R-09-029-063

ANNUAL REPORT

of the

E. O. Hulburt Center for Space Research
Naval Research Laboratory
Washington, D. C.

to

The National Aeronautics and
Space Administration

---

for

Fiscal Year 1969

Herbert Friedman
Chief Scientist

1 July 1969

RECEIVED
NASA STI FACILITY
INPUT BRANCH
OCT 1969

N69-38294
(ACCESSION NUMBER) (THRU)
179 1
(PAGES) (CODE)
CR 105970 30
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)
FACILITY FORM 602

Encl (1) to NRL Letter
7150-6:HF:rmo
SER:

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

CONTENTS

* *

REPORT OF DISBURSEMENTS

NASA GRANT R09-029-063

FISCAL YEAR 1969

1.	Aerobee-170 Rockets and Accessories	$105.0K
2.	Launch Support, Aerojet-General	50.0
3.	PCM Ground Support Equipment	50.0
4.	ACS Preparation & Support, NB 3.205	16.3
5.	Engineering Support, Blue Scout, Jr., Wallops Is.	15.0
6.	WSMR Launch Support	10.0
7.	Land Recovery Systems	15.7
8.	Misc. Materials and Services	38.0
	TOTAL	$300.0K

PRECEDING PAGE BLANK NOT FILMED.

NEW DISCOVERIES IN SPACE SCIENCE AT NRL DURING THE PAST YEAR

The Space Science Division program has had substantial successes in all elements of its flight program during the past year.

The following is a list of some of the more noteworthy results:

1. An X-ray pulsar was found in the Crab Nebula, with a repetition rate of 30.2 pulses/sec. corresponding to previous optical and radio observations. (Aerobee)
2. A more accurate positional measurement confirmed that M-87 is an extragalactic x-ray source. (Aerobee)
3. Bright-giant and super-giant stars appear to be up to one magnitude fainter near 1115 A than main sequence stars of the same spectral class. (Aerobee)
4. The infrared radiation at 63μ from atmospheric atomic oxygen was discovered. It is the principal mechanism of radiative cooling from the atmosphere above 120 km. (Aerobee)
5. Atmospheric radiation in the 10-30 micron band was observed above 160 km altitude. (Aerobee)
6. Geocoronal airglow was found to have short-term fluctuations of less than ±5% superimposed on a monthly variation of solar origin of about 30%. (OGO-IV and OSO-IV)
7. Observations of a series of 128 ultraviolet auroras show only 3 proton-electron separations on the morning side, with the proton aurora being <u>poleward</u> of the electron aurora. (OGO-IV)
8. Far ultraviolet emissions in the equatorial zones were detected which completely encircled the earth at altitudes less than 500 km. (OGO-IV)
9. An appreciable component of the extraterrestrial Lyman-alpha background was found to be solar-related. (OGO-III)

10. Five new sources of water vapor line emission discovered in the galaxy show remarkable time-variability.

11. The small size and high brightness temperature of galactic water vapor sources indicates that the H_2O emission arises from maser action rather than from spontaneous or thermal emission.

12. Observations of ammonia emission in Sagittarius reveal that ammonia is formed in large cool regions of the interstellar medium and that, unlike the observations for water vapor, there is no evidence of maser action.

13. Lunar occultation studies at 21 cm. show that neutral hydrogen is quite uniformly distributed across the region of the galactic center.

14. The temperature of the surface and atmosphere near the surface on the sunlit hemisphere of Vénus is not significantly greater than that on the night side, as revealed from preliminary observations at 2.7 cm.

15. The points of origin of coronal streamers on the sun often do not correspond well with solar active regions. (Aerobee)

16. Vast changes in form and number of solar coronal streamers are found to occur within one day's time. (Aerobee)

17. The minimum solar continuum temperature (in the range 1520-1700A) for July 1966 was 4670°K, a value 300° higher than that inferred from the solar infrared continuum. (Aerobee)

18. A possible detection of localized H-alpha emission on Jupiter (aurora?) was made using a double solid etalon and an S-20 orthicon camera chain.

- - - - - - - - - - -

It will be seen that perhaps the two most remarkable discoveries--those of the emission from galactic water vapor by maser action, and of the x-ray pulsar in the Crab--were made from the earth's surface and from a sounding rocket, respectively. Nevertheless, the satellite programs are broadly productive in providing long-time monitoring or surveys of new phenomena of grand spatial extent. Satellite OSO-5 (OSO-F) was the first of two NASA satellites launched during FY 69 which carried NRL experiments. It has already provided many excellent far ultraviolet spectroheliograms of the sun. The second satellite, OGO-6 (OGO-F), was launched as this review went to press.

UPPER AIR PHYSICS BRANCH

X-RAY ASTRONOMY PROGRAM

A detailed analysis of the data from an Aerobee rocket launched in September 1967 is now complete. The flight obtained detailed x-ray spectra in the photon energy range 1 to 13 KeV, plus an additional spectral point near 1/4 KeV, from Sco SR-1, Cyg XR=1, Cyg XR-2, and a region near the galactic pole. The x-ray spectrum of Cyg XR-1 was found to follow a power law, and was quite different from the exponential character (thermal bremsstrahlung) of the Cyg XR-2 and Sco XR-1 spectra. The flux of Sco XR-1 at 1/4 KeV fell exactly on the extrapolation of its 1 to 13 KeV spectrum, suggesting either very little interstellar absorption between the source and earth or a second, "soft" component of x-ray emission in the source. The Sco XR-1 data were also examined for the possibility of line emission from Fe XXV and Fe XXVI near 7 KeV. An upper limit of 3% of the continuum x-ray flux was obtained, suggesting that this source is not a supernova remnant (from which 8% would be expected), but not eliminating the possibility that iron is present in cosmic abundances (1 - 2% line emission).

Because of the great current interest in pulsars the x-ray counts from Sco XR-1, Cyg XR-1, and Cyg XR-2 were examined for evidence of periodicity, using power spectrum analysis and autocorrelation techniques. These showed that less than 1% of the x-rays from Sco XR-1 (6% for Cyg XR-1 and Cyg XR-2) were pulsed with any period between 0.07 and 4 seconds.

An Aerobee rocket with improved instrumentation was launched in March 1969 to observe the Crab Nebula, and to scan through a region in the galactic plane and through the Coma cluster of galaxies (near the galactic pole). The unexpected discovery of optical pulsations in the Crab prompted the immediate search for periodicity in the Crab x-ray data. This search led to the discovery that the pulsar at the center of the Crab Nebula is also an X-ray pulsar, and that 5 percent of the X-rays emitted by the nebula as a whole occur in the two pulses from the pulsar. Two X-ray pulses are emitted 30.2 times per second with a 12 millisecond separation between the X-ray pulses. The first X-ray pulse is 2.5 milliseconds wide, or less, while the second is about 5.0 milliseconds wide. Both contain about the same X-ray energy. This detection constitutes the first discovery of a pulsating X-ray source and indicates that pulsars emit radiation over an enormously broad spectral range. The X-ray pulse power exceeds the optical power by a factor of 200. Hence, the Crab pulsar should be thought of as primarily an X-ray source, with only incidental energy production in the visible and radio portions of the spectrum.

The rocket that detected the Crab Nebula X-ray pulsar contained detectors with larger collecting areas, with better rejection of cosmic ray particle events, and with improved spectral response (0.8 to 12 KeV range plus points at 0.65 and 0.27 KeV) than the previous experiment. The spectral analysis now in progress, will help to answer questions about the extragalactic x-ray emission, about x-ray absorption in our galaxy, and about the nature of the x-ray sources (continuous and pulsed) in the Crab Nebula.

Another Aerobee rocket, also launched in March 1969, gave a new measurement of much better statistical and positional accuracy on M-87, confirming its existence as an extragalactic X-ray source.

Two additional rocket firings are planned for late fall from White Sands.

SOLAR X-RAY PROGRAM

As will be seen from the following discussion much effort has been expended in doing first-review interpretations of data from satellites launched within the past year and one-half, and in preparing still other experiments for launch. This has necessitated temporary deferment of complete interpretation of earlier rocket data and of detailed examination of some satellite data as they are received.

Solar Monitoring Experiments for NASA Observatory Spacecraft

A. Bragg Crystal Spectrometer for X-ray Flare Spectra, OSO-IV

Two Bragg crystal spectrometers covering the wavelength regions, 0.63 Å to 3.8 Å, and 1.6 Å to 8.4 Å, were launched in October 1967 aboard the OSO-IV spacecraft. These spectrometers have the capability of scanning over their total range in 13 minutes, for a relatively quiet sun, or two minutes for an active sun. Preliminary results of this experiment have provided information which will lead to improved theories of solar phenomena.

Detailed reduction of the data is now being performed. Measurements of recombination edges have been made for the first time. These spectra have shown

(1) the dominance of X-ray continuum emission over line emission below 6 Å in the flare plasma, (2) the existence of innershell transition from partially stripped ions as an important component of the X-ray line emission, (3) electron temperatures of $\sim$ 15 million degrees for the main body of gas emitting between 1 and 8 Å, (4) a deficiency in argon content relative to calcium and iron, and (5) an absence of strong emission from single electron iron and calcium ions.

The instrument is still performing satisfactorily after 1.5 years in orbit and still acquiring useful data although the satellite memory malfunctioned 6 months after launch.

B. X-Ray Ion Chamber Experiment for the Wheel Section of OSO-IV

This experiment is patterned after the SOLRAD experiments. The SOLRAD ionization chamber photometers for the 0.5 - 3 Å, 1 - 8 Å, 8 - 20 Å, and 44 - 60 Å bands are used in conjunction with peak-reading and A/D conversion circuitry to adapt the sensor output to the OSO data format. An aperture wheel is used to reduce experiment sensitivity as required by ground command.

The experiment was constructed by the Electronic Engineering Branch of ESD and was launched in October 1967 aboard the OSO-IV spacecraft. The experiment provided data in both stored and continuously transmitted modes until the satellite's recorders failed in May 1968. Since that time only the continuously transmitted data have been available when recorded by a ground station.

C. X-Ray Ion Chamber Experiment for the Wheel Section of OSO-V

This experiment covers the same X-ray wavelength bands as that constructed for OSO-IV. It was, however, constructed on contract by Consolidated Systems Corporation. The satellite was launched in January 1969 and the experiment is working properly. As yet data are not available from NASA for detailed processing.

D. Spectral Scan, Burst and Mapping Experiment for OSO-G

Three Bragg crystal spectrometers (covering the wavelength regions 0.63 Å to 3.8 Å, 1.6 Å to 8.4 Å, and 5 Å to 25 Å), two pulse height spectrometers (covering the wavelength regions, 0.15 Å to 0.6 Å and 0.6 Å to 6 Å), three broad band detectors to investigate solar regions of interest, and one other broad band detector to monitor the general solar activity and to act as an in-flight calibrator are to be part of an instrument to be launched in the OSO-G spacecraft.

This instrument is designed for peak of the solar activity cycle. The launch is scheduled to take place sometime in July 1969 and is now in the integration and test phase. The results of this experiment will map the time history of the solar spectrum from 0.15 to 25 Å and indicate the regions of solar activity.

E. <u>Solar X-Ray Monitoring Experiments for OGO-II and OGO-IV</u>

OGO-II was launched in November 1965 and operated in the fully-oriented mode for only 11 days. Since the NRL X-ray experiment required proper solar pointing for data acquisition this experiment yielded very few useful data.

The OGO-IV instrument was launched in July 1967 and provided useful data until the satellite's tape recorders failed in January 1969. This experiment was basically similar to the SOLRAD monitoring experiments in that it covered the 0.5 - 3 Å, 1 - 8 Å, and 8-16 Å, and 44 - 60 Å X-ray bands with the standard SOLRAD photometers. It had two advantages over current SOLRAD experiments: much greater dynamic range to permit on-scale measurement during solar flares, and provision for continuous monitoring by means of the spacecraft on-board tape recorder.

F. Proportional Counter Spectrometer for OGO-V

This experiment measures the gross features of the solar x-ray spectrum between 2 and 20 Kev (0.6 - 6 Å). Launch occurred in March 1968. Preliminary data reduction only has been performed as of this date, in part because detector calibration drift must be taken into account. Further data analysis will be performed by the Martin Marietta Co. under NRL direction.

G. Proportional Counter and Scintillation Counter Spectrometer for OGO-F

This experiment is designed to make x-ray spectral measurements in the range 2 to 20 Kev and 20 to about 160 Kev with a 16-channel pulse height analyzer. The instrument was built under contract by Ball Brothers Research Corporation. Integration in the spacecraft was begun in late 1967. Launch is scheduled for June 1969.

H. Solar Radiation (SOLRAD) Monitoring Satellite Program

The objective of the SOLRAD program is to perform continuous monitoring of the solar x-ray and ultraviolet emission in order to obtain data needed to increase our understanding of solar processes, and to provide a set of indices of solar activity upon which a system of ionospheric disturbance forecasting can be based. The program employs small satellites constructed at the Naval Research Laboratory by the Satellite Techniques Branch to carry x-ray and ultraviolet photometers sensitive to solar radiation bands which cause disturbances in the earth's ionosphere. The satellite now operating, SOLRAD 9 (1968-17A), was launched in March 1968 and carries an on-board memory.

The new development of great significance in the current program is the introduction of almost continuous solar monitoring and quick reporting of x-ray flares in the 0.5 - 3 Å, 1 - 8 Å, and 8 - 20 Å bands. These data are recorded by the SOLRAD 9 satellite and the daily time histories are sent to ESSA with a one to two day delay to provide a continuous (except for satellite night intervals) of solar activities. No major flares or other solar activity events can escape notice as long as this system continues to operate. (Major denotes an event lasting at least ½ hour.)

Real-time data from SOLRAD 9 are received at the NRL ground station at Blossom Point, Maryland and simultaneously re-transmitted to the Operational Research Branch at NRL via a hard-line data link. The data are immediately displayed in strip chart form, reduced to energy flux units, and transmitted in a standardized format from the NRL SOFNET teletype

The data are usually transmitted on SOFNET within 10 minutes of the end of a satellite pass. When the data indicate that a solar flare is in progress a special alert message is transmitted before the pass ends to alert personnel of the Solar Forecast Center, NORAD Cheyenne Mountain Complex, Colorado. The data are also transmitted by telephone to Solar Radiation Section personnel who maintain an up-to-date plot of x-ray energy flux. From the analysis of these data, warnings of increased solar activity are sent to the Naval Communications Command.

Data from the SOLRAD 9 memory are also received at Blossom Point. The data are then re-transmitted during regular working hours to the Satellite Techniques Branch at NRL where they are pre-processed and delivered to the Operational Research Branch for processing on the Research Computation Center's CDC 3800 computer. Plots of the memory data are sent by facsimile equipment to ESSA's Space Disturbance Forecast Center (SDFC) at Boulder, Colorado.

The memory data are generally in the hands of SDFC personnel less than 24 hours after memory read-out. During the Apollo-8 and Apollo-10 manned circumlunar flights NRL personnel were on duty around-the-clock in order to send the SOLRAD 9 memory plots to the Space Disturbance Forecast Center within one hour of reception of the data from the satellite.[3] Equipment has been purchased to enable the Operational Research Branch to pre-process the memory data, and it is expected that this burden will soon be removed from the Satellite Techniques Branch.

Although the current SOLRAD program has produced a considerable amount of data over the past few years there are certain inherent limitations to the development of these spacecraft toward continuous solar monitoring. The fact that the satellites are flown in low orbits limits the amount of data that can be collected in real time using a single telemetry receiving station. A data storage system can and, in fact, is used to bridge the periods that the satellite is beyond the reception range of the ground station. Even with a data storage system providing continuous after the fact coverage there are numerous periods that the satellite will spend in darkness due to the low altitude orbit. Increasing data coverage by use of multiple ground stations does not improve real time data acquisition because of the delays involved in transmission of data by ground communications facilities. In addition, low altitude operation requires broom magnets to protect the x-ray photometers from charged particle interference within the Van Allen belts and the South Atlantic Anomaly. The net magnetic moment of the spacecraft is thereby increased and torquing effects are experienced due to interaction with the earth's magnetic field. This torquing results in a decrease of spin rate with time and a precession of the spin axis. Therefore an active attitude control system is required aboard the spacecraft to prevent data loss due to precession. The spin rate must be maintained to minimize precession and permit reliable operation of the attitude control system. Because of these inherent limitations in the operation of low altitude solar monitor spacecraft it has been proposed that the operational SOLRAD program employ high altitude spacecraft. With high-altitude spacecraft it would also be possible to measure solar charged-particle fluxes. This is impossible at low altitudes because of the shielding effect of the geomagnetic field.

Specifically, this phase of the SOLRAD program will employ two or three spacecraft at high altitude. The objective is to make solar x-ray flux data available continuously in real time. Real time data acquisition will enable personnel of the Solar Radiation Section to make timely warnings of increased solar activity to the Naval Communications Command and the SOFNET teletype exchange.

It is proposed than an orbital altitude between 18 and 20 earth radii be chosen. Because of funding and manpower limitations the introduction of this phase is programmed over fiscal years 1969, 1970, 1971, and 1972 in the following steps:

FY 69

Continue design and feasibility studies for SOLRAD-HI to define:

(1) Spacecraft structure,

(2) Data format and on-board data processing required,

(3) Data and command link requirements for spacecraft and ground station development,

(4) Ground based data processing and data dissemination requirements.

Complete design of one low-orbit, spin-stabilized spacecraft (SOLRAD 10) which will point its spin axis toward the sun during all periods of satellite day. This satellite will serve as a prototype of the SOLRAD-HI spacecraft.

FY 70

Construct and launch SOLRAD 10. Complete design and feasibility studies for SOLRAD-HI.

FY 71

Commence construction of two or three SOLRAD-HI satellites.

FY 72

Launch SOLRAD-HI satellites.

Initiate design studies for future spacecraft in the SOLRAD series.

It must be stressed that continuing data analysis and correlations will be performed in order to develop the most reliable criteria for prediction of ionospheric disturbances. This effort is to be directed toward the requirement of a 6-hour warning of communications disturbance.

Funding and a launch vehicle are available for SOLRAD 10. Funding and launch vehicle support for SOLRAD-HI are not yet fully committed.

FAR-ULTRAVIOLET ROCKET ASTRONOMY

As reported in the previous Program Review, an improved version of the all-reflecting image-converter spectrograph used in the flight of 16 March 1967 was constructed, with financial assistance from NASA Marshall Space Flight Center. The improvements included permanent magnet focusing and use of a single large objective grating (rather than the mosaic of four gratings used previously). Also, an improved photometer package, incorporating photon counters with rectangular apertures mounted on a scanning platform, was built. In order to insure that the spectral resolution of the spectrograph would not be degraded by rocket motion during the exposures, a fine-stabilization system, based on a floated rate-integrating gyroscope, was developed which is capable of stabilizing the rocket in the pitch direction (which is also the dispersion direction of the spectrograph) to a limit cycle of better than ± 10 arc seconds.

The first flight of this instrument package took place 10 October 1968. Unfortunately, due to a failure of the rocket attitude-control system, the flight was unsuccessful and no stellar data were obtained.

The instrument package was flown again, this time successfully, on 30 January 1969. Six targets in the constellation of Orion were observed, and stellar spectra in the 1000-1600A range, and photometric data in the 1050-1180 and 1230-1350A ranges were obtained. The fine-stabilization system demonstrated a capability of stabilizing the rocket in pitch to better than ± 10 arc seconds. However, due to an optical problem, the spectral resolution achieved was only about 3A, considerably poorer than the instrumental capability of 1A. Nevertheless, most of the experimental objectives were achieved.

Both the spectra and the photometric data indicate that the previously-reported stellar flux deficiency below 1200A, indicated by the 16 March 1967 flight, was probably instrumental in origin. The spectra from this latest flight are considerably denser, and extend to shorter wavelengths (about 1000A) than the previous spectra. The present results agree quite well with model atmosphere theory in the case of main-sequence stars. Bright-giant and supergiant stars, however, appear to be up to one magnitude fainter near 1115A than main-sequence stars of the same spectral class. The present spectra show, more clearly than on the March 1967 flight, the P-Cygni-type line profiles of the stronger lines produced in the atmospheres of the bright giant and supergiant stars. In addition, these spectra include, for the first time, the strong O VI resonance doublet (1032-1038A).

The present results for the Lyman-α absorption line, due to interstellar atomic hydrogen, agree with previous results, and also include, for the first time, that of the star cluster θ Orionis, which lies within and excites the Orion Nebula. A measurement of the Lyman-α interstellar line in this case is of special significance in that there exist 21-cm absorption measurements of the atomic hydrogen, which provide a more direct and unambiguous comparison with the Lyman-α data than the 21-cm emission measurements, which are all that are available for the other stars. As previously reported, there is a factor of 10 discrepancy between the Lyman-α absorption measurements and the 21-cm emission measurements in the Orion region.

The Lyman-α measurement for θ Orionis indicates a factor of 5 less hydrogen than the 21-cm absorption measurements, assuming a gas temperature of 100 $^{\circ}$K. However, the two agree if a gas temperature of 20 $^{\circ}$K is assumed instead. A number of pieces of evidence indicate that the absorbing hydrogen is concentrated in the close vicinity of the nebula. Therefore, the present results constitute additional support for a model of the interstellar medium in which most of the gas is concentrated in cold, dense clouds in pressure equilibrium with a much more rarefied, and much hotter, intercloud medium.

In addition to its interstellar Lyman-α absorption line, another surprising discovery regarding θ Orionis was that the interstellar continuous absorption by dust particles in the far ultraviolet here is much less than was expected. Extrapolation of the observed absorption at visual wavelengths into the far ultraviolet, using extinction curves found applicable to most other stars, predicts a total absorption of about 5 magnitudes near 1115A. However, assuming θ Orionis to have a normal spectral distribution for its spectral class, as appears true of most of the other stars observed after correcting for reddening, the observed flux corresponds to an ultraviolet absorption only slightly greater than in the visible; the indications are that the absorption is independent of wavelength, or possibly decreasing toward shorter wavelengths, rather than increasing as $1/\lambda$ as expected, and as appears valid for the other stars observed.

IMAGE TUBE RESEARCH

Future developments in image converters for space application include two types we have proposed for studies of extrasolar x-ray sources, in conjunction with a large x-ray telescope on an APOLLO Applications Mission. One device is for direct imaging of x-ray sources, the other is for spectroscopy using a grazing incidence, slit-type grating spectrograph. Both instruments are designed to take advantage of the increased quantum efficiency of alkali-halide photosurfaces for x-rays when used at large angles of incidence. We also plan to develop a slit-type, internal-grating image converter spectrograph for use in the 900-2000A far-ultraviolet wavelength range.

The Naval Electronic Systems Command has been supporting development of an internal-mirror, front-surface-photocathode Schmidt image converter for use in the visible wavelength range. In addition to developing techniques for preparing the visible-sensitive photocathodes, we are investigating the use of microchannel intensifier plates for amplification of the electron image prior to display on a phosphor screen. The microchannel plates can have gains of more than 10^4, with minimal resolution loss, making the image tubes particularly suitable for night-vision devices. However, this also has advantages for space and ground-based astronomy, particularly when television techniques are used. For example, a microchannel intensifier allows the use of a standard vidicon tube in place of the more complicated image orthicon, for low-light-level television imaging.

A vacuum system and test facility for preparation of visible-sensitive photocathodes has been completed and is now in full operation at the NRL-Waldorf Observatory. A vacuum system for test and evaluation of microchannel plates has also been constructed at the same location. Upon completion of the initial phases of these two separate studies, it is hoped to combine them in the construction of a laboratory prototype image converter.

Preliminary tests of low-resolution microchannel plates have been performed, and have verified the potentialities of these devices as indicated above. We are now in the process of obtaining much higher-resolution plates, on which more detailed and complete tests will be performed.

Initial attempts at preparation of visible-sensitive photocathodes were unsuccessful; however, manpower limitations have prevented the problem from being pursued further.

INFRARED ASTRONOMY PROGRAM

As the culmination of five years of instrument development the infrared program is now producing data of great astrophysical and geophysical interest. Problems of cryogenic design have been solved and detectors and amplifiers are adequate for the job at hand even though another factor of 100 in basic sensitivity can probably be attained with effort. Calibration of detectors for both spectral and absolute photometric response continues to limit the accuracy of results obtained and it will probably be necessary to develop an "in-house" capability in this regard.

One significant result of the infrared effort was the discovery of 63-micron radiation from atomic oxygen. This radiation had been predicted more than ten years ago by Professor Bates at Belfast to be the major source of radiative cooling of the upper atmosphere. The radiation was discovered at the level of intensity predicted during the analysis of the latter portion of the infrared astronomy rocket flown in March 1968. The 63-micron radiation was first observed on rocket reentry at 170 km, and was observed to grow until the detection system was saturated at 120 km. Measurement of the intensity of the 63-micron line is significant not only because it is probably the major mechanism of radiative cooling in the atmosphere above 120 km, but also because it will probably turn out to be the most accurate means of measuring the distribution of atomic oxygen with altitude. At 120 km the radiation is optically thin looking up, and the emission is only mildly temperature dependent.

A second result is the controversial, but possibly highly significant detection of strong point sources in the 10-30 micron band of the IR. These point sources are believed to be galaxies radiating 200 $^{\circ}$K radiation at many times their total optical output. However, the results have not yet been checked, and could turn out to be produced by dust moving with the rocket and not too far away. Supporting evidence for the astronomical interpretation of the results is the strong IR emission found by Hoffman of NASA Goddard Institute for Space Studies, New York at 100 microns.

The 10-30 micron detector has about the same sensitivity as the Ge:Ga used to observe the 63-micron line above and it shows saturated signals in the atmosphere at altitudes above 170 km. Similar high altitude fluxes have been reported by Markov but they are generally not believed because the major atmospheric components are atoms or symmetric diatomic molecules which have no emission lines in the 10-30 micron region. We expect that further flights with better calibrated systems will answer this question.

LYMAN ALPHA AIRGLOW OBSERVATION PROGRAM

This year observations of the Lyman-alpha radiation obtained from the Naval Research Laboratory experiments carried on the OGO-IV and the OSO-IV satellites, together with Balmer-alpha and NRL Lyman-beta data, were analyzed by assuming that the radiation seen arises principally from the resonance scattering of solar photons in the atomic hydrogen geocorona. First, the theory of radiative transport in an optically thick, spherical scattering medium was developed for numerical calculation of the intensities to be expected for a variety of geocoronal hydrogen distributions. These results were then compared with the experimental observations and show that if the solar Lyman-alpha flux was 6.5 ergs cm^{-2} sec^{-1} A^{-1} (as was appropriate for the observational epoch) then the mean optical depth above 650 km was about 1.3 (corresponding to 7.0×10^{12} atoms cm^{-2}) for an 1100°K exospheric temperature. This value would correspond to a concentration of 3×10^{7} atoms cm^{-3} at 100 km which is a higher concentration than originally postulated by early theorists, but which stands in contradiction to views of some theorists who have argued that much more hydrogen is present in the atmosphere.

The theory is also consistent with the observed nadir-zenith intensity ratios of 0.84 and 1.20 for night and day, respectively.

