirals that have a pitch angle which decreases with radius, so that far out the field lines are nearly circular (Figure 1). The total magnetic flux ϕ_0 in the z-direction is thus essentially concentrated within a certain radius from the axis. This radius is

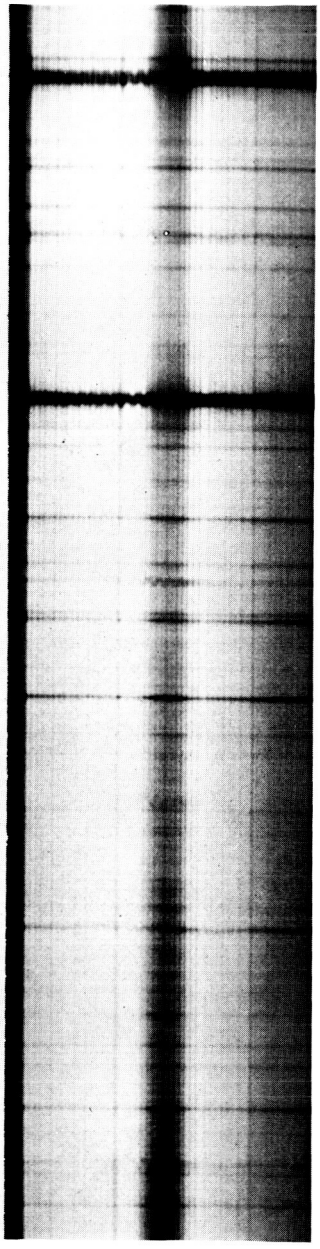
$$b = \left(\frac{\phi_0 c}{4\pi^2 \gamma i_0}\right)^{1/3}$$

where γ is a numerical constant close to 3·1 and i_0 is the current density at the axis. The configuration is in some respects similar to certain types of pinches studied in plasma experiments. Figure 2 shows the components of current and magnetic field as well as the quotient H_ϕ/H_z, which is a measure of the inclination of the field.



Paper 3. V. Bumba and J. Kleczek, Figure 1. For description see text.





Paper 4. V. Bumba, Fig. 1

Fig. 2

FIG. 1. Changes in the values of angles $\gamma_s + \alpha$, γ_s and $\gamma_s - \alpha$ with growing distance α between spot and centre of solar disk. The full curves were computed according to formula (a).

FIG. 2. Photograph of the spectrum of the umbra in closest vicinity of lines D_1, D_2 of Na I with distinct 'disappearance of the serpent-like fringes'.

The time necessary for formation of a filamentary current may in some cases be very long, and in cosmical plasmas we should expect not only configurations like that in the above model but also non-stationary configurations approaching the steady state or decaying from it after the electromotive forces producing them have disappeared.

The filamentary current has, especially during its formation, a tendency to collect matter towards the axis. Hence we should expect the formation of a filamentary current, which is not itself observable, to be accompanied by a formation of a filament of gas, which is observable.

In the cosmical applications the boundary conditions are generally much more complicated than in the simple model and correspondingly complicated magnetic patterns are to be expected. For example, when the magnetic lines of force from a sunspot branch to various parts of the surrounding photosphere or to adjacent spots, electric fields may produce a number of filamentary currents. The corresponding gas filaments collected by the currents may perhaps be identified with certain types of filamentary prominences (**8**).

Other filamentary structures in the corona are polar plumes, equatorial streamers and filaments in the outermost parts of the corona. It is conceivable that all these structures are associated with filamentary currents, which bunch the Sun's general field into magnetic ropes. If a bunching of field lines takes place also in or near the photosphere, the main magnetic flux may pass the photosphere in a number of thin bunches which are difficult to detect with Zeeman effect measurements. This would add another objection (**9**) to the earlier objections against the usual interpretation (**10, 11**) of these measurements.

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DISCUSSION

L. Biermann. For the sake of the audience I raise the question of the origin of the electric fields parallel to the magnetic field **H**, the $[\mathbf{v} \times \mathbf{H}]$ fields being always perpendicular to the magnetic field.

H. Alfvén. With the example of a growing sunspot one can show that induced electric fields will easily form along the lines of force, the electric conductivity across the lines of force being negligible.

8. COSMIC RAY FLARES

M. A. Ellison

This work has been carried out in collaboration with Susan M. P. McKenna and J. H. Reid.

The characteristics of the ten solar flares, which have generated cosmic ray increases recorded at ground level in the years 1942–60, are summarized and reviewed along with their geophysical effects.

The flares observed on the disk were notable for the flash of radiation in Hα, occurring in a time of the order of 2-3 minutes, large area of about 2000 millionths of the hemisphere, twin bright filaments crossing the spot group and running parallel to the 'magnetic axis,' and obscuration of the umbrae with highest field strengths. Type IV continuum radiation of high intensity and long duration was recorded during the last five events and outstanding S.I.D.s were recorded in all cases.

The disk co-ordinates of these flares show remarkable asymmetries in contrast to normal class 3 and 3+ flares. There is a strong preponderance west of the central meridian and five cases occurred close to the west limb. Easier and more direct paths to the Earth evidently exist for high-energy particles from western flares. The implications, in terms of radial magnetic fields in the Sun-Earth space, bent westwards by the Sun's rotation, are discussed.

All the flares except one occurred north of the solar equator (the exception was 2° S). It is suggested that the radial fields are deflected southwards by the Sun's motion towards the solar apex. High-energy particles do not appear to reach the Earth at the times of solar maximum activity.

Some of these flares were among the greatest ever recorded: others were not optically of great importance. It is concluded that the arrival of high-energy particles capable of producing cosmic ray effects at ground level is mainly determined by factors other than flare importance, such as the variable magnetic fields in the Sun-Earth space, the disk position of the flare and the magnetic field conditions in the sunspot region.

DISCUSSION

B. Bell. A comment with reference to the north-south asymmetry in the location of cosmic ray flares: the northern solar hemisphere produced a majority of great geomagnetic storms in the cycles 9, 15, 16, 17, 18 and 19; the southern hemisphere produced a majority in cycles 10-14.

H. Dodson-Prince. I wish to make a constructive suggestion that information regarding the magnetic field in the regions in which flares break out might be obtained by studying magnetic fields of filaments, both quiescent and active, since many flares occur very close to the borders of filaments which cross plages.

M. A. Ellison. There are also cases of flares occurring over umbrae without filaments.

H. Dodson-Prince. Yes, the cosmic ray flares and the polar cap absorption flares do occur over the umbrae of major spots, but the flares do not often start over the umbrae.

W. O. Roberts. Is the bending of the radial fields due to solar rotation sufficient?

M. A. Ellison. The convexity towards the west will increase with time, but we do not know the duration of these ordered radial fields. They probably may last a few days or at most a week. With regard to magnetic fields in the Sun-Earth space, I could not refer to all the evidences produced by the cosmic ray experts. Briefly, in the initial stages of these events high-energy particles arrive from the direction of the Sun or from a point west of the Sun.

At about the time of the maximum cosmic ray effect particles of lower energy begin to arrive isotropically from all directions. These latter are believed to reach us by diffusion and reflection from disordered plasma fields which are present as well as the ordered radial fields in the Sun-Earth space.

R. Lüst. I would like to say that the observed east-west asymmetry of the flares producing cosmic rays could also be explained by a twisted magnetic field which does not extend to the Earth.

9. THE SOLAR MAGNETIC FIELD IN PLAGE REGIONS

R. B. Leighton

The study of solar magnetic fields in plage regions using a photographic technique (Leighton, R. B., *Ap. J.* **130**, 366, 1959) reveals a close geometrical relationship between the bright emission of Ca^+ and magnetic fields. All regions showing magnetic fields of greater strength than the 20-gauss limiting sensitivity of the apparatus also show Ca^+ emission. The bipolar nature of spot groups is clearly revealed, even when no spots of one polarity are present. The field outside spots has a filamentary, patchy appearance. The widely scattered remnants of old spot groups can be seen as patches of magnetic field, each polarity covering a large area.

The fine structure of the magnetic field has been studied, and small tubes of force have especially been looked for. There is no evidence that the magnetic field passes between the granules in small disconnected tubes of force. Tubes as small as 2″ should have been visible if they were present, and if their field strength were as large as perhaps 50 gauss.

DISCUSSION

M. K. V. Bappu. I should like to ask whether the correlation between Ca^+ plage structure and the spatial magnetic field is of a type in which one can assume that actual changes in plage structure denote actual changes in the magnetic field spatial distribution. If it is so, Ca^+ spectroheliograms of the Kodaikanal series of several flares do not show any changes in the calcium plage structure before, during and after flares and, hence, may be considered to indicate that perhaps flares do not actually upset the magnetic field distribution pattern.

R. B. Leighton. Yes, there is a correlation between intensity and magnetic fields in the plages.

R. Michard. What is the magnetic difference between Ca^+ and Hα plages? Do the Hα plages represent regions of transverse and the Ca^+ plages regions of longitudinal fields?

R. B. Leighton. This we do not know.

A. B. Severny. According to W. E. Stepanov there should be a relation of that kind.

10. UN MAGNETOMETRE MESURANT LES CHAMPS MAGNETIQUES PERPENDICULAIRES AU RAYON VISUEL. APPLICATIONS A L'ETUDE DES CHAMPS RADIAUX AUTOUR DES TACHES

A. Dollfus et *J.-L. Leroy*

Un objectif de 10 cm de diamètre, pointé directement sur le Soleil, forme une image du disque solaire de 4 cm, agrandie à 10 cm par une lentille divergente. Un orifice circulaire placé dans le plan de cette image isole une petite portion du flux dans un champ de 5″.

La lumière recueillie de la sorte est ensuite analysée par un polarimètre photoélectrique de très grande sensibilité. A cet effet, elle traverse d'abord une lame de verre ou de celluloid très mince dont l'inclinaison variable permet de compenser la polarisation de la lumière créée par l'instrument. Cette lumière traverse ensuite un jeu de lames inclinées en dièdre donnant une polarisation connue très faible destinée à l'étalonnage de l'instrument. Elle subit ensuite l'effet d'un modulateur ayant pour objet de faire tourner brusquement et successivement, 30 fois par seconde, le plan de polarisation de 90° exactement.

Ce modulateur est constitué par deux lames quart d'onde croisées, dont les axes sont à 45° de la direction de la polarisation incidente. Un petit moteur fait défiler entre ces deux lames les ailettes d'une roue à secteurs équidistants, découpée dans une lame demi-onde.

La lumière séparée enfin en deux faisceaux par un prisme biréfringent, est recueillie par deux cellules photoélectriques à vide, sans multiplicateurs, à très grand rendement optique. Ces cellules opposent leurs courants, de sorte que seule la partie polarisée de la lumière incidente, envoyée alternativement sur chaque cellule, produit un courant modulé. L'amplificateur à résistance d'entrée élevée est suivi d'un redresseur synchronisé avec le modulateur.

Pointé sur le Soleil, l'instrument permet de déceler, en lumière blanche, des polarisations aussi faibles que un cent millième et de dresser des cartes qui donnent l'intensité et la direction de la polarisation sur des champs étendus, avec une résolution de 5″.

La polarisation de la lumière photosphérique est liée aux composantes des champs magnétiques perpendiculaires aux rayons visuels. Un champ transversal décompose en effet chaque raie de Fraunhofer en trois composantes, la raie centrale étant totalement polarisée, les deux composantes symétriques d'intensité moitié possédant une polarisation totale orthogonale. Comme la plupart des raies de Fraunhofer sont partiellement saturées, la composante centrale est plus atténuée par la saturation que les composantes latérales plus faibles, de sorte que l'égalité des deux intensités polarisées est rompue. Une faible proportion de lumière polarisée apparait de la sorte et l'ensemble de la lumière manifeste une polarisation globale, résultant de l'effet de chaque raie. Cette polarisation est dirigée dans la direction du champ magnétique à la profondeur où se forment les raies.

Pour les champs inférieurs à 500 gauss, elle est proportionnelle à $H^2\sin^2\alpha$, dans laquelle α est l'angle que fait la direction d'observation avec les lignes de force. Pour les champs supérieurs à 3000 gauss, la polarisation s'approche d'un maximum voisin de 10^{-2}.

La plus petite valeur décelable vaut 10^{-5} et correspond à un champ de 40 gauss.

Les facules du calcium observées près du bord du disque solaire montrent en lumière totale une faible proportion de lumière polarisée, voisine de 10^{-4}. On peut expliquer ce phénomène en admettant que ces facules délimitent un champ magnétique ayant les lignes de force sensiblement normales à la surface solaire, l'intensité valant environ 150 gauss.

Les taches solaires simples unipolaires montrent dans la pénombre un champ presque exactement radial, qui vaut de 500 à 1000 gauss au pourtour de l'ombre, environ 200 gauss à la limite de la pénombre et diminue vite au-delà de celle-ci. La divergence du flux montre que le gradient vertical du champ au niveau de la formation des raies vaut environ 0·5 gauss/km seulement. Observée près du bord du disque sous une forte inclinaison, une tache simple s'entoure d'un champ très dissymétrique; le champ limité au bord de la pénombre du côté du limbe, s'étend beaucoup plus loin du côté du centre du disque. Cette propriété peut indiquer que les lignes de force quittent la région de l'ombre sous une forte inclinaison et plongent à nouveau vers le bas, au-delà de la pénombre.

Dans les groupes de deux taches bipolaires, les lignes de force joignent généralement les ombres des deux composantes, selon des configurations habituelles aux pôles des aimants.

Les groupes de plus de deux taches donnent des configurations plus complexes, dans lesquelles les champs s'étendent loin des taches entre les composantes, mais quittent généralement celles-ci presque radialement.

Les éruptions solaires ne semblent pas toujours modifier sensiblement les configurations du champ, bien que des variations d'intensité et des changement d'orientation aient pû être observés. Babcock a rapporté les observations du champ magnétique longitudinal, relevées dans un grand groupe le 16 Juillet 1959. Ce même groupe a été observé à Meudon, le même jour, quelques heures avant l'éruption principale, de $6^h\ 30^m$ à 14^h T.U. Le champ transversal n'a manifesté aucune modification apparente pendant toute la durée des observations.

Les cartes du champ transversal montrent que les régions du champ longitudinal, appelées 'points neutres' par Severny, sont généralement le siège de champs magnétiques horizontaux souvent assez forts.

Le premier magnétographe a été étudié et réalisé à l'Observatoire de Meudon; de nombreuses observations ont été recueillies par J.-L. Leroy. D'autres appareils sont construits actuellement pour équiper différents observatoires.

11. MAGNETIC FIELDS IN PROMINENCES AT THE LIMB

H. Zirin

The forms and motions of solar prominences strongly suggest that they are governed by magnetic fields. The height distribution of quiescent prominences, for example, cannot be explained by any hydrostatic or hydrodynamic model, and we must conclude that they are supported by a magnetic field. The beautiful curved arches of loop prominences and their extraordinary fine structure clearly show them to be governed by a magnetic field.

Last year, encouraged by some preliminary observations made by A. B. Severny, we attempted to make measurements of magnetic fields in prominences with the magnetograph of the Crimean Astrophysical Observatory. The measurements were made using the line Hβ, which is bright in prominences and to which the phototubes are sensitive. Hβ is made up of 9 components, each of which has an anomalous Zeeman effect, which however, is approximately similar to the normal Zeeman effect. These lines fall into two components, one of which has a mean g-factor of 0·97 and the other, $g = 1{\cdot}13$. Since the splitting of these components is 0·3 cm^{-1}, small compared to the thermal broadening but large compared to the Zeeman splitting, the magnetograph responds as if to a line with g of 1·05. Thus, the splitting would be about 0·001 Å for a field of 100 gauss. A typical Hβ prominence emission line has a half-width around 0·75 Å.

Drift curves were made with the magnetograph across a number of prominences. Since Hβ is in absorption on the disk and in emission in the prominence, a field of a given sign produces opposite deflections above and below the limb. This characteristic flip-over, which we observe in most cases, shows us that we are really observing fields in prominences. I should like to show some of the better cases observed. I must point out that there are a number of sources of error. The first and most important is simply that during the period of observation there were not always large enough or bright enough prominences to observe. This fact, coupled with poor seeing, made it impossible to make real "magnetic maps" of the prominences. But it was at least possible to make several drift curves through the same point and confirm the observations.

