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SCIENTIFIC EXPLORATION OF SPACE

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BY

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SCIENTIFIC EXPLORATION OF SPACE

by
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The story I am going to try to tell tonight is a relatively untold one; it deals with the events in the life of a satellite that occur after the headline "Satellite in Orbit." The main story of space projects to date seems to focus on advance preparation for the launch and the launch itself. Actually at this point the project has just reached the threshold of its useful life. To end the story here, is equivalent to ending the biography of a great man on the day of his graduation from school.

Perhaps the reason the part of the space story after launch does not have striking news value is because it is so diffuse. Except for the manned space flight projects there is no single personality on whom the spotlight can be concentrated; the job of putting together the cosmic jigsaw puzzle of space from the bits and pieces of data obtained from our satellites is one that engages the efforts of many people throughout the scientific community; and this jigsaw puzzle goes together so gradually that there are no singular events which merit a headline. I suspect that there are Nobel prizes in the making, but it is going to be difficult to determine who should get the medal.

Despite these difficulties this portion of the space effort should be understood not only by the scientific community but by the general public as well. It is the general public who ultimately will make our space policy, and they deserve to do it on the basis of its real accomplishments and potentialities.

I don't pretend to know how this message can be carried to the general public. For this reason I appreciate the opportunity to discuss this matter with a group of professionals in the art of communications such as you. I hope you consider this task a worthy challenge to your profession.

An example of the point I have been making is furnished by Vanguard I. I am sure all of you participated in its pre-launch trials and tribulations, and perhaps contributed your share of "body english" to get it in orbit. But how many realized that this satellite is not only still up there, but that it is still supplying useful scientific data.

(Slide #1 - Vanguard)

A tiny radio transmitter, powered by six solar cells which still put out about 1/10 of a milliwatt when in sunlight, is operating and enabling us to continue to track Vanguard I accurately.

We have tracked this satellite for some four years now.

(Slide #2 - Perigee Height)

Here you see the result of our observations in terms of perigee height vs time after the orbital mathematician has processed the tracking observations which keep coming in at the rate of about six per day. These data seem to pose a question rather than provide an answer. However, from them the solar physicist has been able to deduce something about radiation pressure from the sun; the upper atmosphere physicist has been able to derive the temperature and composition of the atmosphere at extreme altitudes and the influence of the sun on these characteristics; and the geologist has been able to make deductions with respect to the strength of the earth's crust beneath the oceans.

An insight as to how this was done is given on the next slide.

(Slide #3 - Vanguard Orbit Variation)

This long period variation shown by the theoretical line has been explained by the solar physicist as the effect of a force of the order of 1/50 of an ounce, exerted by the radiation pressure from the sun on the satellite, together with the gravitational traction of the sun and moon. This smaller more rapid variation can be explained by a periodic variation in the earth's gravitational pull. With this shred of information the geodesist takes over, and he can reason to a shape of the earth such as shown on this slide.

(Slide #4 - Harmonies of Geoid)

You may ask what is the importance of a 50 ft. variation in a 4,000 mile radius. It is of considerable interest to the geologist who is trying to understand the characteristics of the earth's surface and its interior. From these data he can deduce the bending strength of the earth's crust and its resistance to known distorting forces. One interesting inference has been drawn that this shape was set some 50 million years ago when the day was 23 hours and 30 minutes in length.

In a somewhat similar manner much useful information has been derived about the density and temperature of the upper atmosphere from

Echo I. This 80 ft. balloon, which I am sure you all have seen picking its way across the sky, is very large in proportion to its weight. It is therefore most responsive to small changes in resistance in orbit and its orbital variations have served as a very sensitive measure of the density variations it encounters. A most interesting example of this is illustrated on the next slide.

(Slide #5 - Echo Orbit Variations)

Shown here are the orbital period variations versus time. You will note that at this point there was a marked change in the period, which implies a change resistance. This change occurred at the same time that a Class #3 solar flare was observed from the earth. From information of this type, the upper atmosphere physicist was able to deduce that this flare heated up the atmosphere, causing it to expand, and increased in density at the altitudes of the Echo I orbit.

Extensive correlation with period variation of Echo I and other satellites had led to the conclusion of a marked coupling between the eleven-year solar sun spot cycle, and the temperature of the upper atmosphere. This slide shows the correlation over the past four years during which there have been satellites in orbit.

(Slide #6 - Upper Atmosphere Temperature Variations)

An extrapolation into the future is also shown. Needless to say, this anticipated correlation will be watched for years to come.

Thus far, I have been talking about the "first generation" of satellites. They are characterized by an absolute minimum of instrumentation. Their scientific value has primarily been derived by observing their orbital variations from the ground and then correlating these variations with other physical phenomena. I would like now to shift to the "Direct Measurement" satellites which carry instruments on board to sample and measure the characteristics of the environment in which they find themselves. Explorer I was of this type, and the geiger tube it carried gave first direct evidence of the Van Allen belts. Later satellites carried instruments of considerably increased complexity.

Contemplate for a second the problem this poses. In many cases these are most sensitive instruments of the type which heretofore have only been used to conduct precise experiments in the ideal environment of the laboratory. Such experiments probably have been conducted in an air-conditioned, shock insulated environment with an experienced experimenter in attendance, carefully adjusting conditions and making his own readings. Now we must take these instruments and operate them at great distances, under conditions where they will be subject to extreme variations in the temperature and pressure. To heap insult on injury, these instruments will be placed on top of a rocket before they go into orbit and be exposed to shock and vibration conditions much worse than rolling them down the stairs.

Let's take a look at what we want to observe from these direct measurements satellites. The area of sun-earth relationships promises to be one of the most exciting and fruitful areas of research, and happens to be the one on which we have made the most progress to date. The results previously quoted from Vanguard and Echo hint at the interrelation that exists between the sun and what goes on in the earth's upper atmosphere, and it is easy to speculate that this effect eventually influences variations in our weather. Our objective is a more detailed, quantitative understanding of the physical phenomena involved. I predict that some day in the future the understanding of this sun-earth interrelationship will have a direct impact on our daily lives. I am reminded of Farradays answer to a member of English Parliment when asked about the earthly use of his new invention the electric motor. You will recall that Farraday replied "Someday you will tax this." In a somewhat similar vein it can be speculated that our knowledge of sun-earth relationships derived from satellites will justify the comment that "These results will some day influence the price of beans in Kansas."

This slide indicates the various phenomena of interest in this portion of our space research.

(Slide #7 - Sun-Earth Phenomena)

These can conveniently be divided into three general areas:

The first concerns the sun itself. Previous to the advent of the satellite it has been necessary to study the sun as if thru a translucent blindfold, because the earth's atmosphere cuts out a high percentage of the sun's radiation which tells us what is going on up there. Thus, one objective of our sun-earth study from satellites will be to observe details of sun-spots and solar flares which are the basic cause of the other phenomena of interest. The Orbiting Solar Observatory, launched recently had this as its objective. I will discuss more of this shortly.

The second region of interest is referred to as interplanetary space. It is to be distinguished from the near-earth region in that the phenomena in the interplanetary region are dominated by the sun, and relatively uninfluenced by the earth. In this interplanetary region it will be possible to observe solar electromagnetic radiations and particle emissions, essentially uninfluenced by the earth's magnetic field.

The third region is the near-earth region called the magnetosphere. This is a region in which, as the slide attempts to portray, the magnetic field of the earth exerts a major influence. The magnetic field lines of the earth interact with the electromagnetic radiations from the sun--and divert the flow of energetic particles from the sun. Fortunately, this magnetosphere acts as a protective shield and prevents a major portion of these radiations from impinging on the earth. At the equator, this magnetosphere or shield extends up some six earth radii–24,000 miles; at the magnetic poles the shield is much thinner and solar effects such as the aurora occur at much lower altitudes.

If I were to tell this story by proceeding from that which we know most about to that which we know least, it would go from this near-earth region, to interplanetary space, to the sun, since our knowledge varies in direct relation to the accessibility of these regions. On the other hand, the story makes better sense by going from cause to effect, i.e., to start with the sun.

The satellite from which we are studying the sun is the OSO. It was launched from Cape Canaveral last March. This satellite is now in a near circular orbit about 350 miles above the earth. This slide shows the manner in which it operates.

(Slide #8 - Orbiting Solar Observatory)

Its main object is to keep the instrumentation mounted in this portion here pointed at the sun. This part of the spacecraft is a spinning wheel, which makes the satellite operate like a gyroscope and thus maintain a fixed orientation in space unless precessed by jets, located here. These jets are activated by sun-sensing instruments mounted on this arm. Their job is to keep the arm aimed at the sun, equivalent to aiming a rifle at a 2-1/2 foot balloon at a distance of one mile. The satellite loses sight of the sun each time it goes behind the earth. Since it has completed over a thousand orbits to date (1,071 to be exact) this means it has reaimed itself some thousand plus times. As you can see OSO is not a very relaxing satellite; every morning I have come to work during the last three months since its launch, my first question is–"How is OSO doing?" Its aim remains perfect. It has not missed the sun yet.

The value of OSO of course, is that it looks at the sun from above the earth's atmosphere. As this next slide shows it therefor "sees" the sun in this short wavelength range which are blanked out from any viewer on earth by the earth's atmosphere.

(Slide #9 - Solar Spectrum)

This range here shows the solar radiation that reaches the earth–essentially the visible and radio wave radiation. This is the gamma ray, x-ray and ultra-violet region over which we are observing from OSO. Here is a sample record of what is seen.

(Slide #10 - Spectrum Lines)

Here are spectrum lines which tell much of what is going on on the sun; from a detailed study of these lines it will be possible to deduce the temperature variation in the atmosphere; how it builds up during a solar flare and the like.

To date OSO has enabled us to look at data from about 20 solar flares. While we have only been able to scan the resulting data, we hope to learn more about the flare mechanism and the processes involved in releasing and transmitting energy from the sun during a solar event.

The next region of study concerns the interplanetary space effects. As this slide shows, three satellites have been launched into this area.

(Slide #11 - Interplanetary Studies)

Their trajectories are schematically indicated. You recall Pioneer V which continued transmitting until it was about 20,000,000 miles out from the earth. Explorer X went out some 145,000 miles and Explorer XII had an apogee of some 48,000 miles.

This next slide shows the spacecraft themselves.

(Slide #12 - Spacecraft)

The primary purpose of Explorer X was the measurement of the magnetic field. Since it was expected that this field might range down as low as one gamma,-- $\frac{1}{60,000}$ of the value in this room, it required a very sensitive magnetometer which was mounted on this non-magnetic plastic boom-- away from the magnetic materials in the main structure. Explorer XII carried a total of ten instruments for sensing various types and energy range of particles.

Let us take a look at some of the results these instruments have brought back from space. The next slide shows a piece of the record obtained by a magnetometer on Explorer X.

(Slide #13 - Magnetometer results)

This piece starts at a point 10.5 earth radii out and extends through the following three days of the trajectory out to 38.5 earth radii.

Before examining the data I would like to emphasize a point mentioned previously. Noted on the bottom of the slide are the worldwide stations which recorded each particular segment of data. Thus, this section was recorded at Johannesburg, South Africa, this at Goldstone, California, this at Woomera, Australia. To me this represents one of the more mundane but important problems of the space age, i.e., how to get instruments and people in as many places tuned up and adjusted so that they will obtain data that dovetails as nicely as this set does. This operation must be correlated within milliseconds, and competently operated by an operational crew who cannot possibly be as familiar with the niceties of the results as is the man who conceived the experiment—who incidentally will, in due course, very critically examine the data. It isn't easy, and we don't always succeed as well as these results imply.

Now to examine the data itself. Note the drop off here as the spacecraft gets farther and farther from the magnetosphere. It reaches a general level of 20 gammas. This level is considerably higher than that anticipated for the quiescent state in interplanetary space. It also is quite variable in magnitude as shown on this record, and in direction as shown on other records not reproduced on this slide. Both these conditions fit in with a "solar wind hypothesis" advocated by some theoreticians who postulate conditions such as are shown on this slide.

(Slide #14 - Solar Wind Slide)

They postulate that during quiet periods the sun's magnetic field is like this, in which case the field strength in the location of Explorer X would have been in the range of one to five gammas. However, there are intervals of a "solar breeze" or "wind" shown on the bottom two conditions. In these latter two cases, the magnetic lines are stretched out from the sun. The higher level measured by Explorer X and the somewhat variable conditions tend to support this hypotheses.

Returning to the previous slide. I would like to call your attention to this aspect of the data.

(Slide #15 - Magnetometer Results with Circle)

At this time, visual observations from the ground indicated that a Class #3 solar flare had occurred. We were most fortunate to have Explorer X outside the magnetosphere at this time. It enabled us to record some unique data on the magnetic field and plasma flux associated with this flare. This circle shows the effect. Twenty-eight hours after the flare Explorer X noted this marked change in the magnetic field.

This particular section of the data is reproduced on the next slide.

(Slide #16 - Magnetic field and plasma flow - Explorer X)

On this upper curve is again shown the magnetic field. You can see the general level that the magnetometer was recording prior to the geomagnetic storm–then this marked change. Down below are the results from the plasma probe instrument which recorded the particle concentration. As you can see at the same time as the magnetic field jumped, there was a marked increase in the density of plasma flow, showing the close relationship between these two phenomena.

Now obviously, I have only been able to present a glimpse of the data acquired. When the pieces are put together from Pioneer V, Explorer X and Explorer XII, the tentative picture begins to emerge. I must hedge my subsequent remarks by saying that this picture is very tentative and it will need much more data before it becomes completely clear. There still remain alternative hypothesis. As a matter of fact this states the case rather mildly. I have watched most violent discussions going on relative to these alternatives between scientists who are supposed to be coolly rational. However, with these reservations, here is a qualitative picture.

(Slide #17 - Plasma tongue from solar flare)

As the picture indicates, when a solar event, which is an eruption on the surface of the sun occurs, it sends out a huge tongue of magnetic field lines as shown. According to one hypothesis these lines form in effect a magnetic bottle. Cosmic rays from outer space are excluded by this bottle and bounced off it–and the plasma which erupts from the sun is confined within the bottle. The plasma, which is basically a gas cloud composed of low energy charged particles, in effect creates a magnetic field which moves along with it. Higher energy particles spiral around and are carried along by these magnetic field lines. It still remains unclear and subject to debate as to whether the particles start out with high energies or acquire most of this energy by being accelerated to high velocities when they are pushed along by this magnetic field. In any event by the time these particles–electrons, protons, and neutrons–reached Pioneer V, Explorer X, and Explorer XII, there was a spectrum of energy all the way from relativistic–i.e., traveling with the speed of light–on down.

The next slide shows how the solar tongue continues to expand, eventually enveloping the magnetosphere.

(Slide #18 - Elongated tongue from solar flare)

It distorts the magnetosphere as shown here–compressing it here, stretching it out into tear drop shape on the opposite side. The particles are deflected by the magnetosphere and few reach the earth except at the polar cap. Whether these particles then become the primary source of the particle population of the radiation belt, is another subject on which there are widely diverse views.

Needless to say these solar eruptions are of major concern to the people planning manned space flight missions and measurements such as I have been describing are being used to design the protection which a man will need from exposure to these particles. It would appear that at least for a lunar trip a man can be adequately protected from all but the most extreme events. One objective of our solar studies is to devise a way of predicting when a major event will occur. If this succeeds, manned space shots will be timed to avoid these events, just as a ship avoids a hurricane area at sea.

I believe this clearly demonstrates the close relationship between our scientific efforts and the manned space program. The distribution of harmful radiations in space, the times of their occurrence, the influence of magnetic fields are all important problems that space science investigations must solve before one can safely proceed to send men out into space.

In return, putting a man into space will further aid us in the scientific exploration of the universe.

Next, let us turn attention to the "near-earth" region. As this slide shows, a number of satellites have explored this region.

(Slide #19 - Magnetosphere Satellites)

You will note these satellites are actually directed at two different regions. Explorer VI and Explorer XII were concerned with the energetic particle population of the great radiation belts. Explorer VIII, P-21, the recently launched Ariel, and Tiros, are concerned primarily with the upper atmosphere and ionosphere.

The next slide shows the picture that can be pieced together from the combined results of these satellites.

(Slide #20 - Diagram of magnetosphere and belts)

In this instance, the magnetic field that controls the distribution of the particles is that of the earth; is relatively constant and quantitatively understood so that the path of the captured particles is thus reasonably predictable. They ride along these magnetic lines, converge at the magnetic poles, reverse and wander back to the opposite pole. They come down closest to the earth at these poles, and some investigators think they have an important heating effect on the upper atmosphere, which in turn has a potential influence on the weather. This is the possibility that led me to speculate earlier on the relationship between the sun and the beans in Kansas.

One can stir up another violent argument over the source of these particles. One school of thought thinks they are injected into the magnetosphere by the solar flare mechanism I have just described. Others claim an important source is from neutron decay in the upper atmosphere; cosmic rays from outer space or high energy particles impinge in the upper atmosphere, and produce charged electrons and protons, which then are captured by the magnetic lines in the belt. Before this argument is settled we are going to have to know a lot more about the lifetime of particles in the belt. If it is equivalent to a slowly leaking bucket, the neutron decay mechanism will be sufficient to keep it populated. If the bucket gets kicked over and emptied occasionally, for instance, on the occasion of the previously discussed distortion of the magnetosphere by a solar wind, the more plentiful source of injection from the sun looks likely.