The geocoronal airglow was found to have short-term fluctuations of less than ±5% superimposed on a monthly (or 27-day) variation of about 30%. Thus, these variations for the first time provide evidence for, and a monitor of, the variability of the Lyman-alpha flux at the center of the solar emission line. Radiative transfer theory was applied to the Lyman-beta problem to obtain solutions for comparison with experimental observations of both Lyman-beta and Balmer-alpha. The analysis agrees well with the Lyman-alpha results if a non-terrestrial Balmer-alpha background of some 3 to 4 rayleighs is present in addition to the airglow. This is an important new technique to identify the non-terrestrial component.

Lyman-alpha intensities were also measured from the OGO-III spacecraft at altitudes from 5 to 19 earth radii. The variation of intensity with distance implies a hydrogen density at 50,000 km of about 25 atoms cm^{-3} for the summer 1966 epoch in the antisolar hemisphere. At spacecraft apogee a residual background of 710 to 765 rayleighs was observed. Asymmetry of intensity variation on either side of apogee suggests an additional contribution to the background of 150 rayleighs or more from the region scanned in the galactic plane. (This differs from the preliminary conclusion reported earlier that in the presence of radiation belt interference no enhancement from the region of the galactic plane could be discerned.) Furthermore, variation of the residual background intensity at apogee apparently correlates with the solar rotational cycle. This suggests that an appreciable fraction of the background component is solar-related, and provides a new technique for distinguishing the hydrogen in space which is associated with the sun from the hydrogen in the galaxy beyond.

"First-review" analysis of only the first six-months of the more than $1\frac{1}{2}$ years of data from OGO-IV has now been performed. Processing and interpretation of the remainder of the data is proceeding. Systematic treatment of OSO-IV data has not yet commenced and awaits receipt of the necessary tapes from NASA. During the past year three papers on the current findings have been submitted for publication; others are in preparation. A major unresolved question under review is the factor of two differences in background intensity reported by French and NRL (and other) experimenters. (This may arise from the different areas scanned in the celestial sphere or from the different spectral ranges employed.) Of course, the entire question of the specific origin of the background Lyman-alpha radiation awaits definitive interpretive treatment.

METEOR ASTRONOMY AND ELECTRONIC IMAGING PROGRAM

Auroral Studies

A. Low Light Level TV Project in Norway - This equipment has been in operation since October 1967. A 1200 foot roll of movie film of aurora recorded in Tromso has been sent to us for evaluation. The equipment seems to be performing excellently in the hands of the Norwegians. We have supplied times and look angles of OGO-IV passages near Tromso for simultaneous TV auroral recordings from the ground to correlate with OGO-IV auroral measurements during November and December 1968. However, OGO-IV reduced data is available only from August 1967 to mid-February 1968, and the analysis of this simultaneous data must await OGO-IV data reduction.

It is planned to use a similar L^3TV camera at the Rocket Launch Range in Andenes, Andoya, Norway during the one year sabbatical stay of Grady Hicks in Norway beginning in September 1969. The two L^3TV stations at Andenes and Tromso will be separated by approximately 100 Km and ideally situated to make simultaneous triangulated measurements of the aurora. In particular, a detailed study of pulsating aurora as a function of altitude is contemplated. Another important phenomenon to be investigated with this technique is the altitude of spectral emissions due to excitation of N_2, O_2, and O which is made possible by the high sensitivity of L^3TV equipment.

B. Last year we expressed the hope that NASA funding would be obtained to permit Dr. Mozer (University of California) to launch his auroral electric field experiments from Churchill, Canada. We would then collaborate by performing simultaneous L^3TV experiments from the ground. Unfortunately, the rocket program still awaits the required financial support.

C. We have reduced far ultraviolet OGO-IV data covering the period 1 August 1967 to 12 February 1968. We have begun processing of data for the ensuing year. We are now able to define the geographic positions of proton and electron auroras much more closely. The results of 128 observations show only three proton-electron separations on the morning side with the proton aurora being <u>poleward</u> of the electron aurora. There is an indication of little if any separation at local geomagnetic midnight. The morphology which emerges is very closely that fitting a theoretical model of Axford and Hines (1961) in which a convection system in the

---

Axford, W.I. and C. O. Hines, Can. J. Phys. <u>39</u>, 1433, (1961).

outer portion of the earth's magnetosphere separates electrons and protons which are later deposited in a pattern such as we observe.

It should be noted that the negative signal in the OGO-IV space facing detector which was cited in the previous report is in reality not auroral. Rather, it is due to charging of the detector window by incoming particles crossing the auroral oval.

A new phenomenon has been discovered in the OGO-IV data. Far ultraviolet emissions in the equatorial zones were detected at altitudes less than 500 Km. The occurrence frequency reached a maximum in late October 1967 during the period August 1967 to February 1968. These emissions were seen quite symmetrically at 12-15 degrees on either side of the magnetic dip equator (locus of points where vertical component of the earth's magnetic field is zero) completely encircling the earth. In general, the peak intensity of the emissions was equal north and south of the dip equator but in some cases the intensity was three or four times greater on one side than the other. In rare cases, emission was totally lacking on one side while clearly present on the other. Recent comparisons of "quick-look" simultaneous scanning spectrometer OGO-IV data of C.A. Barth

(University of Colorado) show that the emissions are at 1304 Å and 1356 Å and due to oxygen. A radiative recombination theory

$$O^{+} ({}^{4}S) + e \rightarrow O^{*} + h\nu'$$

followed by

$$O^{*} \rightarrow O ({}^{3}P) + \Sigma h\nu$$

has been proposed by W. B. Hanson (Southwest Center for Advanced Studies) to account for the emissions. The direct recombination photon is represented by $h\nu'$ and $\Sigma h\nu$ represents the photons emitted in the cascade to the ground state.

Two papers on the OGO-IV results are ready for publication. One covers the polar aurora and the other the equatorial aurora/airglow.

AERONOMY

In the Aeronomy program, 1968 has been a year of experiment preparation and data analysis. New instruments and techniques have been developed in both the instrumentation and data reduction areas. In addition, special electronics to meet the needs of the new instrumentation have been developed.

Aerobee NC 3.136

Aerobee NC 3.136 has been in preparation for over a year. When flown in mid-August, at night, it will carry the most complete and complex group of sensors that the Aeronomy Section has assembled into a single payload. Two areas of interest are covered in the payload. First is the instrumentation to measure the ionospheric parameters: positive ion composition, total ion density, and electron density and temperature; second are the optical experiments to measure the resonantly scattered radiation in the 150-1350 Å range that is present in the night sky (also any airglow emissions that occur in the same wavelength range). Four optical spectrometers and four photometers constitute the optical experiments. The optical grating spectrometers with Channeltron multiplier detectors are set to detect the following emission lines:

a. Lyman-α (1216Å)

b. Lyman-β (1026Å)

c. Helium I (584Å)

d. Helium II (304Å)

The optical photometers, also with channeltron multiplier detectors, cover the following wavelength bands:

a. Molecular oxygen absorption cell for a few Angstrom wavelength range in the region of and including Lyman-α,

b. Indium thin film filter for 1070-740Å (Lyman-β),

c. Aluminum thin film filter for 150-800Å (Helium I and II),

d. Aluminum-carbon thin film filter for 150-350Å (Helium II).

With these spectrometers and photometers both line identification and measurement of the intensity of the far ultraviolet resonantly scattered radiation discovered in 1967 will be possible. The spectrometers are new instruments for the Aerobee payload. The photometers are improved versions of the 1967 units. The main area of improvement is in the use of thin film filters, which are insensitive to visible light, look at a smaller field of view for increased angular resolution, and have less response to Lyman-α radiation that penetrates the films.

Electronic Instrumentation

The increasing use of secondary emission electron multipliers (photomultipliers and channeltrons) as photon and charged particle detectors in rocket and satellite-borne instrumentation has prompted the development of high voltage power supplies and pulse amplifiers whose characteristics are insensitive over the -20 to +55°C temperature range. For example, an inhouse-developed power supply having a 100 μ amp output at 3 KV does not vary more than 0.03% over the 70°C temperature range. We do not know of an equivalent commercial unit that has this characteristic. Similarly, the AC pulse amplifier that detects the electron multiplier signal has been made to have nanosecond response and high gain that do not change over the 70°C temperature range. It is anticipated that these improvements in the flight electronics will allow us to exploit the advantages that secondary emission multipliers have over conventional electrometer detectors.

OSO-I

An experiment is being proposed to NASA for the OSO-I spacecraft to fly the photometers developed for the rocket experiment. Such an experiment will provide extensive geographic and temporal coverage of the resonant radiation not available from rocket-borne experiments.

Aerobee NC 3.187 Data Reduction

Data reduction of the Aerobee NC 3.187 flight of 10 August 1967 continues. Considerable progress has been made in the computer reduction of the flight data from magnetic tapes of the flight on the Division's CDC 3100 computer. For example, ion mass spectra can now be analyzed by machine, a task previously accomplished by an individual laboriously scanning a telemetry record and recording signal amplitudes.

Machine reduction of the resonantly scattered radiation measured on this flight continues to provide interesting results. On the ascent leg of flight the Lyman-α ionization chamber detected an extra signal, about 100 Rayleighs out of 2000, above the smooth Lyman-α signal. At first it was thought the extra radiation came from the galactic center region. However, a decrease of the signal with increasing altitude rules out this interpretation and properly ascribes the signal to either a temporal variation or airglow layer emission of a signal in the pass band of the ionization chamber. Work is continuing on the Lyman-α, Lyman-β and

Helium resonant radiation detected on this flight. Of particular interest are the preliminary observations that the directions of maximum intensity of the radiation detected in the Lyman-β and Helium photometers come from different places in the sky. The Lyman-β signal comes from the North North East near the horizontal whereas the Helium signal comes from the East North East at a 65° zenith angle. Unfortunately data reduction has not been completed to permit a detailed discussion of the possible reasons for this difference.

Future Plans

Rockets - After NC 3.136 is flown in August, NC 3.137 will be prepared for a daytime flight. Current plans are to include only ionospheric instrumentation on the flight.

Blue Scout Jr. rockets obtained from the Air Force are available for our use at Wallops Station. We desire to instrument one flight with the ionizing radiation photometers carried on Aerobee NC 3.136, a scanning spectrometer to cover the 300-1250Å range, ion mass spectrometers to cover the 1-35 Amu range, and a neutral helium and nitrogen mass spectrometer. The scanning spectrometer would identify all of the EUV radiation in the night sky. The helium-nitrogen spectrometer would obtain an altitude profile of these two constituents and assist in resolving the problem of the helium budget in the earth's atmosphere.

Infrared - Cryogenic techniques developed by D. P. McNutt at NRL open up the 10-1000 μ wavelength region to investigation by rocketborne instrumentation. Within this range emissions from most of the important minor constituents present in the atmosphere are found, i.e., NO, O_3, O, NO_2, N_2O, etc. It is our intention to exploit this breakthrough to determine the number density and altitude distribution of these minor constituents of the atmosphere which play such an important role in the D and lower E region processes.

RADIO ASTRONOMY - CODE 7130

The basic objective of the radio astronomy program is to conduct fundamental research leading to new information of astronomical and astrophysical importance, and to investigate its application in areas of interest to the Navy. The current scientific program is directed to the molecular and atomic composition and structure of the galactic medium in regions of possible star formation; the structure and magnetic field distribution of the galaxy; the physical properties of cosmic radio sources, i.e., pulsars, quasi-stellar sources, radio galaxies, supernova remnants, and H II regions; planetary surfaces and atmospheres; celestial mechanics; relativistic effects; microwave emission and reflection properties of the sea and planetary surfaces; and possible effects of mass on frequency. Areas of Navy interest to which the program is contributing are: all weather navigation, improvement of time-service in remote areas, very short wavelength radio propagation through the total atomosphere of the earth, remote microwave sensing of ocean surface characteristics, the physical environments of other planets, ultimate sensitivity limitations on radio and radar systems imposed by extraterrestrial radiation and and the atmosphere of the earth, and improvement of astronomical constants.

PROGRAM

I. GALACTIC AND EXTRAGALACTIC RADIO ASTRONOMY

A. Molecular Spectral Lines

The recent discoveries of spectral line emission from two molecular species, water vapor and ammonia, in the galaxy at wavelengths near 1.3 cm wavelength have provided the opportunity to mount a developing scientific program that utilizes the NRL capabilities in both short-wavelength and spectral-line radio astronomy to good advantage. This work has so far been carried out in close cooperation with the group in the physics department of the University of California, Berkeley, which made the original discoveries of the radiation from these molecules in the galaxy.

The first studies of the water vapor line at a frequency of 22.24 GHz with high resolution, both angular and spectral, were carried out using the 85-foot reflector at Maryland Point in January-February 1969 and were followed by a second series of observations in March and April. Ten water vapor sources in the galaxy have been studied to date, of which five were discovered at NRL. In all cases except one the radiating water molecules are found in the same regions where OH molecules have been observed previously. The one exception is the H_2O source discovered at NRL which is associated with the main continuum region in W3 where no

OH has been observed. In a number of cases there are intense infrared sources nearby. The high resolution spectra measured at NRL show a number of sharp, Doppler shifted lines, with some lines as narrow as 40 KHz and some much broader, spread over a considerable range of frequency or radial velocity. In the most outstanding case, the H_2O source associated with W49, the spectrum is spread over a very wide range of at least 200 km/sec in terms of radial velocity or 15 MHz in terms of frequency. Linear polarization was observed for the radiation from two of the sources, but circular polarization, although looked for, has not yet been observed.

The observations at Maryland Point showed that the angular diameters of the H_2O emission regions are small compared with the beamwidth of the 85-foot radiotelescope; certainly less than 1 arc minute. During the observations, it was discovered that the H_2O line emission from several source regions is highly time variable, for example, three of the most intense lines in the W49 spectrum essentially disappeared over three weeks time (Fig. 1). Light travel-time arguments require that the diameters of these emitting water vapor clouds be less than 0.06 light years in diameter with corresponding angular diameters of less than 0.005 arc minutes. These lines were very intense with antenna temperatures of 1700°K, and the brightness temperatures of the sources must be greater than 50,000°K to correspond with

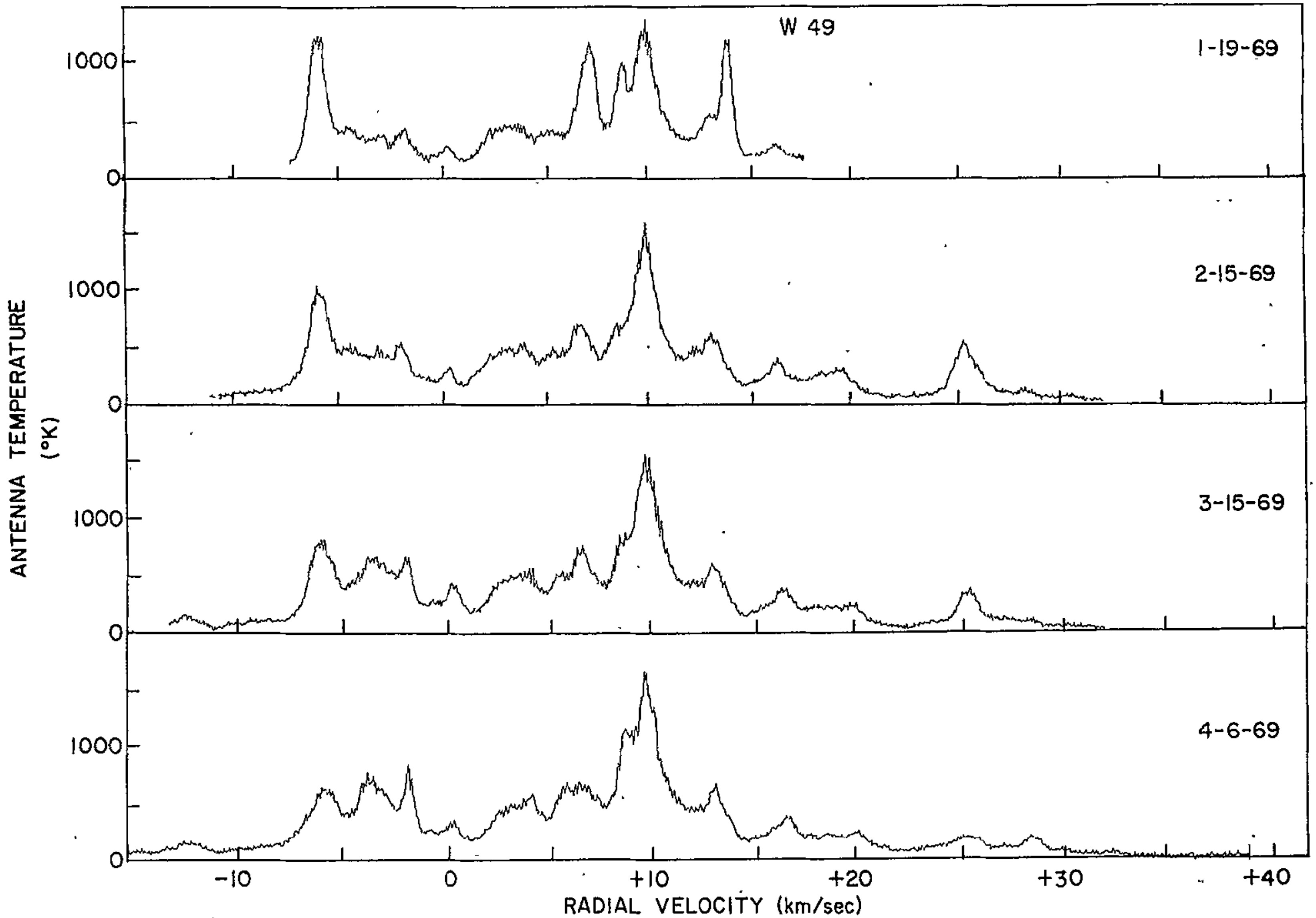


Fig. 1 - Spectra of the central section of the 1.35 cm water vapor line spectrum of the source associated with W49 showing time variations. The upper spectrum was taken in rain accounting for the reduced amplitude.

the direct diameter measurements and of the order of 10^9°K to correspond with the smaller diameters inferred from the short term variability. These extremely high brightness temperatures, greater than the dissociation temperature of water vapor, together with the narrow observed line widths and other arguments indicate that the observed radiation is due to stimulated emission (maser action) rather than normal spontaneous or thermal emission.

In some cases, the radial velocities of the lines in a spectrum appear symmetrical about a center suggesting interesting systematic motions of the H_2O clouds such as rotation, expansion or contraction about a center. The large range of cloud velocities and small sizes of the source regions suggest regions of star formation or activity.

The distribution of ammonia and its velocity and state of excitation have been investigated in the region of Sagittarius B2, the most intense ammonia emission region now known. Relative intensities of the (1, 1) (2, 2) and (3, 3) inversion transitions at 23.69, 23.72, and 23.87 MHz respectively were determined and do not appear to correspond to equilibrium conditions. However, the results indicate that the ammonia is formed in large cool regions of the interstellar medium and that unlike the water vapor, maser action is not observed.

One paper on water molecule line radiation has been published and a second paper is in preparation. A paper on the ammonia line radiation is in preparation.

Because of the scientific importance of these molecular-line discoveries, a program of equipment development related to this project has been initiated. A general-purpose computer-controlled filter-bank system is under construction, and is expected to be completed in late 1969. Development work is also underway for a local-oscillator system to replace the one presently borrowed from the University of California, and for a parametric amplifier to increase receiving sensitivity.

Future plans include an extensive program to determine more precise characteristics of the water-vapor time variations. This should lead to fundamental information about the physical processes involved. The results obtainable with the weaker ammonia radiation have been limited by signal-to-noise considerations. As soon as more sensitive equipment is available, extensive observations of the distribution of ammonia are planned. In connection with this, plans are being formulated for a cooperative program with the NASA Electronics Research Center at Boston using their low noise parametric amplifier. Observations of possible ammonia emission in the Jovian atmosphere and comprehensive searches for other molecules in the galaxy are planned.

B. Pulsars

The new class of radio sources which emits periodic pulses of radio radiation and in one case x-ray and visible light pulses as well, gives opportunities for new information of astrophysical importance. In addition, the accurate timing of the pulses is potentially useful for practical applications and for investigating relativistic effects.

1. Search for Pulsars

In March 1968 a search of the position of the strong x-ray source Scorpius XR-1 was made for the possible presence of radio pulsations. The search was made using the 140-foot radiotelescope of the National Radio Astronomy Observatory at Green Bank, West Virginia at 234, 256 and 405 MHz. No pulsations with a time average flux density greater than 0.03×10^{-26} watts m^{-2} Hz^{-1} and with a repetition period between 0.1 and 5 seconds were found. Scorpius XR-1 has been found by Andrew and Purton to have a flux density of 2×10^{-28} watts m^{-2} Hz^{-1} at 4.6 cm. Extrapolating to 234 MHz, using the typical spectral index of -1 for pulsars, a flux density of 6×10^{-27} watts m^{-2} Hz^{-1} would be expected. This implies that any pulsations present must be less than about 3% of the steady flux of the source.

In addition the positions of several globular clusters and known x-ray sources have been searched at 150 and 405 MHz using the 150-foot radiotelescope at NRL, Sugar Grove, West Virginia. No pulse type radio signals have been found to date.

A search for pulsations from the known radio pulsar CP 1133 at 3 cm wavelength was made using the NRL 85-foot radiotelescope. No pulses were detected and an upper limit to the peak flux of the average pulse at 3 cm was set at 10^{-27} watts m^{-2} Hz^{-1}.

2. Mass on Frequency Effect

Observations of the pulse arrival times from the pulsar CP 0950 were made during the month of August when the line of sight to the pulsar approached within 5 degrees of the sun in order to test a suggested mass-on-frequency effect. The observations were made at 405 and 445 MHz using the 150-foot radiotelescope at NRL, Sugar Grove, West Virginia. Although the predicted mass-on-frequency effect was an order of magnitude greater than the experimental error no evidence for it was found. A period of 0.253 065 032 0 seconds U. T. $\pm 4 \times 10^{-10}$ seconds U. T. was determined for CP 0950 during August.

3. Annual Relativistic Experiment

An experiment using pulsars to measure an effect predicted by general relativity has been in progress since August 1968. This relativistic effect causes the rate of an earth clock to vary as the gravitational potential at the clock changes due to changes in the earth-sun distance during the course of a year. The varying clock rate will result in an accumulated clock "error" with respect to some external constant clock which varies sinusoidally with a period of one year. The maximum "error" is about 1.7 milliseconds and occurs in April and October. In principle, it should be possible to use a pulsar as the external constant clock to compare with the changing earth clock since pulse timings with an rms error of 400 microseconds are routinely made. In practice there are several difficulties. The two most serious are: (1) errors in the doppler correction applied to the pulse arrival times to account for the motion of the earth clock which are generated by inaccurate knowledge of the pulsar position and (2) inherent changes in the period of the pulsations from the pulsar with time. The first of these gives rise to a sinusoidal "error" indistinguishable from the relativistic effect. However, the phase of this error depends upon the pulsar position and can be sorted out by using several pulsars at appropriately selected positions. In order to correct for the second difficulty, the detailed change in the pulsar period must be known. Fortunately it appears that the periods of pulsars are in general increasing at a linear rate. Measurements to date of the five pulsars selected for the annual experiment indicate that $\Delta P/P$ is indeed constant and ranges from 10^{-14} to 10^{-16}. As an example of the magnitude of this effect a period increase of one part in 10^{15} will result in an accumulated pulse delay of one-half second in one year for a pulsar with a period of one second. Even if it is not possible to determine the relativistic effect in the face of these difficulties, measurements of the positions and period time dependence of the pulsars are of great significance in the understanding of the nature of pulsars.

4. Application of Pulsars for Worldwide Timing Service

Dr. G. Winkler, Director of the Time Service of the Naval Observatory, is interested in the possible use of pulsars to supplement the worldwide time service. At present timing signals accurate to 100 μsec or better are available only in restricted areas over the surface of the earth and at some locations accuracies of 1000 μsec at best are available. Dr. Winkler has asked that NRL look into the problem and offer consultation to the Naval Observatory as to the possible use of pulsars to provide worldwide coverage to 100 μsec and provide time reference for deep space probes. To date we have achieved rms timing errors of about ± 400 μsec and are continuing to keep Dr. Winkler appraised of our progress.

5. Anomalous Dispersion Experiment

An attempt was made to detect a relative change in pulse arrival times due to anomalous dispersion in interstellar deuterium as the observation frequency is moved across a resonance line. From the magnitude of the added delay it is possible to estimate the density of deuterium along the line of sight to the pulsar. The line chosen was the 327.4 MHz line of deuterium and the pulsar CP 0328 was used as the pulsar source. No anomalous delay was detected.

C. Variability of Quasi-Stellar Sources

The intensities of both the radio and visible radiation from quasi-stellar sources and certain peculiar galaxies has been found to vary with time. These variations provide an important source of information on the sizes of the radiating regions from the time scale of the variations, and on the nature and evolution of highly energetic sources which may be built up through successive injections of relativistic particles by explosive events.

Results of the variable source observing programs at 1.5 cm- (intensity and polarization) and 9.55 mm-wavelength (intensity) through mid-1968 were submitted for publication. The results of the measurements so far do not enable us to rule out or confirm the applicability of the expanding source model to account for the variability of these sources. In some cases the data are consistent with rates of expansion relative to source radius smaller than previously believed. The program is continuing at 1.5 cm and 9.55 mm, expanded to 7 sources (3C 84, 3C 120, 3C 273, 3C 279, 3C 345, 3C 446 and 3C 454.3) and to measure polarization and intensity at six-week intervals at each wavelength. Because of equipment difficulties and insufficient antenna time, this program has not progressed as planned, but we hope to continue observations at about six-week intervals.

The linear polarization at 2.07 cm wavelength of seven variable radio sources was measured during three observing periods between December 1965 and August 1967. For five of these sources no changes in the degree or position angle of polarization were observed within the limits of error. Two of these, 3C 345 and 3C 454.3, were unpolarized even though their total flux density increased by about a factor of 2 over the observing interval implying that the variable components of those two sources are not highly polarized. The linear polarization of the remaining two sources, 3C 120 and 3C 279, changed significantly over the observing interval. The flux density of both of these sources also approximately doubled over the observing interval. In the case of 3C 120 the polarized flux density and position angle remained unchanged again implying that the variable component is unpolarized. However, in the case of 3C 279 the degree of polarization about doubled as did the total flux and the position angle of the polarization rotated showing that the variable component of this source is partially linearly polarized.

D. Properties of Celestial Radio Sources from their Polarization

The state of polarization is one of the fundamental observable properties of an electromagnetic wave along with its frequency, intensity, and direction of arrival. The intrinsic polarization is determined by the mechanism of generation of the radiation and the physical properties of the source region, and specifically for cosmic synchrotron radiation sources by the magnetic field and relativistic electron distributions.

Data analysis of observations of the linear polarization parameters and the intensities of 152 extragalactic and 4 galactic sources at a wavelength of 21.2 centimeters was completed. The final values and the results of analysis of the degree of polarization of extragalactic sources at this wavelength to study correlations with intrinsic properties of the sources and also at 11 centimeters to investigate galactic depolarization of the radiation of extragalactic sources (see Program Review, 1968) are being published in the June 1969 issue of the Astrophysical Journal (Bologna, J. M., McClain, E. F., and Sloanaker, R. M.). The final results confirmed the preliminary finding discussed in last year's review that there are no outstanding correlations between the degree of polarization at 21 centimeters and the known physical parameters of the sources. In addition to the possible weak correlation with the angular sizes of extragalactic sources previously discussed, the degrees of polarization show a possible weak correlation with the overall Faraday rotation measures of the sources. Both of these effects could be associated with the depolarization of the radiation in transit through our galaxy.