Several active prominences were observed as well as a number of quiescents. I should like to show some of these. In some cases we made several drift curves across the same point, and these are superposed to indicate the amount of noise. In most cases the signal reverses at the limb, indicating that the prominence field has the same polarity as the disk field. It is evident from the tracings that we have considerable fields in both active and quiescent prominences. It is difficult to tell where the measurement of field stops and noise due to seeing on the instrument begins. Thus, one cannot say whether the variations of signal are due to actual field variations or not. In one case, however, the prominence was large enough to make a 'magnetic map'. In this case it is clear that the distribution of magnetic field in the prominence is different at different points.

The quantitative determination of the field intensity is a difficult problem. The signal measured is proportional to $HI\mathrm{d}I/\mathrm{d}\lambda$, where $\mathrm{d}I/\mathrm{d}\lambda$ is the slope of the emission line at the point of measurement. The calibration is made by observing the solar rotation; in this measurement we are using an absorption line, with intensity and shape different from the prominence emission line. It is necessary to take into account all of these factors in calibrating the observations.

After reduction we find that fields in active prominences are around 150 gauss and in quiescents, around 50 gauss. The former is not an unexpected result; the latter is larger than one might expect. It shows that in most cases, the magnetic field energy is far greater than the pressure energy. This is not unreasonable.

We hope to continue these observations with a special magnetograph to be built at Climax.

DISCUSSION

C. de Jager. Did Dr Dollfus make observations of transverse and longitudinal fields?

A. Dollfus. Not yet.

M. Minnaert. I wish to stress the fact that the neutral point of a longitudinal field does not necessarily mean the non-existence of a transverse field component.

A. B. Severny. In the inter-penetration of two fields the neutral points can be common to both the transverse and the longitudinal fields.

M. Minnaert. We can be sure of that only after having performed measurements in both components separately.

A. Dollfus. In many cases the corona structures run parallel to the Hα structures. This means that the latter represent the distribution of magnetic fields.

C. JOINT DISCUSSION

ON

THE DEMANDS MADE ON CELESTIAL MECHANICS BY THE PREPARATION OF EPHEMERIDES

Monday 21 August 1961 at 14^h00^m

ORGANIZING COMMITTEE: F. Arend, D. Brouwer, R. L. Duncombe, W. Fricke (Chairman), W. Markowitz.

REPORT OF THE PROCEEDINGS

R. L. Duncombe and *G. A. Wilkins*

Introduction

The prepared contributions to the Joint Discussion follow this report in the order of their presentation; one paper will shortly appear in print elsewhere and so only a brief summary is given here. In this report of the proceedings we have endeavoured to give a more connected account of the discussion than would result from a verbatim account of the remarks made after each paper. Of necessity, we have made some omissions and some additions, but we hope that those who were present will find this to be a fair report and that readers who were not present will find it a useful introduction to the papers themselves.

The reference numbers in this report refer to the papers presented during the discussion; the authors and brief titles are as follows:

1. *Wilkins.* Computation of the lunar ephemeris.
2. *Eckert* and *Smith.* Numerical development of harmonic series for the Moon.
3. *Brouwer.* Application of von Zeipel's method to the lunar theory.
4. *Duncombe.* Requirements for planetary ephemerides.
5. *Clemence.* Theories of the motions of Mars and the Earth.
6. *Kovalevsky.* Nécessité d'une nouvelle théorie des quatre gros satellites du Jupiter.
7. *Herget, P.* Ephemeris calculations for minor planets.
   The complete paper will appear in the *Astronomical Journal.*
8. *Rabe.* Improvement of astronomical constants in ephemeris computations.
9. *Markowitz.* Astronomical and atomic time in the observation of artificial satellites.

W. Fricke, President of Commission 4, was chairman for the first half of the discussion (papers 1-5), and D. Brouwer, President of Commission 7, was chairman for the second half (papers 6-9).

As this list shows the contributions ranged over most of the major aspects of celestial mechanics and of the preparation of ephemerides, but they were only indirectly related to the title of the discussion. An underlying theme of most of the papers was, however, the changes being brought about in these subjects by the widespread use of electronic computers and, less directly, by the introduction of new techniques of observation. Thus computers are now being used at all stages—in the development of the series expansions of fundamental theories (**2, 3, 5**), in the evaluation of these series (**1, 4**), in the direct numerical integration of the equations of motion (**7**), and in the comparison of observation and theory (**6**). Although computers have eliminated much of the drudgery of numerical calculation from celestial mechanics their efficient use requires the introduction of new forms of ephemerides (**1, 4**) and it was even suggested (**4**) that they may eliminate completely the need for extensive fundamental ephemerides.

The Moon

In order to satisfy the immediate requirements for an accurate ephemeris of the Moon for planning purposes in astronomy and space research, H.M. Nautical Almanac Office has undertaken the continuation of the improved lunar ephemeris for the period 1972–81. Wilkins (**1**) indicated the techniques that are to be used, and drew attention to a recurrence relation, first suggested by Sadler, that leads to a very efficient method for the evaluation of harmonic series that is particularly suited to comparatively slow computers. In reply to a question by Hertz, Wilkins stated that there were no definite plans to prepare an ephemeris in rectangular co-ordinates but that this would be done if the demand were great enough.

The current lunar ephemeris is likely to be superseded in a few years time by one based on the re-development of the Hill-Brown theory to higher accuracy at the IBM Watson Scientific Computing Laboratory (**2**). Brown has estimated that his original development for the main problem of the lunar theory required some nine thousand man-hours of computing, and so it will be realized that this re-development would not have been attempted without the aid of electronic computers. It is a tribute to the accuracy of the original work that Eckert afterwards stated, in reply to Brouwer, that so far no significant errors in the coefficients of the periodic terms had been found. Even so the last word on the lunar theory has not yet been uttered and Brouwer (**3**) described the current investigations at Yale into Delaunay's theory and the possible applications of von Zeipel's method.

The Planets

The current intensive work at the U.S. Naval Observatory on the theories and ephemerides of the planets was reviewed by Duncombe (**4**) and the progress with his new theories of Mars and the Earth was described by Clemence (**5**). In opening the discussion on the first of these papers Fricke considered that ten years ago such a paper would have been incredible, and he later drew attention to the great importance of the new theories, particularly that for the Earth. The results already obtained, together with those that we may confidently expect in the next few years will give astronomers new, or revised, theories of the motions of all of the planets—an achievement that is comparable with that of Newcomb and Hill at the end of the last century.

Duncombe also pointed out that the new techniques of radar astronomy now meant that the distances and line-of-sight velocities of the planets, as well as their directions, can now be observed. Already more precise ephemerides are needed for comparison with the observations, and significant improvements in our knowledge of the solar parallax (see below) and of the motion of Venus are being obtained.

Sir Harold Jeffreys asked whether the anomaly about the rate of change of the obliquity was cleared up yet. Clemence replied that the obliquity was varying more rapidly than was expected and that this might be due to the fact that only a first-order theory is now used, and that it will be of interest to see the results from the second-order theory of the Earth.

Machine-readable ephemerides

Duncombe (4) drew attention to the growing volume of planetary ephemerides that were available on punched cards at the U.S. Naval Observatory and elsewhere. (A committee, under the chairmanship of Eckert, is at present endeavouring to draw up and circulate a consolidated list of all suitable astronomical data, including star catalogues, that are available in machine-readable form.) Much of these data are, however, in the same format as the printed ephemerides and both he and Wilkins (1) considered the possibility of preparing ephemerides that were specially designed for use with electronic computers. Such ephemerides would not only be 'machine-readable', *i.e.* on punched cards or magnetic tape, but would also be 'computer-orientated' so as to require the minimum amount of storage space consistent with ease of use. The discussion that followed these papers showed that the need for such ephemerides is very real and pressing.

Clemence and Eichhorn both asked about the number of terms that would be required in a Chebyshev expansion for the Moon at intervals greater than two days. Wilkins said that the number of terms increased rapidly with the ratio of the interval to the periods of the harmonic terms concerned, and was unable to give any firm estimates. It seems that 12-15 terms would be required for an interval of 10 days and at least 20 terms for 20 days. Sconzo suggested that Hermite polynomials might prove to be more useful.

For the planets Hertz pointed out that heliocentric ephemerides could be given at wider intervals than geocentric ephemerides and he also enquired whether it would be possible to devise a theory that would give the Chebyshev expansions directly. This possibility had been considered by Wilkins but he doubted whether it was practicable, particularly as each Chebyshev expansion is valid only for a finite interval.

Satellites

Kovalevsky presented his paper (6), on the need for a new theory of the first four satellites of Jupiter, in French and then gave an excellent summary in English. He emphasised the difficulties of this theory and made a plea for modern observations of these satellites, which, in common with other natural satellites, have been largely neglected by astronomers over the past half century. In response to this plea Brouwer stated, firstly, that he would look into the collection of Yale plates to see if more observations were available and, secondly, that Jackson was preparing to make a new series of observations at Mount Stromlo. Marsden stated that he had tried to make observations of the four satellites of Jupiter with the catalog camera at Yale but that not all the images were measurable. Strand indicated that a series of observations might be undertaken by the U.S. Naval Observatory. Ashbrook pointed out that his collection of approximately 8000 eclipses of the satellites of Jupiter dated back to the seventeenth century and did not include any new data. Herget mentioned that among modern observations is a series by Aitken who measured the positions of the satellites with respect to each other. In reply to a question about the usefulness of such relative positions of satellites Jeffreys stated that he thought that about two-thirds of the observations of Saturn's satellites that the Struve's used were measures of one satellite from another. In reply to another question it was stated that timing usually presents no difficulty as one second was good enough, but that it was difficult to obtain accurate positions of the satellites.

Minor planets

Herget (7) reported on some recent work to improve even further the methods adopted for the ephemeris calculations for minor planets. It is planned to compute perturbations by the variation of elements using a set which has no reference to the perihelion. This requires the computation of the position of a moving 'departure point'. There are no adverse circumstances, either in the case of a very small or a moderately large eccentricity or inclination. A corresponding set of unknowns for differential correction has the property that they are well separated under these same circumstances. In the discussion of this paper both Herrick and Musen indicated that they had also considered similar sets of elements.

Fundamental constants

After discussing the need for ephemerides of high precision Rabe (8) turned to the consequences of the introduction of space-age methods for the determination of astronomical constants. This paper, as well as that of Duncombe (4), was followed by a lengthy discussion of the results of the recent radar observations of Venus. In response to questions Duncombe stated that, while these observations have added significantly to the evaluation of the astronomical unit, perhaps too much weight has been assigned to them and many more observations are required. Clemence remarked that the 1958 determination of the solar parallax from radar echoes of Venus has been withdrawn. Brouwer pointed out that the Soviet radar-echo result was close to the latest American results. Blitzstein quoted a value of the solar parallax of 8″·79460 obtained from the latest RCA observations of the distance of Venus. Herrick emphasised that the ratio of the light-second to the astronomical unit was more important than the solar parallax itself.

Time

The influence of the introduction of new techniques was also apparent in the last paper by Markowitz (9) who considered the possible uses of artificial satellites in the study of time and who emphasised that caesium-beam oscillators can be used to define a system of time much more precisely than Ephemeris Time can be determined. In the discussion that followed it was clear that confusion is sometimes caused by the use of the term Ephemeris Time for the independent variable of the equations of motion as well as for the systems of time defined by the motions of the Sun and Moon. Herrick suggested that it would be better to use the term 'gravitational time' for the former. Clemence was of the opinion that it was sufficient to use the abbreviation E.T. with appropriate subscripts to distinguish special systems of Ephemeris Time; such a suggestion has been adopted by Commissions 4, 17 and 31. Brouwer emphasised that at present we have no check on the lunar theory and that he thought that there was a need for an artificial Earth satellite which could be accurately observed in order to check the values of Ephemeris Time now determined from the Moon. Markowitz suggested that more transit-circle observations of the Sun were needed and he also stated that Commission 31 has now recommended the use of artificial Earth satellites for use in time determinations.

1. THE COMPUTATION OF THE LUNAR EPHEMERIS, 1972–81

G. A. Wilkins

The computation of the lunar ephemeris from Brown's theory for the years 1972–81 is being undertaken by H.M. Nautical Almanac Office and we consider that some of the techniques that are to be used are of general application. The principal task is the evaluation of the longitude, latitude and parallax from multiple-harmonic series, each of which contains several hundred terms, and we have endeavoured to find methods that are efficient for use with electronic computers. The secondary task is to prepare, from these fundamental values, ephemerides that are in the most suitable form for use by astronomers: in addition to the published hourly ephemeris of apparent right ascension and declination we are proposing to prepare a corresponding ephemeris at a wide interval that is designed for use in automatic computation.

The evaluation of the harmonic series

The major part of the summations of the terms in Brown's Tables (1) was carried out up to the year 2000 by the Office during 1929 using simple punched-card tabulating machines. Some of this work may be used to provide independent checks on the new calculations, but its accuracy is limited by the approximations and omissions of the Tables. The techniques that were used by Eckert and his collaborators to compute an improved lunar ephemeris for the years 1952–71, using the IBM Selective Sequence Electronic Calculator (S.S.E.C.) together with an IBM 604 (and later an IBM 701), have already been fully described (2) but more direct methods requiring simple programs are suitable for modern computers especially if positions are needed mainly for isolated instants. It still seems to be true, however, that when ephemerides are required for many years at a time considerable economies in computer time can be achieved with only a moderate increase in the complexity of the computer program, provided that the computer has adequate storage capacity. In particular we have developed a new technique for the evaluation of sums of terms of the form $K \sin(a + nb)$ in which K, a, b may be treated as constant over a wide range of values of n. We are also of the opinion that there is still a place for the technique of subtabulating the sums of groups of long-period terms; when an electronic computer is used subtabulation by bridging-difference techniques (3) can take place between the calculation of each pivotal value and so no time is wasted by output and re-input of the pivotal values. The use of electronic computers for subtabulation enables wider intervals to be used, and so the fundamental values of longitude, latitude and parallax may be calculated at an interval of 16 hours instead of 12 hours, although here the saving of one quarter of the computing time is perhaps not significant when very fast computers are used.

The secular and additive effects are negligible for the many small terms of the series and so for these it is only necessary to evaluate the sums of groups of terms of the form $K_r \sin(a_r + nb_r)$ for $n = 0, 1, 2, \ldots N$ and $r = 1, 2, \ldots R$, say. Instead of evaluating all the terms for one date at a time, partial sums $S_r(n)$ for all $N + 1$ dates are built up one term at a time by using

$$S_r(n) = S_{r-1}(n) + T_r(n), \text{ for } n = 0, 1, 2, \ldots N,$$

where the term values $T_r(n)$, apart from $T_r(0)$ and $T_r(1)$ which are calculated directly, are given by the second-order recurrence relation

$$T_r(n) \equiv K_r \sin(a_r + nb_r) = 2 \cos b_r \, T_r(n-1) - T_r(n-2).$$

This relation only requires one multiplication and one subtraction for each new term value and so leads to a very simple and efficient program. The errors in using this recurrence relation arise from the accumulation of rounding errors at each step and from the rounding error in the adopted value of the constant $2 \cos b_r$. The former error varies as $n^{1/2}$ cosec b and the latter as n cosec b, but provided that sufficient guarding figures are retained the relation can be

used over very long ranges. In practice, the storage capacity of the computer limits the range since $4R + N + 1$ storage locations, in addition to those for the program itself, are required if $N + 1$ sums for R terms are to be formed. Further N may be limited by the necessity to provide reasonably frequent checks on the accurate working of the computer and to reduce the number of guarding figures required. The overall accuracy of the results is judged by comparing the first sum ($n = 0$) of a new cycle with the final sum ($n = N$) of the previous cycle.

Machine-readable ephemeris

As electronic computers are being more widely used in astronomy so the printed ephemerides are becoming of less value. For example, the comparison of observation with theory is now usually carried out on a computer and we have found it necessary to prepare a machine-readable ephemeris of the Moon for the reduction of observations of occultations of stars. At first this ephemeris will be available on punched cards, but later it could be transcribed on to magnetic tape.

To reduce the amount of storage space required, both physically and in the store of the computer, it seems to be desirable that the ephemeris be at the widest convenient interval. Instead of giving differences, or modified differences, or the coefficients of economised polynomials we are giving for each interval the coefficients in the expansion of the function in terms of Chebyshev polynomials (4). In *The Astronomical Ephemeris* the apparent positions of the Moon are tabulated at an interval of 1 hour, but by using a Chebyshev expansion of the sixth degree an interval of 2 days can be used—this is much greater than the interval at which the differences begin to diverge. Longer intervals require a disproportionately large increase in the number of terms but may be suitable for very fast computers.