Satellites since Explorer I from which Van Allen first identified the belts, have given a more and more detailed picture of the particle population of this belt. We know the particle population fluctuates, and this fluctuation bears some relation to variable solar conditions. It may be necessary to go through an eleven-year solar cycle once or twice, before these fluctuations are completely understood. Next slide shows an average picture obtained from results to date.

(Slide #21 - Belt population)

It can be considered one huge belt with the characteristics of its population varying from the inner to the outer edge.

Information such as shown on this slide will be of considerable importance in planning future communications and weather satellites. These energetic particles not only have a deteriorating effect on a man, but they also cut down the lifetime of solar cells, transistors, and other electronic components. Thus, in planning application satellites in which long lifetime is of primary importance, it will be desired to put these satellites into orbits where they are least affected by these particles.

There is still another region of the magnetosphere that has been looked at in considerable detail. This slide shows P-21, Explorer VIII, and Ariel which were launched into the ionosphere to determine its characteristics.

(Slide #22 - P-21, Ariel and Explorer VIII)

The ionosphere, as you know, is a region extending roughly from some 40 miles to several thousand miles above the earth. There is special interest in it because of its effect on radio transmission. It is this variable ionized region off which radio waves are bounced to obtain long distance transmissions.

High altitude probes and satellites have paid off a special dividend in telling us something about the composition of the upper atmosphere. The next slide shows on the solid line the measured electron density distribution with altitude. What had been expected is shown by the dotted line.

(Slide #23 - Upper Altitude Electron Distribution)

This was based on the general view that at these upper altitudes the main constituent was atomic hydrogen. This deviation is explainable by the existence of a helium layer at these altitudes. This has resulted in a revised view of the composition of the upper atmosphere. As it is now seen there is a layer of ionized helium at altitudes shown here and hydrogen does not dominate until much higher altitudes are reached.

(Slide #24 - Atmospheric Composition)

There is still another type of test I would like to discuss, primarily because it is a means by which we reach out and obtain a sample of the sun. This is done from our upper altitude sounding rocket, fired from Fort Churchill, Canada. This slide shows a rather spectacular view of a launch of a Sparrobee rocket from up there.

(Slide #25 - Fort Churchill Launch)

Fort Churchill is the launching site for these tests because it is far north where the magnetosphere is the thinnest; it is well situated to study polar cap and auroral events by means of sounding rockets. It also is the best place to reach up through the magnetosphere and sample what goes on outside this shield. Ever since the advent of satellites, sounding rocket tests of this type have been most useful, because it is fairly easy to recover the payload after it has been up and thus recover the sample for detail examination.

One method to do this is the nuclear emulsion technique. All of you who recall the story of the discovery of radium by the Curies are familiar with this technique. You recall how a photographic plate revealed the emission from a piece of radium. Nuclear emulsions are just blocks of the same photo-sensitive emulsion used to coat photographic plates. These are sent up to altitudes of about 90 miles on rockets such as the one shown here. Upon recovery these emulsions are developed to see what has hit them.

A sample of two plates is shown on this slide.

(Slide #26 - Nuclear emulsions)

The one on the left was launched during quiet conditions, and as you can see is relatively unexposed. The one on the right was launched right into the middle of a major auroral display, which coincided with a Class #3 solar flare. These tracks you see are tracks of impinging particles. This one is the track of a carbon atom, one of the heavier particles detected. The character of the impinging particle can be determined from detailed study of this track. By such a method the relative abundance of these particles can be determined. The next slide shows the result.

(Slide #27 - Relative abundance)

This depicts a statistical sample of particles which some 30 minutes before had been on the sun! I wish we could get samples of the Moon, Venus, and Mars as easily.

Up to this point all the phenomena that I have been discussing are concerned with our solar system. I would like to discuss for a moment two experiments which have enabled us to reach out and get a hint of what is going on in outer space, outside our solar system.

The first experiment is that conducted on Explorer XI, the gamma ray satellite, shown here.

(Slide #28 - Gamma Ray Satellite)

This satellite carried in it what was in effect a telescope sensitive to gamma rays and its objective was to determine the rate of production of these rays in outer space. Gamma rays as you know are a high energy form of light, and since they carry no charge they travel in a straight line (and are not deflected by magnetic fields, as are cosmic rays).

The gamma rays detected in this experiment could be produced either as a result of the collision of cosmic rays and gas in the galaxy, or the annihilation of matter and anti-matter. This latter possibility is important in connection with the steady state model of the universe, where matter and anti-matter are continuously created and destroyed. This we call the continuous creation model.

The most theoretically pleasing form of this concept would have matter and anti-matter created at equal amounts. Where this is the case, we can estimate the number of matter and anti-matter annihilation and this in turn would result in a gamma ray counting rate for our telescope of about 3,000 per hour.

The next slide shows what has been observed from Explorer XI.

(Slide #29 - Gamma Ray Event)

The slide in effect is a map of the celestrial sphere. These dots show the observed directions of gamma rays. In nine hours of looking into outer space, only twenty-two of these gamma ray messengers from outer space have been observed. This rate of 2.4 per hour as compared to the 3,000 per hour gives strong evidence against this form of steady state theory. This rate is about what one would expect from cosmic ray sources alone.

There has been another observation of outer space that has upset an existing theory. Ultra-violet radiations from various stars have been observed from high altitude rockets. The results have been surprising as shown on this slide.

(Slide #30 - Energy Distribution from Star)

For certain type of young hot stars it was expected that the ultra-violet radiations would approximate this upper curve. The observed results show a much lower level, indicating that the rate of energy release in these stars is much lower than had previously been hypothesized. This rate of energy release is an indicator of the process of development of the star. The experimental results thus seem to imply that our present theories of stellar evolution or the life cycle of stars is incorrect. The astrophysicists have in effect been sent back to the drawing board. I am reminded of a pertinent quote that applies to this situation. It goes this way:

"The terrible tragedy of science is the horrible murder of beautiful theories by ugly facts."

One can predict that with the use of scientific satellites and the accumulation of experimental facts, the murder rate in the field of astrophysics is about to rise. I trust that this trend will be more than compensated by the increase in the birth rate that is stimulated.

The final chapter in my story is TIROS, the weather satellite. Perhaps it is not necessary to tell this chapter, because in contrast to other satellites, the story of TIROS is pretty well known. However, it is one of the highlights of our space accomplishments to date, so I would like to talk about it, even if briefly.

This next slide is more indicative of the potentialities of weather satellites than any other that I have seen. The slide shows a world cloud map made from one day of TIROS passes.

(Slide #31 - TIROS World Cloud Map)

You can see the extent to which even this experimental satellite is able to provide a global prospective of the weather. On it you see the number of hurricane and typhoon disturbances picked up in a single day's pass. This particular cloud analysis spotted Hurricane Esther before it was detected by any other means, and served to alert the hurricane patrol by normal means. We hope that by close examination of the convective cells which grew into Hurricane Esther, more can be learned as to what conditions cause hurricanes. Cloud analysis such as this are distributed over a world-wide Weather Bureau Net and are already serving a useful operational purpose. We are all looking forward to the more complete cloud coverage which will be furnished when TIROS' successor—NIMBUS comes in general use.

This final slide shows the temperature patterns determined from the TIROS infrared data.

(Slide #32 - Temperature Patterns)

These are lines of constant temperature. It has been possible to deduce cloud patterns and probable front lines from data such as this since the tops of the clouds tend to be cold, the unclouded earth or ocean, warmer. Temperature variations in the atmosphere such as these are in some way related to the dynamics of the weather. It will be interesting in the years to come to see if this relation can be made sufficiently quantitative with the help of data such as this--and used in predicting the movement of main weather patterns.

This is the end of my story. I would like to say in concluding this review that it represents the work not only of many men, but many organizations. The characteristic of space science is such that it spreads across many disciplines and a very broad segment of the scientific fraternity is helping unravel the meaning of the new scientific data being brought back from outer space. You must recognize the efforts of the orbital mechanician, physicist with various areas of specialization, astronomers, geologist and geodesist in the analysis of the results I have described.

Each one of these disciplines is finding that it has a new frontier. New areas of research are being created by the data which rockets and satellites provided. We surely have just started to realize their potentialities.

As I said in my introductory remarks, it seems, newspaper, magazine, radio and television accounts of space projects end with a successful launch story. Yet it is precisely at this point and beyond that most of what we call space science begins. The pattern of findings of a family of spacecraft and experiments is what gives the individual efforts meaning.

While I am not in your business, I feel that you have indeed a most challenging opportunity and that is to take the bits and pieces that we are gaining in the form of scientific information and interpret this with meaning and depth. I think this is the real challenge facing the aviation space writers "beat" in this country.

In this endeavor we need your continued support and also your best talents.

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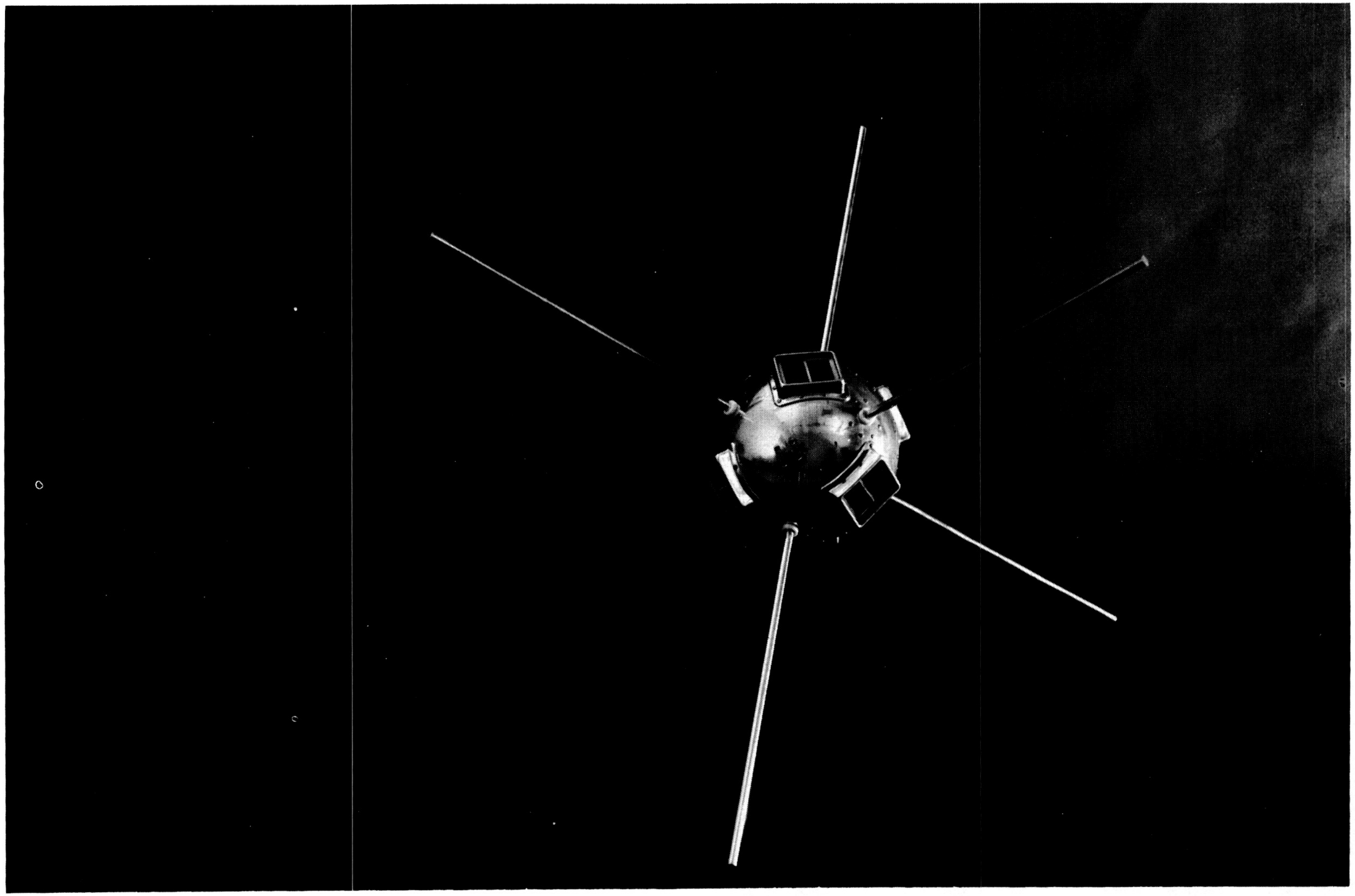
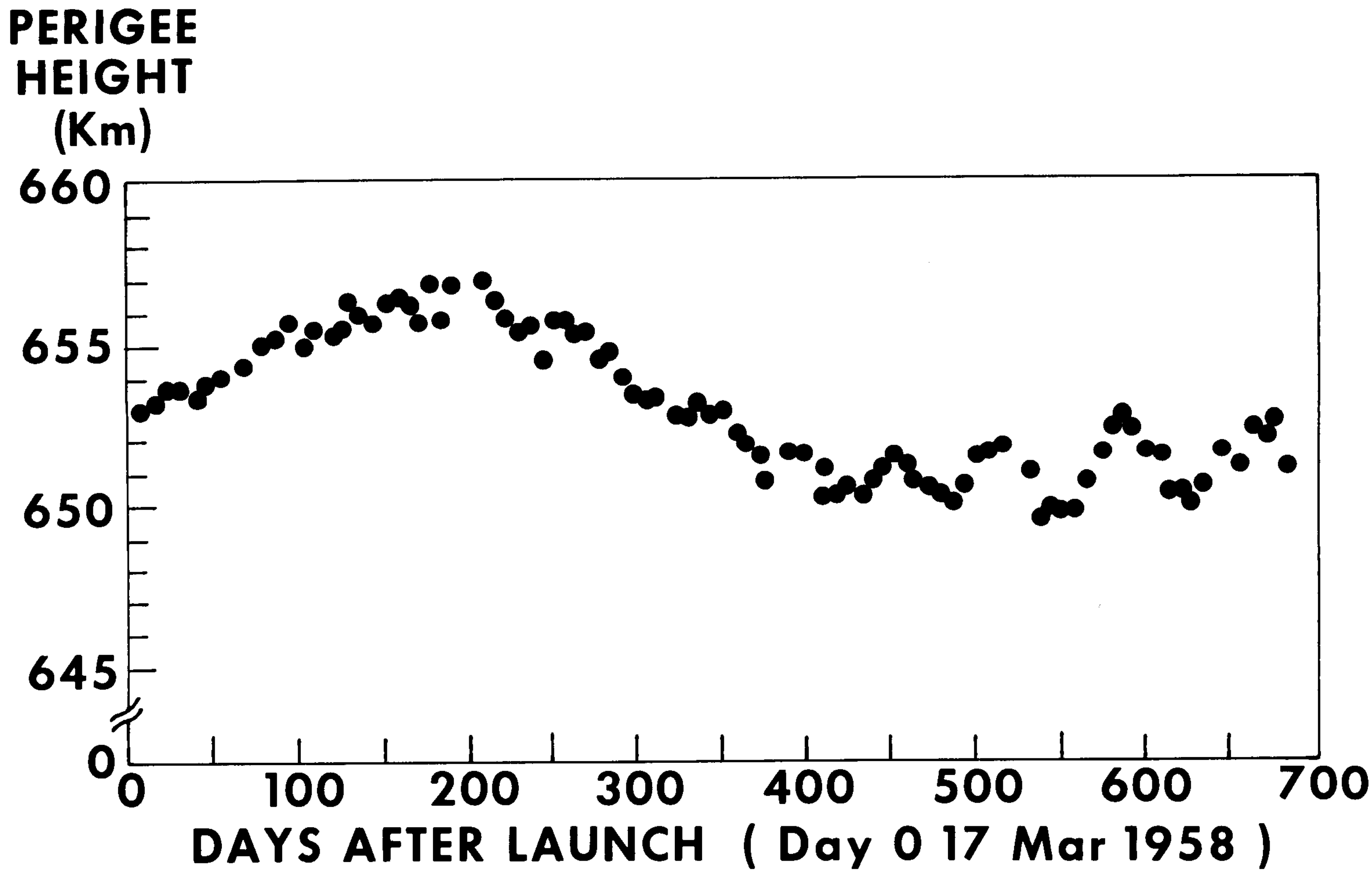