Data reduction of observations of the linear polarization parameters and the intensities of 135 extragalactic sources at a wavelength of 25.5 centimeters was completed.

The polarization of five radio sources was measured at 9.55 mm wavelength. For only 3C 273 and Taurus A was a degree of polarization greater than the errors measured. For Taurus A and Orion A the polarization distribution was mapped with a 1$'$.6 beam. Orion A was, as expected, unpolarized.

The polarization distribution of Taurus A agreed, considering the likely effect of Faraday rotation in the nebula, with the 1.5 cm-wavelength map (see 1968 review) made with the same size beam.

E. The Structure and Magnetic Field Distribution of the Galaxy

The intrinsic polarization of radio sources is modified in propagation through a magnetoionic medium such as the interstellar space of our galaxy, and the resulting depolarization and Faraday rotation of the electric field provide new means for studying the magnetic fields and particles of our galaxy.

Final values have been obtained for the degrees and position angles of linear polarization and the intensities of 135 extragalactic sources from observations at a wavelength of 25.5 centimeters. The degrees of polarization are being used to extend the study of galactic depolarization to this wavelength, where the effect is theoretically expected to be 40 percent stronger than at 21.2 centimeters. The position angles of the planes of polarization measured at both 21.2 and 25.5 centimeters along with position angles at other wavelengths from other observers are being used to determine the overall Faraday rotations of the radiation during its passage through the magnetoionic interstellar medium in our galaxy and hence to study the large-scale magnetic field and electron density distributions in the galaxy. The results so far indicate that many of the approximately 100 measures of overall Faraday rotation that have been reported in the literature by other observers will be revised and that the new data will give determinations of the rotation measures for possibly 40 additional sources.

Both the 21.2 and 25.5 centimeter polarization data have been analyzed to study small-scale structure in the polarized emission from the interstellar medium in our galaxy in directions close to those of the extragalactic sources. (The polarization of the emission from a region 0.6 or 0.7 degree west of the source was measured with respect to that 0.6 or 0.7 degree east of the source as a reference for each of the extragalactic sources.) The polarized galactic emission at these wavelengths is believed to originate within 1 kiloparsec or less of the sun, probably within a few hundred parsecs (e.g., see Mathewson, D. S. and Milne, D. K. 1965, Australian J. Phys., 18, 635; and Bingham, R. G. and Shakeshaft, J. R. 1967, Monthly Notices R.A.S., 136, 347 who present evidence that the polarized emission arises in the local spiral arm). The data show considerable structure in the polarized emission with an angular scale of 1.4 degrees or less corresponding to an extreme upper limit of 25 parsecs and more probably to an upper limit on the order of 5 parsecs for the linear scale of inhomogeneities in the local galactic magnetic field and electron density distribution. Comparison of the 21.2 and 25.5 centimeter results shows that the brightness temperature spectral index of the variable component of the polarized emission is close to +2.5 in agreement with the brightness temperature spectral index of the total intensity of the non-thermal component of galactic emission.

It is planned to extend the decimeter wavelength observations with the NRAO 300-foot antenna of the linear polarizations of extragalactic sources to a wavelength of 31 centimeters for about 200 sources to obtain additional and more reliable rotation measures for extragalactic sources in order to study the large-scale structure of the galactic magnetic field in greater detail. The observations should also yield more detailed knowledge concerning the fine-scale structure and extent and shape of the magneto-ionic medium responsible for galactic depolarization, since the depolarization should be more pronounced at longer wavelengths.

F. Millimeter Wavelength Properties of Radio Sources

New instrumental capabilities are being used to extend the knowledge of cosmic radio sources into the wavelength region near the radio-infrared boundary.

The results of our measurements at 4.3-mm wavelength using the NRAO 36-foot antenna are complete. Seven sources were detected and upper limits were established for sixteen others. The measurements of the flux density of Taurus A, corrected for polarization, indicate that its spectrum is power law through 4.3-mm wavelength and that at 4.3 mm there is no indication that the spectrum is upturned as has been previously suggested by other observers. The measurements of 3C 84, 3C 120, Orion A, 3C 273, and Cassiopeia A agree within errors with measurements either extrapolated from longer wavelengths or at nearby wavelengths. The flux density for planetary nebula NGC 2027 also agrees within error with measurements at longer wavelengths, but the most probable value is considerably higher than the flux density expected for an optically thin source.

At 9.55 mm a new radiometer has been developed using a single ended mixer and wideband (500 MHz) TWT I.F. amplifiers. Its sensitivity is 0.2°K rms with a 2 sec time constant. In a recent observing period with the 85-foot reflector we detected 5 compact H II regions, 2 planetary nebulae and 7 other sources. We plan to extend these observations to detect more weak, quasi-stellar sources, map extended regions, set limits on the flux

2

density from infrared sources, and map polarization distributions. A significant observational factor at this wavelength is that for sizeable fractions of time the atmospheric noise fluctuations seem to be larger than radiometer noise.

We hope also to make measurements of infrared objects and search selected regions of the sky at 3-mm wavelength using the NRAO 36-foot antenna.

G. Lunar Occultation Studies of Hydrogen in the Galactic Center Region

The high resolution given by lunar occultations has been used to investigate the distribution and motions of the neutral hydrogen gas in the galactic center region through observations of the 21-cm hydrogen line.

A series of 5 lunar occultations of the 21-centimeter neutral hydrogen radiation in the galactic center region was observed, and maps of the characteristic occultation pattern were constructed with an angular resolution of 2 arc minutes and a spectral resolution of 4 KHz. The use of several occultations has made possible the construction of a two-dimensional model from the one-dimensional individual occultations. The neutral hydrogen is found to be quite uniformly distributed across the galactic center region, indicating that it is not intimately associated with the core of the galaxy. The results were presented to the American Astronomical Society and a paper is being prepared for submission to Astrophysical Letters. Further observational work on this program is not contemplated, since the series of lunar occultations of the galactic center has now virtually ended.

H. Radio Emission of Infrared and X-Ray Sources

The positions of known infrared and x-ray sources are being examined for associated radiation at short radio wavelengths with higher sensitivity than previously used.

In a project carried out jointly with Dr. Paul D. Feldman, E. O. Hulburt Center appointee, a search was made using the 85-foot telescope for 1.6 centimeter radiation from the nucleii of eight late-type spiral galaxies which may be associated with infrared emission previously observed in the 10 to 30 micron spectral region at the E. O. Hulburt Center for Space Research (Feldman, P. D., McNutt, D. P., and Shivanandan, K. 1968, Ap. J., Letters to the Editor, 154, L131). A possible detection of 1.6 centimeter radiation was obtained for three of the galaxies at an intensity level of about 0.15 flux unit. This is roughly the intensity that would be expected based on the thermal model proposed by Feldman et al. 1968 for radiation from dust grains assuming a source angular diameter of about

2″ and an equivalent black body temperature of about 200°K. However, further measurements are desirable to increase the reliability of the results and it is planned to carry out additional observations in the near future and to extend the measurements to 2.7 centimeters wavelength to determine if the spectra are actually thermal.

We have searched the region of some of the x-ray sources which have well determined positions for 3 cm radiation, and no radiation was found with flux densities greater than a few flux units (1 flux unit = 10^{-26} watts m^{-2} Hz^{-1}).

I. Very Long Baseline Interferometry

The NRL Radio Astronomy Branch has unique facilities in the short radio wavelength region, and the possibilities of setting up cooperative programs with other institutions to carry out very long baseline interferometry is being pursued.

In December 1968 a VLBI experiment was performed in collaboration with NRAO scientists using the 2.8-cm parametric amplifier and the 85-foot reflector as one station and a similarly equipped 60-foot antenna located near Bochum, Germany as the other station. The experiment was designed to place new limits on the sizes of the variable components of quasi-stellar radio source with the capability of resolving angular diameters of 3×10^{-4} arc seconds. The data tapes were lost enroute from Germany and were found only recently. Computer analysis failed to find interference fringes and the reason is not known. It is planned to repeat the experiment between Maryland Point and Cal Tech when VLB data recording and local oscillator equipment becomes available.

II. SOLAR SYSTEM RADIO ASTRONOMY

The effort on solar system radio astronomy during the past year was restricted because of the greater effort demanded by timely galactic and extragalactic work. In particular, the great pressure for 85-foot telescope time made it impossible to secure the observations necessary for some of the planetary programs.

A. Short Wavelength Spectra of the Planets

Good progress was made in the determination of the spectra of Uranus and Neptune. Observations made at 2.7 cm and 1.6 cm wavelengths were successful and enough data are in hand to fix spectral points at 2.7 cm. Additional observations are necessary to firm up the spectral points at 1.6 cm. No measurements have yet been made at 9.5 mm. The measurements of Uranus and Neptune at 2.7 cm wavelength correspond to changes of apparent antenna temperature due to the planetary radiation of only 0.035°K and 0.015°K respectively giving disk brightness temperatures near 200°K in both cases. Measurements of Venus, Mars, Jupiter, and Saturn are being made along with Uranus and Neptune, and good comparative spectra of all of these planets will result.

The 4.3 mm planetary measurements appear to be subject to too great instrumental corrections to be useful. At 9.55 mm the change of gain of the 85-foot reflector with elevation has been determined with sufficient accuracy to establish the reliability of measurements of Mercury, Saturn and Venus. Venus shows no phase effect at this wavelength within the limits of error. A paper describing these results is in preparation.

B. Temperature Distribution Over Venus

Except for isolated space probe measurements, information on the temperature of the surface and lower atmosphere of Venus is available only from measurements of its thermal radio emission. There is presently no reliable information on the temperature of the sunlit surface of Venus from either source. Because the orbit of Venus lies inside the orbit of the earth, we see Venus at all phases of solar illumination. However, when Venus is closest to Earth and the intensity of its radiation highest, we see its dark side. We see its sunlit side only when Venus is farthest from Earth and the intensity of its radiation is about 35 times less. For this reason, most reliable measurements are restricted to the thermal radio emission of the night hemisphere of Venus.

Fairly convincing evidence has recently become available from radar measurements that the absorption of radio waves in the atmosphere of Venus is appreciable at wavelengths as long as 3 cm where $\tau \approx 1$. The thermal emission at wavelengths much shorter than 3 cm must originate in the atmosphere and indicate the temperature at the appropriate atmospheric level. At wavelengths longer than about 3 cm the thermal radiation will originate mainly beneath the surface and indicate the sub-surface temperature decreased by the surface emissivity. The thermal emission at wavelengths somewhat greater than 3 cm should give the best indication of the temperature at and near the surface.

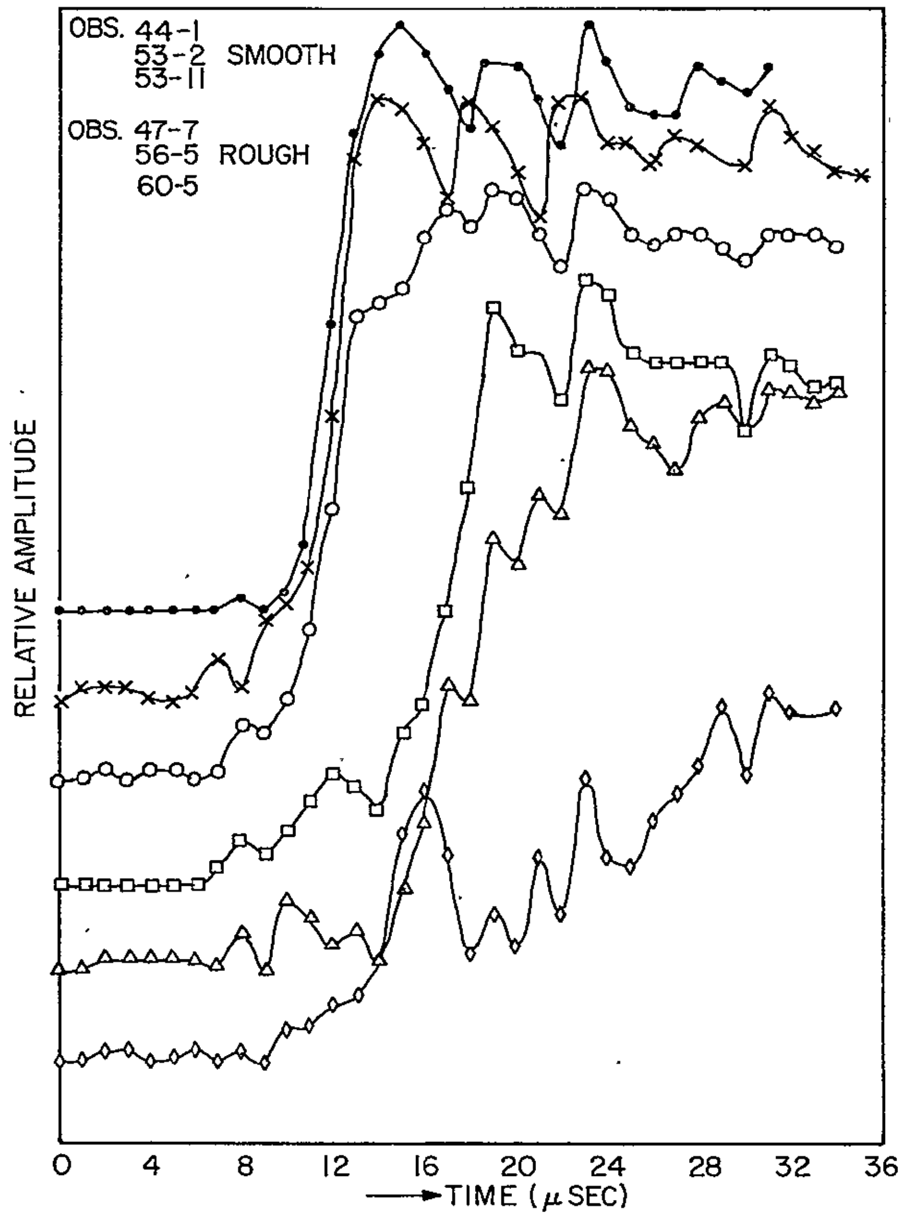
A series of accurate measurements of the thermal emission of Venus at 2.7 cm wavelength using the wide-band tunnel diode radiometer was initiated in July 1968 when Venus was near superior conjunction (sunlit side visible) and will be carried on throughout the 18 month phase cycle to determine the dependence of the average disk temperature on solar illumination. Several other radio sources are used as calibrators and an accurate comparison of the temperatures of the day and night hemisphere should result. Preliminary results of the data obtained so far suggest that the temperature of the surface and the atmosphere near the surface on the sunlit hemisphere is not significantly greater than that of the night side. If a significant phase variation is determined, information on the surface material properties can be derived.

III. RADAR ASTRONOMY

The program of the Radar Astronomy Section has shifted its emphasis in the past year from radar astronomy to radar astro-geodetic measurements. The primary research objectives of the program are the refined determination of the geometric size and shape of the earth and of the moon. To achieve these objectives will require the utilization of high range resolution radar systems in orbiting satellites. This would provide adequate height measurement accuracy and full coverage of the earth's and moon's surfaces. However to satisfy the high accuracy requirements needed in the geodetic application, the interaction of complex surfaces with narrow radar pulses will be investigated to establish the relation between the surface structure and the radar return. This information will be used to provide design criteria for more efficient satellite radar systems and also to indicate how the radar data should be processed for obtaining sea-state conditions of the oceans and topographic information on solid surfaces.

The satellite radar measurements on the earth will be used to describe the ocean surface in terms of its absolute height, height variations and sea-state conditions, and the data will be applied to obtain the mean sea level, the deflection of the vertical, a connection with world geodetic datum, and global synoptic sea state conditions. A similar analysis of lunar orbiter radar measurements will provide the height and topographic information of different regions of the lunar surface. In particular, height measurements of the sub-earth region can be used as reference points in future earth-based radar observations in applications to celestial mechanics, navigation, time synchronization and geometric geodesy.

Existing lunar radar data has been analyzed to evaluate the effect of the surface structure on the shape of radar return when using radar pulses which resolve the surface topography. The results indicate that the characteristics of the leading edge of the returned radar pulse are related to surface structure. Figure 2 shows the rise time of return pulse as a function of increasing surface roughness.



TYPICAL LUNAR RADAR ECHOES FROM DIFFERENT AREAS.

Fig. 2 - Comparison of lunar radar echoes from smooth and rough areas of the moon.

From this effect, it is planned to investigate how narrow pulses which resolve ocean wave heights can be used to describe sea state.

The sea-state studies are being supported by NAVAIR and proposals have been submitted to NASA's GEOS C program for use of an orbiting radar altimeter around the earth. Also plans are being made to study sea-state effects on mean height measurements from either Navy or NASA aircraft. It is expected that NASA's Apollo project will support the lunar radar satellite program.

Studies also have been made, for Naval Ships Systems Command, concerning utilization of the moon as a radar reference point in the sky for navigation and geodetic applications. The study on navigation is completed and will be issued as NRL Report 6814 about May 1969. The geodetic study is ready for TID to process. Future work will be concerned with the implementation of the results of these studies.

IV. MICROWAVE SENSING OF THE SEA SURFACE

This oceanography project supported by SPOC, Nav Oceano, is concerned with investigating the problem of obtaining information about various sea surface parameters from remote passive measurements of the microwave radiation from the sea. The experimental approach is first to make observations from an ocean tower where experimental parameters are most easily controlled and ground truth is readily available. With a basis of tower observations to provide fundamental information and determine radiometer parameters and techniques, measurements will be extended to aircraft platforms with the ultimate goal of recommending a satellite borne system.

The first stage of this program is well underway. Measurements were made during the last two weeks in March from the Argus Island tower, 27 miles southwest of Bermuda, using microwave radiometers and polarimeters at 8.35 and 19.35 GHz. The vertical, 45 degree and horizontal linear polarization components of the total radiation from the sea surface as well as the instantaneous difference between pairs of orthogonal components were measured as a function of incidence angle. Sea conditions during the observing period varied from calm with 2 to 3 foot swells to winds of 24 knots and 6 to 9 foot waves. Good data were obtained for this range of sea conditions and are currently being analyzed. No definite conclusions are possible until the data are completely reduced, but in general, the results agree with theoretical expectations for low sea states. The vertical and horizontal components are equal at normal incidence and the horizontal component decreases with increasing incidence angle while the vertical component increases to a maximum at Brewsters angle near grazing incidence. In general the apparent microwave brightness temperature of the sea is higher at the higher observing frequency. The vertical component at large incidence angles appears to be most sensitive to sea state; decreasing with increasing sea state. The spatial resolution of the radiometers was sufficient to view a single wave at incidence angles below about 65° incidence angle. As the wave passed through the angle of view, microwave brightness temperature changes of as much as 20°K occurred. The changes were highly correlated at the two frequencies and are presumably due to the slope of the wave surface changing the effective angle of incidence as the wave passes through the angle of view. This effect should be a function of wave height and direction and hence may be more sensitive to sea state than a spatial average. It may also make it possible to separate out the detailed effects of foam which are believed to greatly enhance the emissivity of the sea.

Further measurements are planned for this fall when very high sea conditions should prevail at Argus Island. In addition, measurements at Argus Island of the emissivity of artificially generated foam, and simultaneous measurements from the tower and from an aircraft are planned for this summer. Extensive measurements from aircraft are being arranged for later this year.

V. MASS ON FREQUENCY EFFECT

Investigations of a possible change of frequency of radio waves in the presence of mass not predicted by general relativity have been continued.

Comparison of the frequency of a Loran C transmitted wave with a cesium-beam frequency standard which was moved to different distances from the transmitter was repeated with greater care in monitoring possible variables which may affect the measurements. A path was chosen that permitted easy reception of the ground wave which was mainly over water. In addition several intermediate points were taken instead of only two as was done previously. The results shown in Figure 3 indicate a frequency change of about 2×10^{-12} per 1000 km.

A separate experiment was carried out to check the slope of the curve as shown in Figure 3 using a differential technique and hydrogen masers to give absolute frequencies. Under the assumption that hydrogen masers behave as absolute frequency standards and one maser does not differ from another by more than 0.5×10^{-12}, it should be possible to use two different hydrogen masers, one at NASA, GSFC at Beltsville, Maryland and another at NASA, MSC at Houston, Texas for comparing the received Loran C transmission at the respective sites. Since there is a differential in path length from the Loran C transmitter of about 1300 km,

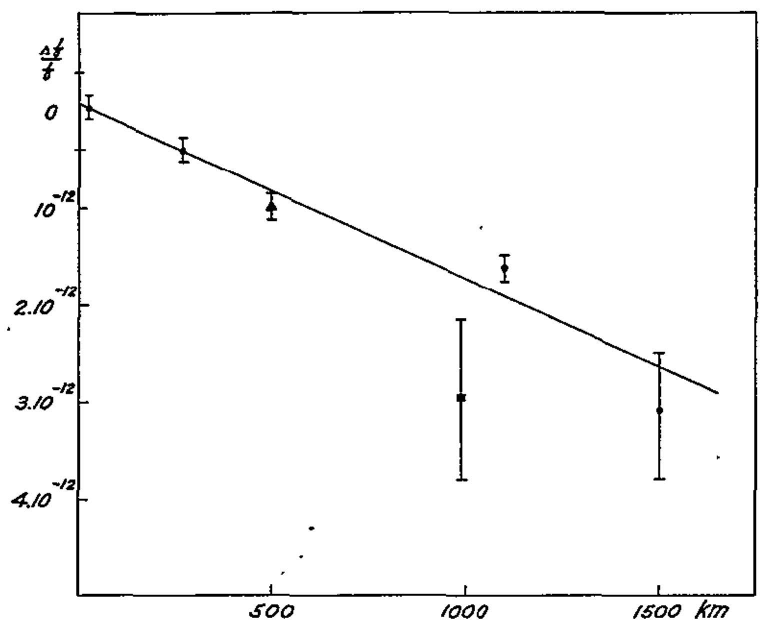


Fig. 3 - Apparent decrease of frequency of the Loran-C transmitted wave with increasing distance from the transmitter measured in summer, 1968.

a $\Delta f/f$ of 2.6×10^{-12} is expected. This experiment was carried out and after making subtle corrections for the respective masers the observed effect was reduced to $1.0 \times 10^{-12} \pm 0.7 \times 10^{-12}$ which makes the noted effect marginal. It is hoped to repeat this experiment, but with greater care in monitoring the masers' effect on the measurements. Also the variation with distance measurements made with the portable cesium standard should be repeated to confirm the previous data.

An attempt to detect an effect of the mass of the sun on the pulse period of a pulsar when its line of sight path approached near the sun showed no effect (see section on Pulsars I.B.2.).

HISTORY AND FORMATION OF THE ROCKET SPECTROSCOPY BRANCH

Optical space research at the Naval Research Laboratory began many years ago with the experiments of Dr. E. O. Hulburt in probing the upper atmosphere by means of searchlight beams. In 1941, studies of the high-altitude daylight sky were commenced by Tousey and Hulburt, in order to investigate the possibility of using stars for navigation of aircraft during the daytime. This involved the brightness of the sky and also the properties of the eye for observing stars against a bright background. The resulting series of papers described measurements of the brightness of daytime, twilight and night sky that have not been superseded even after twenty-five years, and data on the ability of the eye to see point sources of light under varying conditions unaided or with telescopic devices.

The space research program really started on its present course when V-2 rockets became available for scientific research. This Laboratory was fortunate in obtaining the first solar spectrum extending into the ultraviolet, using an instrument carried in one of the first of these rockets in 1946. In the following twenty-three years the program has increased steadily in magnitude, complexity, sophistication and cost. The Rocket Spectroscopy Branch has scored on the average at least one "first" each year and has led all similar research in the USA and elsewhere in almost every respect. It has also been a direct stimulus for the creating of similar projects in the United Kingdom, France, and the USSR, and to lesser efforts in several other countries.

With the creation of the NASA in 1958, a portion of the Branch transferred to the Goddard Space Flight Center, newly formed largely from Naval Research Laboratory personnel, but the majority stayed at NRL and reorganized as the Rocket Spectroscopy Branch of the Atmosphere and Astrophysics Division. This marked a rapid and still continuing increase in the number and magnitude of optical space research projects at NRL. Projects proposed by NRL were soon accepted and funded by NASA.

During the past year over 90% of the work of the Rocket Spectroscopy Branch was carried on with funding direct from NASA.

TECHNICAL PROGRAM

Solar Research Using Rockets

For close to a century before rockets became available, astronomers and physicists had tried unsuccessfully to observe radiation from the sun at wavelengths shorter than about 2900 Å in the ultraviolet. Suddenly, with the possibility of sending instrumentation above the earth's absorbing atmosphere, a tremendous new field of astrophysical research was opened. Within this field, solar research occupies a central position for many reasons. First, the importance of the sun to life can scarcely be overemphasized; solar energy sustains practically every living organism; it controls the earth's atmosphere and the environment for life. Second, through its ionizing radiations, it creates the ionosphere and makes possible long distance radio communication; but flares and solar events sometimes disrupt the layer and make impossible the communications system upon which we now rely.

Third, the sun is a natural high temperature plasma laboratory, providing unique opportunities for the study of plasma physics and magnetohydrodynamics; for example, sunspots, flares, and prominences -- all are examples of the interaction between plasmas and magnetic fields. Thus research in solar physics is of importance to many scientific disciplines, including biology.

Research on the extreme ultraviolet spectrum of the sun, carried on from rockets largely by means of photographic spectroscopy, has been the backbone of the Branch program for twenty-two years. The spectrum is now known fairly well from the ultraviolet through the extreme ultraviolet and into soft x-rays. This means that most of the first generation experiments that are possible with rockets have been done. The second generation has been commenced. These include studies of the different spectral ranges with greatly increased spectral resolution; the recording of the structure present in the sun's atmosphere in selected extreme ultraviolet emission lines, and at increasingly great spatial resolution; the profiles of selected emission lines at extreme resolution; and the observation of the sun's white light corona without the aid of the total eclipse.

The next step forward in solar rocket research is about to be made possible by the completion of simple systems that point an entire rocket, or the separated instrument section, at the sun and stabilize it in all three axes. Until 1969, all research was conducted with biaxial pointing controls which provide only two-axis stabilization and limited space for instrumentation. NRL was the prime mover in inducing NASA to develop the SPARCS (Solar Pointing Aerobee Rocket Control System) three-axis solar pointing system. The first two post-development vehicles, were assigned to us, and were flown in June 1968 and February 1969. This new system stabilizes the forward section of an Aerobee rocket, after separation from the fuel tank section; it permits flying instrumentation nearly twice as long as has been possible up to now.

With the recent near 100% success in parachute recovery, it now becomes possible to conduct rocket experiments much more frequently, by reflying modified or readjusted equipment. This can be done at a fraction of the cost and time required to prepare new instrumentation.