These Chebyshev expansions have the advantages that they give the maximum amount of information in the minimum number of terms and digits, and that the series can be truncated at any point if less than maximum accuracy is required. The expansions are of the form

$$f(x) = \tfrac{1}{2}a_0 + a_1 T_1(x) + \ldots + a_r T_r(x) + \ldots + a_n T_n(x), \text{ for } -1 \leqslant x \leqslant +1,$$

where $T_r(x) = \cos(r \cos^{-1} x)$. These expansions are evaluated by the use of the recurrence relation

$$b_r = a_r + 2x\, b_{r+1} - b_{r+2},$$

for $r = n, n-1, \ldots, 1, 0$; it is subject to the initial conditions that

$$b_{n+1} = b_{n+2} = 0;$$

then

$$f(x) = \tfrac{1}{2}(b_0 - b_2).$$

This is only slightly more complicated than the usual 'nesting' algorithm for the evaluation of a power series, and the number of machine instructions and the time taken are only slightly greater.

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3. H.M. Nautical Almanac Office. *Subtabulation*, pp. 38–54. London: H.M. Stationery Office. 1958.
4. National Physical Laboratory. *Modern Computing Methods*, pp. 71–79. London: H.M. Stationery Office. Second edition, 1961.

2. RESULTS TO DATE IN THE NUMERICAL DEVELOPMENT OF HARMONIC SERIES FOR THE CO-ORDINATES OF THE MOON

W. J. Eckert and *H. F. Smith, Jr.*

The problem is to find for the Moon expressions of the form

$$\begin{aligned} x &= \Sigma\, x_\xi \cos\xi & \xi &= \{p_\xi g + q_\xi c + r_\xi m + s_\xi (1-m)\}\, nt + B_\xi \\ y &= \Sigma\, y_\xi \sin\xi & &= A_\xi\, nt + B_\xi \\ z &= \Sigma\, z_\xi \sin\xi \end{aligned} \qquad (1)$$

that satisfy identically the differential equations

$$x\mathrm{D}y - y\mathrm{D}x + (x^2+y^2) = \mathrm{D}^{-1}\left(x\frac{\partial\Omega}{\partial y} - y\frac{\partial\Omega}{\partial x}\right) + C_1$$

$$\tfrac{1}{2}\mathrm{D}^2(r^2) - \tfrac{1}{2}\{(\mathrm{D}x)^2 + (\mathrm{D}y)^2 + (\mathrm{D}z)^2\} + \tfrac{1}{2}(x^2+y^2) =$$

$$\Omega + \left[r\frac{\partial\Omega}{\partial r}\right] - \mathrm{D}^{-1}\left(\frac{1}{n}\frac{\partial\Omega}{\partial t}\right) + 2\mathrm{D}^{-1}\left(x\frac{\partial\Omega}{\partial y} - y\frac{\partial\Omega}{\partial x}\right) + C_2 \qquad (2)$$

$$x\mathrm{D}^2z + z(-\mathrm{D}^2x + 2\mathrm{D}y + x) = x\frac{\partial\Omega}{\partial z} - z\frac{\partial\Omega}{\partial x}$$

$$-\tfrac{1}{2}\mathrm{D}^2(r^2) + 2(\text{LHS 2nd eq.} - \text{LHS 1st eq.}) + \left(\frac{a}{aa_0}\right)^3\frac{1}{r} = \left[r\frac{\partial\Omega}{\partial r}\right]$$

These are the Euler-Hill-Brown equations.

The method of solution is to substitute an approximate solution of form (1) into equations (2) and to obtain from the residuals corrections δx_ξ, δy_ξ, δz_ξ; δc, δg. The corrections are applied to the approximate solution and the process repeated.

At the last meeting of the IAU we reported that we had substituted, with the IBM 650, Brown's solution into the differential equations and that we were starting the solution of the variation equations. The solution of the variation equations has proved more troublesome than we hoped. We shall discuss this problem briefly.

By neglecting only the squares of the corrections δx_ξ, δy_ξ, δz_ξ, δc, δg it is possible to obtain a set of variation equations of considerable accuracy. We prepared a program for the IBM 650 that gives these coefficients for any required argument. This was done for the results of the IBM 650 substitution.

It was decided to solve this set of 3500 equations in as many unknowns by successive approximations. The approximate values for the unknowns are determined from limited sets of approximate variation equations.

The following approximate equations are obtained by neglecting powers of $(x-1)$, y, z above the first

$$\delta x_\xi = \frac{2A_\xi\, x_\xi\, \delta A_\xi - F_\xi}{1 - A^2_\xi}, \text{ where } \delta A_\xi = p_\xi\, \delta g + r_\xi\, \delta c$$

$$\delta y_\xi = -\frac{y_\xi \delta A_\xi + E_\xi + 2\delta x_\xi}{A_\xi} \qquad \delta z_\xi = \frac{2A_\xi\, z_\xi\, \delta A_\xi - G_\xi}{1 - A^2_\xi} \qquad (3)$$

These equations are obviously indeterminate

$$\text{in } y \text{ for } A_\xi \approx 0 \text{ and in } x, y \text{ and } z \text{ for } A_\xi \approx 1.$$

However, since many of the divisors are not very small we tried the iterative process with these equations. The results indicated that a more sophisticated treatment of the small divisors was necessary.

Figures 1 and 2 show the relations between terms with small divisors. In Figure 1 we have arranged a group of related arguments according to multiples of l and F. Since l and F have motions of 0·9915 and 1·004 respectively, any argument with a small motion will be associated with others as shown in the diagram. Alternate columns represent arguments for x, y terms and for z terms.

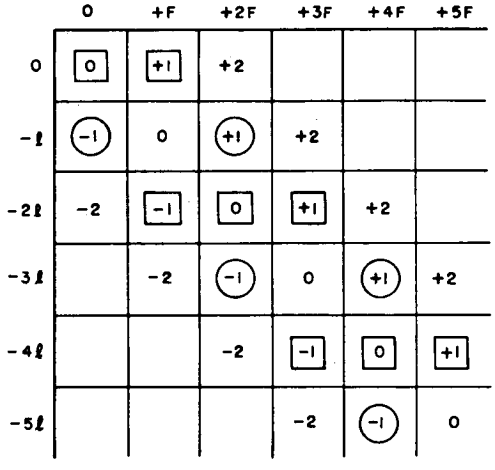

Fig. 1

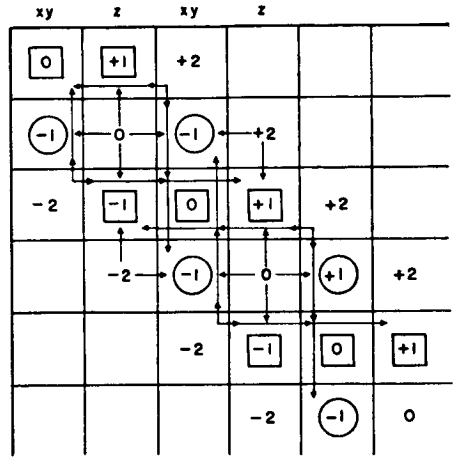

Fig. 2

Figure 2 shows the effect of nearby terms on terms with small divisors. We must also consider the arguments differing by $\pm 2D$ from those on the diagram; these can be thought of as occupying the layers above and below the diagram in a 3-dimensional lattice. Arguments differing by D and by l' are not troublesome because of the small parameters α and e' that accompany them.

To improve the equations we have used a 3-dimensional generalization of a device used by Brown in the one-dimensional case, namely the elimination of the neighboring arguments that do not have small divisors but that strongly influence those that do. The remaining core contains about 20 terms closely inter-dependent but with good separation from the rest of the matrix. We invert the matrix of the equations in the core. For the solution of the full set of variation equations we use for each approximation the values for the terms without small divisors from the equations similar to equations (3) and for the terms with small divisors the values from the inverted matrices.

In this manner we have been able to reduce the residuals in a systematic manner which looks reasonable. This is a necessary but not a sufficient condition. In order to evaluate the process it will be necessary to substitute the corrected solution into the differential equations at least once and to examine the behavior of the residuals.

As planned initially we have coded the substitution for a larger and faster machine, the

IBM 7090. The substitution involves the repeated use of two programs. The first run of the first program gives all second-order product series of the lunar co-ordinates and the left-hand sides of equations (1) - (3); subsequent runs give successively the product series of orders 3, 4, ... The other program computes the Ω terms from the lunar product series. We have used the programs to compute the LHS and the Ω_2 terms.

The new program gives:

(i) an independent check of the IBM 650 substitution;

(ii) a complete substitution in a few days;

(iii) greater over-all accuracy;

(iv) increased accuracy for arguments with small divisors.

The present coding aims at an accuracy of $1'' \times 10^{-5}$ for terms without small divisors, and for an omitted term to be as large as $0''{\cdot}001$ the period would be greater than 2000 years. If the solution to this precision appears to warrant higher precision the coding could be easily modified and the question would be a simple one of economics.

Among the more interesting parts of this work is the determination of the motions of the perigee and node. In view of the fact that the IBM 7090 substitution is almost ready we have decided not to prepare semi-definitive values of these quantities even though we feel that this could be done with a reasonable amount of work from the results at hand. Present indications are that the motion of the node given by Brown in the Memoirs (1) will be changed very little while the motion of the perigee may be increased by thirty seconds per century. Terms not included in the Memoirs and discussed later by Brown (2) account for about half the expected change.

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3. OUTLINE OF AN APPLICATION OF VON ZEIPEL'S METHOD TO THE LUNAR THEORY

Dirk Brouwer

The main problem of the lunar theory has been solved by many investigators by various methods. Yet the problem remains of sufficient interest to encourage further efforts. An investigation in progress at the Yale Observatory has as its principal aims: (*a*) evaluating the effectiveness of the von Zeipel method for obtaining the solution; (*b*) examining the causes of the slow convergence according to powers of n'/n in Delaunay's theory and, if possible, finding a remedy for this defect.

Applications of von Zeipel's method have been presented in several recent papers (1, 2); hence only a minimum of detailed explanation will be given here. The principle of the method is to eliminate the periodic terms in a single transformation or a sequence of transformations with the ultimate object of obtaining a final Hamiltonian that is a function of the variables corresponding to Delaunay's L, G, H.

In dealing with the lunar theory it may be advisable to start with the problem in which the inclination of the Moon's orbit and the eccentricity of the Sun's orbit are ignored, and in which the disturbing function is reduced to its principal part. The third limitation amounts to putting the ratio of a/a' equal to zero. The solution of the problem so simplified should yield those

terms in the Moon's motion that are independent of Delaunay's $\gamma = \sin \frac{1}{2}I$, of e', and of a/a'. The equations may then be put in the form

$$\frac{dx_j}{dt} = \frac{\partial F}{\partial y_j}, \qquad \frac{dy_j}{dt} = -\frac{\partial F}{\partial x_j}, \quad j = 1, 2$$

with

$$x_1 = L = (\mu a)^{1/2}, \qquad y_1 = l,$$
$$x_2 = G = L(1 - e^2)^{1/2}, \quad y_2 = g + h - \lambda',$$

in which L, G, l, g, h are the well-known Delaunay variables, while

$$\lambda' = \nu t + \lambda_0'$$

is the Sun's mean longitude, ν and λ_0' being constants. The designation ν is used for the Sun's mean motion, usually designated by n'.

The Hamiltonian F is

$$F = F_0 + F_1.$$

$$F_0 = \frac{\mu^2}{2x_1^2} + \nu x_2, \qquad F_1 = \frac{1}{4}\frac{\nu^2}{n^2}\frac{\mu^2}{x_1^2}\left\{\frac{r^2}{a^2} + \frac{3r^2}{a^2}\cos(2f + 2y_2)\right\},$$

in which f is the true anomaly and r the radius vector. Throughout the symbol n will stand for μ^2/x_1^3.

F_1 can be expressed explicitly in terms of y_1, y_2 by expansions in elliptic motion,

$$F_1 = F_{1a} + F_{1b},$$
$$F_{1a} = \frac{1}{4}\frac{\nu^2}{n^2}\frac{\mu^2}{x_1^2}\left\{1 + \frac{3}{2}e^2 + \frac{15}{2}e^2\cos 2y_2\right\},$$
$$F_{1b} = \frac{1}{4}\frac{\nu^2}{n^2}\frac{\mu^2}{x_1^2}\left\{\sum_1^\infty C_j \cos jy_1 + \sum_{-\infty}^{\infty}{}' D_j \cos(jy_1 + 2y_2)\right\}.$$

The symbol Σ' indicates that the term with $j = 0$ is to be omitted; this term is included in F_{1a}.

It would be possible to eliminate in a single von Zeipel transformation all the periodic terms having y_1 and y_2 in the arguments. However, terms with y_2 only in the argument will produce a development in powers of ν/n, while terms having y_1 in the argument lead to a development in powers of ν^2/n^2. For this reason it appears desirable to proceed in two steps. In the first transformation only terms with y_1 in the arguments will be included in the determining function S.

S will thus be developed in powers of ν^2/n^2,

$$S = S_0 + S_1 + S_2 + \ldots$$
$$S_0 = x_1' y_1 + x_2' y_2.$$

In the following the primes with x_1, x_2 may be omitted, provided it is understood that in all developments the x-variables are to be considered primed. The expression for S_1 is

$$S_1 = \frac{1}{4}\frac{\nu^2}{n^2}\frac{\mu^2}{x_1^2}\left\{\Sigma\frac{C_j}{jn}\sin jy_1 + \Sigma'\frac{D_j}{jn}\left(1 - \frac{2\nu}{jn}\right)^{-1}\sin(jy_1 + 2y_2)\right\}.$$

In Delaunay's theory the factors $(1 - 2\nu/jn)^{-1}$ are developed in powers of ν/n by binomial expansions. In order to examine the possibility that this feature is the primary cause of the

slow convergence in powers of ν/n, it appears desirable to avoid the binomial expansions, even at the cost of considerable complication of the development.

The part S_2 of S is subsequently obtained from the equation

$$n\frac{\partial S_2}{\partial y_1} - \nu\frac{\partial S_2}{\partial y_2} = \left\{\frac{3}{2}\frac{n}{x_1}\left(\frac{\partial S_1}{\partial y_1}\right)^2 + \frac{\partial F_1}{\partial x_1}\frac{\partial S_1}{\partial y_1} + \frac{\partial F_1}{\partial x_2}\frac{\partial S_1}{\partial y_2} - \frac{\partial F_1^*}{\partial y_2}\frac{\partial S_1}{\partial x_2}\right\}_b$$

the subscript b indicating the part having y_1 in the arguments. The first part in the right-hand member contributes terms with new arguments of the form $jy_1 + 4y_2$ and with factors

$$(1 - 2\nu/jn)^{-1}(1 - 2\nu/kn)^{-1}$$

For $j \neq k$ it is easily seen that this product may be written as a sum

$$\frac{(1 - 2\nu/jn)^{-1}}{1 - j/k} + \frac{(1 - 2\nu/kn)^{-1}}{1 - k/j}$$

with

$$\tfrac{1}{2}(1 - 2\nu/jn)^{-1} + \tfrac{1}{2}(1 + 2\nu/jn)^{-1}$$

as special case for $k = -j$. For $j = k$ no such reduction is available.

In S_2, therefore, factors of this form as well as factors of the form

$$(1 - 2\nu/jn)^{-1}(1 - 2\nu/kn)^{-1}(1 - 4\nu/pn)^{-1}$$

will appear.

Obviously, the complexity of these factors increases with each order. On the IBM 650 and IBM 7090 the calculation of S_2 has been completed with the assistance of Mrs Lois Frampton and Dr G. Hori. The calculations for the higher approximations are in progress.

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4. PRESENT AND FUTURE REQUIREMENTS FOR PLANETARY EPHEMERIDES

R. L. Duncombe

The traditional uses of the planetary ephemerides have been twofold:

(*a*) to predict the places of the planets to facilitate their observation; and
(*b*) to form a standard against which to compare observations.

The long series of published national ephemerides have fulfilled these traditional requirements.

The introduction in astronomy of automatic computing techniques, and more recently of electronic calculators, has provided impetus in the evaluation of planetary co-ordinates over extended periods of time, the analysis of deficiencies in existing planetary theories, and the construction of new theories.

Examples are: the evaluation of Newcomb's tables of Venus, and of the Sun, from 1800–2000; the comparison of observations of Mercury and Venus over the past 200 years with Newcomb's tables of their motion; the simultaneous numerical integration of the equations of motion of the 5 outer planets, from 1653–2060; the comparison of Newcomb's theory of

the Earth with a numerical integration of the equations of motion; and the formation of a new general theory of the motion of Mars.