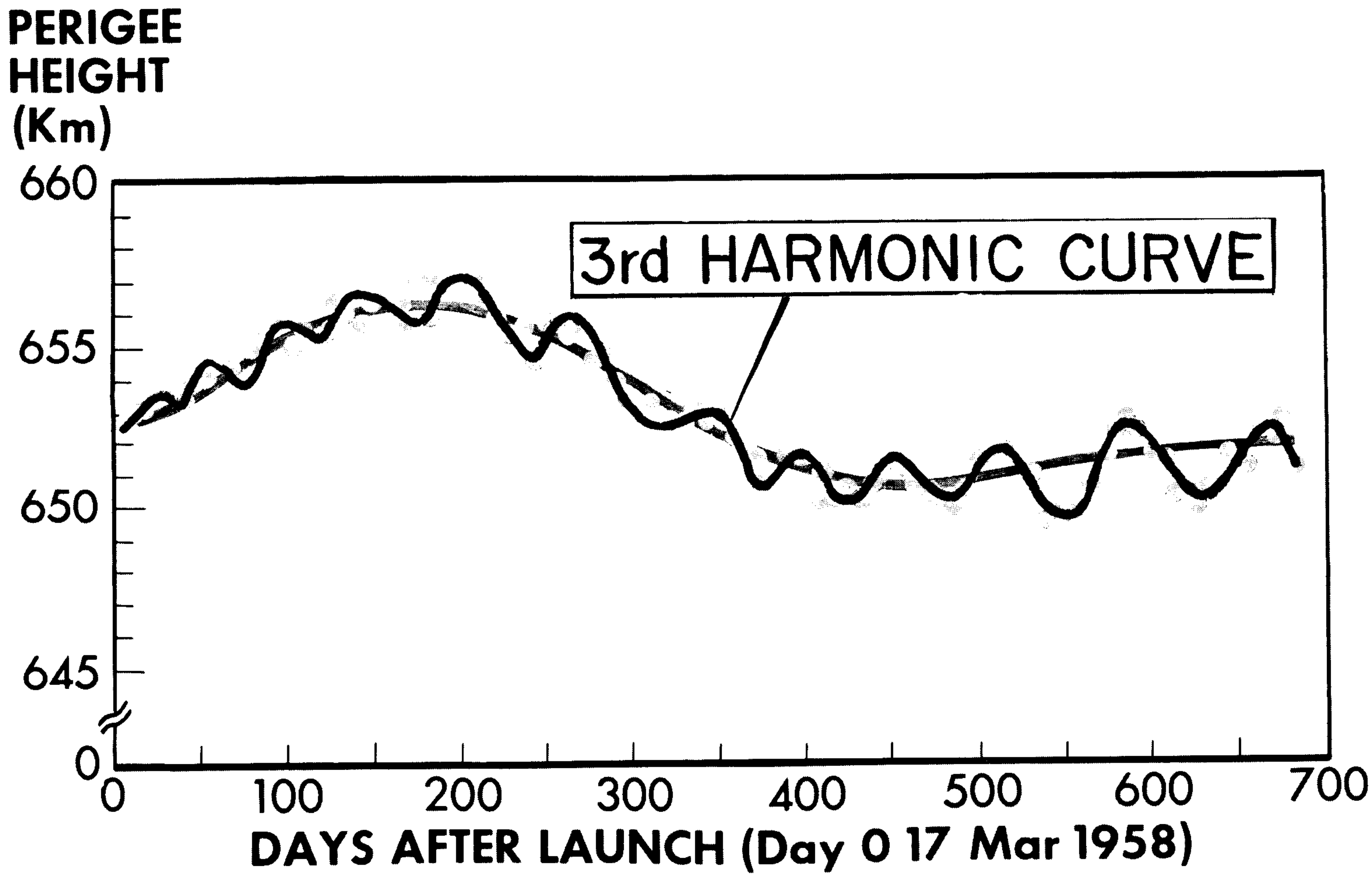
SLIDE #1

PERIGEE HEIGHT - VANGUARD I



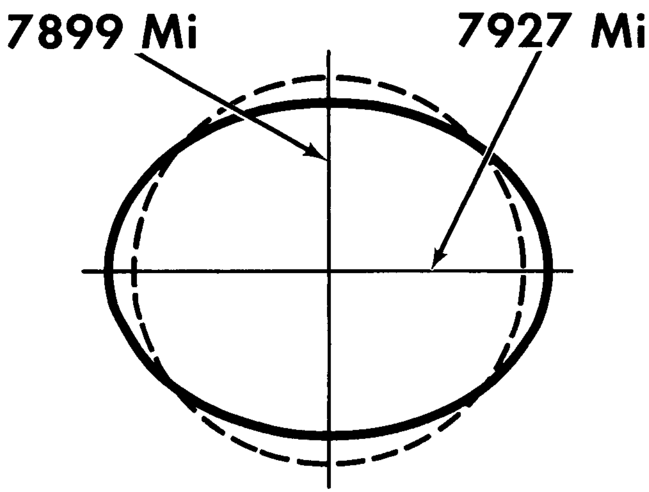
SLIDE #2

PERIGEE HEIGHT-VANGUARD I



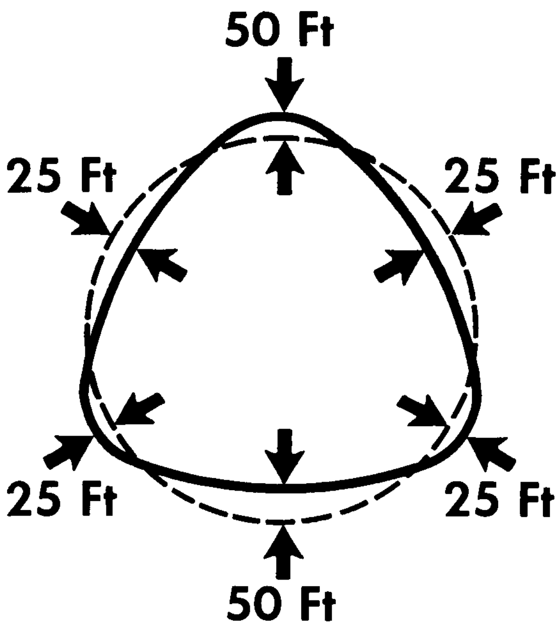
SLIDE #3

HARMONICS OF THE EARTH



Ellipsoid

2nd HARMONIC

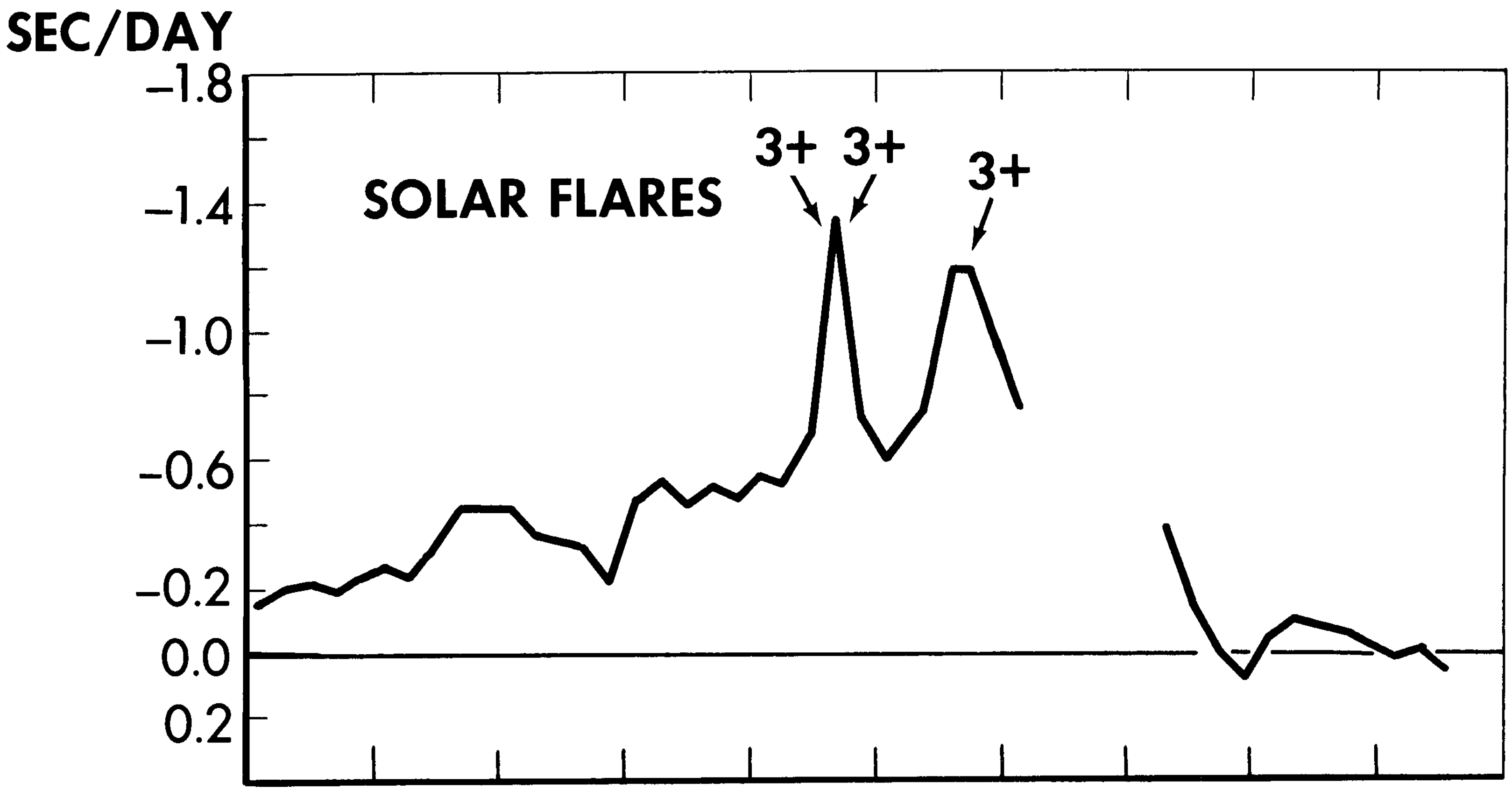


Pear Shape

3rd HARMONIC

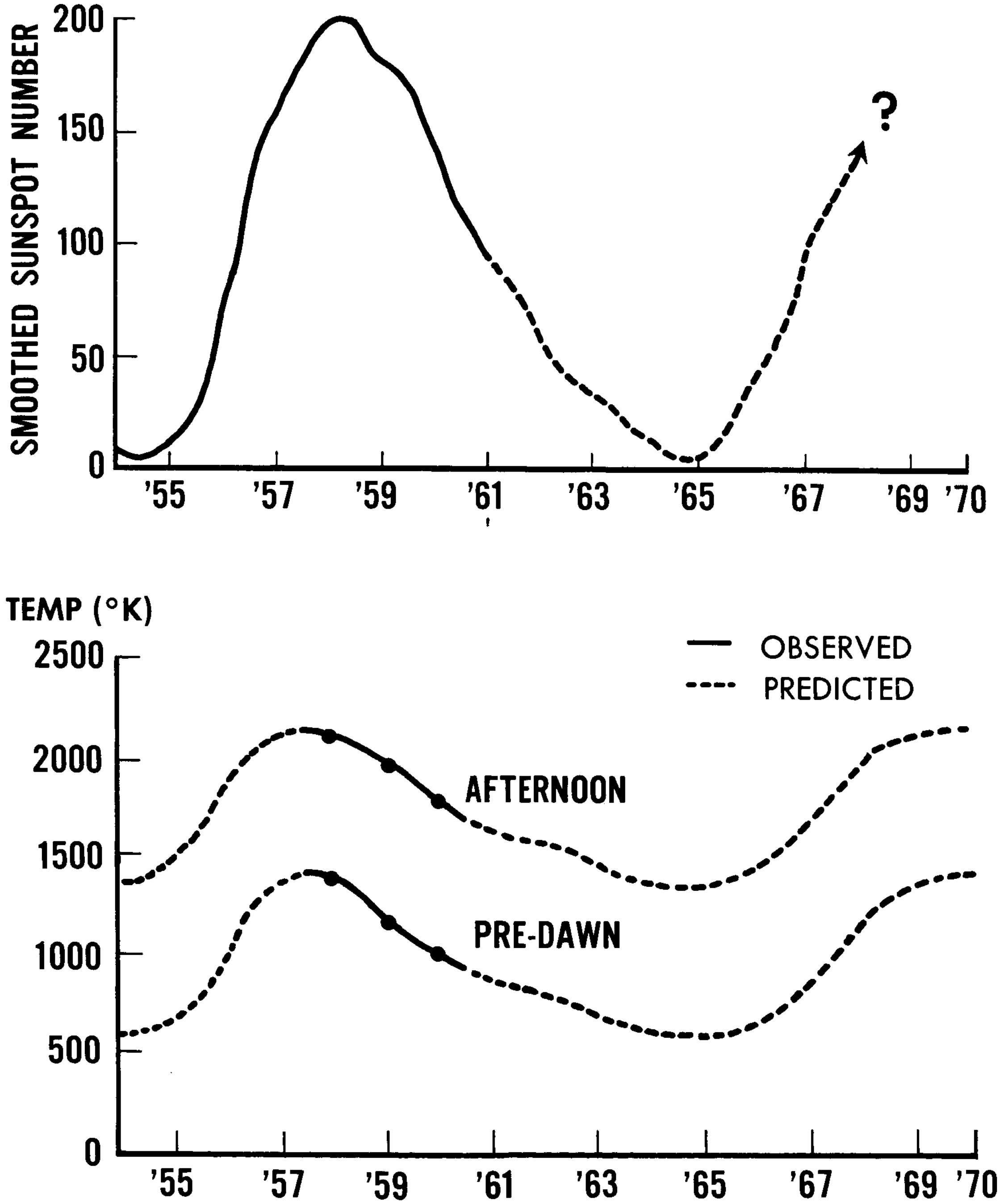
SLIDE #4

VARIATION PERIOD OF ECHO 1

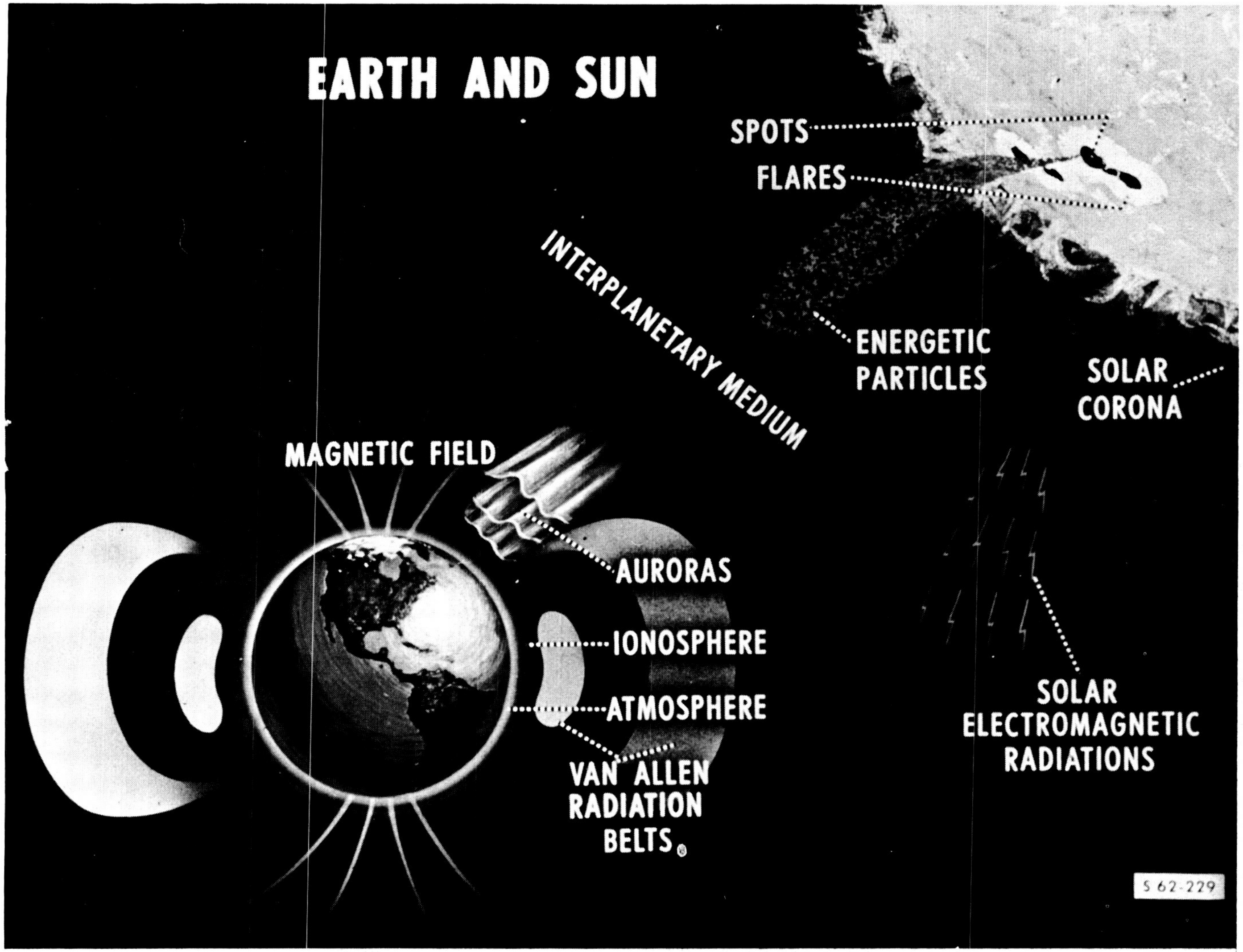


SLIDE #5

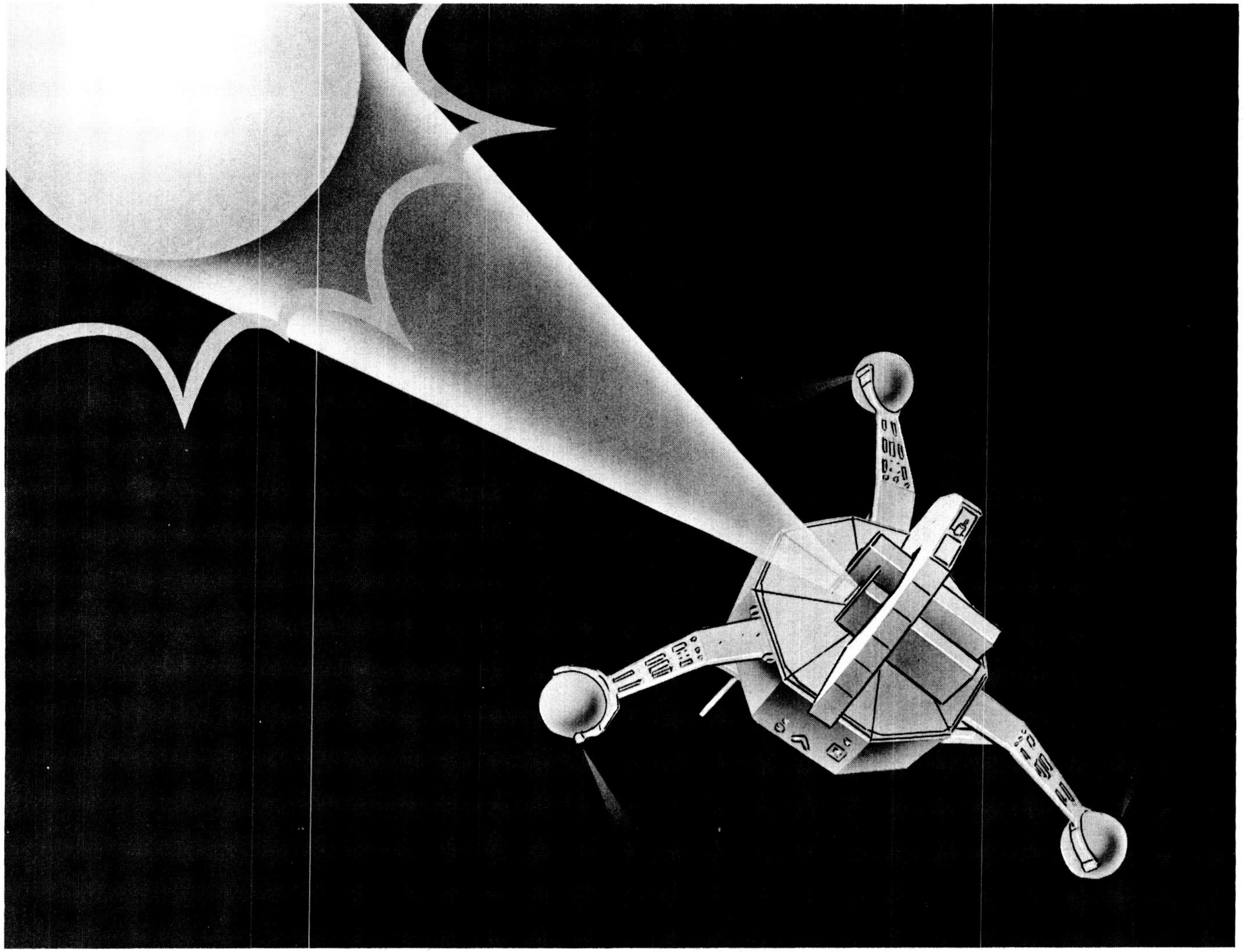
UPPER ATMOSPHERE TEMPERATURE
VARIATIONS DURING SUNSPOT CYCLE



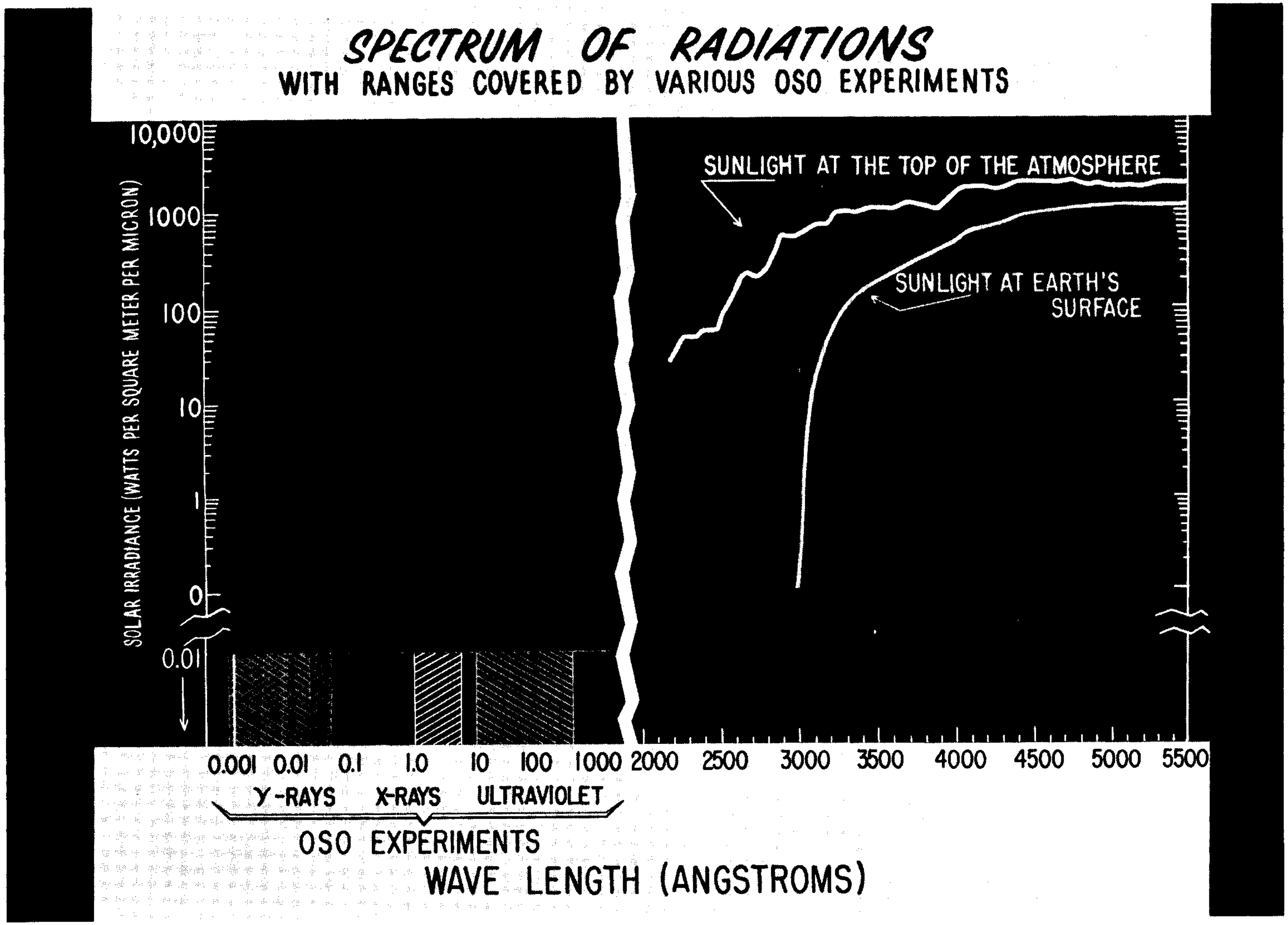
SLIDE #6


EARTH AND SUN