The Future of the Solar Rocket Program

Looking ahead five years or more, we predict that the use of rockets for solar research will not decrease. Experiments conducted with the biaxial pointing control will gradually be phased out and be replaced by larger and more sophisticated experiments flown in the three-axis stabilized solar-pointed rockets. Since the latter are only now becoming available, the experimental program that they make possible is certain to continue for at least five years. Orbiting solar observatories and the manned space program offer, of course, the possibility of accomplishing research that cannot be undertaken from rockets because of shortness of observation time. These orbiting experiments are far more complicated to construct, more expensive, and require a long time to prepare.

The rocket program complements the orbiting and manned space program in two ways. First, it provides the possibility of performing exploratory experiments and conducting research that can be accomplished in a relatively short time. Second, it makes possible the testing of instruments that are prototypes of instruments for the orbiting and manned experiments prior to firming up the final design of these expensive instruments. Therefore, we are certain that the rocket program is here to stay.

Relation Between Solar Research Supported by Navy 6.1 Funds and by NASA

As discussed in the Annual Report for 1968, because of many commitments to NASA, the workload of the Branch has increased greatly in the last two years. The result is, that less than 10% of the Branch funds are from Navy 6.1, more than 90% are from NASA. Of the total FY 1969 budget, 9.2 M, 6.9 M went to outside contracts for the preparation of instruments sponsored by NASA. Funds spent in-house were about 600K RN 6.1, and 1.7M NASA.

The largest single program is the preparation of experiments for the Apollo Telescope Mount (ATM) of the Apollo Applications Program of NASA. It is now realized that this program is far more difficult than was originally anticipated. To meet the current launch date, December 1971, the prototype instruments must be delivered in February 1970, and the flight instruments seven months later.

Instrumentation for the Orbiting Solar Observatories (OSO) OSO-F and OSO-H form the next largest commitment to NASA. OSO-F became OSO-V on 22 January 1969 when it was placed in orbit. The experiments for OSO-H are under construction, and are to be flown in late 1970.

As a result of the NASA satellite programs, the manpower of the Branch has been increased, and has been applied largely on these NASA funded projects.

Only one Navy-funded Aerobee rocket experiment was flown during this reporting period. Work has been in progress toward the preparation of instrumentation for only a single Navy-funded Aerobee to be flown in FY 1970, and this has the Solar Pointing Aerobee Rocket Control System (SPARCS), furnished by NASA. Some instrumentation has been prepared on Navy funds for flight in extra space in several NASA-funded Aerobee rockets.

Reduction of existing data from the solar extreme ultraviolet (XUV) program and the publication of results is lagging, and is a matter of great concern. There are two causes; the one is the great escalation of the NASA-funded space research program, with its absolute requirements to meet deadlines. The other is that it has not been possible to add to the Rocket Spectroscopy Branch staff the required astrophysicists who can accelerate data reduction and general analysis and publications; there is only one reason for this situation -- hiring restrictions.

Photography of the Solar XUV Spectrum -- Status and Progress

1. 3000 -- 2000 Å

The solar spectra obtained with the NRL echelle grating spectrograph in 1962 and 1964 have nearly the ultimate spectral resolution (0.03 Å) and precision of wavelength (0.01 Å); they are limited principally in "cleanness", because stray light, a characteristic of echelle gratings, filled in the bottoms of the Fraunhofer lines. Furthermore, the spectra obtained with the echelle spectrograph were from an average region covering the center of the sun.

The next stage in the study of this spectral range requires the use of a spectrograph employing a large diffraction grating of the usual type, rather than an echelle, in order to reduce the stray light. Also the instrument must accept radiation from a small region of the sun that can be chosen anywhere from the center to the limb or into the chromosphere. Design of a large spectrograph of this type and construction has progressed very well. It is reported in a later section under "ATM". Prior to the flight of ATM, however, it is expected that spectra will be obtained with a large instrument of this kind, flown in an Aerobee-150 or 170 rocket and stabilized with SPARCS.

The reduction of the echelle spectra has progressed during the current year, but is not yet completed. The Atlas of Solar Spectrum Lines containing over 7,000 lines, held up in order to incorporate new laboratory results on the spectrum of iron, will be published by the end of this year.

Determination of the intensity distribution and line profiles from the echelle spectra is important because of its connection with the upper atmosphere and ionospheric physics, and also because the line profiles will make possible the improved determination of the photospheric abundances of the elements in the sun. This project is now approximately 75% complete. The reduction procedure is as follows:

First the reduction from photographic density values to intensities is made by comparing the echelle spectrum with the Göttingen Atlas in the wavelength range 3000 - 3500 Å where they overlap; by computer, the photographic characteristic curve is adjusted until the intensity curve derived from the echelle spectrum is in agreement with the Göttingen Atlas. To wavelengths shorter than 3000 Å two procedures are followed. The first is to deresolve the echelle spectrum until the detail agrees with the older low resolution NRL spectra; the latter offered less difficulty in reduction to intensities and are considered correct. Then the deresolved echelle spectrum is made to agree with the low resolution spectrum by adjustment of the photographic characteristic curve. Finally the characteristic curve, so determined, is compared with the characteristic curve derived for the wavelength range greater than 3000 Å, and possible errors are looked for. Lastly the non-deresolved echelle spectrum is converted to intensities by means of this refined photographic characteristic curve. Comparison is also made with the medium resolution spectra obtained by the USSR for the range 2400 - 3000 Å some ten years ago. This project is suffering for lack of suitable personnel. It has been carried on by Dr. E. F. Milone, an intermittent, but computer programmer assistance has not been sufficient.

2. 2000 - 500 Å

This region has been covered with the NRL double-dispersion normal-incidence grating spectrograph with a resolution varying from 0.2 Å to 0.1 A. Excellent spectra were obtained in 1962 and twice in 1966. This region is of great interest in solar physics. There are many hundreds of lines and the spectrum is very complicated. Within this wavelength range the radiation from the sun undergoes tremendous changes in character. At the long wavelength end it originates largely from the outer edge of the photosphere. Progressing to shorter wavelengths the radiation comes next from the transition region between the photosphere and the chromosphere, where the sun's atmosphere reaches its lowest temperature, currently estimated to lie between 4200° and 4600 °K; then from the bottom of the chromosphere, next from higher in the chromosphere ascending gradually through the chromosphere, and finally from the corona where the temperature has risen to more than one million degrees. This is, of course, an over-simplification, but serves to illustrate why the study in great detail of the spectrum in this range will contribute essential data for explaining and understanding the physics of energy transfer in the sun's atmosphere, which causes energy to flow from a low to a high temperature region. The spectrum itself is a complicated mixture; Fraunhofer lines predominate at the long wavelength end; there follows a continuum from the chromosphere, rather than the photosphere, and overlying it all are many emission lines from atoms in various stages of ionization.

The further study of this region requires spectrographs which are larger than can be flown in the biaxial pointing control. Two such instruments are being prepared -- one for the Aerobee-150 stabilized with SPARCS, and a still larger instrument for the ATM. These will be described later in the section on ATM.

There are three research goals to be achieved with these large instruments. The first is to attain greater spectral resolution; a value 0.05 Å seems feasible. The second is to image the sun on the slit thus making it possible to obtain spectra from the center of the sun, crossing the limb, and into the chromosphere and corona. Both these goals can be realized with the SPARCS stabilized Aerobee rocket and with the ATM. The third research goal is to determine with increased accuracy the intensity distribution within this spectral range, but here there are two persistent difficulties. The first is the calibration of the spectrographic system; standard light sources and methods of measuring radiation intensities are still far from satisfactory within this spectral range. The second difficulty is the elimination of errors in photographic photometry, for example, Eberhardt effect, and also the lack of uniformity of photographic emulsions for the XUV and well-controlled development procedures. Work is progressing to reduce these sources of error in connection with the spectrograph for ATM.

3. 500 Å to Soft X-Rays

Photographic spectroscopy in the wavelength range 500 to 30 Å or less has been made possible by means of grazing incidence grating spectrographs that are equipped with thin unbacked aluminum film filters. NRL has pioneered this work. Spectra have been obtained from 630 Å, overlapping the range covered with normal incidence spectrographs, all the way to 33 Å in soft x-rays with the exception of the range 110 to 148 Å for which a suitable filter has only recently been produced. Experiment S-020 in the Apollo program, is intended to provide the long exposure times required to record this portion of the spectrum with increased resolution and to provide the sensitivity to detect the thousands of faint lines that are believed to be present.

Recently, filters of beryllium have been produced that transmit over the spectral range 110 - 148 Å. Grazing incidence spectrographs, making use of filters of beryllium and other materials, are being constructed for flight in an Aerobee-170 rocket during July 1969. It is hoped with these instruments to cover the entire wavelength range photographically from 1216 Å to 10 Å with no significant gaps, and also to increase the resolution by a factor of 2 or more over previous results. Spatial discrimination of a particular region of the sun is difficult with a grazing incidence spectrograph; a collector has been designed, however, to provide some degree of spatial resolution in the direction parallel to the slit.

The coverage of the region between 1000 and 500 Å is incomplete due to insufficient exposure of the solar spectrum, which becomes weaker as one goes progressively shorter in wavelength. Even exposures for the full 2 to 3 minutes available at rocket altitude record no more than a few dozen emission lines and no continuum at all -- certainly a small fraction of the hundreds of emission lines that must be there. Thus the spectroscopic identification of the emitting ions in the chromosphere and corona is hampered by insufficient wavelength coverage in this region. The answer is probably to be found in a faster optical system and reflectances and/or the longer exposure times available in the Apollo S-020 experiment, being prepared for flight in the Apollo Applications Program.

Extreme Ultraviolet Spectroheliograms

Perhaps the most fruitful method of studying phenomena taking place in the solar atmosphere has been the observation of the sun's disk in various monochromatic radiations, first made possible with the spectroheliograph invented by Hale, and more recently carried out on a routine basis by the H-alpha patrol telescopes that make use of the birefringent monochromatic filter invented by Lyot. These observations made from the ground are confined to the sun's photosphere and the lower chromosphere. Extreme ultraviolet spectroheliograms, which must be recorded from rockets or satellites, offer the possibility of observing for the first time phenomena taking place in the upper chromosphere and corona. Thus they complement the observations from the ground, providing a full-scale, three-dimensional mapping of the sun's outer atmosphere.

NRL has pioneered the development of extreme ultraviolet spectroheliographs, commencing in 1959 with the photograph made in the light of the Lyman-alpha line of hydrogen. Since 1963 spectroheliograms have been obtained in the region from 630 Å to 171 Å, the range where the thin unbacked aluminum film filter, by excluding completely all long wavelength stray light, makes possible the use of diffraction gratings at normal incidence.

During the past year, the NRL normal incidence grating spectroheliograph has been flown successfully on two occasions -- 22 September 1968 and 16 April 1969. The spectroheliograms for 1966 - 1969 show conspicuous changes which are associated with the increase in solar activity as the 1969 maximum of the sunspot cycle is approached. In particular, in 1968 and 1969 the chromospheric fine mottling was present in the line at 630 Å from OV, whereas it appeared to be absent in 1966. The limb-brightened ring surrounding many of the disc images in lines of higher stages of ionization has increased in extent as the solar cycle has advanced, and now encircles the sun completely. The spectroheliograms obtained on 22 September 1968 will be discussed in a later section dealing with this particular flight. XUV spectroheliograms are also being obtained from OSO-V and will be discussed in a separate section.

The future plans are to fly extreme ultraviolet spectroheliographs as often as possible. The instrument flown from 1966 to 1969 produces images of 4.6 mm diameter. This will be reflown at least twice during the forthcoming year, and will be used for XUV flash spectra during the 7 March 1970 eclipse. A larger instrument is to be flown in the SPARCS stabilized rocket as part of the ATM program during the summer, 1969. For further details of this instrument and the ATM spectroheliograph, see section under ATM.

XUV Coronagraphs

The XUV heliograph described in the report for 1967 is now termed an XUV coronagraph, because it produces a photographic image of the sun's corona in the extreme ultraviolet. This instrument, flown for the first time on 27 July 1966 uses an off-axis paraboloid to form a solar image directly on the photographic film. Three thin aluminum filters in series are employed to cut out all solar radiation except the band 171 Å to 500 - 700 Å. Thus, the image is simply that of the complete group of images recorded separately in the spectroheliograms.

In addition to the flights of 27 July and 12 November 1966, XUV coronagraphs have been flown on 9 May 1967, 27 and 29 April 1968; and during this reporting period, on 22 September 1968, and 16 and 17 April 1969. Analysis of the XUV coronagrams has been only qualitative. The images show great detail; of special interest is the region beyond the limb. Here, emission of great intensity extends to about 5 arc minutes beyond the limb, produced by active regions close in front of, on, or behind the limb; This XUV emission corresponds closely to the emission recorded with a Lyot coronagraph from the ground using the Fe XIV 5303 Å line. However, in the XUV the emission is far more intense than in the visible forbidden lines. Great detail is often seen in this coronal emission. On long exposures, however, XUV emission is traced far out from the limb The extent appears to be highly variable. On 9 May 1967 the emission extended to one diameter beyond the limb in the equatorial regions but only about 10 minutes beyond the limb over the poles. On other dates the emission was less.

The excitation mechanism and origin of the XUV coronal emission far from the limb requires elucidation. An instrument for obtaining low resolution spectra of the coronal emission at these great heights has been designed, and was carried in the unsuccessful rocket flight of 14 August 1968. The emission seems to be too intense to be produced by collisional excitation and far too intense, of course, to be attributed to Thomson scattering by electrons, which is the source of the white light corona. It is proposed that resonance scattering of the radiation emitted from the low corona is required in addition to collisional excitation. It is also necessary that the abundance of the iron ions be greater than expected from the photospheric abundance of iron, but this increased ion abundance is already known to be required to explain the relative intensities of the various coronal lines in the XUV.

It is planned to fly an XUV coronagraph on every possible occasion in order to record the changes taking place in the XUV corona over the sunspot maximum. For the TV system, based on this instrument, see the section on ATM. Using three-axis stabilized instruments, it is hoped that detail will either be found, or proved absent, in the XUV corona far above the sun's surface.

<u>White Light Rocket Coronagraph</u>

Until 1962 the sun's white light corona had been observed only when there was a total eclipse of the sun. Rockets offered the possibility of observing the corona without a total eclipse, by carrying coronagraphs to altitudes above the light-scattering atmosphere whose glow prevents detection of the outer corona from the ground, and even from stratosphere balloons. The first rocket coronagraph, flown by NRL in 1963, did indeed succeed in photographing the white light corona without an eclipse from 3 to 11 solar radii.

The coronagraph has been progressively improved. Every flight (except one in 1963) has been successful and the instruments have been recovered with little damage.

The corona has been recorded on the following dates: 28 June 1963; 28 April 1966; 12 November 1966; 9 May 1967; 5 October 1967; 27 and 29 April 1968, 22 September 1968; 16 and 17 April 1969.

The rocket coronagraph work was originally undertaken to prove out the coronagraph to be flown in the second NASA Orbiting Solar Observatory (OSO-II). However, the rocket coronagraph work is continuing, since it is proving valuable for the study of the changing corona. In 1971 it is expected that daily images of the corona will be obtained by a coronagraph being constructed for OSO-H. The rocket coronagraphs will also be flown when OSO-H is in orbit, for calibration purposes.

Use of a three-axis pointing system for Aerobee (SPARCS), is being considered for future rocket coronagraphs, since this makes possible flying a much larger coronagraph, that will enable the corona to be observed somewhat closer to the sun's limb than 3 R, the minimum attainable with instrumentation flown in the biaxial pointing control.

Particles Photographed at High Altitude

The rocket coronagraph described above has the additional characteristic that it can detect minute particles in space with extreme sensitivity provided that they are moving with nearly the velocity of the rocket. This is true because of the tremendously enhanced ability to scatter at very small angles. Thus a particle 1° or 2° away from the sun shines with an intensity of the order of a million times greater than one located 90° from the sun provided it is in the tens of micron diameter range.

On each of the ten rocket coronagraph flights thus far, particles were detected in the altitude range 130 km up to peak (approximately 200 km) both on ascent and descent. In all flights after the first, the use of a pair of coronagraphs made it possible to triangulate and so to determine the distance of each particle from the rocket.

For the particles which stayed longest in the field of the coronagraph, it was determined that they followed approximately the same trajectory as the rocket, and probably originated from it. Many other particles, which passed through the field rather quickly, had an undetermined trajectory. They appeared in groups at a relatively large distance from the rocket, and were not associated with any event on the rocket (e. g., the release of despin weights). These may have been naturally occurring micrometeorites.

Not only does this type experiment provide a possible means for investigating particulate material in space, a practical application of the coronagraph, proposed by Code 7140, is to fly a scaled down coronagraph in the Apollo program in order to investigate the cleanness of the atmosphere and environment in the neighborhood of the Apollo spacecraft. An instrument of this type is being constructed by the Manned Spacecraft Center for flight in AAP-2, making use of the results of a design study conducted in December 1964 by Code 7140 for the Manned Spacecraft Center.

ROCKET EXPERIMENTS LAUNCHED IN FY 1969

XUV Solar Spectrographs and Spectroheliographs [NE-3 183]

An experiment package containing a new, high and spatial resolution hydrogen Lyman-alpha spectroheliograph, various broad-band spectroheliographs, and improved and specialized XUV grazing incidence spectrographs was launched from WSMR on 14 August 1968. Because of a propulsion deficiency the altitude was low and no data were obtained. However, the instruments were recovered in good condition They will be reflown in the summer of 1969, modified, as is described in a later section.

The separate instruments making up the payload for NE-3. 183 were the following:

(a) A hydrogen Lyman-alpha (λ 1216 Å) spectroheliograph designed to produce 5 arc second spatial resolution, some five to eight times better than the original instrument flown in 1959;

(b) An XUV coronagraph (heliograph) with exchangeable filters; 170 - 500 Å using aluminum; 170 - 250 Å using aluminum plus carbon, thus excluding the intense high chromospheric line of He II, 304 Å. By comparison, it was hoped to obtain qualitative new data on the spectral composition of the XUV coronal emission;

(c) Twenty-six pinhole cameras with various filter combinations, to obtain further qualitative information concerning the chromospheric and coronal emissions in the XUV and soft x-ray regions;

(d) Five grazing-incidence grating spectrographs with high spectral resolution and with different filters, covering different wavelength ranges, over the entire range 2 to 260 Å.

(e) A new coronal spectrograph using a grating at grazing incidence and a special, image collector. This instrument was designed to cover 170 to 470 Å, and to image a section of the corona across the spectrum, in order to record changes in the XUV coronal spectrum with height above the sun's limb.

White Light Coronagraphs

(a) Flight during the total solar eclipse of 22 September 1968 [NE-3. 220]

One of the most interesting things to do with the white light coronagraph experiment is to launch during the day when a total solar eclipse takes place. In this way, the corona can be recorded from the sun's limb all the way to 9 solar radii, the inner section from the limb to 3 radii being provided by photographs obtained during the total eclipse from the ground or from aircraft and the outer section obtained with the rocket coronagraphs; at the same time extreme ultraviolet solar images and spectroheliograms can be obtained from the rocket experiment. This was indeed accomplished during the solar eclipse of 12 November 1966.

Another opportunity arose on 22 September 1968. This total eclipse took place in Siberia. No aircraft experiments were carried out to our knowledge. However, several parties from the western world were invited to Siberia. By good fortune, a rainy spell cleared up during the night and the eclipse was seen under ideal sky conditions. However, the sun was low in the sky, hence the attenuation of the light from the sun's corona was increased and the sky was brighter, therefore, the corona was followed only to about 2.5 solar radii.

The NRL rocket flight was highly successful. It took place about four hours after the total eclipse. A composite print of the corona is shown in Figure 1, with an eclipse photograph introduced in the center, to the proper scale and orientation. Also introduced is the prediction of the solar streamers made by Schatten on the basis of the solar magnetic field pattern recorded at Mount Wilson. The difference between the predicted and actual electron streams show the complexity of events occurring on the sun.

The rocket picture has many streamers, some sharp, others diffuse, but without curvature, as has always been found in the rocket corona images. The streamers connect in a general way with the outermost parts of the corona photographed during the total eclipse; but the correspondence is far from perfect. Why? There was a time interval of about four hours between the eclipse photograph and the rocket photograph of the outer corona. Could the corona have changed its structure in that interval? Such changes have not been observed in eclipse photographs, in the rare cases where this time span occurred between observations at either end of a long eclipse path. It does not seem likely that the outer corona would change its appearance more rapidly than the inner corona, although observations are completely absent.

There is another more subtle reason why the rocket photographs may contain coronal features not visible in the eclipse photographs. In the latter, the observed features lie very close to the plane of the visible limb, because streamers projected from the front (or rear) face of the sun, toward (or away) from the observer, would be foreshortened and faint, and practically invisible against the bright limb features. However, in the outer corona, streamers projected from the face of the sun may become visible against the faint general background. Thus, some streamers seen in the rocket photograph may indeed be unrelated to those seen in the eclipse picture.

Rocket coronagraphs can be used to clear up some of these questions, since with them the corona can be observed at nearly any time. Obviously, the possibility of short-time changes in the corona can be investigated by launching two coronagraph instruments several hours apart. If the change in form of the streamers is not great, then it is possible to answer the second of the two questions also; namely, what is the point of origin of the streamers? If the streamers rotate rigidly with the sun, and if the same streamers can be identified in both photographs, then the change in their apparent position will reveal the point of origin.

Such an experiment was carried out in two NASA-supported rockets launched 48 hours apart; the first on the 27th, and the second on the 29th of April 1968. The results were described in the Report for 1968. The results were encouraging, in that the same streamers apparently were registered in both photographs. However, the calculated points of origin did not correspond to significantly active regions on the sun's surface, and it was assumed that the result was distorted by some change in the form of the streamers. It was decided to repeat this dual launch in 1969; the results are described in the next paragraph.

(b) Dual launch of coronagraphs - { 16 April 1969 [NE-3.222]
17 April 1969 [NE-3.223]

This double launch was a reflight of the payloads described above, but with a 24-hour interval between rather than 48 hours.

Excellent records were obtained (Figure 2), but they have compounded the corona mystery rather than solved it. The 24-hour change in the coronal streamers was far greater than in the 48-hour interval previously observed, and no streamer can be identified with certainty from one photograph to the next. It is certain that the changed appearance is only partly due to solar rotation, and that vast changes in form and number of streamers have occurred. This result is unexpected, and requires further analysis. It would be most fruitful to carry out further rocket research during a total solar eclipse. An opportunity to carry out such experiments is presented by the total solar eclipse which passes up the east coast of the United States on 7 March 1970. The experiments to be conducted by Code 7140 are discussed in a later section.

(c) Extreme ultraviolet spectroheliograms

All of the coronagraph experiment packages described above carried XUV heliographs or spectroheliographs to record solar disc features and inner corona. A few from the 22 September 1968 flight are shown in Figures 3 and 4. They are among the best we have obtained; analysis of these images is far from complete.

Figure 3 shows the extreme ultraviolet spectroheliograms for the Lyman-alpha line of He II, 304 Å, and the adjacent resonance lines of Fe XV, 284 Å, and Fe XVI, 335 Å, that originate at a temperature of several million degrees Kelvin. The chromospheric network shows in good detail for the He II image as does an extremely large prominence. The image is covered with centers of activity. The highly ionized iron images, however, show that emission in these lines takes place only from the corona above centers of activity. There is no emission from the disk as a whole, but emission takes place above the limb from the corona produced by the solar surface features both behind and in front of the limb.

Figure 4 shows the detail present in a section where there is high activity. In Mg IX and Fe XV there is much emission above the limb in the corona, but there is structure present in Mg IX that is absent in Fe XV. In He II, 304 Å, the same emission appears to be present, however, it is in reality produced by the resonance line of Si XI which is nearly blended with He II, the separation being 0.4 Å. This is clearly shown by the dark arc that separates the one image from the other. Emerging from the center of the coronal Si XI emission, is a sharply defined curved plume. This is believed to be a surge prominence in He II, 304 Å. The conclusion is that the coronal and chromospheric emission above extremely active regions shows detailed structures that are not alike when observed in lines that originate from different altitudes in the solar atmosphere. Some correlation with the white light coronal structures is expected, but as yet it is not apparent.

XUV High Resolution Spectrograph

An XUV high resolution spectrograph was flown on 11 February 1969. This was the prototype instrument for ATM, known as FDVU-B. It is described as part of ATM on page C44.

ROCKET EXPERIMENTS BEING PREPARED FOR LAUNCH IN FY 1970

XUV Spectroheliographs and Spectrographs

NE-4.234

The experiments for NE-4.234 include those described on pages C18 and C19 and flown unsuccessfully in NE-3.183, with many modifications and additions. This project is mostly financed by RN 6.1, with NASA providing the SPARCS pointing system. The original payload was constructed and flown in a biaxial pointing control, and an Aerobee-150 rocket. Rather than refly the instrument in exactly the same configuration, it was decided to redesign the payload to fly in the SPARCS (the three-axis stabilization system), and an Aerobee-170 rocket.

This was a major decision, but the advantages offered by the new vehicle, three-axis instead of two-axis stabilization, is so great that we decided to proceed at once, even though this meant a delay of four months to a year. NASA was willing to provide one of their first six SPARCS; with the cooperation of NASA, the second Aerobee-170 was made available.

The advantages are, that much more payload space and weight is available, hence more instruments could be flown; and with three-axis stabilization, there is no loss of spatial resolution in spectroheliograms with long exposure times.

The experiments to be flown are the following:

(1) Hydrogen Lyman-alpha (1216 Å) spectroheliograph producing

5 arc seconds or better spatial resolution (see pages C18 and D13).

(2) Two XUV spectroheliographs for 170 - 740 Å. It is hoped that 3 arc seconds spatial resolution can be achieved from 260 to 460 Å, with degradation to no worse than 10 arc seconds at the extreme wavelengths.

(3) Two of the XUV coronagraphs described on page C14 will be flown, one with aluminum, the other with aluminum and carbon filters, to try to analyze, qualitatively, the contribution of the different XUV emission lines to the corona. By photographing with two instruments, simultaneously, more definitive results will be obtained than by photographing alternately, exchanging filters, as attempted before.

(4) <u>Coronal Grazing Incidence Spectrograph</u>

This experiment uses an improved version of the instrument described on page C19e. It employs a far-off-axis paraboloidal surface to obtain spatial resolution along the slit of the spectrograph of 4 minutes or better. This experiment will complement the XUV spectroheliograph experiments described in (2) above; the latter experiment will yield very high spatial resolution of features on the solar disc and extending a short way into the corona; many of these features will be obscured by the overlapping of the disk images produced by spectrum lines that are close together in wavelength. This coronal spectrograph should give a spectrum produced by a single radial slice into the corona, with no problem of overlapping.

(5) Integrated sunlight (no spatial resolution) grazing incidence spectrograph experiments

Several experiments of this type, covering a combined wavelength range of 0 - 1050 Å will be flown. Each of these experiments will have a different grating blazed to have optimum sensitivity in a particular portion of the above wavelength range, and filters which will eliminate blending of lines of higher orders of shorter wavelengths with low order lines. Spectral resolution of from 0.08 Å - 0.005 Å will be obtained.

(6) Low-resolution, multiple exposure grazing incidence spectrograph

The purpose of this experiment is to obtain over the projectory a large number of low resolution spectra taken at different altitudes, in order to determine the effects of spectrally selective atmospheric attenuation on the experiments described in (2) through (5) above.