A requirement made evident by this research is that henceforth planetary ephemerides must be available in machine-readable form.

In America, the U.S. Naval Observatory has been the repository for planetary data in this form. During the past two and one half years, we have filled 44 individual requests from government, university and commercial laboratories for machine-readable planetary ephemerides comprising over 600 000 punched cards. In addition, the Space Technology Laboratory has placed a large part of these planetary data on magnetic tape and has made copies available to numerous other users.

This increasing demand for planetary-co-ordinate data reflects the renewed interest in celestial mechanics engendered by the introduction of electronic calculators, as well as the requirements of space technology for planetary data for the planning of space-probe trajectories, etc.

The comparison of observations with the planetary ephemerides has revealed many minor defects, inconsistencies and some errors. The first step in meeting the requirement for more accurate ephemerides has been the recent introduction of the simultaneous numerical integration of the equations of motion of the 5 outer planets, 1653–2060, by Eckert, Brouwer and Clemence as the basis for the published co-ordinates. This has replaced the previous defective theories of Jupiter, Saturn, Uranus and Neptune, which were all diverging from the observed positions. In addition to improving the basic accuracy, this has also placed the ephemerides of the 5 outer planets on a system of planetary masses consistent with the tables of the inner planets.

The next step in improving the accuracy of the planetary ephemerides will be to replace Newcomb's tables of Mars by Clemence's new theory of the planet's motion. This awaits only the determination of the definitive values of the constants from a comparison of the theory with observations over the past 200 years; a program for this is now in progress at the U.S. Naval Observatory.

Analysis of observations of the Sun, Moon and planets by H. R. Morgan, of Mercury by Clemence and of Venus by Duncombe, have indicated an error in Newcomb's centennial variation of the obliquity. A comparison of Newcomb's tables of the Sun with Herget's numerical integration of the equations of motion of the Earth-Moon system, 1920–2000, confirms the presence of an error in the secular change of the obliquity. Deficiencies in Newcomb's representation of the Earth's latitude were also indicated by this comparison, the largest identified being due to the omission of a periodic perturbation by Saturn with a coefficient of $0''{\cdot}034$. A comparison of Leverrier's tables of the Sun with the numerical integration indicated his expression for the latitude was considerably more accurate than Newcomb's. The observed error in the variation of the obliquity appears to stem from the neglect of a contribution by the squares and products of the disturbing forces, which were calculated on the assumption that all the planets move in exact ellipses.

At the present time, a new theory of the motion of the Earth is being formed by Clemence, which it is hoped, in the future, will replace the defective tables of Newcomb as the basis for the solar ephemeris.

An analysis of observations extending over the past 200 years compared with Newcomb's tables of Venus, while removing the discrepancy between the observed and theoretical motion of the node of Venus, has indicated corrections to the elements of the Earth and Venus. In

order to meet the requirements for an accurate ephemeris of Venus, it would seem necessary in the future to formulate an improved theory of its motion.

With the introduction of radar ranging of Venus, a new dimension has been added to our observations of the planets. Observations extending for several months either side of the April inferior conjunction have been made by the Jet Propulsion Laboratory of N.A.S.A., and the Lincoln Laboratory of M.I.T. These observations, compared with theory, show some systematic discrepancies. Provisional application to the Jet Propulsion Laboratory results of the corrections to the elements of Venus and the Earth summarized in the investigation of the motion of Venus (1) indicate a significant improvement in the agreement of observation with theory. The corrections applicable to the published co-ordinates of Venus and the Earth for the period February to July 1961, resulting from these changes in the elements, are now being evaluated at the Naval Observatory for inclusion in the radar observation reductions.

Continuation of these radar range observations of Venus and also of Mars will provide a valuable source of data which, in combination with the usual angle measurements, may permit a more precise determination of the definitive constants of the theories of their motions.

Requirements have arisen in recent years for accurate computed velocities for the analysis and interpretation of Doppler observations of the planets. Since the published co-ordinates of Mercury, Venus, Earth and Mars are derived from tables as the sums of numerous terms, the accumulation of rounding errors introduces an unevenness in their end figures which make it difficult to derive consistent values of the velocities by numerical differentiation of the co-ordinates. If the requirement continues with the increasing accumulation of radio Doppler observations, it may become necessary to form precise numerical integrations of the equations of motion of these planets, carrying sufficient additional figures to provide velocities having numerical consistency even though the constants of the theory cannot be determined from observation with an equivalent accuracy. The users of such ephemerides would of course be warned that the additional figures were physically fictitious.

The mere storage of, and access to, the extensive tables of planetary-co-ordinate data often overtaxes the memory and data-moving capability of even the larger electronic calculators. Several methods to allow storage of planetary data in a more accessible form have been proposed or are being used. One is the semi-analytical approach where the Keplerian or undisturbed motion is represented by analytical expressions to be evaluated by the computer while the portion due to the perturbations is stored in tabular form. This allows the tabulation of the contribution due to the perturbations at a much larger interval than would have been possible for a tabulation of the co-ordinates themselves, with a resulting economy of storage space.

Another approach is the use of economized polynomial representation of planetary positions over restricted arcs. Here, only the coefficients of the polynomial are required to be stored.

The ultimate and most flexible solution may be the storage and evaluation of the planetary theory itself. Two examples of this come to mind. Clemence's new theory of Mars was evaluated at a four day interval from 1950–2000 on an IBM 650 (a relatively slow electronic calculator); the computation required only one minute per date. Recently scientists at the Jet Propulsion Laboratory have programmed the IBM 7090 to evaluate positions of the Earth directly from Newcomb's theory. For the comparison of Clemence's new theory of Mars with observations it has been necessary to form an ephemeris from 1750–1960. For this purpose co-ordinates of the Earth, consistent with those published in *Astr. Pap. Wash.* **12,** were required for the period 1750–1800. These co-ordinates were evaluated directly from Newcomb's theory for 630 dates on the IBM 7090 in slightly less than 12 minutes.

It is almost certain that no more planetary tables will ever be constructed. Even tables to a

reduced accuracy for use in obtaining approximate positions at remote dates will probably be replaced by ephemerides to a low order of precision extending over the whole of historic time.

Although printed co-ordinates, to a reduced accuracy, will be required for the positioning of telescopes, the fundamental planetary ephemerides, accumulating year after year on library shelves, as the standard for comparison with observations seem certain to be replaced by compilations of data in machine-readable form, since undoubtedly, all future analyses of observation residuals will be performed with the aid of electronic calculating equipment.

While the fundamental ephemerides may no longer be printed in the annual volumes, they should continue to be published, to full accuracy, in the same form as the co-ordinates of the Sun (2) and Venus (3) for 1800–2000. As in these volumes, the rectangular co-ordinates as well as the spherical co-ordinates will undoubtedly be required.

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5. THEORY OF THE MOTIONS OF MARS AND THE EARTH

G. M. Clemence

My first-order theory of the heliocentric motion of Mars was published in 1949 in *Astronomical Papers of the American Ephemeris*, Vol. XI, Part II. The theory has recently been completed by the addition of the perturbations of the second and third orders, which will be published late in 1961 or early in 1962 in Vol. XVI, Part II of the same series. My aim has been to calculate all of the inequalities in the motion having coefficients as large as 0″.0001 in the case of the periodic terms, and 0″.0001 per century in the case of the secular and mixed terms.

The following tabulation shows for the complete theory the number of inequalities in the mean longitude arising from various sources, the mass-factors being denoted by the initial letters of the planets concerned. Thus, S denotes terms factored by the mass of Saturn, V^2 terms factored by the square of the mass of Venus, and J^2ST terms factored by the square of the mass of Jupiter, the mass of Saturn, and the time.

First order		Second order		Third order	
Source	No.	Source	No.	Source	No.
Me	11	V^2 and VM	5	J^2S and JS^2	5
V	45	E^2 and EM	30	J^2ST and JS^2T	37
E	157	J^2 and JM	22	J^2ET	1
J	73	S^2 and SM	5	J^2E	56
S	43	V^2T and VMT	12	Total	99
U	16	E^2T and EMT	47		
N	10	J^2T and JMT	25		
Total	355	S^2T and SMT	14		
		EV	31		
		JE	96		
		SJ	261		
		JV	10		
		SE	13		
		US	7		
		Total	578		

Not all of the 1032 terms are distinct in form; in 160 cases the same arguments arise from more than one source, and these terms may be combined for evaluation. The number of terms in the radius vector is about the same as in the longitude, and the number of terms in the latitude is about half as great. Thus, about 2000 terms must be evaluated in order to obtain the position of Mars at one instant of time.

The crucial test of the theory is of course its agreement with observations, but observations of modern precision have been made only during the past two centuries, the standard error of a single observation varying between 0″·5 and 1″·0. Furthermore, the comparison of the new theory with observations would necessarily be contaminated by defects in Newcomb's theory of the Earth. Desiring to apply a more searching test than existing observations are capable of providing, I have compared the theory with a numerical step-by-step integration of the orbit of Mars, calculated for the years 1919 to 1954 by Dr Paul Herget with the Naval Ordnance Research Calculator. The comparison was made at intervals of 80 days. After removal of an elliptic correction arising from small differences in the constants of the orbit, which amounted to permitting four degrees of freedom in the longitude, none in the radius, and two in the latitude, the standard deviation of a difference in longitude is 0″·02, the largest being 0″·04. The discrepancies in radius vector are of the same order of magnitude, and those in latitude somewhat smaller. Thus, there is some ground for belief that the theory will be practically useful for some centuries to come.

I have commenced a new general theory of the motion of the Earth. The first-order portion is now complete, the perturbations having a precision of 0″·00001. The results agree well with those of Leverrier and Newcomb, my own having, however, two additional significant figures. The interesting portions of the theory will therefore be the higher-order portions, neglected by previous authors.

6. NECESSITE D'UNE NOUVELLE THEORIE DES QUATRE GROS SATELLITES DU JUPITER

J. Kovalevsky

Le problème du mouvement des quatre gros satellites de Jupiter est un des problèmes les plus difficiles qui se posent dans le cadre de l'interprétation, à l'aide de la théorie de la gravitation du mouvement des corps du Systéme Solaire. Etant donné que ce sont, parmi les satellites autres que la Lune, ceux qui sont les plus accessibles aux observations, il est naturel que les grandes éphémérides leur consacrent une partie importante de la place réservée aux satellites, en particulier pour la prédiction des configurations, des éclipses, des occultations et des passages. Il est probable que, dans un proche avenir, des éphémérides très précises soint demandées pour ces corps. Or la théorie est actuellement loin de pouvoir satisfaire à de telles exigences.

Dans le passe, très peu de théories de ces corps ont été développées et encore moins ont été achevées au point de donner lieu à des Tables qui permettent le calcul d'éphémérides. En fait, depuis Laplace, seuls Damoiseau et Sampson ont fait le travail complet, tandis que Delambre, Souillart et de Sitter ont fait une théorie incomplète ou inachevée.

La raison de cette carence ne reside pas dans le fait que les théories existantes seraient satisfaisantes. Elle sont loin de l'être. La raison réside bien dans la difficilté et la complexité du problème. Une thèorie complète des quatre satellites entraine, par exemple, la détermination de 31 constantes: les 24 constantes d'integration pour les satellites, leurs quatre masses et trois paramètres déterminant le bourrelet équatorial de Jupiter en grandeur

et en position. Même si ces dernières quantités sont déduites du mouvement au Ve satellite, ce qui parait la méthode la plus sûre, il reste encore 28 constantes arbitraires à déterminer et ceci situe bien la difficulté de problème.

La théorie de Sampson, qui sert de base aux calculs d'éphémérides, prévoit à l'heure actuelle les phénomenes avec des erreurs de l'ordre de la minute ou même de plusieurs dans certains cas. Ceci est en soi-même une indication suffisante sur la nécessité de refaire une théorie. Le tableau suivant présente une des raisons de cette différence: si on compare les masses obtenues par Delambre et appliquées par Damoiseau, puis celles obtenues par Sampson et celles, enfin, obtenues par de Sitter, on a

No. du Satellite	*Delambre*	*Sampson*	*de Sitter*
I	1700	4497	3796
II	2300	2536	2477
III	8800	7988	8201
IV	4248	4504	4523

(unité: 10^{-8} de la masse de Jupiter)

On peut donc, sans supposer que les masses données par de Sitter sont parfaites, en considérant que la différence de Sitter moins Sampson donne l'ordre de grandeur de l'incertitude des masses actuellement employées, affirmer que la masse du premier satellite n'est connue qu'à 20% près et celle des autres à quelques pour cents près. Ceci veut dire que les perturbations du premier ordre d'un des satellites sur les autres ne sont connues qu'avec cette précision ou, plus exactement, l'interprétation des perturbations effectivement observées n'est exacte que dans ces proportions. La théorie elle-même, represente les observations sur lesquelles elle est basée bien mieux, mais c'est obtenu en forçant la théorie erronée à satisfaire les observations par un choix adéquat des constantes d'intégration, ce qui est possible parce que les observations sont peu nombreuses et que certaines perturbations, sont difficilement séparables des autres et telle ou telle inégalité peut avoir plusieurs interprétations. Mais cette erreur apparait dans les prévisions à longue échèance lorsque la separation des termes a eu le temps de se faire, et peut expliquer de gros écarts.

On peut donc affirmer que la théorie de Sampson est insuffisante et doit être remplacée. Le problème se pose de savoir s'il faut terminer le travail de de Sitter ou en entreprendre un nouveau. Pour répondre à cette question, voyons les grandes lignes des resultats d'une théorie.

On sait que le phénomène principal est la résonnance entre les trois premières satellites, dont les longitudes moyennes obéissent à la relation.

$$\lambda_1 - 3\lambda_2 + 2\lambda_3 - 180^\circ = 0 \qquad (1)$$

de façon très rigoureuse, aux erreurs d'observation près (10^{-8}). On peut poser en fait cette relation comme une donnée d'observation et avoir ainsi deux relations entre les constantes d'intégration. Pratiquement on pose

$$\lambda_1 = (4 - \kappa)\tau$$
$$\lambda_2 = (2 - \kappa)\tau + 180^\circ$$
$$\lambda_3 = (1 - \kappa)\tau$$
$$\text{avec } \kappa = (n_2 - n_3)$$

n_2 et n_3 etant les moyens mouvements des satellites II et III. Avec ces notations, les termes qui entrent dans la théorie sont de quatre types.

1. Les termes à courte période comprenant les equations du centre, en $(\lambda_j - \varpi_j)$ les grandes inégalités, provenant des pérturbations à courte periode (proportionnelle à τ) et d'autres perturbations. Une grande difficulté provient du fait que les grandes inégalités sont plus

importantes que les équations du centre. En d'autres termes, ce qui est, dans la méthode des variations des constantes, une perturbation du premier ordre est plus grand que les inégalités du mouvement elliptique non perturbé. Ceci est du au fait que les excentricités moyennes sont très faibles.

La difficulté introduite par ce fait a été la raison de l'échec de Souillart. Sampson a essayé de la surmonter par l'introduction d'une equation du centre induite, comptée à partie du périjove de l'astre perturbateur et traitée néanmoins comme une équation du centre ordinaire. de Sitter introduit une orbite periodique de deuxième espèce de Poincaré comme orbite intermédiaire tenant compte de ces termes.

2. Les termes de période moyenne, de un à deux ans en $\kappa\tau$

3. La libration autour de la position de résonnance. En fait elle a une très faible amplitude et une période trés mal determinée de l'ordre de 6 ans. Cependant elle est très sensible à une erreur sur les masses.

4. Les termes à longue periode, d'origine solaire ou provenant des mouvements des pèrijoves ou des noeuds.

Les termes du 2^e et 3^e type proviennent des quasi-doubles résonnances et de triple le résonnance. Les autres sont similaires à ceux des théories des planètes qui ont cependant aussi des termes du 2^e type comme par exemple la grande inégalité de Jupiter et de Saturne. Cependant alors que pour les planètes extérièures, par examples nous avons 200 années d'observations, si nous comparons ces problèmes en réduisant l'unité de temps à la période de révolution du satellite le plus proche, nous trouvons que les observations que nous désirons satisfaire sont l'équivalent de millions d'années d'observations de ces planètes. Une théorie du type planétaire, qui admet un développement en série de Taylor des termes du 4^e type est impossible ici. Donc, en fait, nous devons ici construire une théorie planetaire générale, ce qui n'a encore été jamais fait pour une planète.