SPOTS
FLARES
INTERPLANETARY MEDIUM
ENERGETIC PARTICLES
SOLAR CORONA
MAGNETIC FIELD
AURORAS
IONOSPHERE
ATMOSPHERE
VAN ALLEN RADIATION BELTS
SOLAR ELECTROMAGNETIC RADIATIONS
S 62-229

SLIDE #7

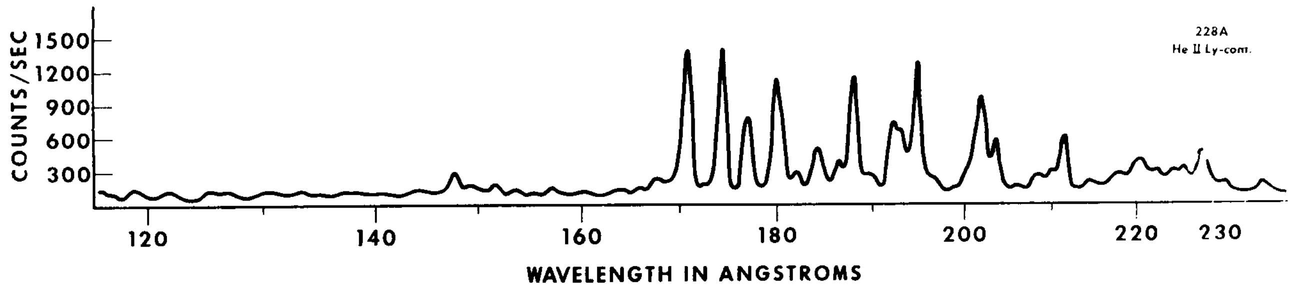


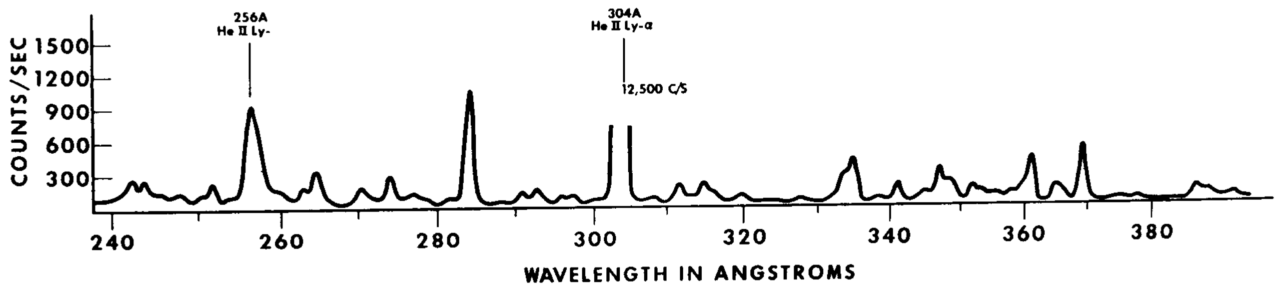
SLIDE #8


SPECTRUM OF RADIATIONS
WITH RANGES COVERED BY VARIOUS OSO EXPERIMENTS
SOLAR IRRADIANCE (WATTS PER SQUARE METER PER MICRON)
10,000
1000
100
10
1
0
0.01
SUNLIGHT AT THE TOP OF THE ATMOSPHERE
SUNLIGHT AT EARTH'S SURFACE
0.001 0.01 0.1 1.0 10 100 1000 2000 2500 3000 3500 4000 4500 5000 5500
γ-RAYS X-RAYS ULTRAVIOLET
OSO EXPERIMENTS
WAVE LENGTH (ANGSTROMS)