(7) Pinhole camera experiments

Several pinhole camera experiments to obtain low spatial resolution images of the solar disk and corona in integrated sunlight of different bandpasses within the wavelength ranges 0 - 170 Å, and 510 - 1100 Å will be flown as complementary experiments to the XUV coronagraph experiments discussed in (3) above.

An attempt will be made to launch this payload during a solar flare. All the instruments that provide spatial resolution (1), (2), (3), (7), would be expected to record the flare; (2) will produce flare spectra; (1) and (3) will show the development of the flare during the four minutes of time covered by the useful part of the flight. The spectrographs (5) will show many more lines if the flight occurs during a flare.

Thanks to the expected stabilization produced by SPARCS (1 arc second or better), these experiments should yield, for the first time, spatial resolution of XUV solar features that equals the resolution in the visible region of the solar spectrum that is achieved by ground-based solar observatories.

XUV Line Profile Experiments

NE-3.157 -- Launch date: 1970

The following instruments have been designed and constructed with RN 6.1 funds:

(a) Lyman-alpha and Lyman-beta profile spectrograph;

(b) XUV spectroheliograph (170 Å - 600 Å);

(c) λ 304 Å profile spectrograph or grazing incidence spectrograph.

It is not certain when these instruments can be flown. Most of the construction has been completed, but the process of focussing and adjustment is likely to require considerable time. It is hoped to launch during FY 1970, but we are committed to much additional work in the experiments for the total eclipse of 7 March 1970.

Rocket Experiments connected with ATM

These are described under ATM. A reflight of FDVU-A is planned for the summer of 1970, and of FDVU-B on 11 September 1970.

Solar Eclipse of 7 March 1970

On 7 March 1970 a total solar eclipse will come up from Mexico to the east coast of the United States. The most unique aspect of this eclipse is that its shadow can be reached by rockets launched from Wallops Island. Code 7140 plans one launch from Wallops Island and two from the White Sands Missile Range.

I. Rocket Observations in the Total Eclipse Shadow

The proposal by Code 7140, accepted by NASA, is to launch an Aerobee-170 rocket out of the Wallops Island Aerobee Tower into the shadow. This rocket will carry seven different experiments, all requiring precise pointing to the sun, which until now has not been possible during an eclipse. A special new pointing system for this purpose has been developed by Code 7140 together with the Aerojet-General Corporation to achieve precise pointing at the sun's thin remaining crescent, just before entry of the vehicle into the total shadow, and then to keep this pointing during totality. The system is now under construction at Aerojet-General Corporation.

The seven experiments are the following:

(1) XUV Spectroheliograph I (150 - 437 Å)

This instrument is designed to photograph the ultraviolet spectrum of the corona containing the high-ionized iron lines, with very high spatial resolution during the flash phase of the eclipse, and to obtain a long exposure of this region during totality, showing the spectrum of the corona. The scientific goal is to obtain with high spatial resolution information about the chromosphere-corona transition region. The different iron lines from Fe IX to Fe XVI and Mg IX represent a wide variety of different temperatures. By observing their intensities during the flash phase we should be able to analyze and localize the temperature jumps from the chromosphere into the corona. It is also possible to determine iron abundances as function of altitude in the corona, if any change is present. Using this slitless type spectroheliograph provides us during the eclipse with the unique opportunity to obtain pure spectra of the corona, not overlapped by spectra from the active regions on the disk. It also allows us to abandon the previously used aluminum filters and in this way to increase the speed of the instruments.

(2) XUV Spectroheliograph II (449 - 782 Å)

The goals are the same as for XUV Spectroheliograph I, but other lines will be observed (Ne VII, Si XII, He I, O IV, Ne VI, Ne V, O III, Mg X, O V, N III, O III, O II, O V, N IV, Ne VIII).

(3) Hydrogen-Lyman-Series Spectroheliograph (727 - 1060 Å)

This instrument is designed to obtain the flash spectrum of the chromosphere in all the Lyman lines except Lyman-alpha, and also the Lyman continuum. Measurements of the intensities of those lines as function of altitude in the chromosphere will for the first time allow us to determine the population of all hydrogen levels and to check theories about deviations from local thermodynamic equilibrium. Beside the Lyman series lines a number of other lines that originate in regions of different temperatures can be measured with very high spatial resolution.

(4) Hydrogen-Lyman-Alpha Spectroheliograph (1216 Å, resolution 0.8 Å mm^{-1})

This instrument will photograph the hydrogen-Lyman-alpha line in the chromosphere with very high spatial and spectral resolution; it will enable us to determine the profile of this line as function of altitude in the chromosphere.

(5) Schumann-Region XUV Spectroheliograph (1350 - 1900 Å)

This instrument is designed to photograph the flash spectrum of the photosphere-chromosphere transition layer. The continuum in this region is believed to originate in the very outermost and coolest region of the photosphere. The eclipse provides a unique opportunity to check this theory, and to measure the exact value of the photospheric boundary temperature. Also it will be possible to record the CO absorption bands which are important to explain the intensity of the ultraviolet spectrum in this region.

(6) Multichannel Photoelectric XUV Narrow-Band Spectrophotometer (1300 - 2000 Å)

This instrument covers the same region as Instrument No. (5) above. It does not allow investigation of different regions in the chromosphere around the solar limb, but will provide exact photoelectric measurements from which the temperature profiles can be derived. Use of this photoelectric instrument insures obtaining new results even if the payload should not be recovered from the sea.

(7) Multicolor Visible-Light Corona Camera

This experiment is designed to obtain photographs of the corona and measure polarization in three different wavelength bands. It will photograph the corona out to 50 solar radii into the transition region corona-zodiacal light. The main goal of the experiment is to separate in this region the K and F corona by determining the wavelength dependency of the polarization, which is caused by scattering of sunlight by small particles and electrons.

II. Rocket Launches at White Sands Missile Range

Solar Eclipse of 7 March 1970

Two unexpected and important results of the rocket coronagraph experiments are described on pages C20-C22, (1) the features of the outer white light corona change very rapidly, and (2) there is an apparent mismatch between eclipse coronal features and outer coronal features when these are photographed within four hours of each other. The mismatch may be due to the time interval or because the rocket coronagraph can record foreshortened streamers not detectable in an eclipse photograph.

An opportunity to investigate both these matters more fully occurs during the total eclipse of 7 March 1970. One coronagraph package would be launched from the White Sands Missile Range while the inner corona is simultaneously being recorded on the east coast. A second flight from White Sands would be launched later that day or early the following day to record the short term change in the outer corona. Either of the choices would give an interval less than the 24 hours between the 16 and 17 April 1969 launches, which revealed such large changes in the outer corona.

EXPERIMENTS IN THE NASA ORBITING SOLAR OBSERVATORIES (OSO)

1. OSO-V (formerly OSO-F)

The proposal to repeat the OSO-II (OSO-B2 prior to flight) spectroheliograph experiment in OSO-F was accepted by NASA on 19 August 1963. The experiment has been improved in many respects; for example, twice as many wavelengths as in OSO-II will be monitored. Every precaution possible was taken to make the NRL experiment immune from the electrical breakdown problems that beset the earlier effort. NRL also assumed the responsibility for integrating the University College of London (UCL) x-ray experiment into the NRL instrument case.

Much difficulty was encountered with the reliability of the Bendix Channeltron photomultiplier detectors used for sensing the XUV radiation. The probable explanation of many of the failures that occurred during testing was fracture of the delicate glass capillary ($\frac{1}{2}$ mm bore, 1 mm o. d., 50-mm long and bent into a semicircle), which was encapsulated together with a preamplifier in a ceramic-filled hard epoxy potting compound. It appeared that the encapsulating material was not sufficiently elastic to prevent breakage of the capillary during thermal cycling. As a result, a great deal of effort was expended from September 1968 to January 1969 in preparing for flight, channel photomultipliers which were built by the Mullard Research Laboratories, Redhill, Surrey, England, and were twice as large and therefore stronger than those made by Bendix.

The OSO-F satellite was successfully launched on 22 January 1969 and thereupon became officially known as OSO-V. The NRL spectroheliograph has operated almost perfectly from the electrical point of view. Excellent spectroheliograms with 1 arc minute spatial resolution are being obtained in the Lyman-alpha line of H I, 1216 Å, and the Lyman-alpha line of He II, 304 Å. The spectroheliograms in Si XII, 499 Å, Ne VII, 465 Å, and in Fe XVI, 335 Å, are very good. The sixth detector, for Fe XV, 284 Å, although electrically sound, seems to lack sensitivity to this wavelength and little but 1216 Å stray light is being detected.

After three months of operation, the instrument sensitivity is still high, even though it has decreased by nearly an order of magnitude. This is believed to be caused by contamination of the grating, that reduced the reflectance.

In the OSO-V experiment, the objective-type grating spectrograph forms a spectrum of solar images in the plane of the photomultiplier detectors. As the spacecraft makes a raster scan of the sun, each detector traces out a square pattern centered at a predetermined wavelength. The number of picture elements per square raster is restricted to 1920 by the limitations of the telemetry system. With 48 elements per raster per scan line and 40 lines per raster, each element has an aspect ratio of 5:6 and covers approximately 1 arc minute on a side. Appropriate signals for synchronization purposes are included in the data to facilitate picture reproduction in the laboratory.

A system has been developed to produce pictorial images from the satellite data. First the raw data received from the Goddard Space Flight Center on magnetic tape are processed by the NRL Research Computation Center (3800-Computer), and put on perforated paper tape. This tape is then read into System Logic which controls an oscilloscope. The scope traces the 40 raster lines, each containing 48 digital words; a photograph of the scope reproduces the original raster scan of the sun. The part of the system that required a special design technique was the production of the picture-forming element on the oscilloscope in the rectangular form required to reproduce a satisfactory picture.

Some typical solar images are illustrated in Figure 5.

2. OSO-H

On 1 July 1966 a proposal was submitted to NASA to fly an improved OSO-II white light coronagraph and also a coronal XUV photometer. This was accepted. The primary object of the double experiment is to observe solar burst phenomena associated with flares, first as an enhancement in the XUV corona, and then as a travelling bright spot in the white-light electron corona, associated with a region of increased electron density. A second object of the white light and XUV coronagraph experiments is to record the day-to-day changes in the coronal streamers that form a part of the solar wind, to separate them from the zodiacal corona, and to correlate them with the XUV corona. Launch is planned for December 1970.

The investigations of the white light coronagraph were concentrated on the choice of a new detector to improve considerably the signal to noise ratio of the low contrast picture of the outer corona. Proposals for point-by-point scanning procedure were considered, but rejected because of the long sampling period required to obtain a single coronal picture. We decided to use the newly developed SEC Vidicon which is able to integrate all picture elements simultaneously and store the picture for a long period, during which readout into the spacecraft telemetry can be done. Furthermore by applying a data compression scheme, one entire coronal picture can be read into the spacecraft telemetry in approximately 6 - 8 minutes. A study contract to build a breadboard instrumentation of the experiment, awarded to Electro-Mechanical Research (EMR), Sarasota, Florida, about a year ago, has been followed by a production contract.

The XUV coronagraph, imaging the sun in the 150 - 650 Å band, will use the scanning scheme of OSO-II - OSO-V with four detectors at four different positions in the image plane. The arrangement of the detectors together with the 60 × 60 arc minute field covered during the spacecraft raster-scan mode will allow covering the corona in XUV out to 3 solar radii, thus overlapping the field of the white light coronagraph.

Progress on OSO-H has been slower than expected because of the described difficulties encountered with OSO-V. However, in the spring of 1969 NASA announced its decision to construct OSO-I, J, and K in a much larger configuration, and also to build OSO-H in this same improved form. As a result, the NRL OSO-H instrument package is being redesigned for a box with dimensions $12 \times 6 \times 52$ inches, instead of $8 \times 4 \times 48$ inches. This is a great advantage because with twice the volume, interface problems are greatly reduced; also with the new spacecraft much greater power is available and weight is no longer critical.

It is required, however, to attempt to maintain the same schedule -- prototype delivery, April 1970; launch, December 1970. Therefore the work is proceeding on a crash basis.

3. Apollo S-020 Solar XUV Spectrograph

The objective of the experiment is to photograph the XUV and x-ray spectrum of the sun in the wavelength region from 200 to 10 Å. The wavelength region below 200 Å is more variable during periods of enhanced solar activity than any other solar radiation; hence it is of direct interest in connection with flare prediction, and the prediction of the quality of radio communications at various frequencies during solar storms. This spectrum is also of interest in connection with the development of methods for nuclear power production because of the physics of the sun's high temperature plasma is directly related to laboratory plasma research.

Low resolution spectra of the sun in the wavelength region from 33 Å to 100 Å using grazing incidence spectrographs have been obtained by NRL with sounding rockets on various occasions and have recorded the region from 2 Å to 28 Å with an x-ray crystal spectrometer. However, all devices utilized to measure radiation in these wavelength regions are inherently insensitive and the exposure time possible during a sounding rocket flight is limited to 4 minutes. By making exposures of up to an hour's duration during the flight of an Apollo spacecraft, utilizing an instrument with finer spectral resolution, it is anticipated that as many as an order of magnitude more spectral lines can be recorded.

This experiment has completed environmental testing and was originally scheduled for flight on the second Apollo manned mission. However, all experiments not directly related to the Lunar Mission have been removed from main-line Apollo Lunar Missions.

In January 1969 the Manned Space Flight Experiment Board (NASA) restored Experiment S-020 and authorized its flight in AAP-1/2, the first two flights of the Apollo Applications Program. [ATM, in AAP-3/4, docks with AAP-2, which is the Orbital Workshop, to complete the "Cluster".]

The project has been reactivited, and work is in progress. Several modifications will be necessary to accommodate existing experimental hardware to its new interfaces in the Cluster. Flight hardware delivery is scheduled for August 1970, and the AAP-1/2 launches are scheduled for August 1971.

4. Apollo Telescope Mounting (ATM)

The experiments for ATM being undertaken by Code 7140 are the most complex program ever undertaken by the Branch. The first instrument is an XUV photographic spectroheliograph covering the wavelength range of 170 - 650 Å and is four times larger than the largest ever flown in a rocket. The second experiment is a photographic spectrograph designed to provide high resolution spectra of very small selected features on the sun, covering the wavelength range 970 - 3940 Å. The third instrument is an XUV closed-TV system that will produce an image of the sun for study by the astronaut, for his use in pointing the instruments and deciding when to make exposures, and for providing valuable scientific material for study by the scientific staff after transmission to ground.

The present ATM concept represents the culmination of a program commenced in 1964, when NASA authorized the development of the Advanced Orbiting Solar Observatory (AOSO). Code 7140 proposed experiments which were accepted for flight in the first AOSO and contracted the development and construction of the instruments to the Ball Brothers Research Corporation (BBRC). In September 1965, three months after cancellation of the AOSO spacecraft program, we were asked to consider flying the same or modified instruments in the manned Apollo program. Our proposal was accepted and design and construction of these instruments began on 12 September 1966.

The development of the instrumentation and also of the ATM itself has proved to be extremely difficult, largely because of the time schedule which was compressed from the very beginning. This shortness of time required that the design of the different experiments and the various components of the ATM itself be carried on in parallel, and there was little opportunity for intercommunication. As a result, a great deal of iteration has been required in order to avoid conflicts between the different subsystems (and so to arrive at a complex system that will attain all the scientific objectives). In spite of every effort, the initial schedule has had to be extended. Currently the launch date is set for the second quarter of FY 1972. The second ATM mission for which this Laboratory was authorized to design instruments has been tabled, and no work by NRL is in process.

The cost of the project has increased with its complexity and with the time required before launch. The current forecast for the cost of this project through launch is approximately 27 million dollars. Although the greatest part of the work is being done by BBRC under contract to NRL, a considerable amount of research is required in-house at NRL. Furthermore, the task of monitoring the outside contract is formidable and the equivalent of twelve persons (full time) are involved. This is insufficient to handle the project properly; several more persons are needed at the present time and the peak involvement has not yet been reached.

a. ATM Instruments

The ATM coronal XUV spectroheliograph is a normal-incidence concave grating instrument employing a 4-meter radius of curvature, 3600 lines/mm diffraction grating to form a spectrum consisting of monochromatic images of the sun. The spectrum will be photographed through a thin unbacked aluminum filter which eliminates long wavelength stray light. Two positions of the grating permit photographing the spectrum from about 171 to 650 Å. The resolution over this range will vary depending on wavelength, approaching 1 arc second in the optimum region, averaging better than 5 arc seconds, and reaching 10 arc seconds at the long wavelength end. Sufficient film will be carried to make 800 exposures during the mission. The instrument will be operated by the astronaut in several modes. In one mode, routine exposures will be made once each day for monitoring purposes. In a second mode, exposures in rapid succession will be made when a flare takes place to study the change in both emission spectrum and area of the sun's surface from which the various emission lines in the flare spectrum originate.

The second instrument, the XUV chromospheric spectrograph, employs a 2-m radius 600-line/mm grating at normal incidence together with two predisperser gratings mounted on a turret so that they can be interchanged. The one predisperser selects the first order spectrum from the main grating which covers the wavelength range 1940 - 3940 Å; the second predisperser selects the second order spectrum from the main grating which covers the range 970 - 1970 Å. The spectral resolution goal is 0.04 Å in the short wavelength range and 0.08 Å in the long. The sun's image is focussed on a slit with an off-axis paraboloid in such a way that it is possible to record the radiation from a selected area of the sun as small as 2 arc seconds wide and 20 arc seconds long. Provision is made for 6400 separate exposures. The instrument will be operated in three principal modes by the astronaut. In the first mode, spectra will be taken across the photosphere-chromosphere-corona interface in steps that may be as small as 2 arc seconds, i.e., 1500 km on the sun. In the second mode, the instrument will be pointed at particular regions which are of special interest such as plage regions, prominences, and filaments. Changes in the spectrum of a given plage can be followed as it approaches the limb during the course of the sun's rotation. In the third mode, the spectrum of a flare will be photographed. This will be accomplished by pointing the instrument at an active region where a large flare is likely to appear, and waiting until the flare does appear. In this way, it will be possible to obtain spectra during the initial explosive phase of the flare.

The third instrument to be flown is an XUV closed-TV system. This is a novel instrument, the first of its kind. It employs a 1-m off-axis paraboloid to form an image of the sun on a phosphor surface which is covered with a thin aluminum filter. Thus radiation, restricted to the range 171 Å to approximately 600 Å, falls on the phosphor and is converted into visible light. The phosphor is placed in contact with the fiber optics faceplate of an SEC Vidicon camera and the output from the camera is displayed on a TV scope viewed by the astronaut and is transmitted to the ground when the ATM is over selected receiving stations. The XUV solar image shows many features that simply do not exist as seen from the ground in H-alpha or CaK light. Thus the XUV monitor will provide data on the XUV appearance of the sun, with the aid of which the astronaut will be able more intelligently to operate the XUV spectrographic instrumentation. These XUV images can be transmitted to ground in real-time, if suitable equipment is installed in the Cluster. It appears probable that this will be done, and that ATM will provide XUV images of the sun in real-time.

5. The Future of ATM

It now appears quite certain that the first ATM mission will be launched during early 1972. The NRL experiments are on schedule and developing well. Follow-on missions, however, are under study by NASA. It seems clear that the ATM project at NRL will extend through 1972; then reduction of the spectra will require some years.

6. ATM Rocket Flights

In association with the ATM project, prototypes, or flight design verification units (FDVU) have been developed for flight in the Aerobee-150 rocket, stabilized to point at the sun in all three axis by means of SPARCS. There are two instrument packages. The first, FDVU-A, carries a half-sized photographic spectroheliograph and an XUV TV system making use of the SEC Vidicon. Signals from the Vidicon are transmitted in real-time to ground, where a TV picture is reconstructed. The second, FDVU-B, carries a scaled-down photographic spectrograph equipped with a limb pointing system.

a. FDVU-A

The first flight was scheduled during May and June 1968. An attempt was made to launch from White Sands during a solar flare. The White Sands Missile Range personnel provided a great deal of support and had things arranged so that the rocket could be held ready for almost instant launch during the greater part of three weekends as well as some time during the week. Because the sun was quite inactive, a solar flare did not appear until the last possible day made available for the project. The rocket was indeed launched during an importance-one N-flare on 8 June 1968. Launch took place 3 minutes after the flare was observed at the flare station in ESSA, Boulder, Colorado, and reported to the personnel at the Blockhouse. Unfortunately the mechanism provided by NASA for separation of the payload from the tank section failed to operate and the SPARCS was required to stabilize the entire rocket along with the payload. This was a task far beyond its design and pointing was not achieved. No data were obtained, and the instrument was destroyed because the parachute failed to deploy (due to the separation system malfunction).

This instrument is now nearly reconstructed. Launch is planned for the summer of 1969; and again, the flight will be made when a solar flare has appeared.

b. FDVU-B

The XUV spectrograph was finally placed in satisfactory flight condition in late December 1968. Flight took place from the White Sands Missile Range on 11 February 1969. The flight was excellent in all but one respect. Correct absolute pointing of the instrument was not achieved, through a combination of unusual errors; the instrument was pointed 70″ off-limb in lieu of on-limb. However, the SPARCS held the pointing with excellent stability, and the instrument was recovered in good condition.

Faint, but valuable spectra, Lyman-alpha of hydrogen, and two coronal lines of Fe XII were obtained. The instrument is being prepared for reflight on 11 September 1969.

7. The Real-Time Vector Magnetograph

In order to assist the astronauts in preparing for flares, NRL proposed to construct a real-time magnetograph for use on the ground. Information furnished by this instrument might well alert the astronaut as much as several minutes before an active region commences to blossom into a flare.

A second purpose for the magnetograph project is to obtain new, critical solar information that may lead to an understanding of the nature of solar flares. This, in turn, will assist greatly in flare prediction, and thus contribute importantly to ionospheric warnings.

We are, as of now, far away from an understanding of the mechanisms which can trigger flares in active regions. It seems to be certain that the initial energy of a flare can be a release of magnetic field energy, but even this process is not at all understood. Furthermore it seems quite uncertain whether all the energy released in a flare is of magnetic origin. Hydrogen-alpha pictures, which represent to a certain extent the chromospheric magnetic structures, do not show very much change before and after a great flare has occurred. Therefore possible other energy sources remain to be taken into account. To get more insight into the flare triggering mechanisms, extensive studies of the magnetic field structures and the electrical current systems accompanying the magnetic fields have to be made.

Most of the observations until now deal only with the longitudinal component of the magnetic vector. It has been found that flares occur preferentially at points where the longitudinal component is zero. This has not yet led to a plausible flare theory; the reason for this is that the observations of the longitudinal field describe only a part of the entire magnetic vector. Furthermore, they have rarely been made with sufficient frequency.

The real-time vector magnetograph was designed in the first place to measure all three components of the magnetic field, and in the second place to present a record of the changing field that is continuous in time.

Three proposals have been prepared concerning the "Real-Time Solar Magnetograph". Early in the planning we were engaged, together with Westinghouse Defense and Space Center, Baltimore, in evaluating a real-time magnetograph which uses an analog computer for immediate data display on a TV screen.(G. Brueckner, "Real-Time Solar Magnetograph", A. Jensen, "Solar Magnetograph Imaging and Display System"). It became obvious, however, that the technical difficulties of such a system would be tremendous and furthermore that the costs of the apparatus would be very high.

As an alternative to this situation, we proposed using an already existing third generation digital computer for the data reduction which has the necessary time sharing devices to use the instrument in discrete short time intervals over a long time period. If such a computer can be used, the development of new electronic systems can be abandoned.

The optical design uses as the key element a 0.15 Å half-width Zeiss birefringent filter to isolate the magnetic sensitive iron line, 5250 Å. Two KDP crystals will be placed in front of the filter to use the instrument as an analyzer for either circular or linear polarized light. To derive all four Stokes parameters it is necessary to obtain six different pictures and get the different pictures of the three pairs of opposite position of the analyzing optics. For this purpose an image will be generated behind the birefringent filter on the faceplate of an SEC Vidicon tube. After integrating the picture on the tube's target this can be read out and by means of an analog to digital converter transferred via a buffer storage memory into the computer. The design also included an automatic shifting device to shift the passband of the birefringent filter from the center to the wings of the 5250-Å line to get optimum signals for the longitudinal and for the transverse Zeeman effect. Furthermore, local Doppler-effect line displacements can be measured in this way and can be taken in account by the computer for the data reduction However, NRL does not have at its disposal a computer which meets that requirement.

About a year ago, an agreement was reached between NRL's Space Science Division and the Space Science Laboratory of the Marshall Space Flight Center to build the magnetograph as a joint project. NRL is designing and fabricating the optical system behind the telescope, and is also supervising a contract for design and fabrication of the electronic system which is necessary to convert the polarized pictures into digital signals which can be fed into a computer. NRL's responsibility includes guidance to develop the necessary computer software for an appropriate data reduction to transform the polarized pictures into magnetic field strength maps. MSFC is providing an 1108-UNIVAC computer, which is equipped with time-sharing devices and which is able to take on-line data with a 1 MHz-bit rate. MSFC is also providing a 30-cm Cassegrain telescope, a tower for this telescope, and the necessary buildings. Furthermore, MSFC will provide the data communication link from the telescope to the computer and the necessary data display units. Beside the Space Science Laboratory at MSFC, the Computation Laboratory is engaged in establishing the complicated computer programs.

The status of the project as of now is the following:

(1) Telescope: The 30-cm Cassegrain telescope has been modified to increase its stability. An H-alpha telescope is under installation now, to provide the H-alpha pictures simultaneously with the magnetograms. A video link system has been installed to transmit H-alpha pictures and magnetograms. An interference filter of 30-cm diameter for the main telescope has been purchased to serve as a prefilter for the magnetograph and keep the solar heat out of the telescope.

(2) Buildings: The new solar tower at Huntsville, Alabama, which will carry the instrument has been completed.

(3) The data link between instrument and computer has been installed also.

(4) Electronics: Because of lack of funding the entire electronics system could not be ordered as early as desired. The contract was awarded in March 1969, delivery is expected in September. The system design is finished, it is now only a matter of fabrication.

(5) Birefringent Filter: This key element was received from Zeiss during the summer of 1968, and has been tested at the Kitt Peak National Observatory. The quality of the filter exceeds all expectation. The half-width of the transmission curve is 130 mÅ, which is the theoretical value.

(6) Optical Transfer System: The optical system, which provides a parallel beam through the Zeiss filter and a relay lens to transfer the monochromatic image onto the SEC Vidicon, has to be provided by NRL. The mechanical parts have not been completed (as of now because of delays in ESD). The

contract for the optical components has been awarded. It is expected that the system can be assembled sometime in August.

If the present schedule can be maintained, the magnetograph should be assembled this fall and be operational by next spring at the latest.

The financial situation of the project is rather bad. There is no money available if, during the checkout period, additional equipment will be needed or changes have to be made. No funds have been provided to operate the system and work on the reduction of the data. This will therefore be taken over entirely by the Marshall Space Flight Center. NRL's role in this very promising project will decrease necessarily.