Le traitement de de Sitter consiste d'abord à étudier l'orbite periodique intermèdiaire que nous avons citée, puis en calculer les perturbations, en introduisant les 7 autres arguments angulaires que se presentent dans le problème plan. Le calcul des termes à longue période est aussi rejeté à la fin alors qu'ils sont très importants pour les éphémérides. C'est en fait un procédé tout à fait analogue à celui de Hill-Brown pour la Lune.

Toutefois, on peut se demander si une procédure inverse ne serait pas souhaitable: éliminer les termes à courte période qui sont lourds et génants, pour concentrer les efforts sur les termes à longue, puis à moyenne période qui fourrissent l'aspect général du mouvement. Une telle méthode existe c'est celle de von Zeipel qui a été appliquée avec un grand succés à la théorie, bien plus simple certes, des satellites artificiels par Brouwer, et qui est maintenant appliquée à la Lune. Une telle procédure serait certainement plus fructueuse que celle de de Sitter et devrait être préferée à la reprise du travail inachevé de ce dernier.

Il m'est très agrèable de signaler que Marsden, à Yale, a entrepris une telle recherche par cette mèthode. C'est un travail qu'il faut encourager. Nous avons montré les difficultés de la théorie. Elles demeurent même dans cette méthode ou il faudra éliminer successivement un très grand nombre d'arguments. Néanmoins, si même seulement l'efficacité de cette méthode pouvait être montrée, ce serait un grand pas de fait dans la résolution de ce problème. En tous cas la possibilité d'appliquer le calcul électronique à ce problème est un atout considérable qui manquait à nos prédécesseurs. Mais ce n'est pas tout, et on devra au préalable prendre un certain nombre de décisions sur la manière d'envisager la méthode. En particulier, il me semble que la réussite ou l'insuccès de cette entreprise dépendre essentiellement du choix du système de variables canoniques. Vu la petitesse des excentricités, il est possible que les variables de

Delaunay soient mauvaises et qu'il faudra s'orienter vers les variables de Poincaré au un système du même type. Un autre facteur du succès réside dans la manière dont les observations seront interprétées. Il est trés dangereux d'essayer d'interprèter sèparément les diverses inégalités fournies par les observations et séparées par des méthodes parfois peu rigoureuses. Il faudra, dans la mesure du possible, traiter la solution en bloc et déterminer en bloc toutes les inconnues, procédure qui est maintenant rendue possible par les grands calculateurs électroniques.

Enfin, je voudrais dire quelques mots des observations dont dispose le théoricien. Ce sont principalement:

(*a*) Le catalogue d'eclipses d'Ashbrook, commençant en 1668, mais assez pauvre en observations modernes qui sont insuffisamment nombreuses.

(*b*) La série photométrique de Harvard (1878–1903) sur laquelle est essentiellement basée la théorie de Sampson.

(*c*) Des données heliometriques et photographiques de la fin du siècle dernier.

(*d*) D'autres observations épases, se terminant presque toutes vers 1930.

Il y a donc un manque facheux d'observations modernes, qui seraient pourtant indispensables pour mieux avoir la théorie dans le proche avenir. L'Observatoire de Yale envisage de commencer une série d'observations. Il serait désirable et urgent que d'autres observatoires consacrent une partie de leurs moyens à ce problème.

8. SOME REMARKS ON THE FURTHER IMPROVEMENT, BY CONVENTIONAL AND NEW METHODS, OF ASTRONOMICAL CONSTANTS INVOLVED IN EPHEMERIS COMPUTATION

Eugene K. Rabe

Astronomers have been reluctant to change the values adopted for the planetary masses and other constants involved in the preparation of ephemerides. Such changes would destroy the homogeneity of the theories or numerical integrations and would complicate the task of subsequent improvements of the orbital elements and various constants. Also the inner accuracy of the theories of most major planets has proved to be rather limited, so that premature revisions of the planetary masses and other constants alone would not be sufficient to provide us with more precise ephemerides.

As soon as more precise theories or numerical integrations have been adopted, however, the situation is a quite different one. We then have, as in the cases of the 5 outer planets, orbital trajectories of very high internal accuracy, and in order to produce an ephemeris in the best possible agreement with observations, we may have to introduce more precise values of the planetary masses and related constants. A very good illustration of such a changed situation is the recent discovery by Krotkov and Dicke (**1**) of periodic oscillations of the order of $0''{\cdot}25$ in the longitude of Jupiter, and their subsequent removal by Clemence (**2**) by means of an improved mass of Saturn. Obviously the situation will be similar for the inner planets, when more precise theories become available. For Mars, Clemence's new theory should very soon establish this changed situation. Then a better theory of the Earth's motion will be urgently required, too, since the computation of any geocentric ephemeris involves the orbit of the Earth-Moon system and the lunar equation.

In addition to the needs of astronomers, the space age is making new demands on the ephemerides of the major celestial bodies, too, as far as the accuracy of the predicted positions is concerned. The needs of astronautics have also added a new 'dimension', because for space probes the conversion of distances from astronomical into terrestrial units and *vice versa* is as

important as the determination of directional co-ordinates. While previously the astronomer needed the solar parallax only for the reduction from topocentric to geocentric place, for which purpose in most cases a limited accuracy was sufficient, except for close approaches to the Earth, the astronaut requires the knowledge of this basic constant to the highest possible degree of accuracy.

The questions to be answered obviously are the following two. First, how accurately do we need to know the various constants, and secondly, what are the present prospects of obtaining them to the required degree of accuracy? The answer to the first question greatly depends on the inner accuracy of the improved, new planetary theories. Clemence undertook his new theory of Mars (3) with the aim of a precision of 0″·01 in longitude, and we may do well to adopt this figure as a standard criterion. This precision requires a formal accuracy of about 0″·0003 for most of the periodic terms involved, to allow for the accumulation of rounding errors, but the values used for the various disturbing masses have to be equal to the true values only to the extent of the ± 0″·01 precision. Since the largest periodic terms produced by the Earth and by Jupiter in the motion of Mars are of the order of 20″, a knowledge of these disturbing masses to 4 significant figures would be sufficient, as far as these periodic terms are concerned. It seems that such an accuracy has already been achieved in the determination of the mass of Jupiter. For the mass of the Earth-Moon system, this degree of accuracy should finally be secured in the near future, too, depending on the corresponding results for the solar parallax.

It must be recognized that the space age is not only making new demands on the precision of astronomical ephemerides, but that it also affords us entirely new possibilities for the more accurate determination of some of the basic constants involved in the construction of such ephemerides. The same space probe, for the launching of which the rocket engineers are interested in a more precise value of the astronomical unit, may actually, from the analysis of its observed motion, provide us with such an improved value of the solar parallax and of the mass of the Earth-Moon system. Similarly, Earth satellites approaching the Moon more closely, or lunar satellites should eventually give us results for the mass of the Moon and consequently for the constant of the lunar equation, which are superior in accuracy to all previous determinations by conventional astronomical methods.

As far as the solar parallax is concerned, the picture presented by the already numerous results obtained by 'space-age methods' is still confusing. If one looks at these results as exhibited in Table 1, then it is evident that they are scattered over a range quite comparable to the size of the discrepancy between the 'astronomical' determinations by Spencer Jones and Rabe. Clearly the probable errors listed with the results in Table 1 are not compatible with the differences between the various values, unless one discards all the determinations except for the three last ones obtained in 1961. On the other hand, it is reported that investigators in the U.S.S.R. have just obtained another Venus echo result in good agreement with the first two values listed in Table 1, but definitely not with the last three and supposedly more accurate ones obtained in 1961.

Table 1. Solar parallax results from new methods

Method	*Place, Year*	*Solar parallax*
Venus Radar Echoes	Millstone Hill (1958)	8″·8022 ± ″·0001
Venus Radar Echoes	Jodrell Bank (1959)	8·8020 ± ·0005
Artificial Planet, Pioneer V	Space Technology Laboratories (1960)	8·7974 ± ·0008
Venus Radar Echoes	Jodrell Bank (1961)	8·7943 ± ·0003
Venus Radar Echoes	Millstone Hill (1961)	8·79450 ± ·00008
Venus Radar Echoes	Jet Propulsion Laboratories (1961)	8·79443 ± ·00009

While the 1961 results listed in Table 1 seem to have a much greater weight than the earlier Venus echo determinations in 1958 and 1959, these previous derivations claim to be of very high precision, too, and agree surprisingly well with each other. The discrepancies are rather puzzling and suggest the involvement of some yet unknown systematic source of error. It is of some interest that the only dynamical determination, from Pioneer V, is in fair agreement with the comparable results from Eros.

The discrepancies exhibited in Table 1 not withstanding, one may yet expect to find either their explanation, or new and better results finally converging towards some definite value in the not too distant future. As soon as this is achieved and astronomers can agree on a solar parallax secured to the fourth significant figure, the ephemeris requirements postulated above can be satisfied, as far as the mass of Earth + Moon is involved. A still higher accuracy remains desirable, of course, for the conversion of distances from astronomical into terrestrial units.

Once the solar parallax and the mass of the Moon have been secured to a higher degree of precision from the various new methods now available, related constants such as that of the lunar equation and the constant of aberration may also be established more accurately. This short discussion does not attempt to exhaust all the aspects and all the constants involved. It seems justified, however, to conclude that space probes and the modern methods of radio astronomy will soon provide us with rather accurate values of some of those fundamental constants, which in turn will justify and require the construction of planetary theories and ephemerides of highest precision. Especially better theories of the Earth and of Venus, to be preceded perhaps by more rapidly obtainable numerical integrations of high internal accuracy, appear as some of the most urgent tasks and challenges now confronting celestial mechanics. It goes without saying that the availability of such precise ephemerides would in turn facilitate the determination of improved constants by means of conventional methods, such as a fuller utilization of all the observations of Eros, of Mars, and of Venus in corresponding differential corrections.

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9. ASTRONOMICAL AND ATOMIC TIME INVOLVED IN THE OBSERVATION OF ARTIFICIAL SATELLITES

W. Markowitz

The independent variable, t, in the orbit and in the ephemeris of a planet or satellite, natural or artificial, is Ephemeris Time. The term 'Ephemeris Time' is used in astronomy in two senses:

(*a*) In the general sense, as the independent variable of dynamical astronomy.

(*b*) As a specific measure of time, defined by a resolution adopted by the IAU.

The definition of E.T. in the sense of (*b*) is contained in a resolution adopted jointly by Commissions 4 and 31 at the tenth General Assembly (1). The basis of the measure of E.T. is the orbital motion of the Earth about the Sun. For the purpose of obtaining Ephemeris Time rapidly, other orbital motions may be used. Specific recommendations concerning the

determination of Ephemeris Time from the motion of the Moon were made by Commission 31 at the ninth General Assembly (**2**). Observations of the Moon are the principal means of determining Ephemeris Time at present. It should be realized, however, that the ephemeris of the Moon must be brought into accordance with the ephemeris of the Sun from time to time and that it is the motion of the Sun which provides the fundamental definition of Ephemeris Time.

When the equations of motion of celestial mechanics are written down, the independent variable is Ephemeris Time. When the equations are solved an orbit is obtained, from which there is prepared an ephemeris. The independent variable in the orbit and in the ephemeris is E.T. Thus, the preparation of an ephemeris imposes no requirement on celestial mechanics in order that the ephemerides shall have Ephemeris Time in the general sense as the independent variable.

An observation of a planet or satellite, denoted J, for which an ephemeris has been prepared will provide a value of E.T. for the epoch of observation. A series of such values may be compared with the value of E.T. obtained from observations of the Sun. In general, the two will differ. If this is so, the orbital constants of J have to be revised if the two are to be equivalent. Such comparisons, however, are made on only few occasions, as when deriving the theory of a planet or satellite based upon centuries of observation. Hence, there appears to be no immediate requirement for having values of E.T. from the Sun available with high precision at all times.

The question arises whether we can find an object which is superior to the Sun as the basis for the definition of E.T. The Moon is not a satisfactory object because of uncertainties in the effect of tidal friction upon its orbital motion. An artificial satellite might be used, but this seems doubtful. Artificial satellites will be affected by non-gravitational forces whose effects probably cannot be calculated with sufficient rigour for thousands of years. Thus, it does not appear likely that in the foreseeable future an artificial satellite will replace the Sun as the fundamental measure of E.T.

Artificial satellites, however, can be useful in the solution of certain problems, for example, in studying whether the gravitational and atomic time scales are equivalent. Any satellite which can provide E.T. proportional to E.T. from the Sun with high precision will suffice.

Ephemeris Time cannot be obtained readily with high precision from observation, and Atomic Time may be used as a substitute. It has been found that the frequency of the cesium beam atomic oscillator is 9 192 631 770 cycles per second of Ephemeris Time, as determined through observations of the Moon (**3**). This value serves as the basis of the system of Atomic Time denoted A. 1, which is based on the operation of a number of cesium beam oscillators, located in various countries. The system A.1 provides intervals of Atomic Time with a precision of about 5 parts in 10^{11}, approximately 1 millisecond per year. Any possible divergence between gravitational time and Atomic Time may be ignored in reducing satellite observations extending over a few years, except when this divergence itself is being studied.

The apparent position of an artificial satellite as observed from the surface of the Earth depends upon both its orbital position and the location of the observer. The latter depends upon the rotational position of the Earth, which is given by U.T. 1. Hence, both Atomic Time and U.T. 1 are required for reducing observations of satellites and for predicting apparent positions.

Observations are recorded with respect to U.T. 2, generally with respect to some particular time signal transmission. Preliminary times of emission of signals with respect to U.T. 1, U.T. 2, and A. 1 are distributed weekly by several observatories. These quantities vary

slowly, and the reduction of satellite observations at a central location may be made with sufficient precision by use of these values.

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D. JOINT DISCUSSION

ON

PROBLEMS REQUIRING RADIO-ASTRONOMICAL OBSERVATIONS OF HIGH SENSITIVITY AND RESOLUTION

Monday 21 August 1961 at 14^h 00^m

This Joint Discussion was arranged at rather short notice, primarily as a joint session of Commissions 28 and 40.

	Commission 28	Commission 40
PRESIDENTS:	N. U. Mayall	J. F. Denisse
SECRETARIES:	G. C. McVittie	R. N. Bracewell

SUMMARIES OF PREPARED CONTRIBUTIONS

1. REVIEW OF PROBLEMS REQUIRING A RESOLUTION OF ONE MINUTE OF ARC

J. H. Oort

If we had a one-minute beam, solar maps at 400 Mc/s could be obtained during the few minutes at meridian transit, and lunar temperature distributions could be obtained. Resolution of planets is unattainable, except for radiation belts, but detection of outer planets would become possible. The nearest stars might be received, and more distant stars of high radio output would almost certainly be detected. Emission nebulae could be observed throughout the galactic system, and perhaps located optically by high-selective filters. Much fainter nebulae than the Orion nebula could be detected. About 10 supernova remnants of type I should be discoverable in the Galaxy. Support for an instrument in the southern hemisphere would be most desirable.

The disk structure of the Andromeda nebula should exhibit a brightness temperature of about 80° K, but the halo would give only a few degrees. Apart from M81, detailed structure of the normal galaxies would not be accessible to a one-minute beam, but abnormal galaxies offer a rich field.

With the area of 500 000 square metres planned for the Benelux Cross, a distinction should be possible between different cosmological models.

2. NEW RADIO RESULTS ON THE STRUCTURE OF, AND MOTIONS IN, THE MAGELLANIC CLOUDS

F. J. Kerr

The clouds are the only external systems that we can hope to study in very fine detail. Hindman and McGee have mapped the neutral hydrogen distribution, and the velocity distribution, with 2° resolution. The relative positions of the clouds are not yet known without ambiguity, but are needed in order to interpret the neutral hydrogen bridge connecting them. The two clouds are clearly joined in a single composite body. The rotation of the large cloud has been re-determined, and other internal motions studied. Our next step is to study the internal motions with a 15-minute beam.

3. 21-CM RADIATION FROM GALAXIES: LEIDEN AND JODRELL BANK

L. Volders

21-cm observations of galaxies have been made at Leiden, Harvard and Jodrell Bank. Total, about 25 galaxies: Sb and Sc spirals; irregulars and ellipticals.

Leiden: systematic velocities, hydrogen mass and, for some of the nearby galaxies, rotation and hydrogen density distribution. Total mass, estimated from velocity spread, gives M_H/M of 1 to 10% for Sb and Sc; 10 to 20% for the irregulars; and an upper limit of 4% for the elliptical M32.