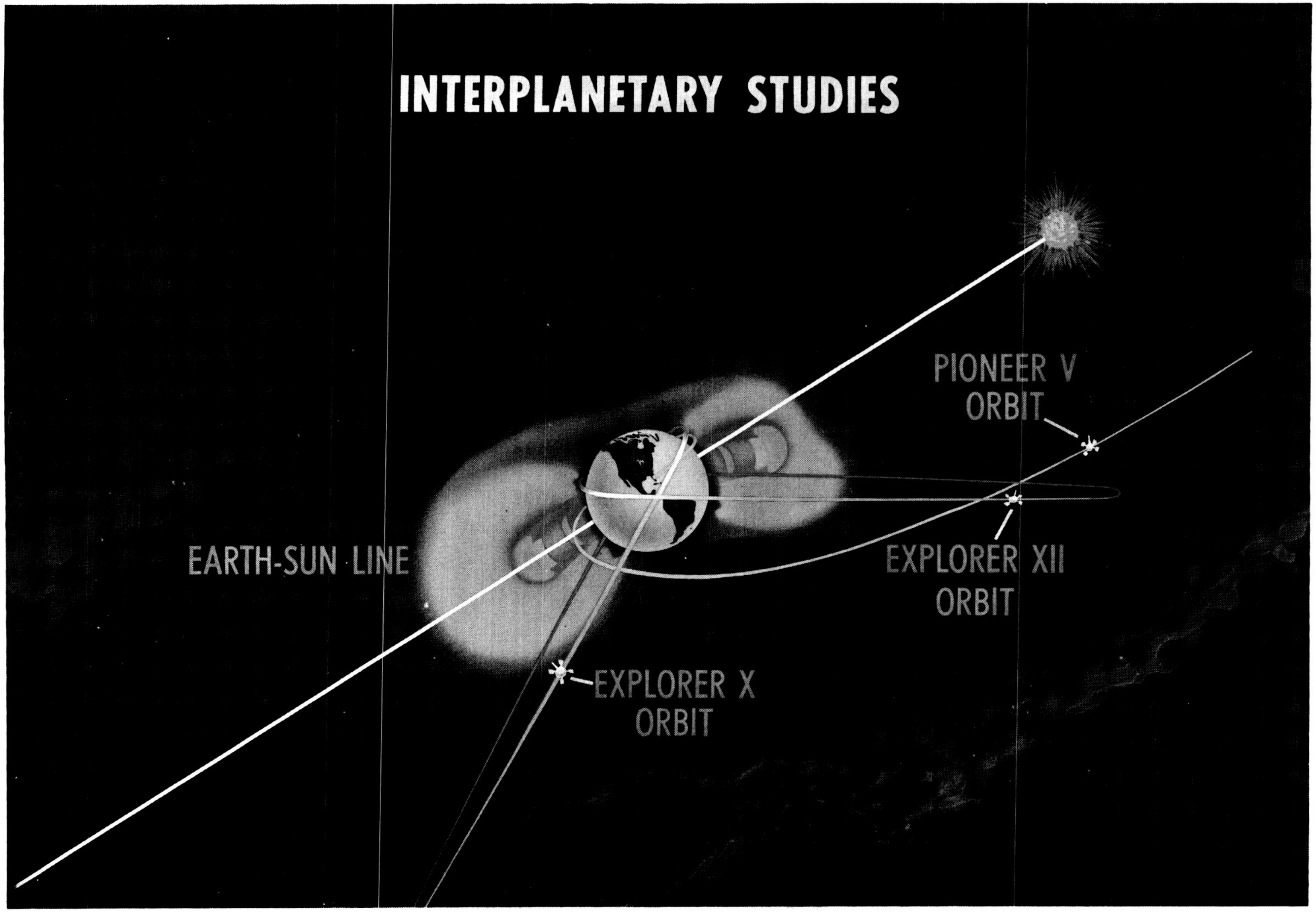
SLIDE #9

SOLAR SPECTRUM (120A-400A)
SEPT 30 1961
TIME 14:33 (GMT) ALT. 201 TO 216 KM

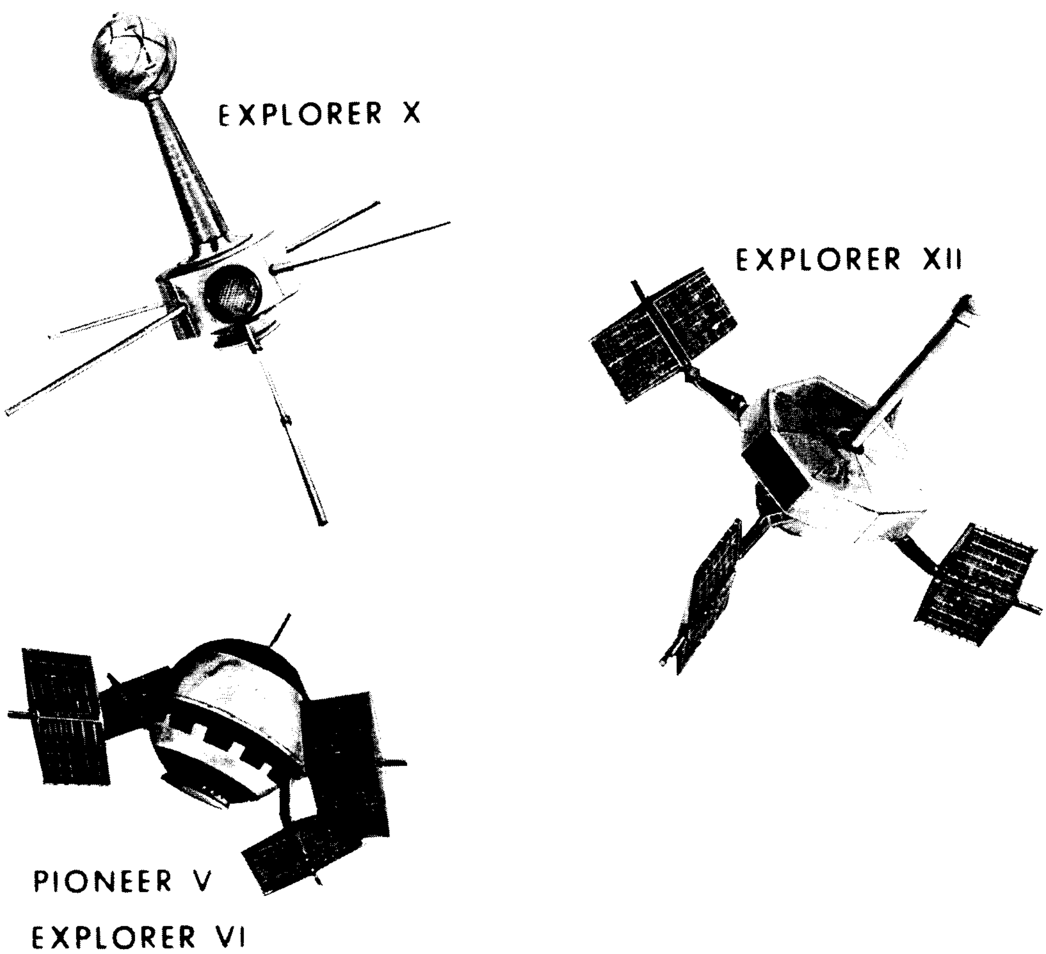




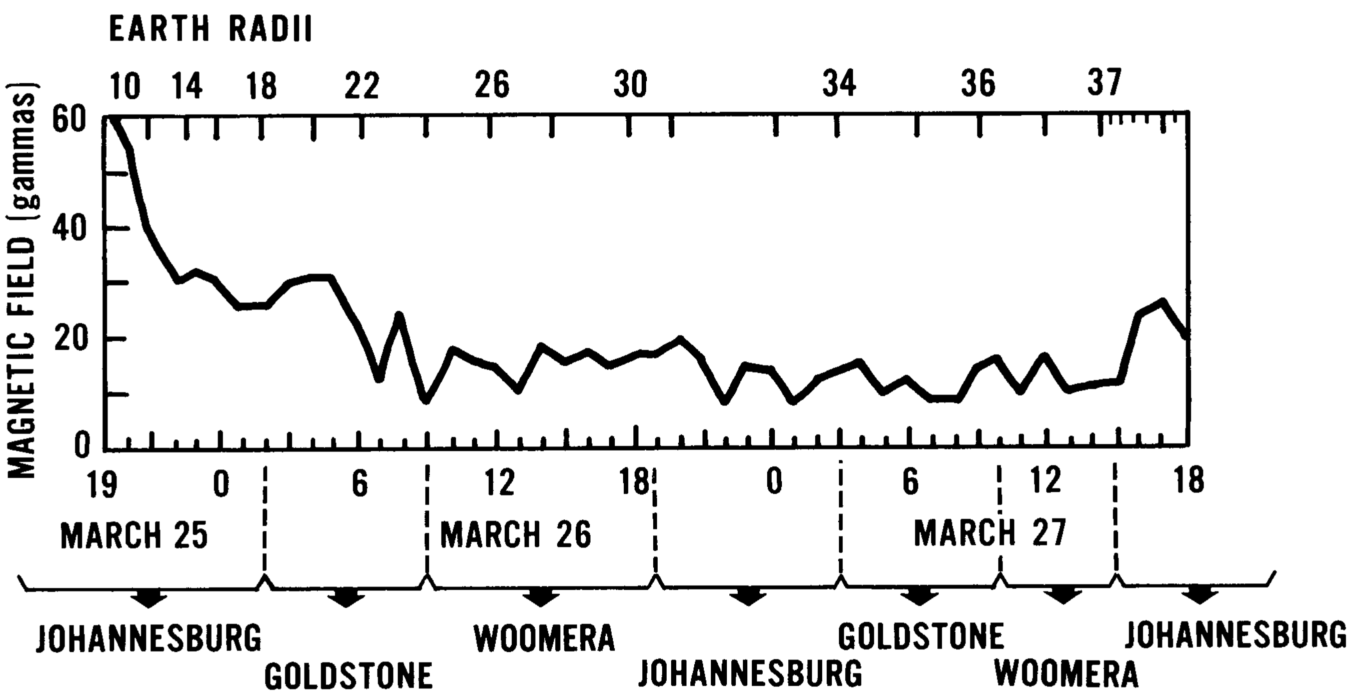
SLIDE #10


INTERPLANETARY STUDIES
PIONEER V
ORBIT
EARTH-SUN LINE
EXPLORER XII
ORBIT
EXPLORER X
ORBIT

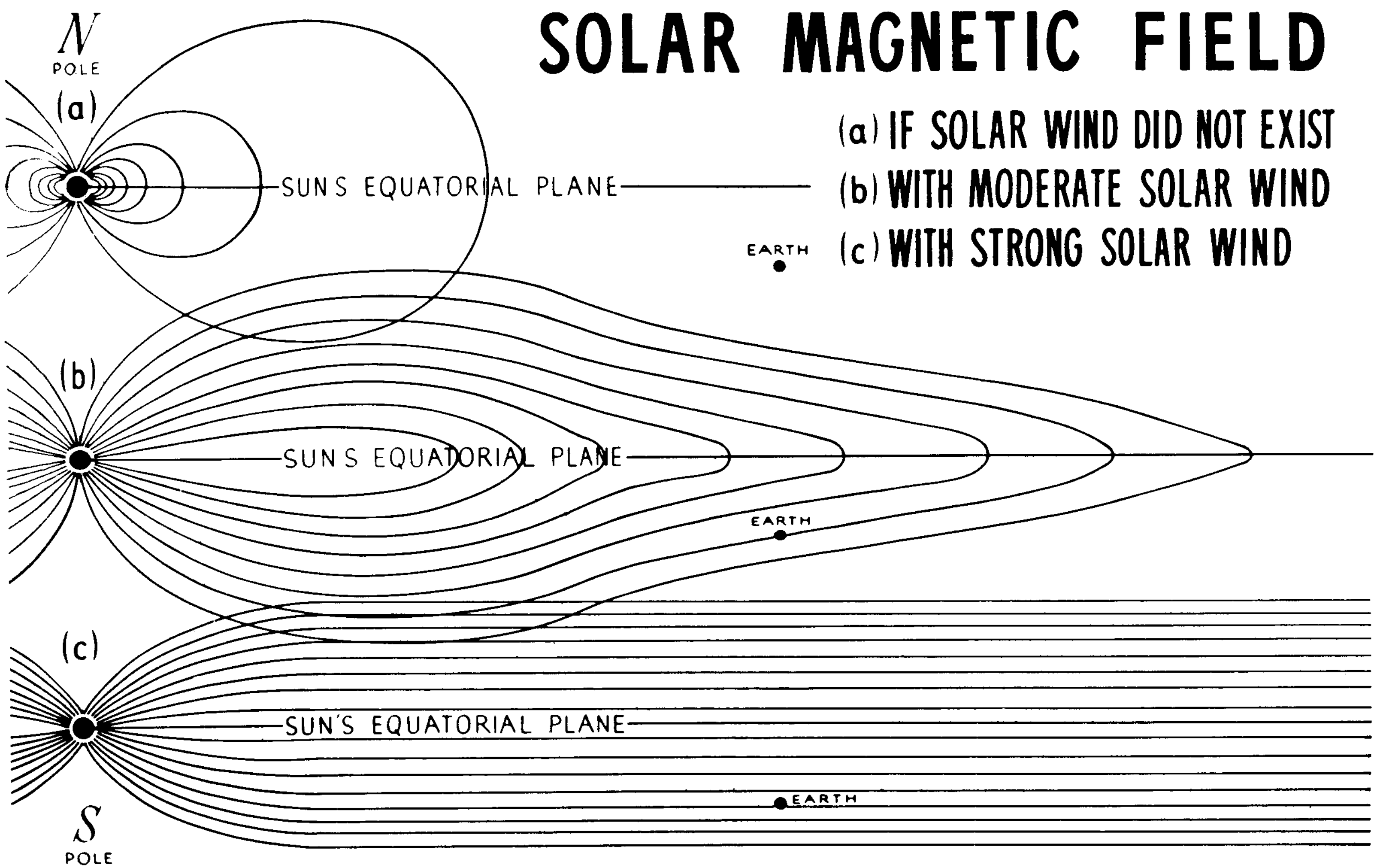
SLIDE #11



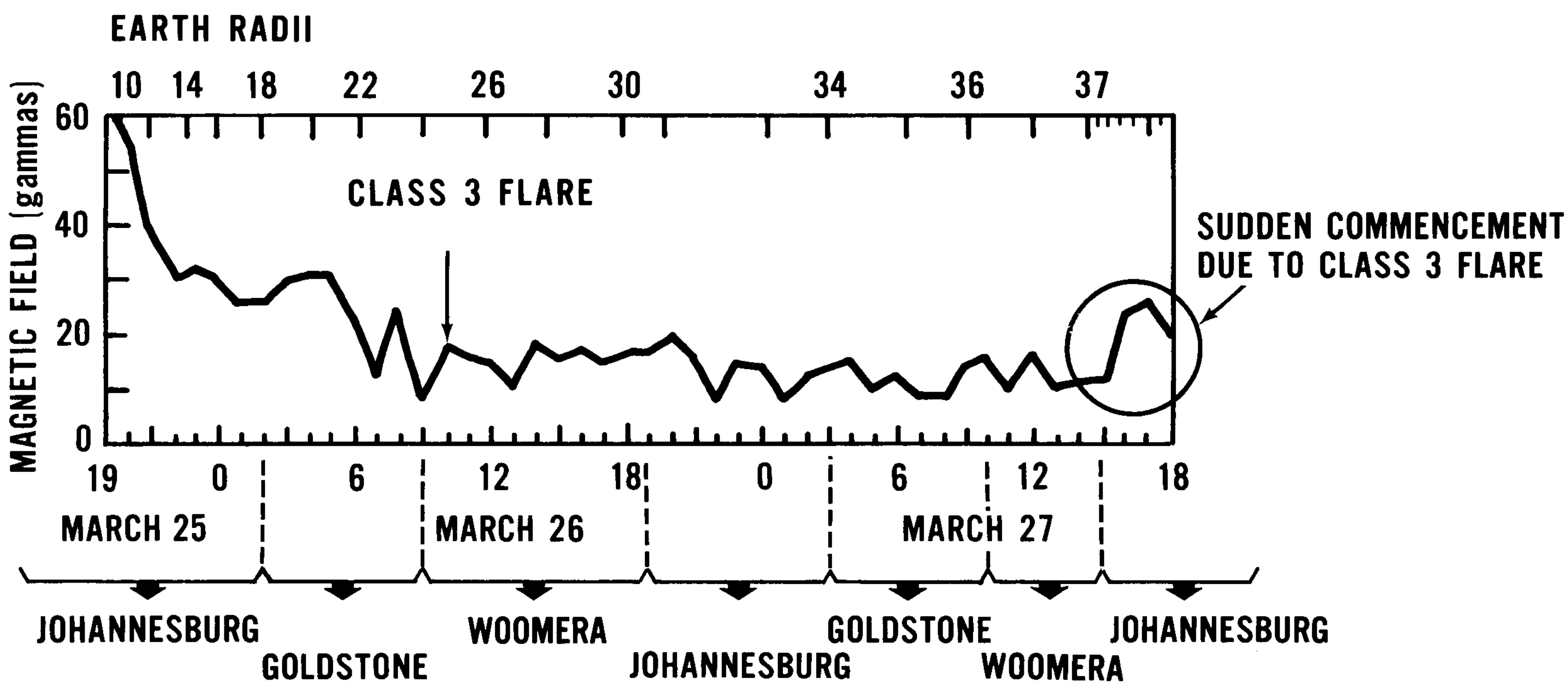
SLIDE #12


EARTH RADII
10 14 18 22 26 30 34 36 37
MAGNETIC FIELD (gammas)
60 40 20 0
19 0 6 12 18 0 6 12 18
MARCH 25
MARCH 26
MARCH 27
JOHANNESBURG
GOLDSTONE
WOOMERA
JOHANNESBURG
GOLDSTONE
WOOMERA
JOHANNESBURG

SLIDE #13

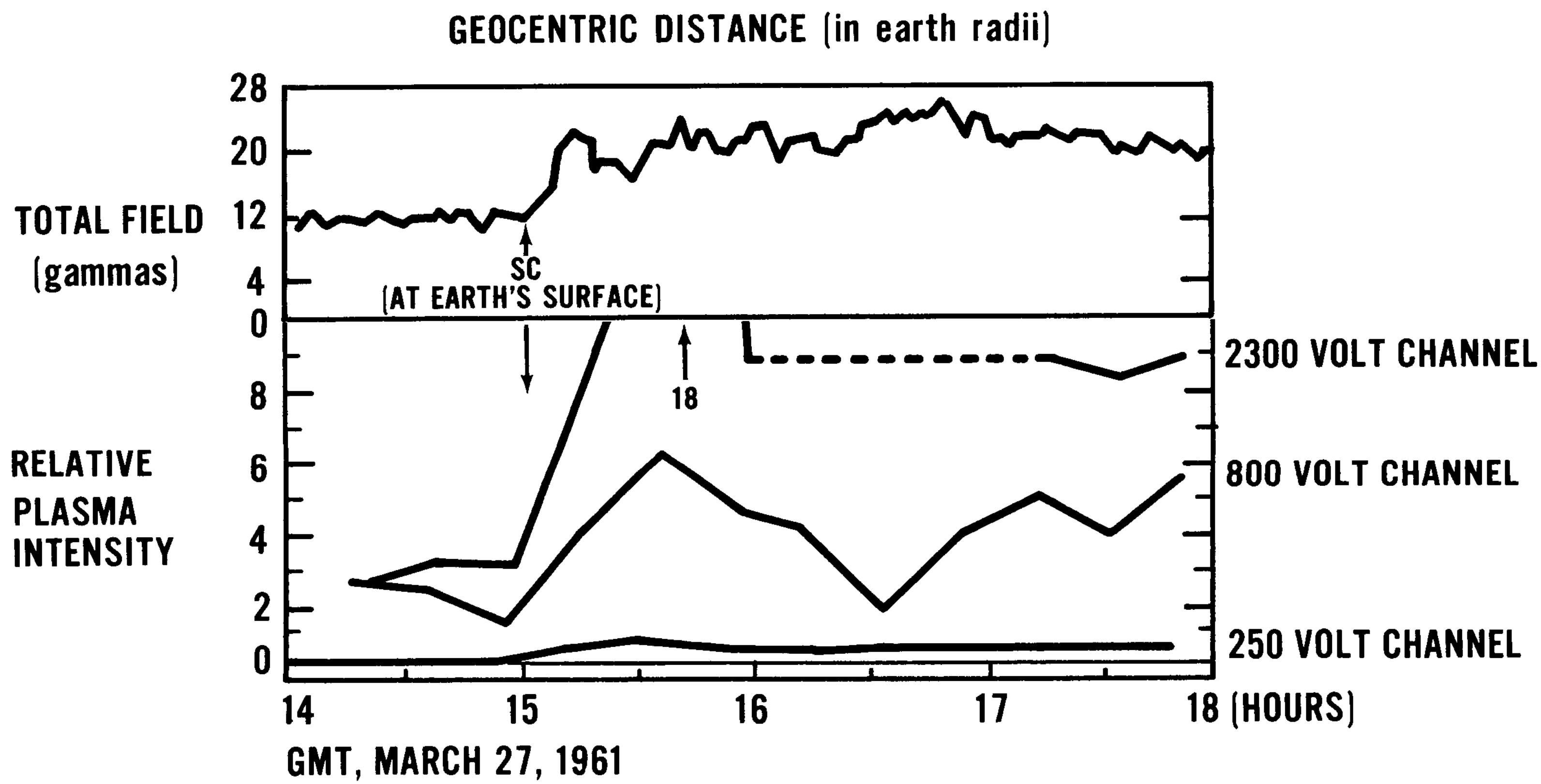

SOLAR MAGNETIC FIELD
(a) IF SOLAR WIND DID NOT EXIST
(b) WITH MODERATE SOLAR WIND
(c) WITH STRONG SOLAR WIND
N POLE
S POLE
(a)
(b)
(c)
SUN'S EQUATORIAL PLANE
SUN'S EQUATORIAL PLANE
SUN'S EQUATORIAL PLANE
EARTH
EARTH
EARTH

SLIDE #14

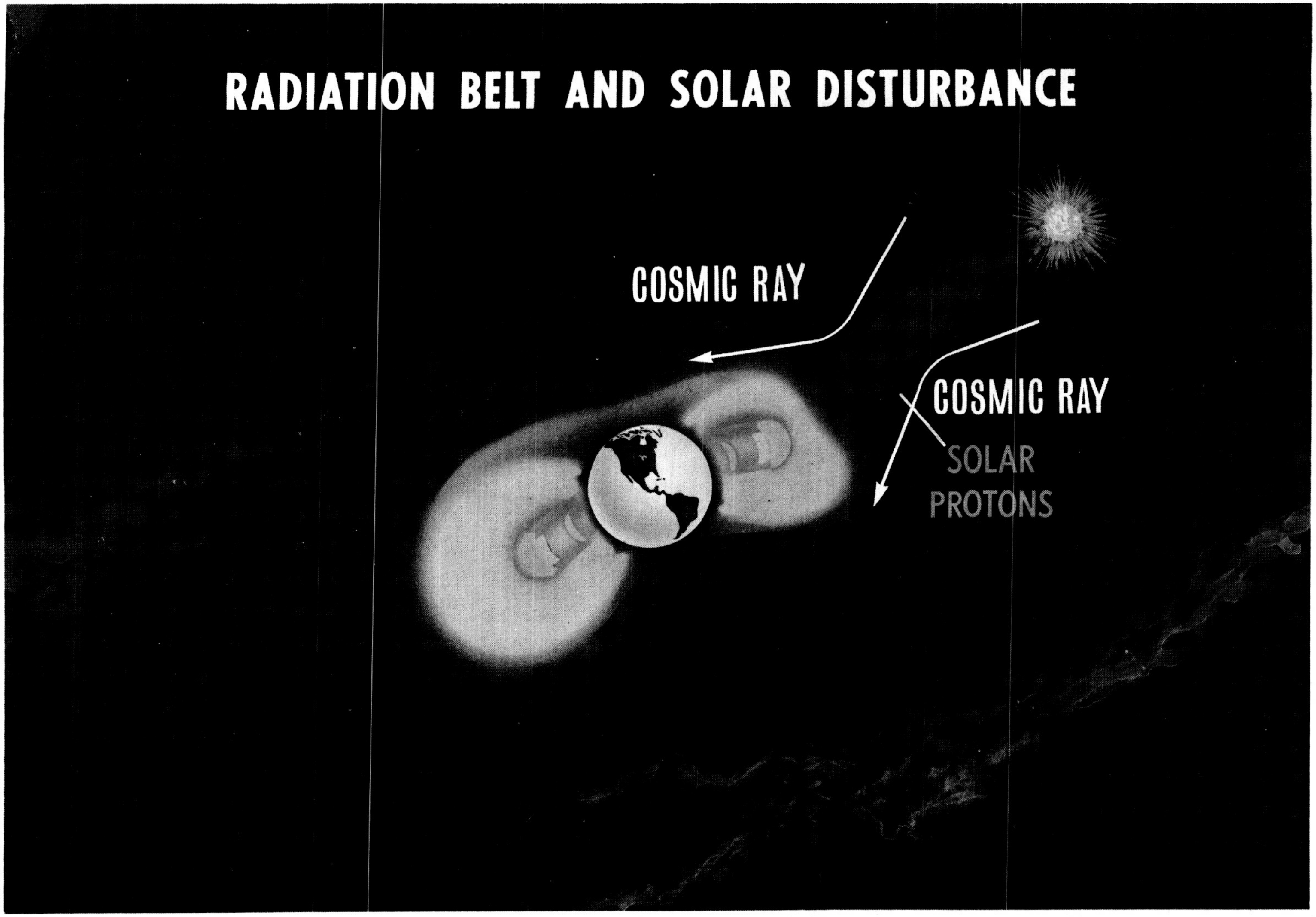


EARTH RADII
10 14 18 22 26 30 34 36 37
MAGNETIC FIELD (gammas)
60
40
20
0
CLASS 3 FLARE
SUDDEN COMMENCEMENT
DUE TO CLASS 3 FLARE
19 0 6 12 18 0 6 12 18
MARCH 25
MARCH 26
MARCH 27
JOHANNESBURG
GOLDSTONE
WOOMERA
JOHANNESBURG
GOLDSTONE
WOOMERA
JOHANNESBURG