Night Airglow

1. Night Airglow Research from Rockets

Support for night airglow research from rockets by RN 6.1 funds was withdrawn as of 1 July 1968. During FY 1969, at the request of Dr. H. Friedman, a brief article was written summarizing the work during the International Year of the Quiet Sun (IQSY) for inclusion in the ANNALS OF THE COSPAR. Further reports concerned with the results of this program will be written as time permits. A large amount of data, accumulated since the start of the program in 1955, remains to be reduced and interpreted, especially results on the OH layer.

2. Airglow Research in the NASA Manned Spacecraft Program

As a follow-on to the program of airglow horizon photography conducted by Code 7140 in Gemini IX, XI, and XII, an airglow experiment was approved in 1966 for flight on main-line Apollo and given the number S-063. The object was to photograph the sunlit earth in spectral bands that include and exclude the ozone ultraviolet absorption bands; the resulting photographs would provide a global mapping of ozone clouds. A second object was to photograph the twilight airglow horizon, to obtain global altitude distributions of resonantly emitted airglow lines; a final choice of emission lines had not been made, but 3914 Å of N_2 and 2972 Å of O I were under consideration.

After the Apollo fire, development of this experiment was terminated. Recently, however, the Manned Space Flight Experiments Board of NASA placed it in the active category and authorized its flight in AAP-1/2 provided certain technical problems could be solved. Code 7140 is currently studying the situation but has not yet reached a decision whether to continue the program or to decline.

III. Supporting Research in the Laboratory

A program of research in the extreme ultraviolet (XUV) spectral region is carried on in the Laboratory, largely in support of the XUV space research program of the Division. This receives 30% funding from ONR, and 70% from NASA. Two laboratories are involved; the one, in charge of W. R. Hunter, is devoted to research in optical and photoelectric properties of materials. This includes mirrors, gratings, films, and photomultipliers and a contract for research in gratings. The other, under Dr. S. G. Tilford, is a modern spectroscopic facility for the study of atomic and molecular XUV spectra of astrophysical interest.

Dr. Marshall L. Ginter, Associate Professor at the Institute of Molecular physics at the University of Maryland is engaged on an intermittant basis in work in the XUV spectroscopic laboratory reducing XUV spectra of the hydrogen-halide molecules, obtained with the 21-ft vacuum spectrograph. He has also contributed to the planning and design of components for the high temperature furnace system. In addition Dr. Ginter has been involved with the analysis of the emission spectra of the '3A' bands of carbon monoxide.

1. Research on Optical and Photoelectric Properties of Materials

(1) Reflective coatings and optical constants

One of the major problems to be overcome in the design of sophisticated XUV instrumentation for space research is to produce mirror surfaces of high reflectance, in order to permit the use of a number of reflecting elements. (Transmission optics cannot be used, of course.) This is especially difficult for normal incidence, and becomes more difficult the shorter the wavelength.

Past studies have shown that those materials that have intrinsically high reflectance, such as aluminum, are chemically active and quickly form compounds, e.g., aluminum oxide, that reduce the reflectance greatly. Hence they must be protected by an overcoating to prevent conversion of the material to oxide or contamination by other active compounds or elements. A good example of this procedure is the highly reflecting films of aluminum overcoated with MgF_2 or LiF developed at NRL in collaboration with Dr. G. Hass, Director of the Night Vision Laboratories of Ft. Belvoir, Virginia.

The high reflectance of these protected coatings is limited to wavelengths longer than about 1000 Å because the overcoating materials become absorbing at the shorter wavelengths causing a reduction in reflectance. Below 1000 Å, the best reflectors yet discovered are platinum and iridium, and they have less than half the reflectance of dielectric coated aluminum at wavelengths greater than 1100 Å, its region of high reflectance.

There are many materials that have not yet been studied; usually there are special difficulties in producing smooth coatings. Work is continuing in the search for a single material, or a combination of materials that have higher reflectances than platinum, iridium, or gold. These studies include not only reflectance measurements at normal incidence, but also the determination of the optical constance, n, the index of refraction and k the extinction coefficient, from oblique incidence reflectance measurements. When the optical constants of a number of materials are known, multilayer reflecting coatings can be designed that will have special properties for use in the design of rocket and satellite instrumentation. The optical constants themselves are also of interest in connection with solid state theory and the structure of solids.

Another possible approach to the production of a highly reflecting coating is by alloying of materials, however, this program has not been implemented to date because of manpower shortages.

(2) Thin unbacked film filters

Quite a bit of effort has been put into the study of aluminum films to increase their transmittance, to ruggedize them so they can withstand the vibrational and acoustic environment of satellite launchings, and to decrease and prevent formation of pinholes. This work continues since aluminum filters are very essential for the solar program. Several filter materials other than aluminum have been used in rocket instruments, for example, indium. Transmittance characteristics of other materials such as silicon, germanium, tin, and bismuth are under study. Eventually, as the optical properties of filters are cataloged, multilayer filters will be possible. Also, as with reflecting coatings, alloying may prove useful. Because of the importance of this program and the manpower limitation, research on thin film filters has been carried out on contract and is directed by Code 7140 personnel. One contract is with personnel at the University of Pennsylvania. This has resulted in small, but highly valuable pinhole-free filters of beryllium, carbon, titanium, tellurium, antimony, and samarium. These materials have high transmittance in the difficult regions 110 - 150 Å, and 620 - 710 Å, together with special transmission characteristics elsewhere in the XUV. The project is continuing in an effort to produce rugged filters of these materials that are large enough for use with the XUV spectroheliographs.

The second contract on thin film filters is with Sigmatron, Incorporated. The purpose is to develop the large aluminum filters (1 x 10 inches) required for the XUV spectroheliograph for the Apollo Telescope Mission. The filters are supported on a mesh. They must withstand extremely high vibration and acoustic environments, and must not acquire pinholes or otherwise deteriorate over a period of several years. Progress here has been slow, but satisfactory. This contract is expected to be continued until ATM is in orbit and there is no longer a possible need for these large filters on an emergency basis.

(3) Diffraction gratings

Diffraction gratings are the only dispersing devices available for the XUV, where prisms are opaque. Bausch and Lomb Incorporated (B&L)

is far ahead of any other company in producing diffraction gratings for this spectral range. However, there is a great deal that is still accomplished by trial and error. With the support of NASA, NRL has conducted a joint program of research on diffraction gratings with B&L since January 1964. The purpose is to improve the efficiency of diffraction gratings for the XUV by better control of the groove form and increased reflectance of the coating. The joint effort has been applied to three areas -- (1) improvement in grating efficiency by better control of groove shape, blaze, and selection of the material to be ruled; (2) study of gratings used in grazing incidence in the XUV; and (3) a study of the suitability of replica gratings for use in experiments that will be in orbit for long periods of time.

Considerable improvement has been made in control of groove shape and blaze by the perfection of an electron microscope technique to measure the groove shape, and by ruling in gold, rather than the usual aluminum. The electron microscope technique is now routinely used to measure groove shape of test rulings before starting the ruling of a master grating, and also to examine portions of the master after ruling to check that no mishaps occurred during ruling. Also, as a result of studies using this technique, B&L can now make very finely spaced rulings (3600 - 4800 grooves/mm), with a high degree of success.

To study gratings in grazing incidence, B&L has had designed and constructed by its subsidiary, ARL, a special instrument that can measure the efficiency of gratings in grazing incidence and can accommodate a wide

3

variety of gratings. Efficiencies can be measured from about 13 Å to greater than 100 Å. This instrument can also be used to measure mirror reflectances at grazing incidence. It is now being installed at the B&L plant in Rochester, New York.

Exposures to high vacuum and temperature cycling simulating the conditions expected in earth-orbiting vehicles has demonstrated that B&L replica gratings should not degrade when used in satellites. A study still to be done is to investigate the effect of particle radiation on replica gratings.

An important part of the NRL in-house grating program is the precise measurement of grating efficiencies for the actual gratings that are flown in rocket and satellite instruments. These data are required for the development and calibration of all work back from the XUV solar instruments flown in the space program. On these measurements depend the accuracy of the results on the intensity distribution, both relative and absolute, of the sun's radiation.

(4) Photomultipliers

Research on photomultipliers for use in the XUV has been in progress since about 1963. One part of this work has as its purpose the improvement and perfection of photomultipliers for use in the laboratory to make the measurements described in the previous sections. No one type of photomultiplier (PM) has been found that is universally acceptable for all tasks; windowless PMs employing metallic or semiconducting cathodes and dynode surfaces have very low noise levels and are extremely useful for looking at very weak signals, however, their response is highly nonuniform for different positions on the cathode. On the other hand, visually sensitive PMs, coated with a fluorescing material are much more uniform, and despite their comparatively high background current and sensitivity to long wavelength stray light, are most useful in precise photometric measurements.

Another part of the program is the study of the tiny single-channel PMs that were chosen for use in the NRL experiments OSO-II, OSO-V, and to be flown in OSO-H. These have been studied in both the current measuring mode and the pulse counting mode. Also studied are the stability, sensitivity, over-all life, and freedom from breakdown. Many improvements have been made in the method of using these detectors, for example, encapsulation of the detector and a solid state preamplifier in plastic. The use of this type of multiplier was pioneered at NRL and only recently has this work been commenced at other laboratories such as the Harvard College Observatory.

In an attempt to improve the efficiency of PMs at very short wavelengths (less than 300 Å), a study of the photoelectric emission from metal, compound and multilayer cathodes will be initiated. Reports of quantum yields reaching as much as 70% at isolated wavelengths in this region from metal cathodes coated with dielectrics indicate the desirability of conducting such a program. This study, in turn, will require establishing a subsidiary program to measure absolute intensities. This subsidiary program will also be very useful in calibrating rocket and satellite instruments.

(5) XUV optical research conducted by W. R. Hunter at the Imperial College, London

While on sabbatical leave from September 1967 - 1968 at the Imperial College of Science and Technology, London, W. R. Hunter developed instrumentation for studying the XUV transmittance of window materials at low temperatures. He succeed in measuring the change in the short wavelength transmission limit of a number of materials as a function of temperature, over the range 10 °K to 373 °K. Because these window materials are in common usage in XUV space instrumentation, the knowledge of change in cut-off with temperature is of practical value, and is necessary also for proper interpretation of results.

Mr. Hunter has proposed a laboratory study of the XUV optical properties of ice containing controlled amounts of various impurities, because, according to current theories, this is the composition of interstellar grains. Procurements for this project are awaiting funding.

(6) Vacuum contamination monitors

In the Apollo Telescope Mission there exists a need for real-time monitoring of the cleanness of very large vacuum systems in which the entire ATM is to be tested. It is of utmost importance to prevent the deposition of contaminants on the optical surfaces of the experiments, because to remove the experiments and clean or replace the surfaces is a million-dollar undertaking. Jointly with Dr. G. Hass of Ft. Belvoir, development of two real-time XUV reflectometers is underway. When placed in the thermal vacuum chamber, these devices should warn of the presence of a contaminant before it has caused a significant degradation of the experiments. Involved in this work is the general study of contamination of optical surfaces.

2. Research in XUV Spectroscopy

A laboratory XUV spectroscopic program was initiated at the Naval Research Laboratory in 1961 under the work unit title "XUV Spectroradiometry" (71N01-02). The function of this program is to assist and furnish guidance to the Branch in interpreting results of rocket investigations, and to develop experimental laboratory programs in the vacuum ultraviolet region. Specifically, the the laboratory was designed to conduct original spectroscopic investigations of gases that might be observed, spectroscopically, in the atmospheres of the sun and the planets. Such information is necessary for identifying and analyzing spectra obtained in the Branch's program and for a complete understanding of fundamental physical and chemical processes occurring in both the atmospheres of the sun and the planets.

This increased understanding of the elements and compounds occurring in the sun and the atmosphere of the earth, is required for developing theories which will make possible the correct forecasting and prediction of solar and subsequent terrestrial events. The forecast of such events is of fundamental importance because they affect radio communications, and probably also cause changes of some kind in the weather pattern.

Equipment available for experiments on atomic and molecular systems in the laboratory includes a 21-foot normal incidence vacuum spectrograph, a 3-meter grazing incidence vacuum spectrograph, a 1-meter normal incidence vacuum spectrometer, and a photoelectric comparator-microphotometer equipped with a magnetic tape recording system.

The high resolution instruments are used to study molecular species of atmospheric interest and highly ionized atomic species. The monochromator is employed to study light sources and to perform absorption coefficient and pressure dependent absorption studies. Most of these experiments are conducted in the vacuum region below 2000 Å.

Specific problems under investigation include the observation, interpretation, and classification of the vacuum ultraviolet spectra of the atomic species N IV, O V, N III, O IV, O III, Ne IV, Ne V, Ne VI, H and He; the molecular species N_2, O_2, CO, NO, CO_2, HCl, DCl, HBr, DBr, HI, and DI; and the line and band spectra which occur in airglow, aurora, and the sun.

The spectroscopic laboratory has been available to E. O. Hulburt Center Associates, and NRC-NAS postdoctorals for pursuing their individual research projects, and also to several Universities to perform experiments which could not be accomplished at their own laboratories. Universities which have utilized our facilities include Rice University, the Pennsylvania State University, Vanderbilt University, the University of Arizona, the University of Maryland, York University, the Catholic University of America, and Georgetown University.

During the past year much time and effort have been expended in setting up and putting back into operation the experimental equipment listed on the previous pages after the move into the new building. Both high-resolution vacuum spectrographs have now been reinstalled and refocusing is nearly completed. In addition, a new grating mount has been installed in the 21-foot instrument. A magnetic tape unit has been installed on the Grant comparator to permit completely automatic recording of photographic density as a function of position on a photographic plate or film. Upon completion of computer programs already initiated, the time required to reduce photographic spectral data will be greatly reduced. Our high temperature vacuum furnace has also been delivered and many of the auxiliary vacuum pumping, fill, and optical systems have also been built. With this high temperature system, we plan to look at unstable species likely to be present in the solar spectra; it will be operational by the middle of this year.

From our high resolution studies of the CO molecule, both absorption and emission, all Rydberg states below 12 e.v. have now been observed and correctly characterized. This includes the $C\ ^3\Pi$ state which formerly was thought to be a $^3\Sigma$ state and the new $j\ ^3\Sigma^+$ state. These identifications and characterizations provide the first example of a complete correlation between theoretically predicted and experimentally observed electronic states for a molecule with a molecular weight greater than four. For the important fourth positive system of CO we have found that the maximum occurs in the potential energy curve for this state, at least 350 cm^{-1}.

above the accepted dissociation limit. This indicates an unusual perturbation between this state and one of the higher energy electronic states which may give some insight into the dissociation process of CO.

The analysis of the spectrum of N IV is almost completed. Numerous levels, many showing unusual autoionization effects, have been classified above the first ionization limit. Many new levels also have been assigned in the spectrum of N III.

Almost the complete spectrum has now been photographed for each of the hydrogen halide molecules HCl, DCl, HI, DI, HBr, and DBr. These spectra are of interest because infrared vibration-rotation lines have recently been identified in some planetary atmospheres. However, the first electronic transitions for these molecules occur in the vacuum ultraviolet region which cannot be observed from the ground. Such transitions may be very important when rocket or satellite spectra are obtained from such sources. These six molecules also provide one of the few examples at present available to study a spectrum at high resolution, up to and beyond the ionization limit, and at the same time to study a series of molecules which exhibit many similar molecular, physical, and spectral characteristics. So far, more than forty-five bands have been analyzed for HCl, forty bands for DCl, fifty bands for H I, several for DI; about thirty-five each for HBr and DBr have previously been partially characterized. These band systems appear to exhibit some unusual electronic coupling characteristics, but do not show well pronounced Rydberg series.

We have also reported some unusual auroral displays which we observed from Ft. Churchill during a solar flare. These results indicate an unusual enhancement of the OI 6300 Å radiation which correlates with an apparent enhancement in the vibrational temperature of molecular nitrogen. In the future we plan to extend and expand the program of new observation, identification, and classification of electronic energy levels of atoms and molecules of astrophysical interest which have not yet been investigated. This includes the search for new species with the high temperature furnace and the study of emission sources in the vacuum ultraviolet.

We shall continue the study of interactions between the various energy levels atomic and molecular systems, and compare and correlate the observed results with present theoretical predictions. We also plan to develop high resolution photoelectric techniques and investigate improved wavelength standards in the vacuum ultraviolet region.

3. Interpretation of Results

Data reduction and interpretation of results are carried on within the Branch in a variety of ways. Generally, each group has the responsibility for its own data reduction, interpretation, and writing up of the results. There is frequent collaboration, however, between different groups. For example, the observations of the OI 5577 Å and 6300 Å lines in the night airglow made by the night airglow rocket group were interpreted jointly by them and Dr. S. G. Tilford of the laboratory spectroscopy group.

The solar XUV program, however, has resulted in such a large mass of data that a separate group has been formed to assist in the reduction and analysis. This is in charge of Dr. K. G. Widing who is assisted by one half-time professional, E. O. Hulburt Associates, and summer students as available. The data reduction itself is extremely time consuming and requires meticulous work. Following this, comes the analysis of the observations and interpretation.

The principal results from this program in the last year or so are the following:

The preliminary work on the energy distribution in the solar continuum down to 1450 Å was completed. The principal observational material utilized was the set of ten rocket spectra photographed 27 July 1966 for the specific purpose of obtaining a set of graded exposures suitable for photometric calibration. Of especial interest is that measurements of the continuum in the previously uncalibrated spectral band 1520 - 1750 Å are available for the first time.

Continuum measurements in this spectral band are of significance to solar physics because the radiation in the 1520 - 1700 Å range is believed to originate in the coolest surface layers of the sun, and the equivalent black body temperature of the radiation should measure the value of the minimum temperature at the solar surface. In agreement with this expectation, the measured continuum temperature of $4670 \pm 75\,^{\circ}K$ in the 1520 - 1700 Å band was lower than anywhere else in the solar ultraviolet spectrum.

Although the measured temperature passes through a minimum in the 1520 - 1700 Å band, the value determined (4670 $\pm$ 75 °K) is in conflict with observations in the solar infrared continuum, where the measured minimum temperature is 4350 $\pm$ 200 °K. The reason for this discrepancy is not yet clear.

The status of the program of wavelength measurement and line identification in the solar ultraviolet spectrum is as follows:

The reduction of the measurements and line identifications below 800 Å is nearly completed. Some 800 chromospheric and coronal emission lines were recorded, mainly on grazing incidence spectra (33 - 600 Å) photographed in May and September 1963, and February and July 1966. The accompanying variation in the relative line intensities as the solar activity decreased from the high levels of 1963 toward the low level of February 1966 provided physical support to the line identifications based on wavelength coincidence by enabling us to pick out the "hot" ions from the cooler ones (for example, Fe XVI 335 Å). Reference also was made to the XUV spectroheliograms of solar active centers, where the lines of the high temperature ions are always enhanced.

The installation of a large Grant measuring engine with digital readout of the screw position onto IBM punched cards will greatly speed up measurement of solar spectra and spectroheliograms. The programs to process the digitized positions from punched cards into calculated wavelength are already available.

4. Future Plans

A large amount of solar XUV material is on hand awaiting study, analysis, interpretation. It is clear that our theoretical group will have to be increased, if we are to fulfill our responsibility to NASA to make available within a reasonable time the results of investigations carried out with their funds.

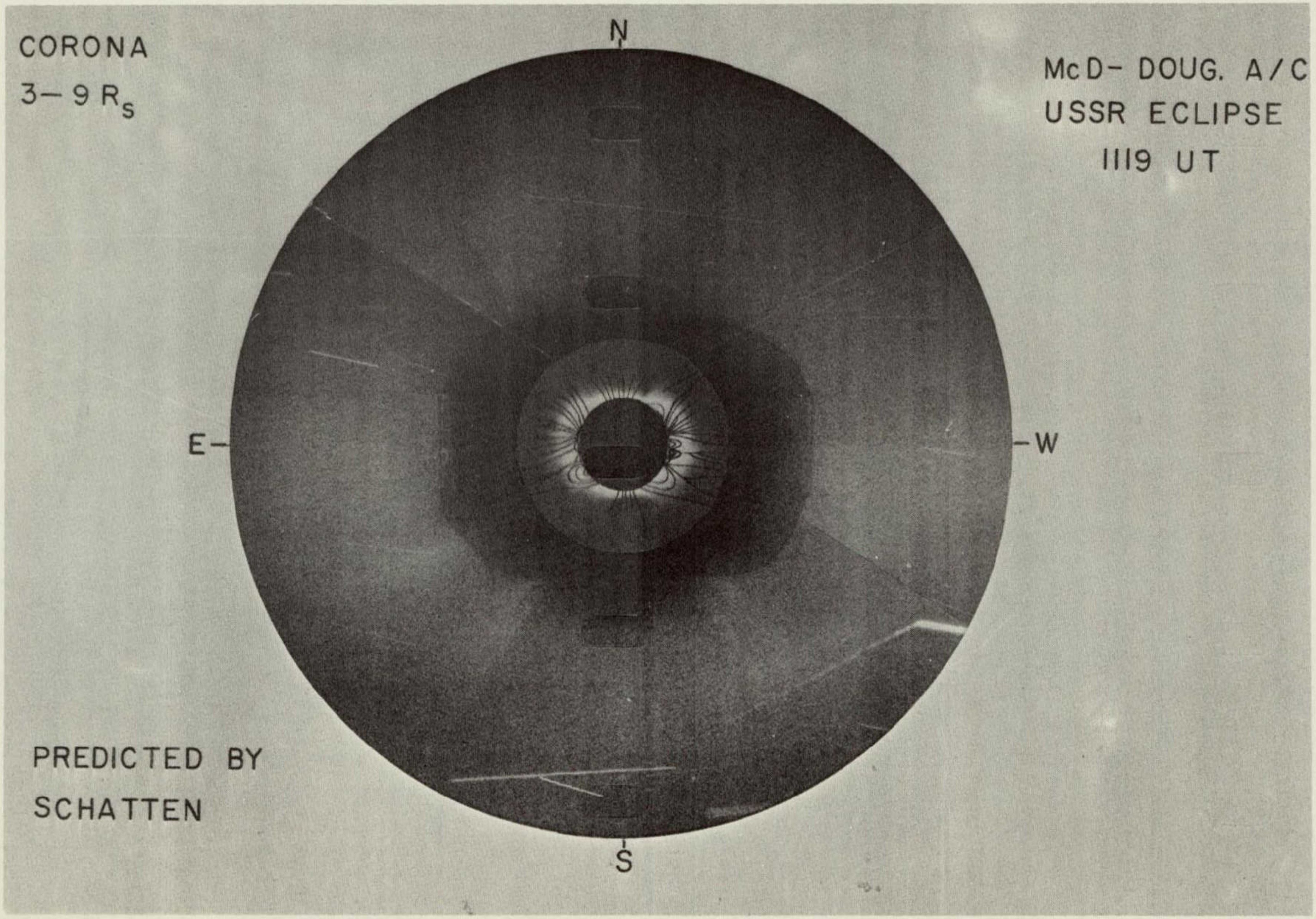
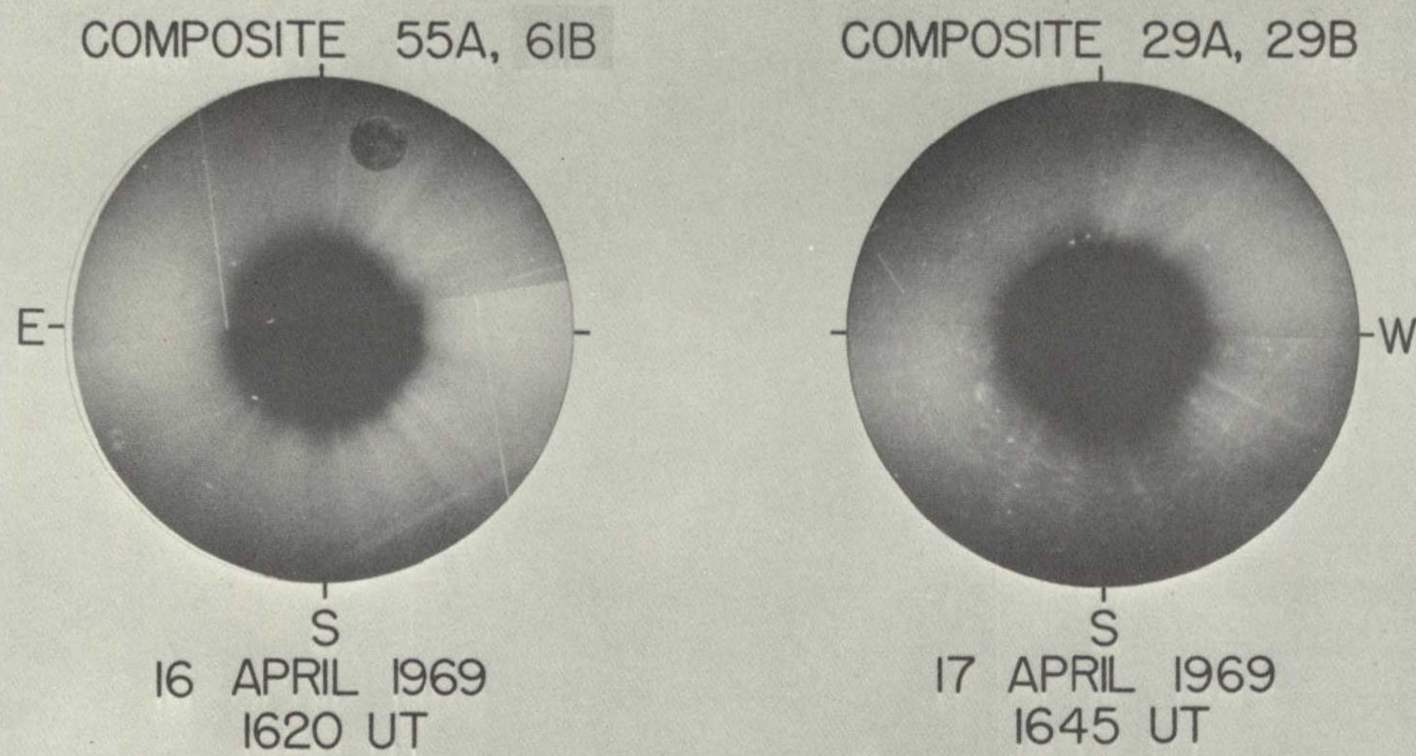
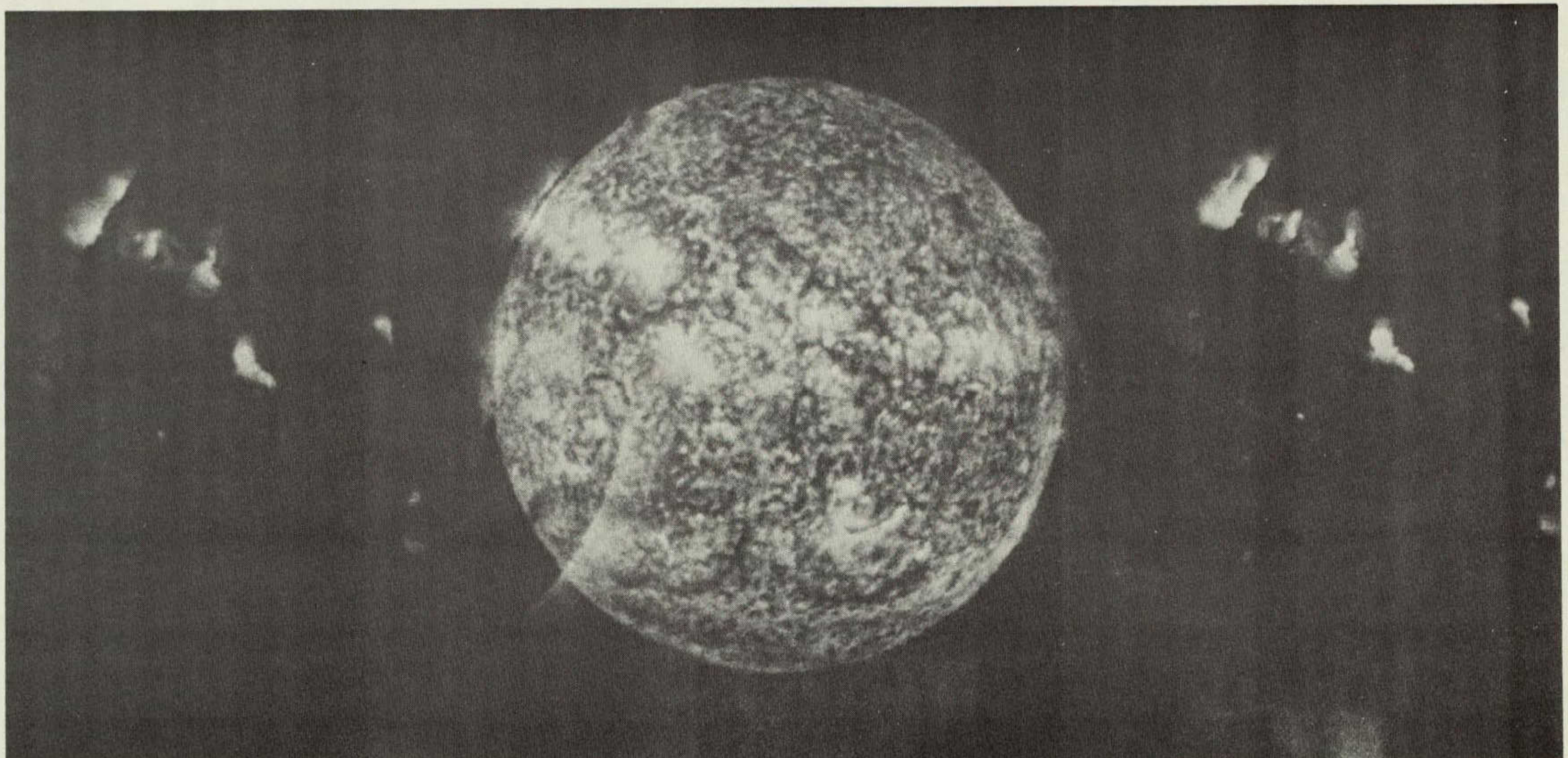