Jodrell Bank has much higher resolving power and has taken drift curves for M31, M33 and few others. M31 shows a density in the centre less than at 1° along the major axis. The density distribution in M33 has a flattened top.

4. REPORT FROM HARVARD

M. H. Roberts

Harvard uses a maser (constructed by B. F. C. Cooper of the Radio-physics Laboratory of Sydney and J. V. Jelley of Harwell) and goes to fainter galaxies of greater radial velocities. Using $M/L = 5$, they find that, for Sc, $M_H/M = 10\%$.

5. RADIO SOURCES: IDENTIFICATION, STRUCTURES AND DIAMETERS OF 175 SOURCES

T. A. Matthews

90 were observed in two position angles. Of the 90, 45 were unresolved. Three-quarters of the resolved sources are elongated with axial ratio greater than 2. An hypothesis of two well-separated equal regions explains one-quarter, but one-half are unsymmetrical by as much as 10 to 1. At Nançay, measurements out to 7000 Mc/s have confirmed Cal. Tech. results in general. The central component of NGC 5128 consists of two equal components at 960 Mc/s; but direct observations at Stanford show that at 3300 Mc/s the eastern component is larger and stronger. Cygnus A shows two components, with signs of some emission between them and edge-brightening on the outer edges; observations elsewhere at other frequencies show somewhat different intensity ratios, spacings and position angles. Three out of the 45 objects show jets which, however, could easily be overlooked at great distances, and about 15 have known redshifts.

6. LUMINOSITY FUNCTION OF RADIO SOURCES

R. Minkowski

Lack of distance measures hinders progress. At present we must first make an optical identification, then estimate the distance by redshift.

A luminosity function determined from about 45 identified sources is $\log n = 6{\cdot}9 + 0{\cdot}48\,M$ where n is the number of sources per cubic megaparsec stronger than M. This leads to a computed curve, of source counts against distance, in agreement with that observed by Mills.

7. THE RADIO LUMINOSITY FUNCTION AND THE NUMBER FLUX-DENSITY RELATIONSHIP FOR THE DISCRETE SOURCES.

M. Ryle

Observations have been made at Cambridge with a radio telescope whose resolving power and sensitivity would permit the detection of a source similar to Cyg A or 3C295 at a redshift $(\Delta\lambda/\lambda) \approx 3$ (velocity of recession $\approx 0{\cdot}9\,c$).

By relating: (*a*) the number of sources observed in different ranges of flux-density S; (*b*) the isotropy found in their distribution at $|b| > 20°$; and (*c*) their contribution to the background emission, we can show that in areas away from the galactic equator, only a few per cent of the observed sources are within the galaxy. From the upper limit of the extra-galactic component of the background emission, we conclude that most of the sources observed in a given range of S must have an emission at 178 Mc/s greater than 10^{24} watts $(c/s)^{-1}$ ster^{-1} (about 1000 times that of M31); their determination is independent of assumptions about the nature of the sources.

If most sources are supposed to have $M_p \approx -20{\cdot}4$, as suggested by Minkowski's analysis of positive identifications, the results of a further search in the positions of several hundred sources on the 48-inch Sky Survey prints suggest that most of the sources must have an emission greater than 10^{26} watts $(c/s)^{-1}$ ster^{-1}. A similar result is given by the new observations of surface brightness at Jodrell Bank, on the assumption that the sources have a physical extent similar to that of Cyg A.

From these determinations of the radio luminosity, we can derive limits to the expected number-flux-density relationship according to different world models. The new observations, when corrected for the effects of partial resolution of extended sources, clustering, etc., give a relationship:

$$\log N = 50{\cdot}1 - 1{\cdot}8 \log S \text{ for } 2 < S < 100 \times 10^{-26} \text{ watts } (c/s)^{-1}\ m^{-2}$$

This relationship does not appear to be compatible with that predicted by the steady-state model if the sources have the same large-scale distribution as the galaxies. It appears necessary to introduce evolutionary effects, and the observations could, for example, be explained on an Einstein-de Sitter model if the average source emission has decreased from 5×10^{26} to 10^{25} watts $(c/s)^{-1}$ ster^{-1} over the past 5×10^9 years.

DISCUSSION

H. Bondi. I am impressed with Minkowski's agreement with the Mills counts.

F. Hoyle. If you have a mixture of intrinsically weak and strong sources, the proportions counted depend on the flux density level.

B. Y. Mills. We are happy Cambridge now agrees with the Sydney observations. But we still differ over interpretation. I think the slope is between $-1{\cdot}6$ and $-1{\cdot}7$, but a value of $-1{\cdot}8$ is compatible with our range of uncertainty.

T. Gold. Earlier Cambridge observations were interpreted over-optimistically. What is the difference between the new catalogue, as yet unpublished, and the old one? Why was a different value of slope obtained formerly when it was claimed that overlap of sources could not change the slope?

M. Ryle. This depended on the 2C catalogue, which was wrong. With 3C we found an uncorrected slope of $-3{\cdot}0$ which is compatible with our present value of $-1{\cdot}8$.

SUMMARY AND CONCLUSIONS

G. C. McVittie

In the cosmological domain, the problems which await solution with the aid of radio telescopes of high resolution and sensitivity are, I believe, the following: identifications with optical sources, the structure of individual sources, 21-cm studies of nearby sources, the distances of sources which are not optically identified, the spectra of Class II sources, their angular diameters and their distribution in space and luminosity function. Clearly the identification problem is one of fixing the position of a radio source accurately enough for a search with the 200-inch telescope to be worthwhile. The field of this telescope is 10′. Bolton and Minkowski have shown how this can be done in their work on 3C295 in the cluster 1440 + 5224. Identifications serve many purposes; for example, they throw light on the optical peculiarities of a galaxy that is a Class II radio source. The apparent magnitude and the redshift of the object can also be measured in the optical domain and its distance estimated. This in turn leads to the absolute radio magnitude (intrinsic power output) and this is needed for the luminosity function.

High resolution enables us to study the positions of radio emission regions in nearby galaxies and their coronas. I refer to the curious pairs of emission centres in such objects as Cygnus A and NGC 5128. An analogous problem concerns clusters of galaxies: is the emission from a cluster really produced by a few exceptional galaxies of the cluster? I need not stress the interest that 21-cm studies of nearby galaxies possesses. But I would like to point out the importance of measuring, if we can, the radio redshift of some moderately distant Class II source like Cygnus A.

The nature of the energy distribution function in the radio spectra of Class II sources has an interest in its own right. The (frequency)^x law, with the spectral index x treated as a constant, is usually employed. But the character of the energy-distribution function may have an additional consequence. Evidence from the case of Cygnus A suggests that the spectral index x may vary with frequency. Should this be confirmed by the study of more Class II sources, there is a possibility of determining the redshift, and hence the distance, of a Class II source that has not been optically identified. We have to assume that the spectral index of the source changes with emission frequency in the same fashion as it does for a pre-selected standard source whose redshift δ_s is known. The observer would measure the flux-density of the standard source and of the one whose redshift, δ, is being sought at two frequencies f_2 and f_1, say. Then it can be proved that, to the first order in the redshifts

$$\log \{S(f_2)/S_s(f_2)\} - \log \{S(f_1)/S_s(f_1)\} = \{x(f_2) - x(f_1)\}(\delta - \delta_s)/E,$$

where S denotes the flux-density, suffix s indicates the standard source and $E = 2{\cdot}303$. Thus the redshift δ can be found.

The determination of the angular diameters of Class II radio sources is also a very important item of information. Are these angular diameters, in a statistical sense at least, effectively the same for all sources? If this is so, then the theory of uniform model universes predicts that the angular diameters will vary with the redshift in a different way from the variation of flux-density (also assumed statistically constant for all sources) with redshift. Hence additional information about the parameters of the model universes would be obtained. You will remember that it was pointed out by Hoyle at the Paris Symposium on Radio Astronomy in 1958, that in certain model universes there could be a minimum to the angular diameter. After this minimum was attained—in the Einstein-de Sitter model at the distance corresponding to a redshift of 1·25—the angular diameter increased again. A couple of years earlier I had pointed out that essentially the same effect existed in another, admittedly rather artificial,

model universe. In the same model one can also show that, if all Class II radio sources have the same intrinsic power output and the same value, −1, for their spectral index, then there will be a minimum of observed flux-density at a distance corresponding to a redshift of 1·9. These theoretical predictions show how important it is to press statistical investigations of the angular diameters and flux-densities of Class II radio sources to as low values as possible.

Counts of the numbers of Class II radio sources to successive limits of flux-density, made over sufficiently large areas of the celestial sphere, are also of great cosmological significance. Here good resolution is perhaps more important than sensitivity. Each model universe has its own theoretical law for the increase of this number N, with limiting flux-density, S. The ideal procedure would be to carry out the observational survey and then fit the results in turn to the predicted theoretical formulae until the best-fitting uniform model universe was found. Apart from the question of the luminosity function of Class II radio sources, the interpretation of those counts that have been made seems to me to have been confused by the notion that the classical 'minus three-halves' law between N and S is the norm and that without it, uniformity of distribution in space is absent. This is an illusion, as the study of any uniform model universe filled with an expanding distribution of sources will reveal. Indeed, it can be shown that a minus three-halves law of distribution in an expanding universe implies that Class II radio sources must have been more numerous in the past than they are now under the assumption that all of them have the same intrinsic power output. This, however, is an artificial assumption and an escape from it may lie in the luminosity function. This gives, of course, the fraction of the total number of sources, in each unit volume of space, having some particular observed intrinsic power output, or absolute radio magnitude. The investigations of this problem that I have seen all appear to contain the same curious feature. Part of the derivation of the luminosity function is carried out as if the radio sources were at mutual relative rest in the classical Euclidean universe; the remainder is performed as if they were in relative motion in a uniform model universe. Now the majority of Class II sources appear to be remote and their redshifts are therefore not negligible. Thus the use of the hypothesis of mutual relative rest in any part of the investigation is not very satisfactory. Therefore, while the observers are accumulating the data on which to base the luminosity function, the theoreticians have a problem to solve. It is this: How does one establish the luminosity function of a class of objects in an expanding universe, taking account of such matters as the effects of the redshift on distance-moduli and of the fact that the unit volume for remote objects is smaller than for nearby ones? At no point in this theory should one fall back on the traditional results which refer to objects whose relative velocities are all very small compared with that of light.

INTER-UNION COMMISSION

ON

SOLAR AND TERRESTRIAL RELATIONSHIPS

INAUGURATION, CONSTITUTION AND HISTORY

INAUGURATION

The Commission held its inaugural meeting on 14 August 1961, prior to the Eleventh General Assembly of the International Astronomical Union. Professor C. W. Allen was elected to the Chair.

MEMBERSHIP

The initial membership of the Commission (subject to the acceptance of the nominees) was announced as follows:

IAU (Astronomy)	IUGG (Geodesy and Geophysics)	URSI (Scientific Radio)
C. W. Allen (U.K.)	J. Bartels (Germany)	G. M. Allcock (New Zealand)
J. F. Denisse (France)	B. Haurwitz (U.S.A.)	D. K. Bailey (U.S.A.)
R. Giovanelli (Australia)	F. Link (Czechoslovakia)	R. Coutrez (Belgium)
E. R. Mustel (U.S.S.R.)	M. Nicolet (Belgium)	A. H. Shapley (U.S.A.)

Allen, Denisse, Giovanelli, Mustel, Nicolet, Bailey and Shapley were present. In response to an open invitation there was also an audience of about fifty, drawn mainly from IAU membership. Some of these contributed to discussions.

The following Officers were elected:

as President	C. W. Allen
as Secretary	D. K. Bailey

The meeting also appointed E. N. Parker as a Corresponding Member.

The President made reference to the main points of the Constitution which had been drafted by the General Secretary of the IAU. The Constitution adopted by the Commission reads as follows:

CONSTITUTION OF THE INTER-UNION COMMISSION ON SOLAR AND TERRESTRIAL RELATIONSHIPS

Constitution

1. The International Astronomical Union (IAU), in co-operation with the International Union of Geodesy and Geophysics (IUGG) and the International Scientific Radio Union (URSI), establishes an Inter-Union Commission on 'Solar and Terrestrial Relationships' ('Relations entre les Phénomènes Solaires et Terrestres') as a successor to the former Joint Commission of the International Council of Scientific Unions.

2. The Commission operates under the general rules governing Commissions of the IAU and reports to the IAU, which undertakes to consult the other Unions in all appropriate matters.

Composition

3. The Commission consists of twelve members, four of whom are appointed by each of the three co-operating Unions. At least one of the four members appointed by each Union is to be replaced, at intervals of not more than three years, by a new member who has not served as a member of the Commission during the previous six years.

4. The Commission appoints its President, and other Officers, from among its members. Officers may not serve in the same capacity for more than six years.

5. The Commission may appoint Corresponding Members, up to six in number, to serve as advisers.

Meetings and Publications

6. The Commission will meet at least every three years.

7. The Commission is encouraged to organize symposia, either in conjunction with its meetings or at other times.

8. The Commission is authorized to arrange for the publication of the proceedings of meetings and symposia.

9. In accord with Article 2, the arrangements for meetings, and summary reports of those meetings, are to be reported to the General Secretary of the IAU. Proposals for symposia, and for publications, are to be submitted to the IAU for approval in consultation with the other Unions.

Finance

10. The IAU, through arrangements with the other Unions and other agencies, assumes responsibility for financial support of the Commission and its activities.

11. The Commission will submit requests for financial support, estimates of costs of symposia and publications, and accounts of income and expenditure to the IAU in accord with usual procedures.

Explanatory notes

In addition to supplying the draft Constitution the General Secretary of the IAU provided a useful Addendum explaining how the Commission might be expected to operate in matters not formally treated in the Constitution. Important points from this addendum are:

(*a*) The IAU will attempt to arrange that the membership from the three Unions should be in accord with adequate scientific and regional representation.

(*b*) The President and Secretary should not be members appointed by the same Union, nor nationals of the same country.

(*c*) The General Secretary of the IAU should be fully informed of all activities. Reports will be sent to other Unions.

(*d*) Commission meetings will generally be held in close association with a General Assembly of the IAU or one of the other Unions.

(*e*) Publication of the proceedings of meetings or of symposia will require approval by the three Unions.

(*f*) Limited funds will be available for secretarial expenses. The travelling expenses (in part or in total) of the President and Secretary in attending meetings will be reimbursed, and a grant will be available to assist the other members.

(*g*) The IAU will endeavour to obtain funds to meet expenses incurred by the Commission from sources outside its own proper income; to the extent to which it is unable to do this it will call on the other Unions for contributions.

RECENT HISTORY

The President then gave a brief account of the activities of the last three years which had led to the formation of the new Inter-Union Commission on Solar and Terrestrial Relationships (IUCSTR) in replacement of the old Joint (or Mixed) Commission on Solar and Terrestrial Relationships (JCSTR). At the last meeting of the JCSTR (*Geophys. J.* **2**, 369, 1959) the retiring President, Dr L. d'Azambuja explained that the future of that Commission was hanging in the balance. Various proposals were made for the continuance of the work. However later in 1958 the JCSTR was dissolved by the International Council of Scientific Unions (ICSU). At the same time ICSU attempted to set up a Committee of three to advise on future action. The formation of this Committee was attended with some unavoidable delays, and the final composition was

Professor C. W. Allen, London (IAU) (Convenor)
Dr A. H. Shapley, Colorado (URSI)
Professor J. T. Wilson, Toronto (IUGG)

The recommendations of this Committee, reported in 1960, were:

1. That the JCSTR be reconstituted as an Inter-Union Commission.

2. That the new Commission be established by the IAU, the IUGG, and the URSI, with IAU as parent Union.

3. That the new Commission consist of 12 members.

4. That the constitution be based on the Draft Constitution outlined by the General Secretary of the IAU.

5. That the Executives of each of the Unions—IAU, URSI and IUGG—be invited to nominate four initial members of the proposed new Commission.

6. That a meeting be held in London in September 1960 (during the General Assembly of URSI) when the present position could be explained to Members and Councillors of the old JCSTR, and some future activities planned.

The report was accepted by the ICSU and future action based on it.

The recommended meeting was held in London in September 1960 and was attended by C. W. Allen, A. H. Shapley, G. Righini, M. Waldmeier, E. Vassy, J. Rösch, M. Nicolet, and D. K. Bailey. The main purpose of the meeting was to act as some liaison between the old and the new Commissions and make any proposals that might be helpful to the incoming Commission. It was suggested that the main part of the Berkeley Meeting of the Commission might take the form of a Symposium on 'Solar Terrestrial Relations—insight resulting from the International Geophysical Year'.