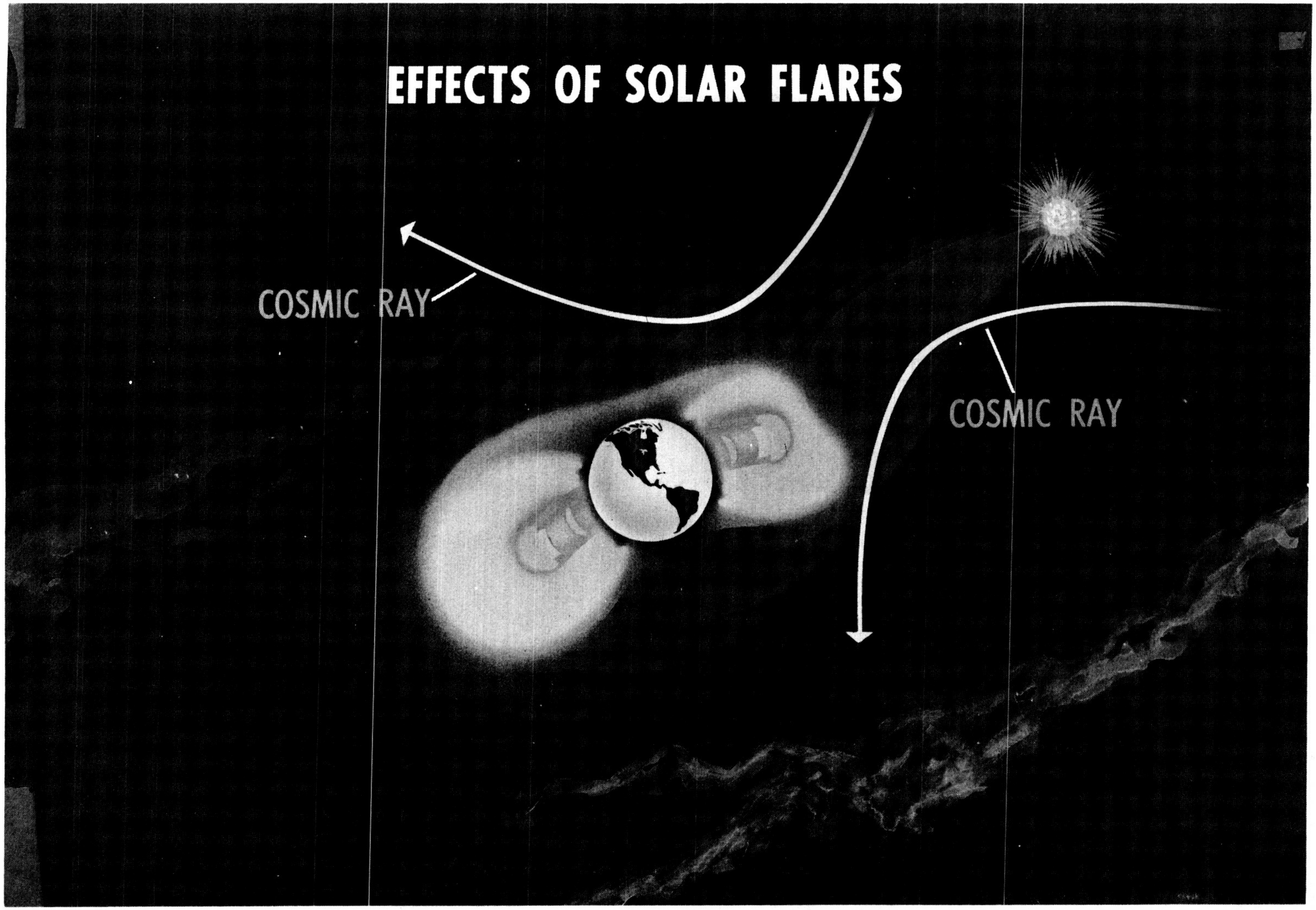
SLIDE #15


GEOCENTRIC DISTANCE (in earth radii)
TOTAL FIELD (gammas)
RELATIVE PLASMA INTENSITY
SC (AT EARTH'S SURFACE)
18
2300 VOLT CHANNEL
800 VOLT CHANNEL
250 VOLT CHANNEL
14
15
16
17
18 (HOURS)
GMT, MARCH 27, 1961