CORONA
3— 9 R_s
McD- DOUG. A/C
USSR ECLIPSE
1119 UT
N
E
W
S
PREDICTED BY
SCHATTEN

FIGURE 1



SOLAR CORONA RECORDED SUCCESSIVE DAYS.
NRL CORONAGRAPHS, NASA AEROBEES 4.247DS
AND 4.274DS

FIGURE 2



Fe XV 284A He II 304A Fe XVI 335A

22 SEPTEMBER 1968

FIGURE 3

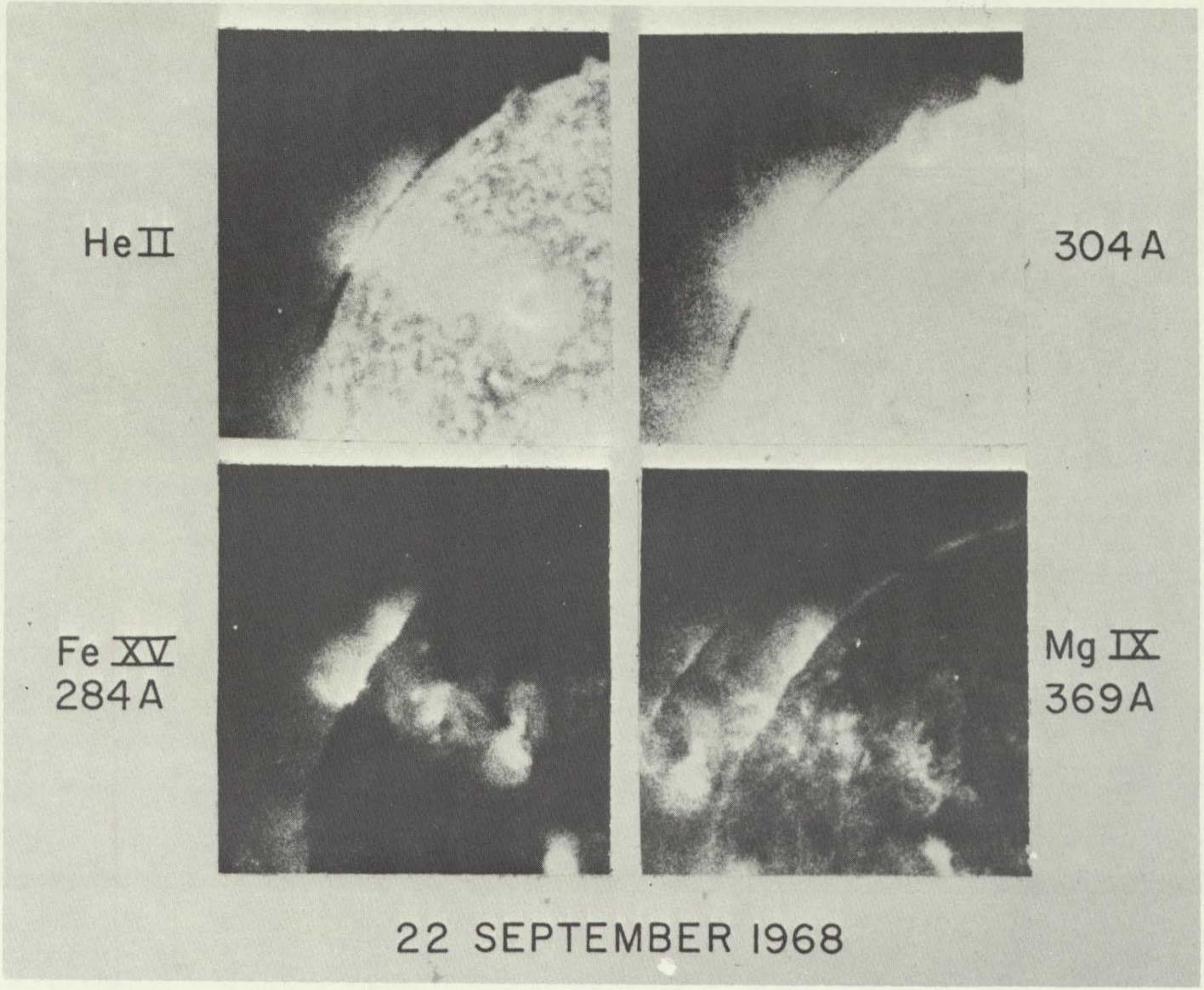


FIGURE 4

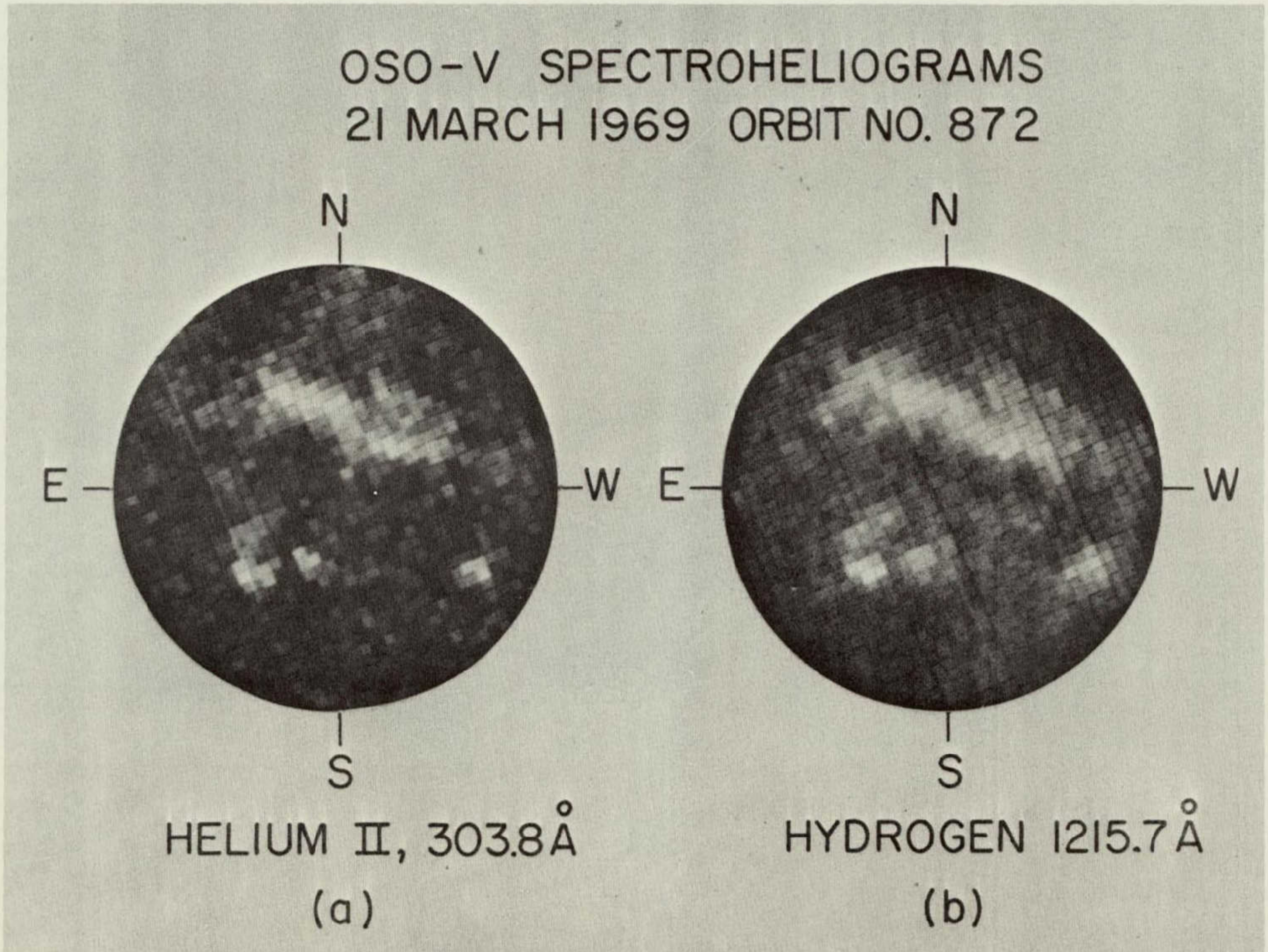

OSO-V SPECTROHELIOGRAMS
21 MARCH 1969 ORBIT NO. 872
N
E
W
S
HELIUM II, 303.8 Å
(a)
N
E
W
S
HYDROGEN 1215.7 Å
(b)

FIGURE 5

THE HULBERT CENTER APPOINTEES

APPOINTEE	PARENT INSTITUTION	PROJECT	STATUS
Dr. George A. Doschek	Univ. of Pittsburgh	X-ray flare spectra planning for OSO-I	Data analysis
Dr. Paul D. Feldman	Johns Hopkins	Solar Infrared Astronomy, 10-500 μ. Aerobee + BPC	Aerobee NF 3.193 scheduled to be launched August 69 (Dr. D. P. McNutt)
Dr. Richard C. Henry	Johns Hopkins	Celestial X-ray sources, UV Airglow studies. Blue Scout, Jr + Pointing Control	Experiment in Blue Scout Jr scheduled for launch Aug. 69 (Dr. G. R. Carruthers). Data analysis
Dr. Stephen W. Kahler	Univ. of Calif., Berkeley	Solar X-rays, laboratory x-ray studies	Data analysis (Mr. J. F. Meekins)
Dr. James D. Kurfess	Rice University	Celestial gamma-ray spectroscopy, x-ray balloon experiments. Balloons	Balloon experiments tentatively scheduled for launch ______ and ______ (Dr. T. A. Chubb)
Dr. Barry K. Moritz	Univ. of Maryland	Theory and Behavior of solar corona	Data analysis
Dr. N. Paul Patterson	Yale University	Ultraviolet radiation from celestial sources. Aerobee + ACS	Aerobee NB 3.202 scheduled for launch August 69 (Dr. G. R. Carruthers)
Dr. Dianne K. Prinz	Univ. of Maryland	Lyman-α solar flare studies. Aerobee + BPC	Experiment in Aerobee NE 3.183R scheduled for launch July 69 (Mr. J. D. Purcell)
Dr. Thomas C. Winter, Jr.	US ARMY	Planning and preparation of NRL ATM experiments	ATM Team
Dr. James H. Hunter, Jr.	Yale	Stellar formation, low light level photometry of variable stars and the planets	Observation and data analysis
Dr. Eugene F. Milone	Gettysburg	Solar Spectroscopy	Data analysis
Dr. Marshall L. Ginter	Univ. of Maryland	Laboratory Astrophysics	Data analysis
		FISCAL YEAR 1970	
Dr. Seth Schulman	Columbia	X-Ray Astronomy, particle physics	

Code 7100

SPACE SCIENCE DIVISION
and
E. O. HULBURT CENTER FOR SPACE RESEARCH

Publications and Talks

1 July 1968 - 30 June 1969

H. Friedman (7100)

PUBLICATIONS

1. Publications in Refereed Journals:

**R. C. Henry, G. Fritz, J. F. Meekins, H. Friedman and E. T. Byram

"Possible Detection of a Dense Intergalactic Plasma," Astrophys. J. 153, L11-18 (1968).

**G. Fritz, J. Meekins, R. C. Henry, E. T. Byram, and H. Friedman

"Soft X-rays from Scorpius XR-1," Astrophys. J. 153, L199 (1968).

**J. F. Meekins, R. W. Kreplin, T. A. Chubb and H. Friedman

"X-ray Line and Continuum Spectra of Solar Flares from 0.5 to 8.5 Angstroms," Science 162, 891 (1968).

H. Friedman

"Cosmic X-rays," Nature 220, 862 (1968).

***H. Friedman, G. Fritz, R. C. Henry, J. P. Hollinger, J. F. Meekins and D. Sadeh

"Absence of Pulsar Characteristics in Several X-ray Sources," Nature 221, 345 (1969).

**G. Fritz, R. C. Henry, J. F. Meekins, T. A. Chubb and H. Friedman

"X-ray Pulsar in the Crab Nebula," Science 164, 709, (1969).

**G. Fritz, J. F. Meekins, R. C. Henry, and H. Friedman
"On X-Ray Line Emission from Scorpius XR-1," Astrophys. J. 156, L33 (1969).

2. Other Major Publications:

H. Friedman

"Discrete X-ray Sources," Vol. VII, Stars and Stellar Systems, ed. B. M. Middlehurst and L. H. Aller (Univ. of Chicago Press, 1968), pp. 685-706.

H. Friedman

"Surveys of X-ray Sources," Highlights of Astronomy, ed. L. Perek, (D. Reidel Publ. Co., Dordrecht, Holland, 1968) pp. 180-183.

** Joint research with Code 7120. Papers are also listed with 7120 publications.

*** Joint research with Codes 7120 and 7130; listed with 7120 papers.

Papers submitted for publication:

** J. F. Meekins, R. C. Henry, G. Fritz, H. Friedman and E. T. Byram

"X-ray Spectra of Several Discrete Cosmic Sources," Astrophys. J (In Press, July 1969).

H. Friedman

* "Cosmic X-ray Observations," Proc. of Discussion Meeting on Cosmic X-ray Astronomy, The Royal Society, London, November 1968 (In Press).

H. Friedman, T. A. Chubb, R. Tousey and C. H. Mayer

"Observatory Report: E. O. Hulburt Center for Space Research," Bull. Astron. Soc. (In Press, July 1969).

* H. Friedman

"Space-Oriented Satellites," Britannica Yearbook of Science and the Future (To be published).

2. Other Major Publications - 7100 (Cont'd):

H. Friedman

"X-ray Astronomy: New Window to Space," Britannica Yearbook of Science and the Future, 1968, pp. 196-209.

H. Friedman

"X-ray Observations of Solar Flares," Solar Flares and Space Research, ed. Z. Svestka and C. deJager (North-Holland Publ. Co., Amsterdam, 1969), pp. 87-94.

**R. W. Kreplin, D. M. Horan, T. A. Chubb and H. Friedman

"Measurements of Solar X-ray Emission from the OGO-IV Spacecraft," ibid., pp. 121-130.

H. Friedman

"Energetic Solar Radiations," Proc. IQSY/COSPAR Symposium on Results of the IQSY, London 1967, Annals of the IQSY, Vol. 4 (MIT Press, Cambridge, 1969), pp. 36-56.

H. Friedman

"Solar Flares," Astronautics & Aeronautics 7, No. 4, 14 (1969).

**T. A. Chubb and H. Friedman

"Glimpsing the Hidden X-ray Universe," Astronautics and Aeronautics 7, No. 3, 51 (1969).

SPECIAL REPORTS:

Physics of the Earth in Space, A Program of Research: 1968-1975, Report of a Study by the Space Science Board, August 1968, Woods Hole, Massachusetts, Chairman: H. Friedman; Vice Chairman: F. S. Johnson; NAS-NRC Report, October 1968, 109 pages.

NRL Space Research Seminar, Dedication Talks and Commemorative Document of Dedication April 17, 1968, 88 pages.

H. Friedman (Code 7100)

Talks and Lectures, July 1, 1968 to June 30, 1969:

* 1. "X-ray Astronomy," 1968 Pittsburgh Diffraction Conference, Pittsburgh, November 6-8, 1968.

2. "Soft X-rays from Cosmic Sources," Space Astrophysics Seminar, Maryland University, November 18, 1968

* 3. "Cosmic X-ray Observations," Cosmic X-ray Astronomy Meeting, The Royal Society, London, November 27, 1968.

* 4. "X-ray Astronomy," 1635th Meeting of The Philosophical Society of Washington, Washington, D C., February 21, 1969.

* 5. "High Energy Astronomy," Distinguished Lecturer Series, McDonnell Planetarium, Forest Park, Illinois, March 19, 1969.

* 6. "X-ray and Gamma Ray Astronomy," Spring 1969 Meeting of the New York State Section of The American Physical Society, State University of New York at Binghamton, April 11, 1969.

7. "Spectrum of X-ray Pulses in the Crab Nebula," Annual Meeting, National Academy of Sciences, Washington, D. C., April 28-30, 1969.

* 8. "General Survey on X-ray Sources," Non-Solar Gamma and X-ray Astronomy Symposium No. 37, I.A.U., Rome, May 8-10, 1969.

9. "X-ray Pulsar in the Crab Nebula," ibid.

* 10. "Solar Terrestrial Studies During Eclipses," NATO Advanced Studies Institute on Solar Eclipses, 1969 Lecture Series, Lagonissi, Greece, May 26-June 4, 1969.

* 11. "The Quiet Sun," Lecture, June Institute on Modern Astrophysics, David Dunlap Observatory, University of Toronto, June 11, 1969.

* 12. "Solar Flares," ibid., June 12, 1969.

* 13. "Models of X-ray Sources," ibid., June 13, 1969.

* 14. "Background Radiation and Cosmology," ibid., June 13, 1969.

* Invited

SPACE SCIENCE DIVISION

Code 7120

Publications in Refereed Journals

Chubb, T. A.
"X-ray Emissions from Solar Flares and From Celestial Sources," Proc. A.S.A. 1, 4-5 (1967) (not carried in 1967 publication list).

Henry, R. C., G. Fritz, J. F. Meekins, H. Friedman and E. T. Byram
"Possible Detection of a Dense Intergalactic Plasma," Astrophys. J. 153, L11 (1968).

Rouse, C. A.
NOTE: "Formal Numerical Solution of the Equation of Radiative Transfer," J. Quant. Spectro. Radiat. Trans. 8, 1167 (1968).

Opal, C. B., H. W. Moos, W. G. Fastie and M. Bottema (Johns Hopkins University) and R. C. Henry (NRL and Johns Hopkins University)
"The Far-UV Spectral Intensity of a BeV Star," Astrophys. J. Ltrs. 153, L179-L183 (1968).

Fritz, G., J. F. Meekins, R. C. Henry, E. T. Byram and H. Friedman
"Soft X-rays from Scorpius XR-1," Astrophys. J. 153, L199-L202 (1968).

Sloan, W. A.
"Intensity Measurements of Chromospheric Fine Structures in Lyman-α," Solar Physics 5, 329-337 (1968).

Shivanandan, K., J. R. Houck* and M. O. Harwit* (*Cornell University)
"Preliminary Observations of the Far-Infrared Night-Sky Background Radiation," Phys. Rev. Ltrs. 21, No. 20 (1968).

Meekins, J. F., R. W. Kreplin, T. A. Chubb and H. Friedman
"X-ray Line and Continuum Spectra of Solar Flares from 0.5-8.5 A," Science 162, 891-895 (1968).

Sadeh, D., J. P. Hollinger and S. H. Knowles
"Search for an Effect of Mass on Frequency During a Close Approach of Pulsar CP 0950 to the Sun," Science 162, 897 (1968).

7120 Publ. cont'd. (Refereed)

G. R. Carruthers
"Some New Instrumentation Techniques for Far-Ultraviolet Studies from Sounding Rockets," Proceedings XIth COSPAR Meeting, Tokyo, May 1968, Small Rocket Instrumentation Techniques, ed. K. Maeda (North-Holland, 1969), pp. 168-175.

Shivanandan, K., J. R. Houck, and M. O. Harwit
"Preliminary Observations of the Far Infrared Night Sky Background Radiation," Phys. Rev. Ltrs. 21, 1460 (1968).

Feldman, P. D. (Johns Hopkins Univ. and NRL), D. P. McNutt and K. Shivanandan
"Rocket Observations of Bright Celestial Infrared Sources in Ursa Major," Astrophys. J. 154, L131-L136 (1968).

Friedman, H., G. Fritz, R. C. Henry, J. P. Hollinger, J. F. Meekins and D. Sadeh
"Absence of Pulsar Characteristics in Several X-ray Sources," Nature 221, 345-347 (1969).

Henry, R. C.
"K-Line Photometry of A Stars," Contribution No. 368, reprinted by Kitt Peak National Observatory, operated by the Association of Universities for Research in Astronomy, Inc. under contract with the National Science Foundation, Astrophys. J. Supplement 18, 156 (1969).

Fritz, G., J. F. Meekins, R. C. Henry and H. Friedman
"On X-ray Line Emission from Scorpius XR-1," Astrophys. J. 156, L33-L36 (1969).

Fritz, G., R. C. Henry, J. F. Meekins, T. A. Chubb and H. Friedman
"X-ray Pulsar in the Crab Nebula," Science 164, 709 (1969).

J. F. Meekins, R. C. Henry, G. Fritz, H. Friedman and E. T. Byram
"X-ray Spectra of Several Discrete Cosmic Sources," Astrophys. J. (In Press, July 1969).

G. R. Carruthers
"Magnetically Focused Electronographic Image Converters for Space Astronomy Applications," Applied Optics 8, 633 (1969).

G. R. Carruthers
"Observations of the Lyman-alpha Interstellar Absorption Line in Theta Orionis," Astrophys. J. (Ltr) 156, L97 (1969).

J. H. Hunter, Jr.

"The Collapse of Interstellar Gas Clouds and the Formation of Stars," Mon. Not. Roy. Astron. Soc. 142, 473-498 (1969).

7120 Major Publications

Meier, R. R.

"The Hydrogen Lyman-Alpha Airglow," Astronautics and Aeronautics 7, 68-75 (1969).

Chubb, T. A.

"Glimpsing the Hidden X-ray Universe," Astronautics and Aeronautics 7, 50-55 (1969).

McNutt, D. P.

"Rocket Infrared Astronomy-On the Track of the 'Big Bang'," Astronautics and Aeronautics 7, 44-49 (1969).

Carruthers, G. R.

"Far-ultraviolet Stellar Astronomy," Astronautics and Aeronautics 7, 56-63 (1969).

Rouse, C. A.

"The Screened Coulomb Electronic Partition Function," Proceedings of the 8th International Conference on Phenomena in Ionized Gases, Vienna 1967, p. 267 (1968).

7120 Formal Reports

Rouse, C. A.
"Tables of Ionization Equation of State at Stellar Temperatures and Densitites," NRL Report 6756 (1968)

Meier, R. R.
"On the Plane Parallel Representation in Atmospheric Radiation Transfer," NRL Report 6799 (1968)

Kreplin, R. W. and D. M. Horan
"The NRL SOLRAD 9 Satellite Solar Explorer B 1968-17A," NRL Report 6800 (1969).

Horan, D. M., and R. W. Kreplin, A. T. McClinton, Jr., and L. C. Schneider
"Using Solar X-rays as Indicators of Solar-Flare Activity," NRL Report 6884 (1969).

Meier, R. R.
"A Calculation of Geomagnetic Time," NRL Report 6815 (1969).

7120 Other Publications

"Solar X-rays by Satellite," Solar-Geophysical Data IER-FB-291, 85-86, Jan.-Dec. 1968 (12 reports submitted).

NRL Experimenters: A. T. McClinton, Jr., R. W. Kreplin, T. A. Chubb and H. Friedman
"DATA USERS' NOTE NSSDC 68-21:
Explorer 30 (1965-93A) NRL X-ray and Ultraviolet Monitoring Experiment (Dec. 1968) (Data and material furnished by NRL Experimenters) Published by NASA-National Space Science Data Center, GSFC, Greenbelt, Maryland. (Editors P. S. McHugh and C. L. Marks).

McClinton, Jr., A. T.
"NRL Solar Radiation Monitoring Satellite 1965-16D X-ray Data Plots," Space Disturbances Laboratory, Solar Geophysical Data Descriptive Text and Index, Dept. of Commerce, ESSA, Boulder, Colorado (1968).

7120 Other Publications Cont'd.

Rouse, C. A.
"Hydrogen to Helium Ratio in the Solar Photosphere," Final Report on NSF Grant NSF GP-7788, University of California (Berkeley), Space Science Lab. Series 9, Issue 36 (1968).

J. H. Hunter, Jr.
"Observational Studies Relating to Star Formation. II.," Department of Astronomy Report, Yale University 1969.

Papers Submitted for Publication:

Carruthers, G. R.
"On the Far-Ultraviolet Interstellar Extinction Law in the Orion Nebular Region," Ap. J. Letters (Submitted May 1969).

Carruthers, G. R.
"Far-Ultraviolet Photometry of Orion Stars," Astrophysics and Space Science (Submitted May 1969).

Chubb, T. A.
"Far Ultraviolet Studies of Daytime and Nighttime Aurora," J. Geophys. Res. (Submitted February 1969).

Feldman, P. D. and McNutt, D. P.
"A Rocket Borne Liquid Helium Cooled Infrared Telescope, II: Photoconductive Detectors," Applied Optics (Submitted March 1969).