It had been intended that the present meeting should follow this recommendation as far as possible, and to this end a number of speakers were to speak on items concerned with this general topic. It had to be remembered however that the meeting in progress was formally a Commission Meeting—not a symposium. Business of the newly formed Commission should take first priority. The meeting proceeded to a discussion on the future of the IUCSTR.

THE FUTURE OF THE IUCSTR

Scope of 'Solar and Terrestrial Relationships'. It was suggested that an important function of the IUCSTR should be to fill the gap between solar observations (Commission 10) and terrestrial observations (IUGG). The main subject matter of the Commission concerns (a) disturbances in optical photon emission from the Sun, and (*b*) corpuscular disturbances from the Sun; but the Commission must be ready to consider effects that do not fall into these categories. Measurements of interplanetary space are particularly the concern of COSPAR and a widespread overlap must be avoided. It was agreed we should concentrate on *observations* of the Sun *connected with* corresponding *measurements* on the Earth.

Review report. The major activity of the old JCSTR has been the triennial publication of its report *Relations entre les phénomènes solaires et terrestres.* It is hoped that in the new IUCSTR it will be possible to produce a report that is somewhat similar but with a wider distribution. This should be instead of the usual President's report that is issued by IAU Commissions. In addition to reports on progress in the last few years it is desirable to include some reports defining, as far as possible, independent present-day views on long-standing controversial subjects. The possibility of publishing flare-event lists was also discussed.

Symposia and meetings. The IUCSTR is encouraged to organize symposia, but all proposals require the approval of the IAU, in consultations with the IUGG and URSI. It is to be remembered that such symposia are to some extent in competition with those of other Unions, Commissions, learned societies, etc. The meeting hoped that it would be possible to hold some symposia in connection with IUGG or URSI meetings. It was recommended that a business meeting of the IUCSTR should be associated with each General Assembly of the IAU and that on these occasions there should also be a scientific session at which short contributions could be offered. Symposia might be held at other times and dominated by invited papers.

Quarterly Bulletin of Solar Activity. Dr M. Waldmeier said that it would be helpful if the IUCSTR could act as an advisory committee for the Quarterly Bulletin. The Commission expressed its willingness to act in this capacity, and suggested that the request for any such action should come from the IAU through Commission 10. The President of Commission 10 (Dr A. B. Severny), who was present, promised to consider this matter in his Commission meeting. [It was later agreed by the Executive Committee of the IAU, after consultation with Commission 10, that the IUCSTR be invited to act as an advisory committee.]

International Quiet Sun Year. Consideration was given to the part of the IUCSTR in the coming IQSY. It was decided that the IUCSTR should send a reporter to meetings of the IQSY when possible, and the Secretary (D. K. Bailey) was named as reporter to the next CIG (*Comité Internationale de Géophysique*) meeting in January or February 1962.

Operation. The President and Secretary are expected to act as convenors for the operations of the IUCSTR. The role of the Commission will be somewhat that of a consultative council. It may be necessary to form sub-committees. It was felt that in addition to the Commission Members and Corresponding Members, it was necessary to set up a Roster of Active Workers, which should be representative of all workers that are active in this field. It might be expected that the list would contain more than 100 names and be open to anyone willing to take part in the wider activities of the IUCSTR. The purpose of this roster would be for (*a*) seeking advice, (*b*) distributing notices of activities, and (*c*) requesting review articles.

COLLOQUIUM ON SOLAR-TERRESTRIAL RELATIONS

At this colloquium speakers were invited to give special consideration to insight resulting from the International Geophysical Year. Contributions are only briefly reported since it may be expected that fuller reports will appear elsewhere.

M. Waldmeier, A direct observation of a solar stream.

The motion of an ascending prominence, observed on 1961 March 18, and reaching a height of 733 000 km has been analysed by measuring trajectory and velocity. The trajectory was very similar to the shape of a coronal streamer observed during the total eclipse of the Sun on 1961 February 15, at the same latitude. The velocity was increasing outwards but the acceleration was decreasing; it seemed that the velocity would approach about 500 km/s. During the ascent the equation of continuity (r^2vp = constant) was fulfilled. From the observations it was concluded that the prominence was taken away from the Sun by the 'solar wind'. Hence the long rays of the corona represent a stationary streaming, and the velocity of the stream can be deduced from prominences floating in it.

V. A. C. Ferraro, The possible emission of electric current-bearing streams from the Sun.

Bennett and Hulbert have pointed out that during the passage of a corpuscular ionized stream emitted from the Sun through the interplanetary gas, the stream electrons tend to be slowed down more rapidly than the stream ions by collisions with the interplanetary particles. This means that an electric current develops in the stream which Bennett and Hulbert thought might be large enough to constrict the stream into a jet. However, Bennett and Hulbert neglected the effect of self induction which tends to limit the current considerably. When this is taken into account it is found that the current in the stream cannot much exceed about a thousand amperes—a value far too low to be of geomagnetic interest.

D. K. Bailey, A survey of polar cap absorption events in the period 1952 through 1960.

A complete catalogue was submitted of the 46 polar cap absorption events detected in this period together with details of possibly related preceding solar flares and short-wave fade outs.

E. R. Mustel, Preliminary comparison of geomagnetic disturbances with events on the Sun during the IGY period.

The relation between geomagnetic disturbances and the central disk passage of plages was demonstrated graphically. Various maxima and minima in the superposed epoch graph were explained to result from the auto-correlation of plages at set longitude differences.

J. W. Chamberlain, Theory of auroral bombardment.

A mechanism is proposed for ejection into the atmosphere of geomagnetically trapped protons and electrons. An irregularity in longitude distribution is assumed and the tendency for positive and negative particles to drift in opposite directions will lead to momentary electrostatic fields. Some of the particles drifting into this potential will spiral out the ends of the flux tube into the atmosphere. Density fluctuations in the auroral plasma can maintain their identity and cause the auroral ray structure. Various other consequences of the theory are examined. It is proposed that an $\mathbf{E} \times \mathbf{B}$ drift accounts for the statistical preference for auroral patterns to move towards the sunlit hemisphere and for the departures of auroral forms from alignment along circles of geomagnetic latitude. Other morphological features are explained.

Constance S. Warwick, Phenomena of solar proton events.

Systematic analysis of data on solar flares and bursts shows that polar cap absorption is most closely associated with solar events observed at long wave-lengths. Delay time of PCA tends to be longer near maximum solar activity and is related much more strongly to phase of the solar cycle than to flare position or to magnitude of the flare-burst event. Properties of solar particles of higher energy (causing an increase of cosmic ray monitors at ground level) and of low energy (causing geomagnetic disturbance) show that the probability that an interplanetary magnetic field will stop, delay, or deflect solar particles increases as the individual particle energy increases and is greatest near maximum phase of the solar cycle. Observed energy spectra show that relativistic solar particles will act as single particles in interplanetary fields, while particles causing geomagnetic disturbances, and, in general, those causing PCA will act co-operatively. Characteristics of propagation of solar particles can be explained by a model in which a weak ($< 10^{-6}$ gauss) uniform field, which may be identified with the galactic arm field approximately normal to the ecliptic plane, is compressed by outward moving solar plasma clouds into concentrations of 10^{-5} to 10^{-4} gauss.

Helen Dodson-Prince, Characteristics of flares associated with polar cap absorption.

A careful study of those flares most probably associated with polar cap absorption has shown that many of the flares show no great intensity or any other severe abnormality. The most characteristic property of these flares is that they cover the umbrae of sunspots.

A. D. Fokker and *H. P. Th. van Lohvizen*, The correlation between impulsive micro-wave flares and geomagnetic crochets.

Observations of micro-wave solar radio outbursts and geomagnetic crochets have been obtained by the Ionosphere and Radio Astronomy Section of the Netherlands PTT. It has been found that strong micro-wave outbursts of the impulsive type are often associated with crochets. If the bursts' peak intensity (in 10^{-22} W m^{-2} (c/s)$^{-1}$) be denoted P and its impulsiveness (= peak intensity/rise time) be I, then:

(*a*) of the SID-associated micro-wave bursts with $\log P < 1{\cdot}7$ and $\log I < 1{\cdot}5$ only 3·6% are associated with crochets;

(*b*) of micro-wave bursts with $\log P > 2{\cdot}3$ and $\log I > 2{\cdot}1$ as much as 55% are crochet-associated.

Geomagnetic effects and corresponding micro-wave bursts start practically simultaneously, and durations are usually the same. Both impulsive micro-wave flares and crochet flares tend to recur within one and the same active centre.

D. H. Menzel, The role of magnetic fields in solar prominences.

H. Friedman, Solar x-rays and the E-region. *G. Righini*, Publication of plages from Arcetri.

G. Piccardi, Chemical tests and solar activity. (This paper showed recent trends.)

P. Bernard, A new solar weather relation.

The speaker discussed certain specific cases when the evenness of the Earth's rotation appears to have been influenced by, or associated with, flares and micro-seisms.

G. E. Moreton, Optical detection of 1000 km/s disturbances.

Small movements and changes of filaments and other features have revealed very rapid and widespread disturbances emerging from a flare.

PART 6

STATUTS ET REGLEMENT
STATUTES AND BY-LAWS

COMITE EXECUTIF
EXECUTIVE COMMITTEE

COMPOSITION DES COMMISSIONS
MEMBERSHIP OF COMMISSIONS

LISTE ALPHABETIQUE DES MEMBRES
ALPHABETICAL LIST OF MEMBERS

UNION ASTRONOMIQUE INTERNATIONALE

STATUTS

I. Objets de l'Union

1. L'Union Astronomique Internationale a pour objet:

(*a*) de faciliter les relations entre les astronomes des divers pays, lorsqu'il est utile ou nécessaire d'organiser une coopération internationale;

(*b*) de favoriser l'étude et le développement de toutes les branches de l'Astronomie.

2. L'Union adhère au Conseil International des Unions Scientifiques.

II. Adhésion des Pays

3. (*a*) Un pays peut adhérer à l'Union par l'Organisme par lequel il adhère au Conseil International des Unions Scientifiques, ou par un Comité National d'Astronomie habilité par cet organisme.

(*b*) Un pays qui n'adhère pas au Conseil International peut adhérer à l'Union par un Comité National d'Astronomie agréé par le Comité Exécutif de l'Union.

(*c*) Dans les 'pays' sont compris les Dominions, les protectorats diplomatiques, ainsi que les territoires ayant une activité astronomique indépendante.

4. Les pays adhérents sont répartis en huit catégories numérotées de 1 à 8. Tout pays qui demande son admission désigne la catégorie dans laquelle il désire être rangé. Sa demande peut être rejetée par le Comité Exécutif, si la catégorie proposée est manifestement inadéquate.

III. Membres de l'Union

5. L'Union se compose de Membres, agréés, sur proposition des Organismes ou Comités Nationaux adhérents mentionnés à l'article 3, par le Comité Exécutif, en raison de leur activité dans une branche de l'Astronomie.

IV. Assemblée Générale

6. (*a*) L'activité de l'Union est dirigée par l'Assemblée Générale des représentants des pays adhérents et des Membres de l'Union. Chaque pays fait connaître le représentant auquel il a donné mandat de voter en son nom.

(*b*) L'Assemblée Générale établit un Règlement fixant les modalités d'application des présents Statuts.

(*c*) Elle nomme un Comité Exécutif chargé d'exécuter les décisions de l'Assemblée Générale et de gérer les affaires de l'Union dans l'intervalle des sessions de l'Assemblée. Le Comité Exécutif rend compte de sa gestion à l'Assemblée Générale.

7. (*a*) Sur toute question d'ordre administratif, ou d'ordre à la fois administratif et scientifique, mais sans répercussion financière, le vote à l'Assemblée Générale a lieu par pays, chaque pays disposant d'une voix. Ne peuvent participer aux votes les pays qui n'ont pas acquitté les cotisations dues au 31 décembre de l'année précédant l'Assemblée Générale.

(*b*) Sur toute question ayant une répercussion financière, le vote a lieu également par pays, dans les mêmes conditions et sous la même réserve qu'à l'article 7(*a*), le nombre de voix attribué à chaque pays étant égal à l'indice de sa catégorie défini à l'article 4, augmenté d'une unité.

(*c*) Les Organismes ou Comités Nationaux adhérents peuvent voter par correspondance sur les points figurant à l'ordre du jour de l'Assemblée Générale.

INTERNATIONAL ASTRONOMICAL UNION

STATUTES

I. Objects of the Union

1. The objects of the International Astronomical Union are:

(*a*) to facilitate relations between astronomers of different countries where the organization of international co-operation is useful or necessary;

(*b*) to promote the study and development of Astronomy in all its departments.

2. The Union adheres to the International Council of Scientific Unions.

II. Adherence of Countries

3. (*a*) A country may adhere to the Union by the Organization by which it adheres to the International Council of Scientific Unions, or by a National Committee of Astronomy approved by that organization.

(*b*) A country not adhering to the International Council may adhere to the Union by a National Committee of Astronomy recognized by the Executive Committee of the Union.

(*c*) Within the term 'country' are included Dominions, diplomatic Protectorates, and any territory in which independent astronomical activity has been developed.

4. Adhering countries are classified in eight categories, numbered 1 to 8. A country requesting adherence shall specify the category in which it desires to be classed. Such a request may be refused by the Executive Committee if the category proposed is manifestly inadequate.

III. Members of the Union

5. The Union is composed of Members approved, on the proposals of the Adhering Organizations or National Committees referred to in article 3, by the Executive Committee, on the basis of their achievement in some branch of Astronomy.

IV. General Assembly

6. (*a*) The work of the Union is directed by the General Assembly of representatives of adhering countries and of the Members of the Union. Each country nominates a representative authorised to vote in its name.

(*b*) The General Assembly draws up By-Laws governing the application of the Statutes.

(*c*) It appoints an Executive Committee to implement the decisions of the General Assembly and to direct the affairs of the Union in the interval between meetings of the Assembly. The Executive Committee reports to the General Assembly.

7. (*a*) On questions of administrative, or of mixed scientific and administrative, character, not involving questions of finance, voting at the General Assembly is by country, each country having one vote. Countries which have not paid their subscriptions up to 31 December of the year preceding the General Assembly may not participate in the voting.

(*b*) On questions involving finance, voting is similarly by country, under the same conditions and with the same reservation as in article 7 (*a*), the number of votes for each country being one greater than the number of its category, as defined in article 4.

(*c*) Adhering Organizations or National Committees may vote by correspondence on questions on the agenda for the General Assembly.

(*d*) Un scrutin n'est valable que si les deux-tiers au moins des pays disposant du droit de vote en vertu des articles 7(*a*), 7(*b*), et 7(*c*) y prennent part.

8. Sur toutes les questions scientifiques, les Membres de l'Union disposent chacun d'une voix.

9. Dans les cas visés aux articles 7 et 8, les décisions sont prises à la majorité absolue des suffrages, sous la réserve formulée au paragraphe 13 ci-après.

V. Budget

10. Le Comité Exécutif prépare un projet de Budget pour chaque année de la période comprise entre deux sessions de l'Assemblée Générale. Il soumet ce projet, avec les comptes des exercises précédents, à une Commission Financière nommée par l'Assemblée Générale. La Commission Financière examine les comptes et le projet de Budget, sur lesquels elle établit deux rapports distincts, qu'elle soumet à l'approbation de l'Assemblée Générale.

11. (*a*) Les pays adhérents versent annuellement à l'Union un nombre de parts contributives égal à l'indice de leur catégorie.

(*b*) Le taux de la part contributive unitaire est fixé par l'Assemblée Générale sur la proposition du Comité Exécutif, après avis de la Commission Financière. Il ne peut excéder 900 francs-or, le franc-or étant équivalent à 9/31 gramme d'or fin.

(*c*) Le paiement des cotisations est assuré par les Organismes ou Comités Nationaux adhérents.

(*d*) Tout pays qui cesse d'appartenir à l'Union pour quelque motif que ce soit perd de ce fait ses droits sur l'actif de l'Union.

12. Le siège légal de l'Union est fixé à Bruxelles. Les dons et legs sont reçus et gérés conformément à la législation belge.

VI. Modification des Statuts

13. Les présents Statuts entrent en vigueur dès leur adoption par l'Assemblée Générale de 1961. Ils ne peuvent être modifiés que par une décision de l'Assemblée Générale prise à la majorité des deux-tiers des voix des pays adhérents qui disposent du droit de vote en vertu de l'article 7(*a*).