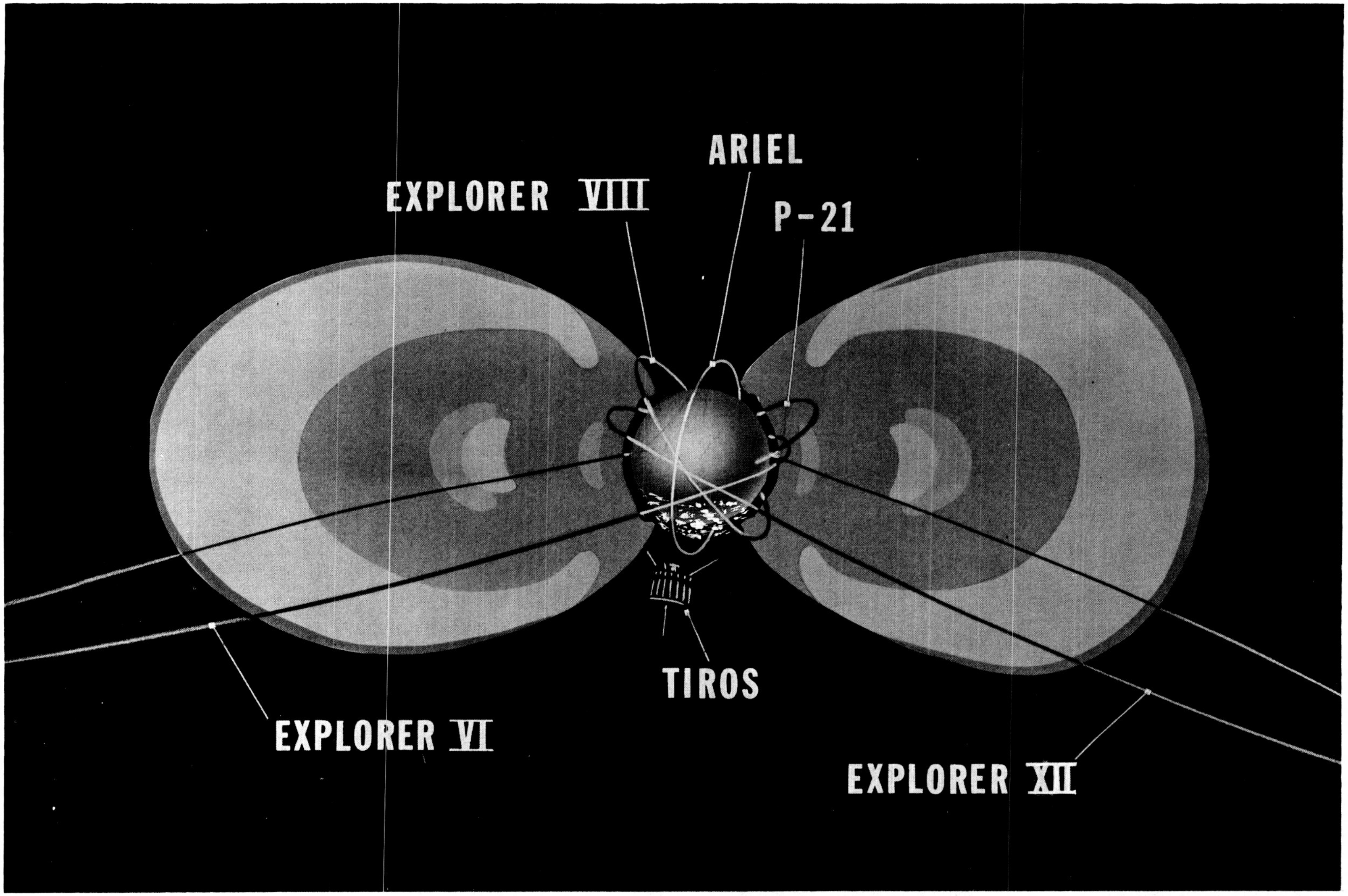
SLIDE #16


RADIATION BELT AND SOLAR DISTURBANCE
COSMIC RAY
COSMIC RAY
SOLAR
PROTONS

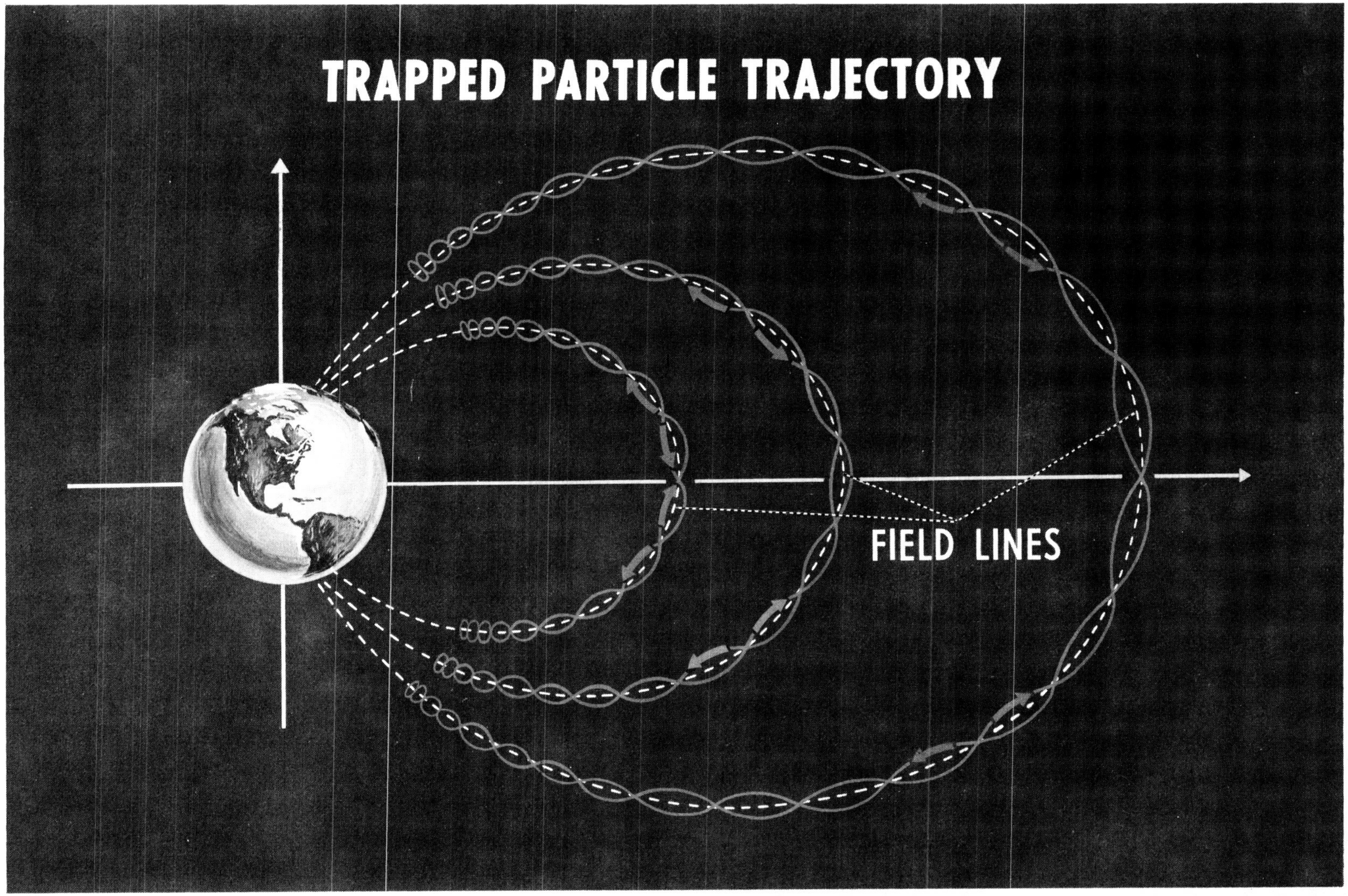
SLIDE #17



SLIDE #18

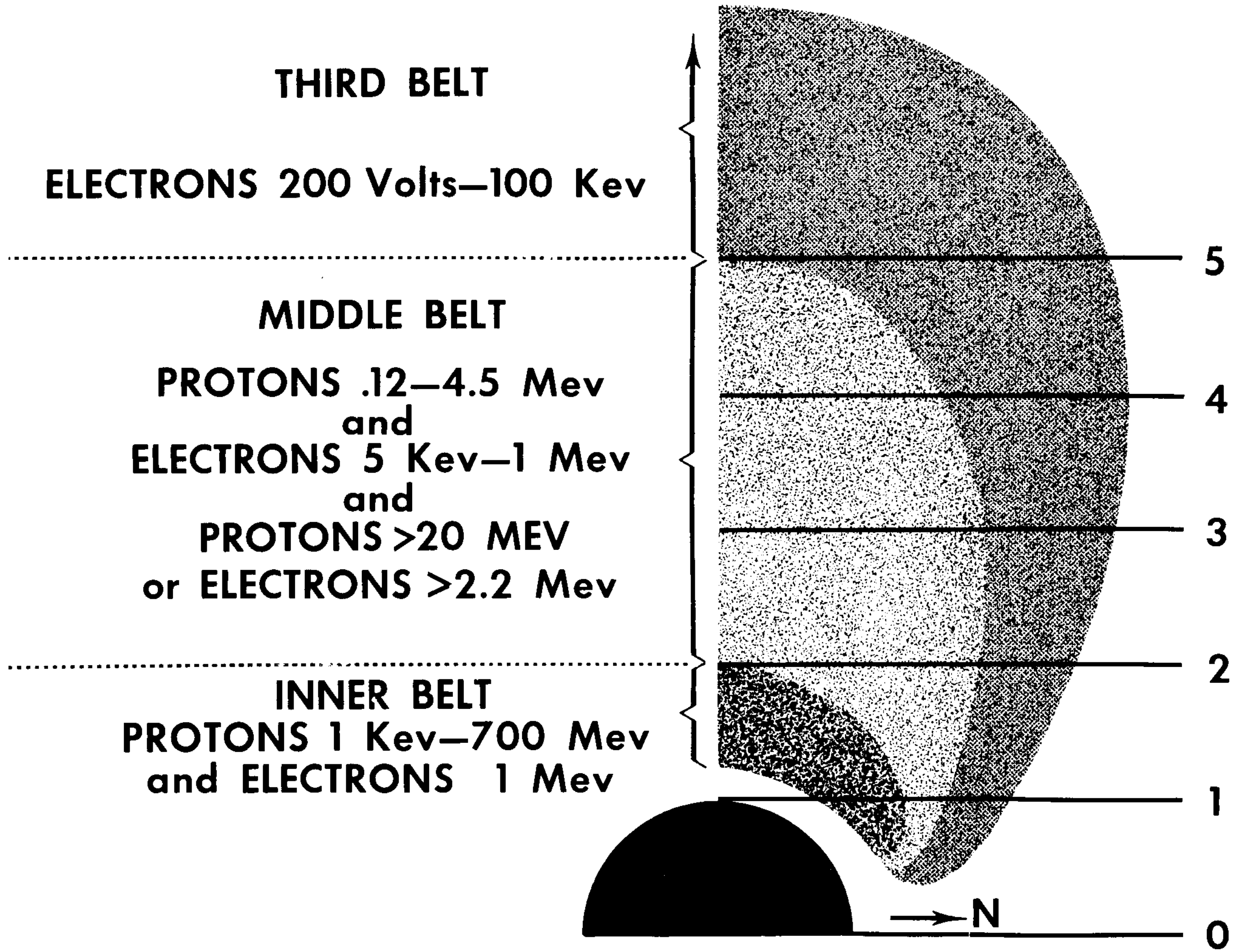


SLIDE #19

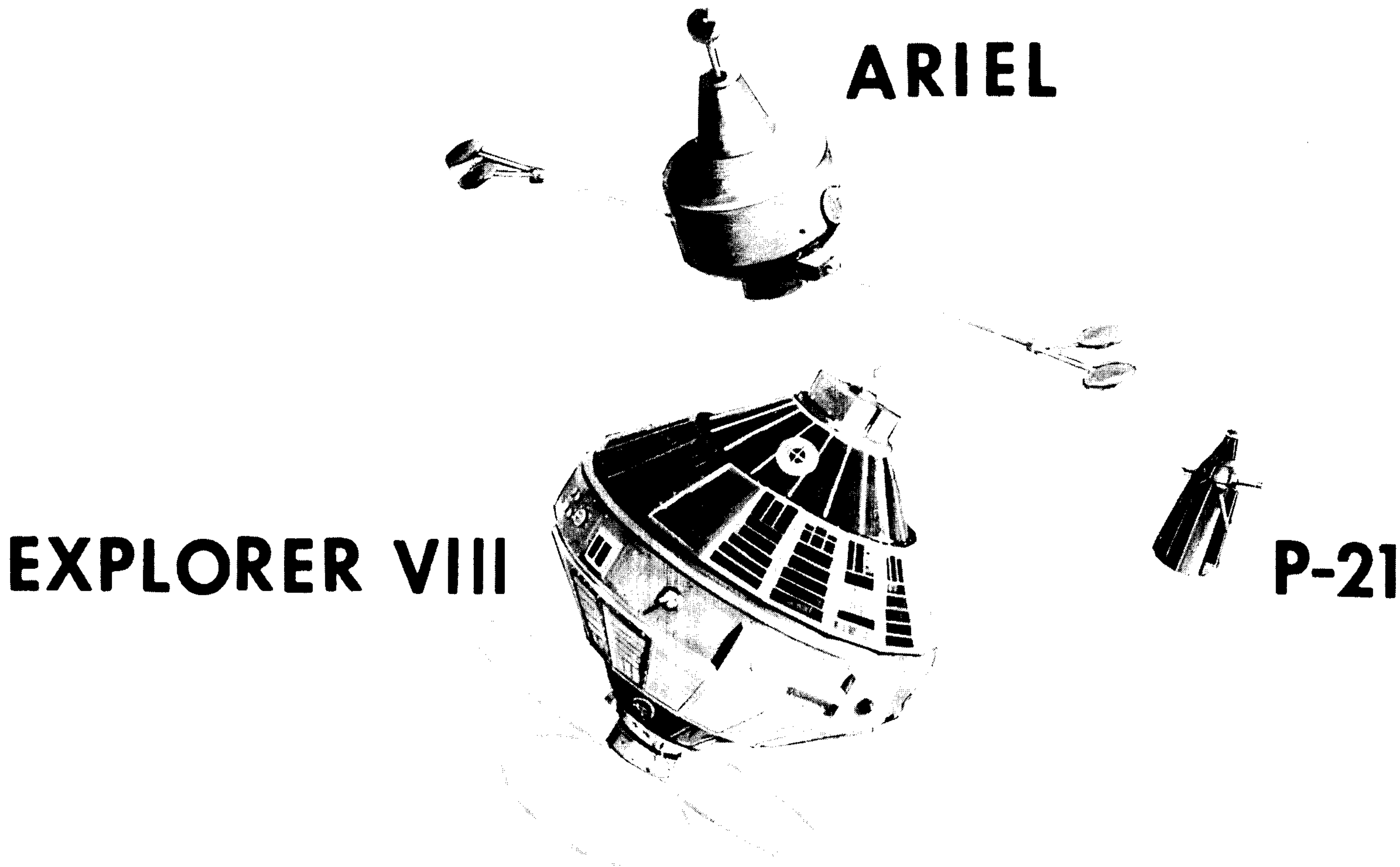


SLIDE #20

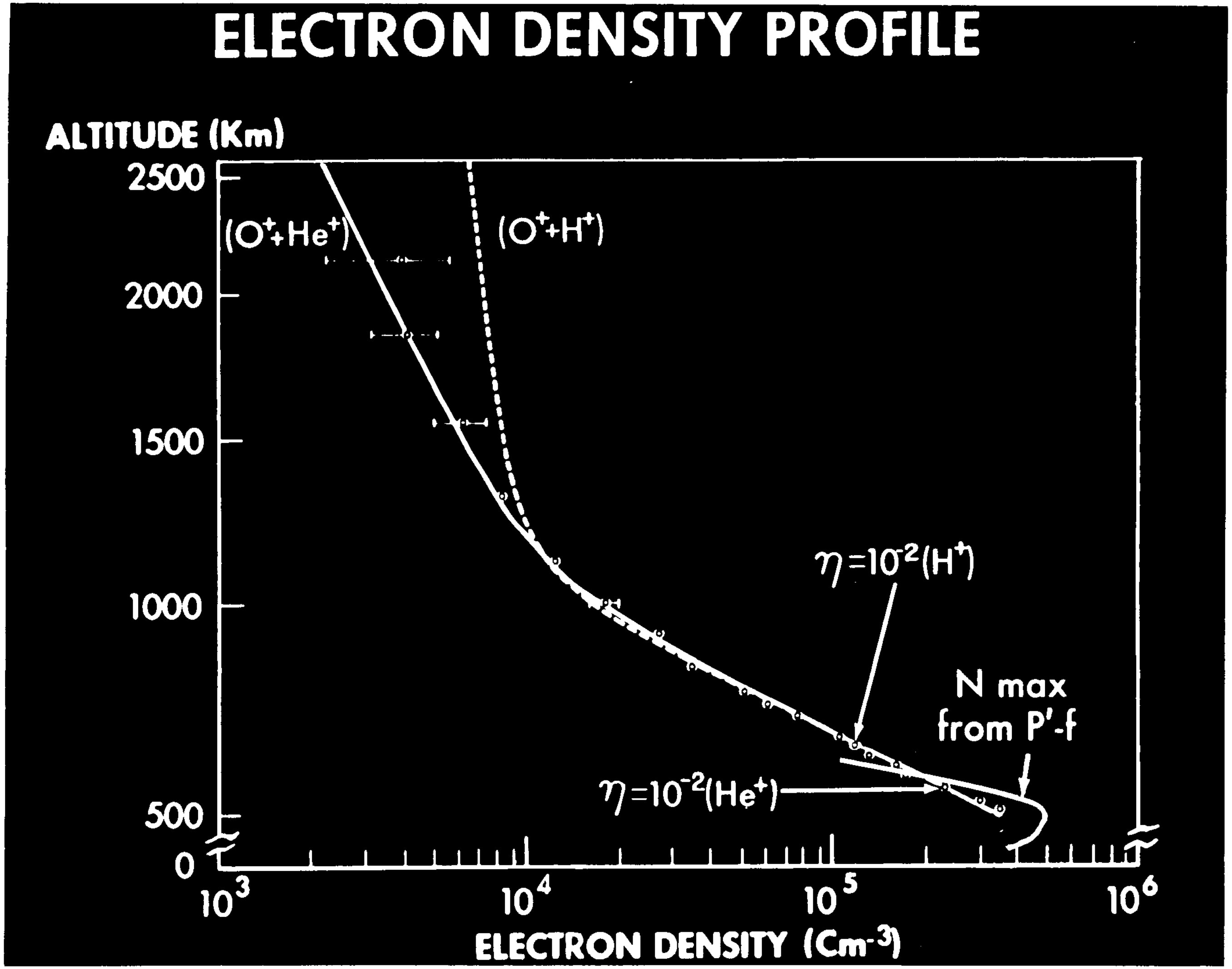
COMPOSITION OF RADIATION BELT



SLIDE #21



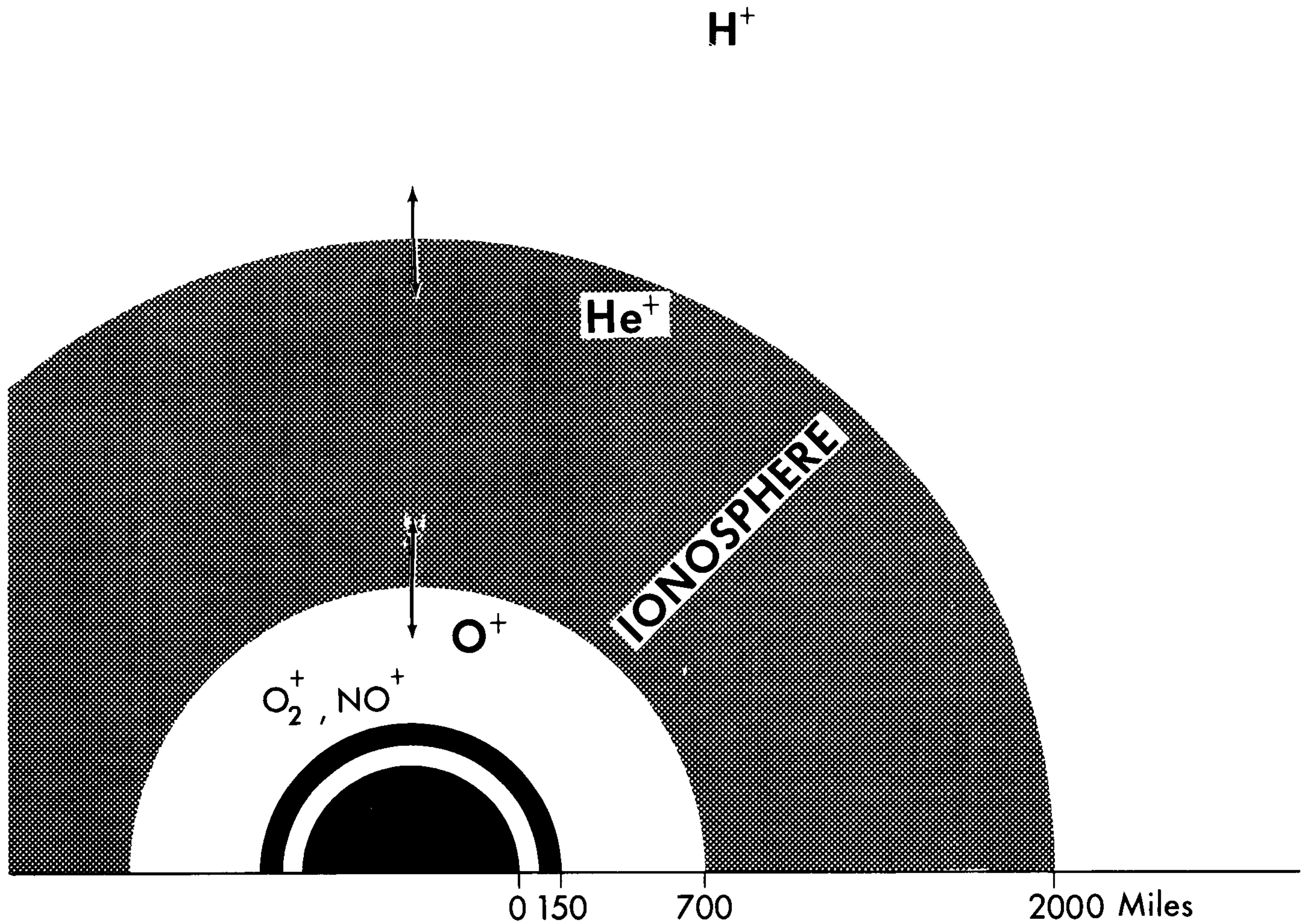
SLIDE #22



ELECTRON DENSITY PROFILE
ALTITUDE (Km)
2500
2000
1500
1000
500
0
$(O^+ + He^+)$
$(O^+ + H^+)$
$\eta = 10^{-2}(H^+)$
N max
from P'-f
$\eta = 10^{-2}(He^+)$
10^3
10^4
10^5
10^6
ELECTRON DENSITY (Cm^{-3})