Feldman, P. D. and McNutt, D. P.
"Far Infrared Nightglow Emission from Atomic Oxygen," J. Geophys. Res. (Submitted May 1969).

Hunter, J. H.
"Hα Auroral Activity on Jupiter," Nature (Submitted May 1969).

Meier, R. R.
"Balmer α and Lyman β in the Hydrogen Geocorona," J. Geophys. Res. (Submitted January 1969).

Meier, R. R.
"Temporal Variations of Solar Lyman-α," J. Geophys. Res. (Submitted May 1969).

McNutt, D. P., Shivanandan, K., and Feldman, D. P.
"A Rocket Borne Liquid Helium Cooled Infrared Telescope, I. The Dewar and Optics," Applied Optics (submitted March 1969).

Pipher, Judith L., Harwit, Martin, McNutt, D. P., Feldman, P. D. and Shivanandan, Kandiah
"Limb Darkening on the Earth's Night Side at 1 to 3μ Wavelengths," J. Atmos. Sciences (Submitted April 1969).

Refereed Journals
Papers Submitted for Publication (Continued)

Rouse, C. A.
"Determination of the Helium Abundance of the Sun by the Theoretical Prediction of Line and Continuum Radiation from Solar-Model Photospheres," Astrophys. J. (submitted January 1969).

Hoffman, J. H., Johnson, C. Y., Holmes, J. C., and Young, J. M.
"Daytime Mid-Latitude Ion Composition Measurements," J. Geophys. Res. (Submitted May 1969).

McNutt, D. P. and Feldman, P. D.
"Letter to the Editor: Far Infrared Observations of the Night Sky," (Technical Comment) Science (Submitted June 1969)

Major Publications

Kreplin, R. W.
"Solar X-rays," Astronautics & Aeronautics (In Press).

Hicks, G. T. and Chubb, T. A.
"Equatorial Aurora/Airglow in the Far Ultraviolet," Proceedings of 3rd International Symposium on Equatorial Aeronomy (To be published); also submitted to J. Geophys. Res. (February 1969).

Other Publications

Horan, D. M., McClinton, A. T. Jr., and Kreplin, R. W.
"Solar X-ray Emission during the Flight of Apollo 8 (21 Dec. 1968-27 Dec. 1968)," NRL Report #6917 (to be published).

McClinton, Jr., A. T.
"NRL Solar Radiation Monitoring Satellite 1965-16D X-ray Data Plots," Space Disturbance Laboratory, Solar Geophysical Data Descriptive Text and Index, Dept. of Commerce, ESSA, Boulder, Colorado 1968 (to be published).

SPACE SCIENCE DIVISION

7120 - Talks

Kreplin, R. W.
"The SOLRAD Satellite Program"
NRL Ionospheric Propagation Symposium
Naval Research Laboratory
Washington, D. C.
10 October 1968

Johnson, C. Y.
"Rocket Sounding of the Ionosphere"
NRL Ionospheric Propagation Symposium
Naval Research Laboratory
Washington, D. C.
11 October 1968

Carruthers, G. R.
"Interstellar H and H_2 from Rocket Observations"
Department of Physics
Space Astrophysics Seminar
University of Maryland
28 October 1968

Feldman, P. D., D. P. McNutt and K. Shivanandan
"Rocket Observations of Bright Celestial Infrared Sources in Ursa Major"
AAS Meeting
Austin, Texas
12-19 December 1968

McNutt, D. P.
"Infrared Astronomy From Above the Atmosphere"
University of Wisconsin- 10 November 1968
Marquette University - 18 November 1968
University of Chicago - 21 November 1968

Shivanandan, K.
"Infrared Rocket Astronomy"
Air Force Cambridge Research Lab
Cambridge, Massachusetts
27 November 1968

Carver, J. H.
"Photoelectron Spectroscopy and the Upper Atmosphere"
Department of Physics
Penn State University
University Park, Pennsylvania
20 November 1968

7120 Talks Cont'd.

Friedman, H., G. Fritz, R. C. Henry, J. P. Hollinger, J. F. Meekins and D. Sadeh
"Absence of Pulsar Characteristics in Several X-ray Sources"
AAS Meeting
Austin, Texas
10-13 December 1968

Shivanandan, K.
"Preliminary Measurements of the Far Infrared Background"
Department of Physics
University of Missouri
Rolla, Missouri
30 January 1969

Hicks, G. T. and T. A. Chubb
"Equatorial Aurora/Airglow in the Far Ultraviolet"
3rd. Intl. Symp. on Equatorial Aeronomy
Ahmedabad, India
3-9 February 1969 (also)

COSPAR Meeting (Presented by R. R. Meier)
Prague, Czechoslovakia
11-24 May 1969

Johnson, C. Y., J. C. Holmes and J. M. Young
"Ionizing Resonance Radiation and the Nighttime Ionosphere"
AGU Meeting
Sheraton Park Hotel
Washington, D. C.
21-25 April 1969

Meekins, J. F., R. W. Kreplin and T. A. Chubb
"0.6-8.5 A Spectra from Several Solar Flares"
AGU Meeting
Sheraton Park Hotel
Washington, D. C.
21-25 April 1969

Hoffman, J. H., C. Y. Johnson, J. C. Holmes and J. M. Young
"Daytime Mid-Latitude Ion Composition Measurements"
AGU Meeting
Sheraton Park Hotel
Washington, D. C.
21-25 April 1969 (also)

COSPAR Meeting (Presented by P. Mange)
Prague, Czechoslovakia
11-24 May 1969

Meier, R. R. and Mange, P.
"Geocoronal Atomic Hydrogen Density Obtained by Satellite Lyman-α Measurements," 50th Annual AGU Meeting, Washington, D. C., 21-25 April 1969.

7120 Talks Cont'd.

Meier, R. R.
"Observations of Lyman-α and the Atomic Hydrogen Distribution in the Thermosphere and Exosphere"
COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

Mange, P. and R. R. Meier
"Lyman-alpha Intensity and the Hydrogen Concentration Beyond 5 Earth Radii
COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

Kreplin, R. W. and P. J. Moser
"Flare X-ray and Radio Wave Emission"
COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

Meekins, J. F., R. W. Kreplin and G. A. Doschek
"X-ray Spectra from Solar Flares"
COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

Feldman, P. D. and D. P. McNutt (Presented by R. R. Meier)
"Far Infrared Nightglow Emission from Atomic Oxygen"
AGU Meeting
Sheraton Park Hotel
Washington, D. C.
21-23 April 1969 (also)

COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

Chubb, T. A. and G. T. Hicks
"Far Ultraviolet Studies of Daytime and Nighttime Aurora"
AGU Meeting
Sheraton Park Hotel
Washington, D. C.
21-23 April 1969 (also)

COSPAR Meeting
Prague, Czechoslovakia
11-24 May 1969

7120 Talks Cont'd.

Rouse, C. A.
"Hydrogen to Helium Ratio in the Solar Photosphere"
APS Meeting
New York, New York
3-6 February 1969

Carruthers, G. R.
"Development of Electronographic Image Converters for Far Ultraviolet Space Astronomy Applications"
NASA-Sponsored Workshop
Voltage Breakdown in Electronic Equipment at Low Air Pressures
California Institute of Technology
Pasadena, California
5-7 March 1969

Carver, J. H.
"Atomic and Molecular Photodisintegration"
Department of Physics and Astronomy
University of South Carolina
27 March 1969

Meekins, J. F.
"Solar Flare X-rays"
National Capital Astronomers
Washington, D. C.
5 April 1969

Shivanandan, K.
"Infrared Astronomy" (5 Lectures)
1969 Erice Summer School on Cosmic Physics
Erice, Sicily
19-24 May 1969

Henry, R. C.
"X-ray Pulsar in the Crab Nebula
Summer Scientific Meeting
Astron. Soc. of the Pacific
Flagstaff, Arizona
26 June 1969

Carruthers, G. R.
"Far Ultraviolet Intensities of Orion Stars"
IAU Symposium #36
UV Stellar Spectra and Related Ground Based Observations
Lunteren, The Netherlands
24-27 June 1969

SPACE SCIENCE DIVISION

Code 7130

Publications in Refereed Journals

Shapiro, A., E. A. Uliana, B. S. Yaplee and S. H. Knowles
"Lunar Radius from Radar Measurements,"
SPACE RESEARCH VIII, Moon and Planets II, Proc. VIIIth International Space Science Symposium, London, North Holland Publ. Co., Amsterdam, 34-46 (1968).

** Sadeh, D., S. Knowles and B. Au
"The Effect of Mass on Frequency," Science 161, 567 (1968).

Hobbs, R. W.
"Polarization of Strong Radio Sources at 9.55 MM Wavelength," Astrophys. J. 153, 1001 (1968).

Hobbs, R. W., T. P. McCullough and J. A. Waak
"Measurements of Mars at 1.55 and 0.95-Cm Wavelengths," Icarus 9, 360 (1968).

Hobbs, R. W. and J. P. Hollinger
"Linear Polarization of Radio Sources at 2.07-Centimeter Wavelength," Astrophys. J. 154, 423 (1968).

Hobbs, R. W., J. P. Hollinger and G. E. Marandino
"Variability of the Linear Polarization of 3C 120 and 3C 279," Astrophys. J. 154, L49 (1968).

** Sadeh, D., J. P. Hollinger, S. H. Knowles and A. B. Youmans
"Search for an Effect of Mass on Frequency During A Close Approach CP-0950 to the Sun," Science 162, 897 (1968).

*** Friedman, H., G. Fritz, R. C. Henry, J. P. Hollinger, J. F. Meekins and D. Sadeh
"Absence of Pulsar Characteristics in Several X-ray Sources," Nature 221, 345 (1969).

Hobbs, R. W., H. H. Corbett and N. J. Santini
"The Flux Density of Taurus A at 4.3 mm Wavelength," Astrophys. J. 155, L87 (1969).

** Joint Research with Code 7120

*** Joint research with Codes 7100 and 7120; listed with 7120 papers.

7130 Publications Cont'd

Knowles, S. H., C. H. Mayer, NRL; Cheung, A. C., D. M. Rank, and C. H. Townes, Univ. of Calif., Berkeley
"Spectra, Variability, Size, and Polarization of H_2O Microwave Emission Sources in the Galaxy," Science 163, 1055 (March 1969); Erratum Science 164, 57 (1969).

Knowles, S. H.
"Determination of the Astronomical Unit from Hydrogen-Line Radial-Velocity Measurements," Astron. J. 74, 291 (1969).

Hobbs, R. W., H. H. Corbett and N. J. Santini
"Observations of Variable Radio Sources at 9.55 MM Wavelength," Astrophys. J. 156, L15 (1969).

Bologna, J. M. E. F. McClain, and R. M. Sloanaker
"Polarization of Discrete Sources at 21-Centimeters Wavelength and Galactic Depolarization," Astrophys. J. (In Press, June 1969).

SPACE SCIENCE DIVISION

Code 7130

Papers Submitted for Publication:

Refereed Journals:

Johnston, K. J. and Hobbs, R. W.
"Polarized Brightness Distribution of Taurus A and Brightness Distribution of Orion A at 9.55-MM Wavelength," (Submitted to Astrophys. J., January 1969).

Hobbs, R. W., Corbett, H. H. and Santini, N. J.
"Observations of Radio Sources at 4.3 Millimeters Wavelength," (submitted to Astrophys. J., January 1969).

Knowles, S. H., Mayer, C. H., Cheung, A. C., Rank, D. M. and Townes, C. H.
"Observations of H_2O Line Emission at 1.35 cm Wavelength in the Interstellar Medium," (Submitted to Astron. J., April 1969).

Knowles, S. H., Mayer, C. H., Sullivan, W. T. III, and Cheung, A. C.
"Further Observations of Variability of Galactic Water Vapor Emission," (Submitted to Science, May 1969).

Cheung, A. C., Rank, D. M., Townes, C. H., Knowles, S. H. and Sullivan, W. T. III
"Distribution of Ammonia Density, Velocity, and Rotational Excitation in the Region of Sagittarius B2," (Submitted to Astrophys. J. Ltrs., May 1969).

McCullough, T. P. and Waak, J. A.
"Intensity and Polarization Measurements of Variable Sources at 1.55-CM Wavelength," (Submitted to Astrophys. J., March 1969)

Shapiro, A., Uliana, E. A., and Yaplee, B. S.
"Direct Planetary Topographic information for Radar Measurements," (Submitted to J. Geophys. Res., May).

Papers Submitted for Publication (Cont'd):

Other Major Publications:

Mayer, C. H.
"Thermal Radio Emission of the Planets and Moon," Chapter, Surfaces and Interiors of Planets and Satellites, ed. A. Dollfus (Academic Press, London), In Press.

NRL Formal Reports

Shapiro, A. and Yaplee, B. S.
"A Lunar Radar Navigation Concept," NRL Report 6814 (In Press).

Other Publications:

Hollinger, J. P.
"Remote Microwave Sensing of Sea State," Informal Letter Report 7130-235, NRL Problem 71G01-04, December 1968.

SPACE SCIENCE DIVISION

7130 Talks

Knowles, S. H.
"Application of Spectral-Line Radial Velocity Measurements to Solar Parallax Determination"
Harvard University Colloquium
Cambridge, Massachusetts
11 September 1968

Knowles, S. H.
"Measuring the Solar System with Radio Astronomy Techniques"
National Capital Astronomers
Washington, D. C.
5 October 1968

Knowles, S. H. and W. T. Sullivan (Univ. of Maryland)
"21-cm Lunar Occultations of the Galactic Center"
AAS Meeting
Austin, Texas
10-13 December 1968

Friedman, H., G. Fritz, R. C. Henry, J. P. Hollinger, J. F. Meekins and D. Sadeh
"Absence of Pulsar Characteristics in Several X-ray Sources"
AAS Meeting
Austin, Texas
10-13 December 1968

Hobbs, R. W.
"Millimeter Wave Radio Astronomy"
Four College Observatory, Amherst
Mount Holyoke, Smith Colleges and
University of Massachusetts
Amherst, Massachusetts
10-11 March 1969

Shapiro, A.
"Planetary Topography from High Range Resolution Radar Measurements"
Conf. on Scientific Applications of Radio and Radar Tracking in the Space Program
JPL
Pasadena, California
9-11 April 1969

7130 Talks Cont'd.

Hobbs, R. W.
"Observations of Radio Sources at Millimeter Wavelengths"
University of Texas Seminar.
Austin, Texas
13 May 1968

Hobbs, R. W.
"Very Long Baseline Interferometry As A Means of Determining Distance"
DoD Geodetic/Geometric Tri-Service Quarterly Meeting
Naval Research Laboratory
22 May 1969

Hollinger, J. P.
"A Consideration of the Possible Uses of Pulsar Type Radio Sources to Geodesy"
DoD Geodetic/Geometric Tri-Service Quarterly Meeting
Naval Research Laboratory
22 May 1969

SPACE SCIENCE DIVISION

Code 7140

Publications in Refereed Journals

Koomen, M. M., R. Tousey and R. T. Seal, Jr.
"The Lunar Crescent and Earthshine Observed at 2^{o} Solar Elongation," MOON AND PLANETS (Vol. II) ed. A. Dollfus (North-Holland Publ. Co.) 187-195 (1968).

Purcell, J. D., R. Tousey and M. J. Koomen
"Extreme Ultraviolet Heliograms and the Sun's Corona," Space Research VIII, Vol. I, ed. A. P. Mitra, L. G. Jacchia and W. S. Newman (North-Holland Publ. Co.) 450-457 (1968).

Koomen, M. J., R. T. Seal, Jr., and J. Lintott, NASA/MSFC, Houston.
"Photograph of the Night Airglow from the Gemini Series of Manned Spacecraft," Space Research VIII, Vol. I, ed. A. P. Mitra, L. G. Jacchia and W. S. Newman (North-Holland Publ. Co.) 683-691 (1968).

Tilford, S. G., and J. T. Vanderslice (Univ. of Maryland)
"High Resolution Vacuum Ultraviolet Absorption Spectra of the $B^1\Sigma^+ - X^1\Sigma^+$, $C^1\Sigma^+ - X^1\Sigma^+$, and $j^3\Sigma^+ - X^1\Sigma^+$ Transitions in Carbon Monoxide," J. of Molecular Spectroscopy 26, 419-431 (1968).

Tilford, S. G., J. D. Simmons and A. M. Bass (NBS)
"The High Resolution Absorption Spectrum of the Carbon Monoxide Fourth Positive System in the Vacuum Ultraviolet Region," Astrophys. J. 155, 345-358 (1969).

Tilford, S. G.
"Evidence for the Reclassification of the Upper State of the '3A' Bands in the Spectrum of CO: The $c\ ^3\Pi \leftarrow X\ ^1\Sigma^+$ Transition," J. of Chemical Physics 50, 3126-3127 (1969).

7140 Major Publications

Tousey, R.
"Line Identifications in the Solar Extreme Ultraviolet and X-ray Regions," Beam-Foil Spectroscopy, Vol. II, ed. Stanley Bashkin (Gordon and Breach Publ. Co.) 485-524 (1968).

Widing, K. G.
"Solar Research from Rocket and Satellites," Astronautics and Aeronautics 7, 36-43 (1969).

Winter, T. C., Jr.
"Apollo Solar Experiments--Paving the Way for Advanced Space Observatories," Astronautics and Aeronautics 7, 64-71 (1969).

Tousey, R., G. D. Sandlin and M. J. Koomen
"Photographs of Coronal Streamers from a Rocket on 9 May 1967" IAU Symp. No. 35, Budapest, Hungary, ed. K. O. Kiepenheuer (D. Reidel Publ. Co.) 385-388 (1968).

7140 Formal Reports

Winter, T. C., Jr. and G. E. Brueckner
"Effects of High-Energy Protons on Photographic Film," NRL Report 6797 (1969).

7140 Other Publications

Koomen, M. J., R. T. Seal, Jr., J. D. Purcell and R. Tousey
"More on the 22 September 1968 Solar Eclipse," Sky and Telescope 37, 356-357 (1969).

Winter, T. C., Jr.
"The Army's Role in Space"
Military Reviews, 48 No. 7, 82-86 (1968).

7140 Publications in Refereed Journals (Submitted)

Widing, K. G. and J. D. Purcell
"Brightness Temperatures in the Solar Ultraviolet Continuum"
1450-2080 A"
submitted for publication in Astron. J. January 1969

Tilford, S. G., J. W. Meriwether and W. M. Benesch
"Correlation of a Solar Flare with a Visual Aurora"
submitted for publication in JGR February 1969

Howard, R. A., J. T. Vanderslice and S. G. Tilford
"Ion Densities in the Night Ionosphere"
submitted for publication in Planetary and Space Science
April 1969

Innes, K. K., H. D. McSwiney, Jr., J. D. Simmons and S. G. Tilford
"Analysis of the $\tilde{A}\ ^1B_1 - \tilde{X}\ ^1A_1$ Electronic Transitions of
Pyrimidine-d_o and d_4 Vapors"
submitted to J. Molecular Spectroscopy April 1969

Hunter, W. R. and S. A. Malo
"The Temperature Dependence of the Short Wavelength Transmittance Limit of Vacuum Ultraviolet Window Materials"
submitted to J. Physics and Chemistry of Solids May 1969

Hunter, W. R.
"Comments on Optical Surface Degradation from Combined UV Radiation and Outgassed Materials"
submitted to J. of Vacuum Science and Technology June 1969

Ginter, M. L. and S. G. Tilford
"Reanalysis of the '3A' Bands of CO: The $c^3\Pi$ and $^3\Pi$ Transition"
J. Molecular Spectroscopy (In Press)

7140 Other Publications (Submitted)

Winter, T. C., Jr.
"DoD Solar Experiments in NASA Prototype Space Station"
submitted to Military Review (Dept. of the Army) January 1969

SPACE SCIENCE DIVISION

7140 Talks

Packer, D. M. and I. G. Packer
"Optical Techniques for Study of the Upper Atmosphere"
Annual Meeting of the Optical Society of America
Pittsburgh, Pennsylvania
9-12 October 1968

Tousey, R.
"Spectroscopy from Space Vehicles"
Delaware Valley Section of the Society for Applied Spectroscopy
Philadelphia, Pennsylvania
15 October 1968 (Invited)

Tousey, R.
"Two Decades of Space Spectroscopy"
NBS
Gaithersburg, Maryland
4 October 1968 (Invited)

Brueckner, G. E. and M. Magyard
"Calibration of Solar Magnetograms Obtained with Narrow Band Birefringent Filters
AAS Meeting
Pasadena, California
18-21 February 1969

Koomen, M. J., R. T. Seal, Jr., and R. Tousey
"Coronal Streamers Photographed on April 27 and 29, 1968"
AAS Meeting
Pasadena, California
18-21 February 1969

Widing, K. and J. D. Purcell
"Brightness Temperatures in the Solar Ultraviolet Continuum: 1450-2080 A"
AAS Meeting
Pasadena, California
18-21 February 1969

Purcell, J. D. and R. Tousey
"XUV Solar Features Observed on September 22, 1968"
AAS Meeting
Pasadena, California
18-21 February 1969

7140 Talks Cont'd.

Winter, T. C.
"Apollo Telescope Mount"
NBS
Washington, D. C.
27 February 1969

Hunter, W. R., G. Hass and J. B. Ramsey
"Reflectance of Semitransparent Platinun Films on Various Substrates in the Vacuum Ultraviolet"
Optical Society of America Meeting
San Diego, California
11-14 March 1969

Hunter, W. R.
"Light Sources for Stellar Telescope Calibration from 700 A to 7000 A"

Hunter, W. R.
"Light Sources for Stellar Telescope Calibration from 700 A to 7000 A"
Workshop on Optical Telescope Technology
NASA-MSFC
Huntsville, Alabama
17 May 1969

Sandlin, G. D.
"Solar UV Observations"
Department of Astronomy
University of Maryland
26 May 1969

E. O. HULBURT CENTER FOR SPACE RESEARCH

and

LABORATORY FOR COSMIC RAY PHYSICS

JOINT COLLOQUIA

For

Fall 1968 - Spring 1969

E. O. HULBURT CENTER FOR SPACE RESEARCH

AND

LABORATORY FOR COSMIC RAY PHYSICS

JOINT COLLOQUIA

Fall 1968 - Spring 1969

---

29 August 1968
"BOUNCE-RESONANT SCATTERING OF AURORAL-ZONE ELECTRONS"
Dr. Aharon Eviatar, Tel-Aviv University, Ramat-Aviv, Israel

6 September 1968
"COLLAPSE OF INTERSTELLAR GAS CLOUDS AND FORMATION OF STARS"
Dr. James H. Hunter, Upper Air Physics Branch, Space Science Division, NRL

19 September 1969
"HIGHLIGHTS OF THE COSMIC-RAY CONFERENCE IN CAMBRIDGE"
Dr. Maurice M. Shapiro, Chief Scientist, Laboratory for Cosmic Ray Physics, NRL

26 September 1968
"DISCOVERY OF HIGH ENERGY GALACTIC GAMMA RAYS"
Dr. George W. Clark, Center for Space Research, Massachusetts Institute of Technology

3 October 1968
"GYRO SYNCHROTRON RADIATION AND SOLAR RADIO BURSTS"
Dr. Reuven Ramaty, NASA, Goddard Space Flight Center, Greenbelt, Md.

17 October 1968
"PULSARS"
Prof. Frank D. Drake, Director, Arecibo Ionospheric Observatory, Puerto Rico

31 October 1968
"LEMAITRE TYPE OF COSMOLOGICAL MODELS"
Prof. Edwin E. Salpeter, Inst. of Theoretical Astronomy, University of Cambridge (Leave of absence from Cornell University)

14 November 1968
"X-RAY SPECTROSCOPY OF THE SUN FROM OSO-III"
Dr. Werner Neupert, NASA, Goddard Space Flight Center, Greenbelt, Md.

21 November 1968
"SOME RECENT ADVANCES IN GALACTIC RADIO ASTRONOMY"
Prof. Gart Westerhout, Director of Astronomy, University of Maryland, College Park, Maryland

5 December 1968
"COSMOLOGICAL MODEL OF OUR UNIVERSE"
Dr. Hong-Yee Chiu, NASA, Institute for Space Studies, New York

9 December 1968
"OSCILLATING MODELS OF THE UNIVERSE"
Prof. Nathan Rosen, Technion--Israel Institute of Technology

17 December 1968
"DISCOVERY OF MICROWAVE EMISSION OF NH_3 MOLECULES IN THE DIRECTION OF THE GALACTIC CENTER
Dr. D. H. Rank, University of California, Berkeley

6 January 1969
"STRUCTURE AND MOTIONS OF THE FILAMENTARY ENVELOPE OF CRAB NEBULA"
Dr. Virginia Trimble (leave of absence from Cambridge University) Department of Astronomy, Smith College, Massachusetts

16 January 1969
"THE EARTH'S PARTICLE RADIATION ENVIRONMENT"
Dr. James I. Vette, Goddard Space Flight Center, Greenbelt, Maryland

23 January 1969
"ARE COSMIC ELECTRONS ANISOTROPIC?"
Prof. James A. Earl, Department of Physics and Astronomy, University of Maryland, College Park, Maryland

30 January 1969
"ATMOSPHERIC PHYSICS PROGRAM AT ADELAIDE"
Prof. John H. Carver (Visiting Scientist from University of Adelaide, Australia), Space Science Division, NRL

12 February 1969
"THEORY OF THE ISOTROPY OF THE COSMIC BACKGROUND"
Prof. Charles Misner, Department of Physics, University of Maryland, College Park, Md.

27 February 1969
"RADIATIVE TRANSFER IN THE PLANETARY NEBULAE"
Dr. George A. Doschek, Research Associate, E. O. Hulburt Center for Space Research, NRL

20 March 1969
"100 MICRON OBSERVATION OF THE GALACTIC CENTER"
Dr. William F. Hoffman, Goddard Institute for Space Studies, New York

24 March 1969
"ON THE ORIGIN OF THE MOON"
Dr. Fred Singer, Deputy Assistant Secretary of Interior, Department of Interior, Washington, D. C.

3 April 1969
"MODELS OF DISCRETE X-RAY SOURCES"
Dr. Herbert Friedman, Chief Scientist, E.O. Hulburt Center for Space Research, Space Science Division, NRL

7-9 April 1969
LECTURE SERIES:
No. 1 - "ENERGY TRANSFER FROM THE SUN'S CENTER THE THE EARTH"
No. 2 - "THE SOLAR MAGNETIC FIELD"
No. 3 - "THE FATE OF THE MAGNETIC FIELD"
No. 4 - "SOLAR FLARES"
Dr. David M. Rust, Sacramento Peak Observatory, Air Force Cambridge Research Laboratories,

10 April 1969
"THE LIGHT OF THE SUPERNOVA OUTBURST"
Prof. Phillip Morrison, Massachusetts Institute of Technology, Cambridge, Massachusetts

17 April 1969
"OBSERVATIONS IN INFRARED ASTRONOMY"
Prof. G. Neugebauer, Dept. of Physics, California Institute of Technology, Pasadena, California

23 May 1969
"USE OF THE PEPSIOS SPECTROMETER IN AERONOMY AND ASTRONOMY"
Prof. F. Roesler, Department of Physics, University of Wisconsin, Madison, Wisconsin