14. Le présent texte français sera seul utilisé pour l'interprétation des Statuts.

REGLEMENT

I. Membres de l'Union

1. Les changements à apporter à la liste des Membres sont soumis par le Comité Exécutif au Comité des Présentations, composé d'un représentant de chaque pays adhérent désigné par l'Organisme ou Comité National adhérent.

2. Les Commissions peuvent proposer la cooptation de personnalités appartenant à des pays qui n'adhèrent pas à l'Union. Si ces personnalités sont admises comme Membres de l'Union, elles en conservent la qualité jusqu'à la fin de la réunion ordinaire de l'Assemblée Générale qui suit leur désignation.

3. Le Secrétaire Général publie la liste des Membres de l'Union après chaque réunion ordinaire de l'Assemblée Générale.

II. Assemblée Générale

4. L'Union se réunit en Assemblée Générale ordinaire en principe tous les trois ans. Si l'époque et le lieu de la réunion n'ont pas été arrêtés par l'Assemblée Générale précédente, ils

(*d*) A vote is valid only if at least two-thirds of the countries having the right to vote by virtue of articles 7 (*a*), 7 (*b*) and 7 (*c*) participate in it.

8. On scientific questions the Members of the Union each have one vote.

9. On all questions in articles 7 and 8, decisions are taken by an absolute majority of the votes cast, subject to the reservation in article 13 below.

V. Budget

10. The Executive Committee prepares an estimate of the budget for each of the years intervening between two General Assemblies. It submits this estimate, together with the accounts for the preceding years, to a Finance Committee nominated by the General Assembly. The Finance Committee examines the accounts and the estimate of the budget, on which it presents two separate reports, and submits them to the General Assembly for approval.

11. (*a*) Each adhering country pays annually to the Union a number of units of contribution equal to the number of its category.

(*b*) The amount of the unit of contribution is fixed by the General Assembly, on the proposal of the Executive Committee and with the advice of the Finance Committee. It may not exceed 900 gold francs, the gold franc being equivalent to 9/31 grammes of fine gold.

(*c*) The payment of contributions is the responsibility of the Adhering Organizations or National Committees.

(*d*) A country that ceases, for whatever reason, to adhere to the Union, resigns at the same time its rights to a share in the assets of the Union.

12. The legal domicile of the Union is in Brussels. Gifts and bequests are received and administered in accord with Belgian legislation.

VI. Revision of the Statutes

13. The present Statutes enter into force with their adoption by the General Assembly in 1961. They may not be changed except by a decision of the General Assembly taken with the approval of two-thirds of the votes of the adhering countries having the right to vote by virtue of article 7 (*a*).

14. The French text (of which the above is a translation) is the only authority for the interpretation of these Statutes.

BY-LAWS

I. Members of the Union

1. Proposed changes in the list of Members are submitted by the Executive Committee to the Nominating Committee, consisting of one representative of each adhering country designated by the Adhering Organization or National Committee.

2. Commissions may propose the co-option of scientists from countries which do not adhere to the Union. If such scientists are admitted as Members of the Union, they retain their membership to the end of the ordinary meeting of the General Assembly next following that at which they were admitted.

3. The General Secretary publishes a list of Members of the Union after each ordinary meeting of the General Assembly.

II. General Assembly

4. The Union meets in ordinary General Assembly, as a rule, once every three years. The date and place of the meeting, unless determined by the General Assembly at its previous meeting,

sont fixés par le Comité Exécutif et communiqués six mois au moins à l'avance aux Organismes ou Comités Nationaux adhérents.

5. Le Président peut, avec le consentement du Comité Exécutif, convoquer une réunion extraordinaire de l'Assemblée Générale. Il est tenu de le faire à la demande du tiers des pays adhérents.

6. L'ordre du jour d'une session est fixé par le Comité Exécutif et communiqué aux Organismes ou Comités Nationaux adhérents quatre mois au moins avant l'ouverture de la session. Toute motion ou proposition ne figurant pas à l'ordre du jour arrêté par le Comité Exécutif n'est prise en considération qu'avec l'assentiment préalable de la moitié au moins des voix des pays représentés à l'Assemblée Générale.

7. Toute motion ou proposition reçue par le Secrétaire Général cinq mois au moins avant l'ouverture d'une session, soit de l'un des Organismes ou Comités Nationaux adhérents, soit d'une Commission de l'Union ou d'une Commission mixte affiliée à l'Union, est inscrite d'office à l'ordre du jour.

8. S'il y a doute sur le caractère administratif ou scientifique d'une question donnant lieu à scrutin, l'avis du Président est prépondérant.

9. En cas de partage égal des voix, l'avis du Président est prépondérant.

10. L'Assemblée Générale désigne les représentants de l'Union au Conseil International des Unions Scientifiques.

11. Le Président de l'Union peut inviter à assister aux séances de l'Assemblée Générale (*a*) des hommes de science, et (*b*) de jeunes astronomes.

III. Comité Exécutif

12. Le Comité Exécutif de l'Union comprend un Président, six Vice-Présidents au plus et un Secrétaire Général, élus par l'Assemblée Générale.

13. Le Président demeure en fonction jusqu'à la fin de la réunion ordinaire de l'Assemblée Générale qui suit celle de son élection; les Vice-Présidents et le Secrétaire Général demeurent en fonction jusqu'à la fin de la deuxième réunion ordinaire de l'Assemblée Générale qui suit celle de leur élection. Le Président et les Vice-Présidents ne sont pas immédiatement rééligibles. L'élection des membres à remplacer dans le Comité Exécutif a lieu dans la dernière séance de l'Assemblée Générale, la présentation des candidats ayant été faite dans l'avant-dernière séance. Le Président sortant et le Secrétaire Général sortant restent membres du Comité Exécutif avec voix consultative, lorsque leur mandat prend fin et jusqu'à la fin de la réunion ordinaire suivante de l'Assemblée Générale.

14. Le Comité Exécutif peut pourvoir aux vacances qui surviendraient dans son sein. Toute personne désignée dans ces conditions demeure en fonction jusqu'à la réunion ordinaire de l'Assemblée Générale suivante, qui doit procéder à une élection définitive. Le membre ainsi élu achève le mandat de celui qu'il s'agissait de remplacer.

15. Un Bureau administratif, sous la direction du Secrétaire Général, expédie la correspondance, gère les ressources et assure la conservation des archives ainsi que la préparation et la distribution des publications approuvées par l'Assemblée Générale.

IV. Commissions

16. (*a*) L'Assemblée Générale peut créer des Commissions pour l'étude de sujets déterminés d'astronomie, pour l'encouragement d'entreprises collectives et pour l'examen de questions de conventions et de normalisation internationales.

(*b*) Ces Commissions établissent des rapports sur les questions dont elles sont chargées.

shall be fixed by the Executive Committee and communicated at least six months beforehand to the Adhering Organizations and National Committees.

5. The President, with the consent of the Executive Committee, may summon an extraordinary meeting of the General Assembly. He must do so at the request of one-third of the adhering countries.

6. The agenda of business for each meeting is determined by the Executive Committee and is communicated to the Adhering Organizations and National Committees at least four months before the first day of the meeting. A motion or proposal which does not appear on the agenda prepared by the Executive Committee shall only be discussed with the prior approval of at least one-half of the votes of the countries represented at the General Assembly.

7. Any motion or proposal received by the General Secretary at least five months before the first day of a meeting, whether from an Adhering Organization or National Committee, from a Commission of the Union, or from an Inter-Union Commission affiliated to the Union, must be placed on the agenda.

8. If there is doubt as to the administrative or scientific character of a question giving rise to a vote, the President determines the issue.

9. Where there is an equal division of votes, the President determines the issue.

10. The General Assembly appoints the Union's representatives to the International Council of Scientific Unions.

11. The President of the Union may invite (*a*) scientists and (*b*) young astronomers to participate in the meetings of the General Assembly.

III. Executive Committee

12. The Executive Committee of the Union consists of a President, not more than six Vice-Presidents and a General Secretary elected by the General Assembly.

13. The President remains in office until the end of the ordinary meeting of the General Assembly next following that of his election; the Vice-Presidents and the General Secretary remain in office until the end of the second ordinary meeting of the General Assembly following that of their election. The President and the Vice-Presidents are not eligible for immediate re-election. The election of their successors takes place at the last session of the General Assembly, the names of candidates proposed having been announced at the preceding session. The retiring President and General Secretary remain members of the Executive Committee in a consultative capacity until the end of the next ordinary meeting of the General Assembly following their retirement.

14. The Executive Committee may fill any vacancy occurring among its members. Any person so appointed remains in office until the next ordinary meeting of the General Assembly, which then proceeds to an election for the remainder of the normal tenure of the member who is being replaced.

15. An Administrative Office, under the direction of the General Secretary, conducts the correspondence and administers the funds of the Union, preserves the archives, and prepares and issues the publications approved by the General Assembly.

IV. Commissions

16. (*a*) The General Assembly may form Commissions for the study of special branches of Astronomy, the encouragement of collective investigations, and for the discussion of questions relating to international agreements or to standardization.

(*b*) These Commissions prepare reports on the work with which they are concerned.

17. Chaque Commission comprend:

(*a*) Un Président et un Vice-Président élus par l'Assemblée Générale sur la proposition du Comité Exécutif. Ils demeurent en fonction jusqu'à la fin de la réunion ordinaire de l'Assemblée Générale qui suit celle de leur élection. Ils sont rééligibles.

(*b*) Un Comité d'Organisation, dont les membres sont désignés par la Commission, leur désignation étant soumise à l'approbation du Comité Exécutif et de l'Assemblée Générale. Le Comité d'Organisation assiste le Président et le Vice-Président dans leur tâche.

(*c*) Des Membres de l'Union, agréés ou choisis par le Président, le Vice-Président et le Comité d'Organisation, en raison de leur spécialité, et dont la désignation est soumise à l'approbation du Comité Exécuitif.

18. Dans l'intervalle de deux réunions ordinaires de l'Assemblée Générale, les Commissions peuvent coopter parmi les Membres de l'Union de nouveaux membres des Comités d'Organisation ou de la Commission elle-même.

19. Les Commissions établissent elles-mêmes leur règlement intérieur. Les décisions au sein des Commissions sont prises à la majorité des voix des membres et non par pays.

20. Avec l'approbation du Comité Exécutif, une Commission peut avoir ses propres publications et confier une partie quelconque de ses travaux à des institutions ou même à des particuliers.

V. Comités Nationaux

21. Les Comités Nationaux ont pour attributions de faciliter et de coordonner, sur leurs territoires respectifs, l'étude des diverses branches de l'Astronomie, envisagées principalement du point de vue international.

Ils ont le droit de soumettre au Comité Exécutif des propositions à discuter par l'Assemblée Générale.

VI. Finances

22. Les recettes de l'Union sont consacrées à couvrir les dépenses suivantes:

(*a*) frais de publication et dépenses accessoires d'administration;

(*b*) aide financière à des entreprises astronomiques qui nécessitent la coopération internationale;

(*c*) cotisation due par l'Union au Conseil International des Unions Scientifiques.

23. Les ressources provenant de dons sont utilisées par l'Union en tenant compte des désirs exprimés par les donateurs.

VII. Publications

24. Les *Transactions* de l'Union sont fournies gratuitement:

(*a*) à tous ceux qui, à l'époque de la réunion de l'Assemblée Générale, étaient Membres de l'Union, y compris les Membres cooptés au titre de l'article 2 du présent Règlement;

(*b*) aux institutions dont la liste est arrêtée par le Comité Exécutif;

(*c*) aux Organismes ou Comités Nationaux adhérents.

25. Le Comité Exécutif décide des modalités de distribution des autres publications.

26. Les Membres de l'Union peuvent acquérir les publications à prix réduit.

VIII. Modification du Règlement

27. Le présent Règlement entrera en vigueur dès son adoption par l'Assemblée Générale. Il pourra être modifié sous les formes prévues pour les Statuts dans leur article 13.

17. Each Commission consists of:

(*a*) A President and a Vice-President elected by the General Assembly on the nomination of the Executive Committee. They remain in office until the end of the ordinary meeting of the General Assembly next following their election, and are re-eligible.

(*b*) An Organizing Committee, whose members are appointed by the Commission subject to the approval of the Executive Committee and the General Assembly. The Organizing Committee assists the President and the Vice-President in their duties.

(*c*) Members of the Union, approved or chosen by the President, Vice-President and the Organizing Committee, in consideration of their special interests; their appointments are submitted to the approval of the Executive Committee.

18. Between two ordinary meetings of the General Assembly, Commissions may co-opt, from among Members of the Union, new members to the Organizing Committees or to the Commissions themselves.

19. Commissions draw up their own by-laws. Decisions within Commissions are taken by a majority of the votes of members and not by countries.

20. With the approval of the Executive Committee, a Commission may issue its publications independently, and may entrust any part of its work to any institution or to individuals.

V. National Committees

21. The functions of the National Committees are to promote and co-ordinate, in their respective territories, the study of the various branches of Astronomy, more especially in relation to their international requirements.

They are entitled to submit to the Executive Committee motions for discussion by the General Assembly.

VI. Finance

22. The income of the Union is to be devoted to:

(*a*) costs of publication and expenses of administration;

(*b*) the promotion of astronomical enterprises requiring international co-operation;

(*c*) the contribution due from the Union to the International Council of Scientific Unions.

23. Funds derived from donations are used by the Union in accordance with the wishes expressed by the donors.

VII. Publications

24. The *Transactions* of the Union are distributed free of cost to:

(*a*) all those who, at the time of the meeting of the General Assembly, were Members of the Union including those co-opted by virtue of article 2 of the present By-laws;

(*b*) institutions on a list approved by the Executive Committee;

(*c*) Adhering Organizations or National Committees.

25. The distribution of other publications is decided by the Executive Committee.

26. Members of the Union may purchase the publications at reduced prices.

VIII. Revision of the By-laws

27. The present By-laws come into force as soon as they are adopted by the General Assembly. They may be modified with the same procedure as for the Statutes in article 13 of the Statutes.

N63-17792 16-05

INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

EXECUTIVE COMMITTEE — COMITE EXECUTIF

APPOINTED AUGUST 1961 — ÉLUS AOÛT 1961

PRESIDENT — PRÉSIDENT

Professor V. A. AMBARTSUMIAN, President of the Academy of Sciences of Armenian S.S.R. Erevan, Armenia, U.S.S.R.

VICE-PRESIDENTS — VICE-PRÉSIDENTS

Professor L. GOLDBERG, Harvard College Observatory, Cambridge 38, Massachusetts, U.S.A.

Professor Y. HAGIHARA, Department of Astronomy, Faculty of Science, University of Tokyo, Bunkyo-ku, Tokyo, Japan.

Professor G. HARO, Observatorio Astronomico Nacional, Apartado Postal 25264, Ciudad Universitaria, Mexico 20, D. F., Mexico.

Dr R. M. PETRIE, Dominion Astrophysicist, Dominion Astrophysical Observatory, Victoria, B.C., Canada.

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Commissions Nos. **1, 2, 3, 11, 13, 18, 32** and **39** have been discontinued.

† Indique mort depuis août 1961; indicates death since August 1961.

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44. Commission des Observations Astronomiques au dehors de l'Atmosphère Terrestre. (Astronomical Observations from outside the Terrestrial Atmosphere.)

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ALPHABETICAL LIST OF 1289 MEMBERS

LISTE ALPHABETIQUE DES 1289 MEMBRES

Names are given under the first letter of the first word, for example the name *Van den Bos* will be found under V.

The names of the countries are given in their English form.

Please inform the Assistant Secretary of the I.A.U., Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England, of any errors you may find in this list.

The list has been corrected to July, 1962.

Les noms figurent sous la première lettre du premier mot, par exemple le nom *Van den Bos* se trouverait sous V.

Les noms des pays ont été publiés en anglais.

Prière de bien vouloir signaler les erreurs qu'on relèverait dans la présente liste à la Secrétaire Adjointe de l'U.A.I., Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

La liste a été corrigée jusqu'à juillet, 1962.

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The following, who were Members of the Union in August 1961, have since died:

Les personnes suivantes, qui étaient Membres de l'Union en août 1961, sont décédées depuis cette date:

W. Dziewulski, T. Hattori, K. Lassovszky, R. R. McMath, N. V. E. Nordenmark, H. S. Spigl, P. ten Bruggencate.