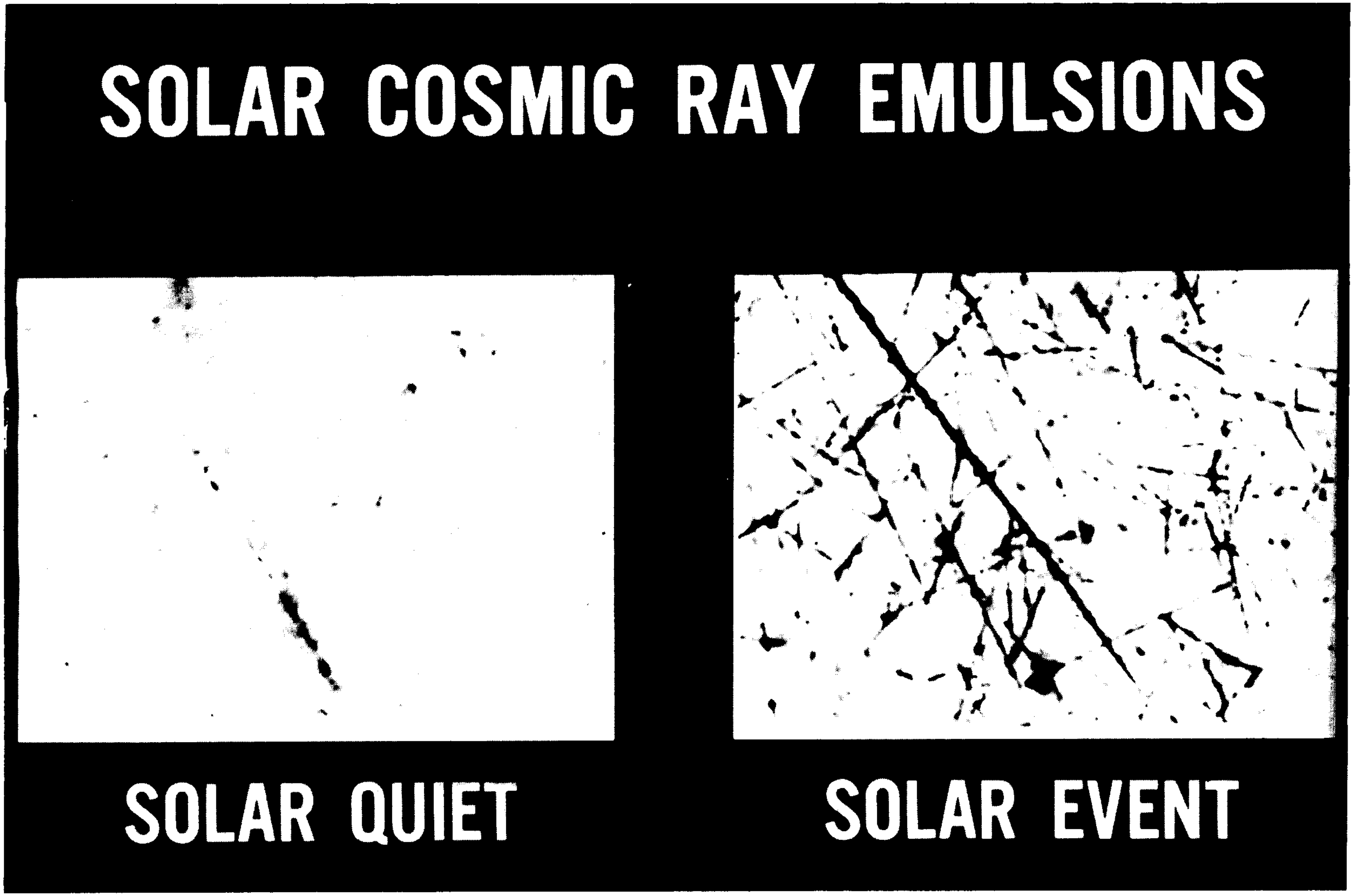
SLIDE #23

PRINCIPAL ATMOSPHERIC IONS



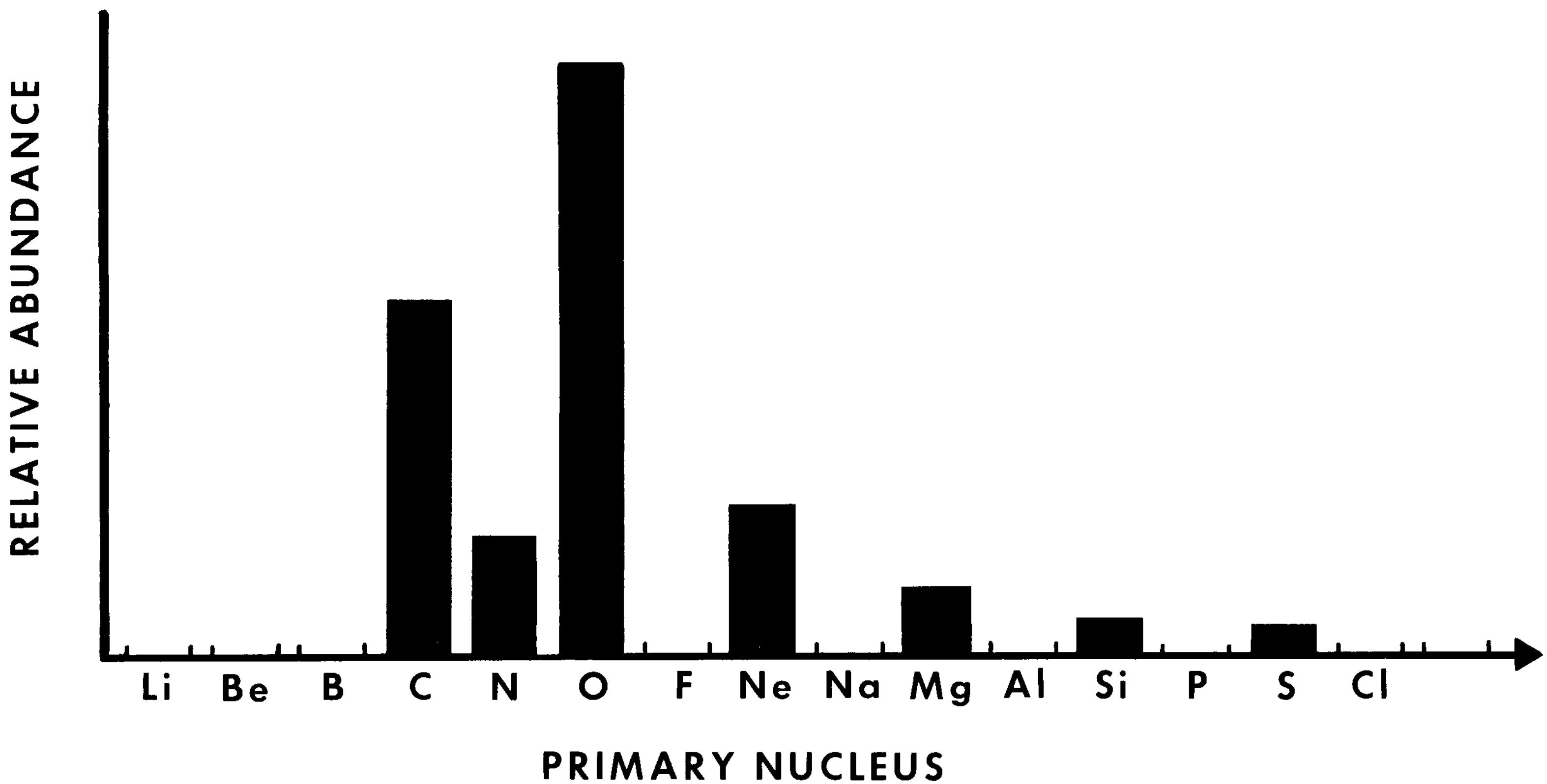
SLIDE #24

SLIDE #25

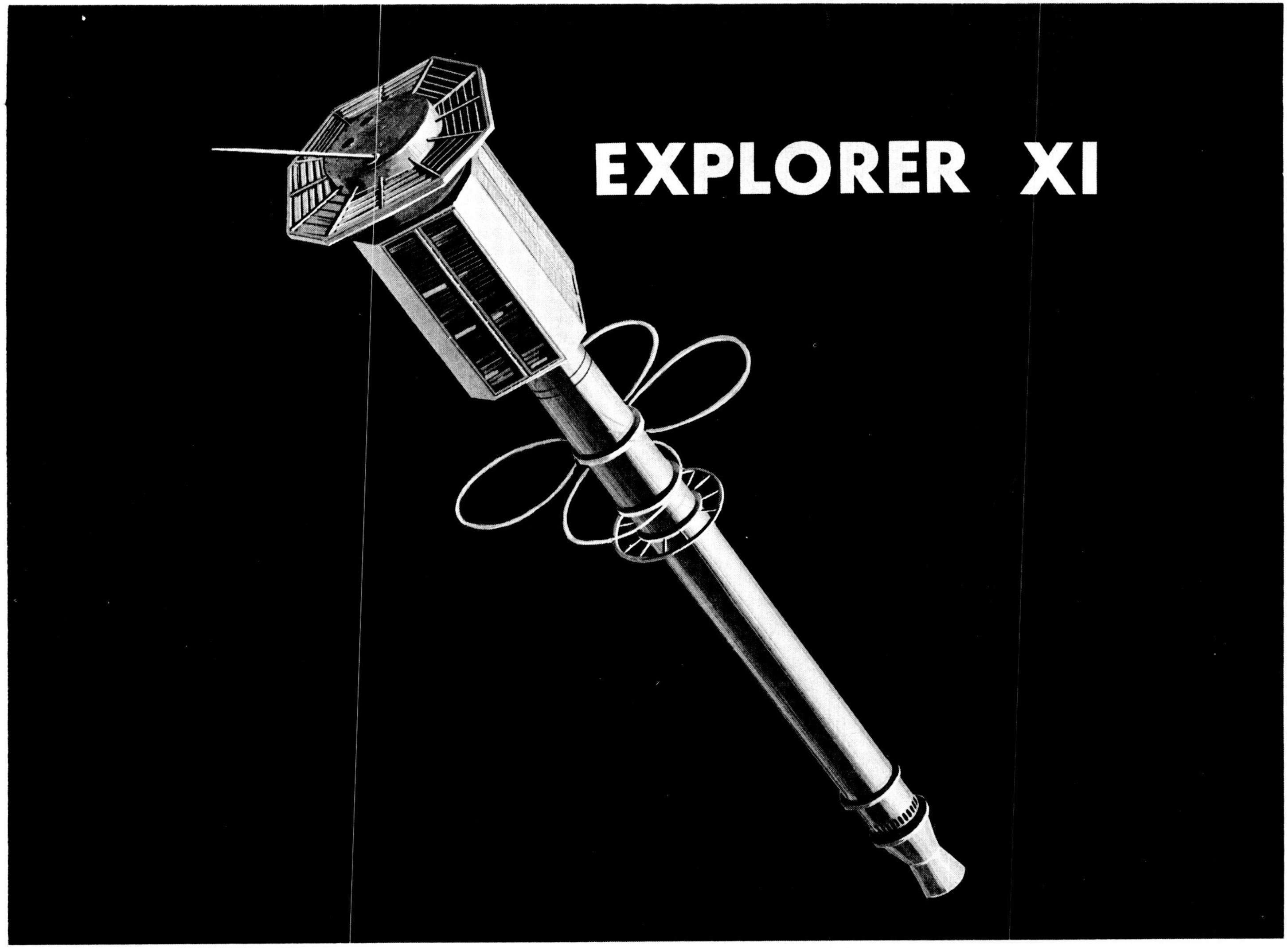


SLIDE #26

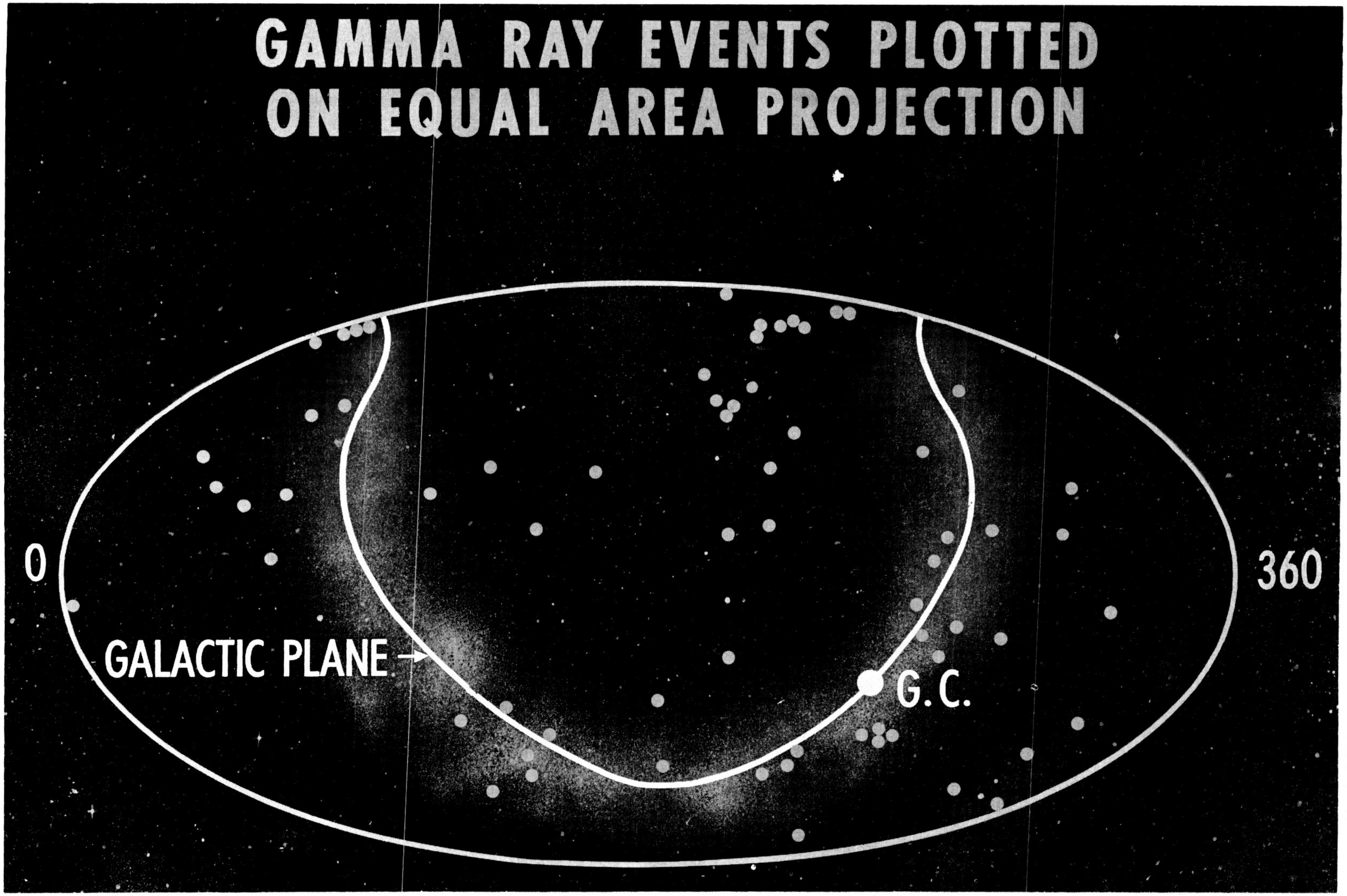
CHARGE DISTRIBUTION OF HEAVY NUCLEI IN A SOLAR COSMIC RAY EVENT



SLIDE #27

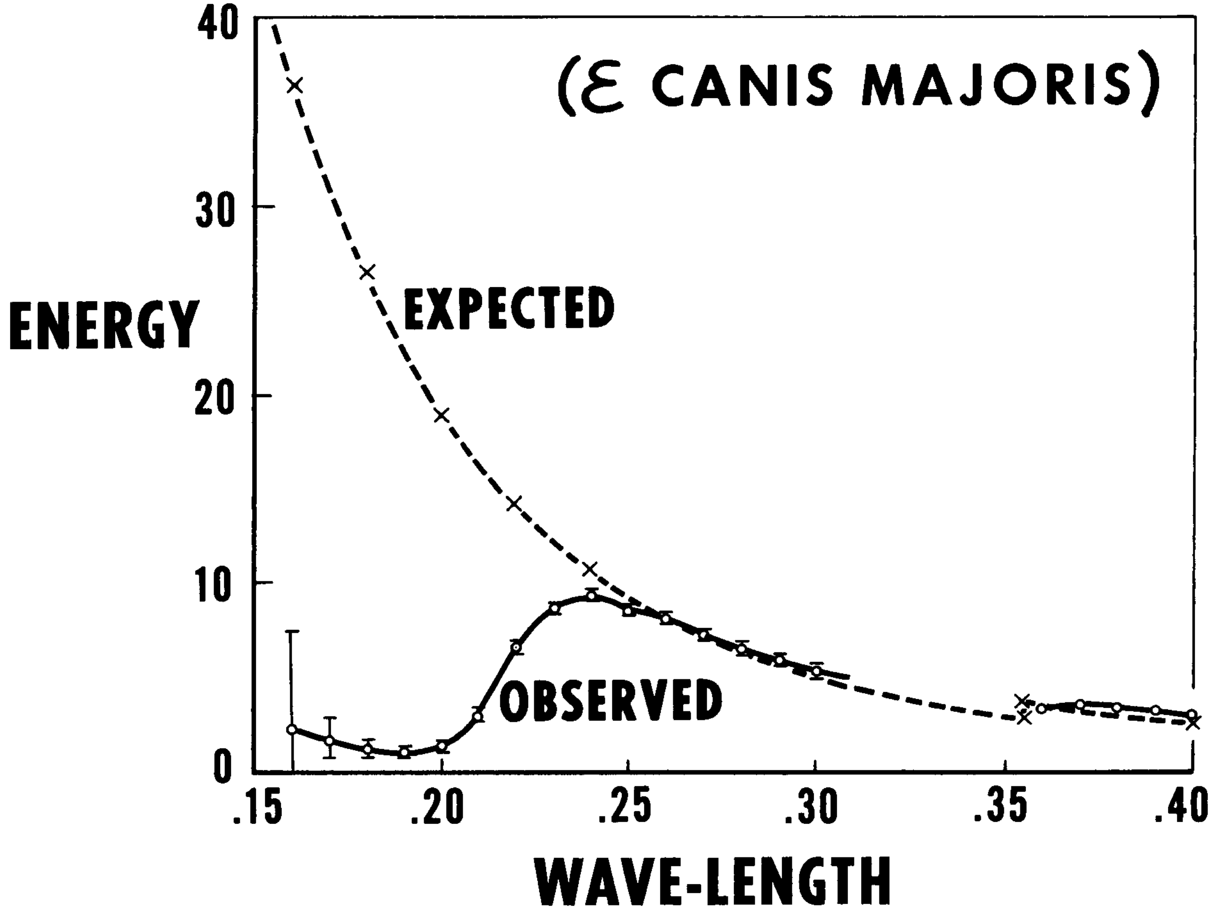


SLIDE #28

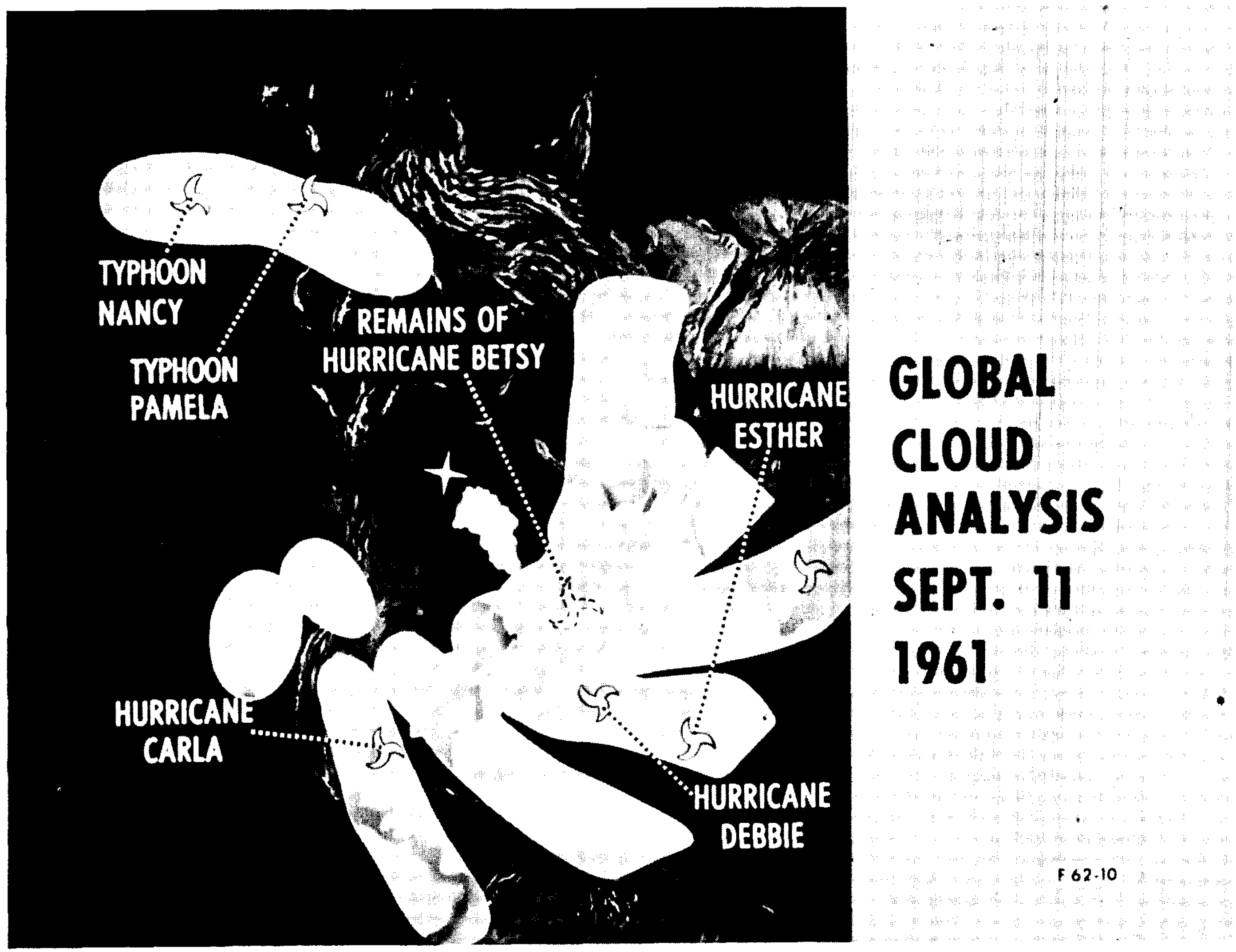

GAMMA RAY EVENTS PLOTTED
ON EQUAL AREA PROJECTION
0
360
GALACTIC PLANE
G.C.

SLIDE #29

ENERGY DISTRIBUTION OF EARLY TYPE STAR



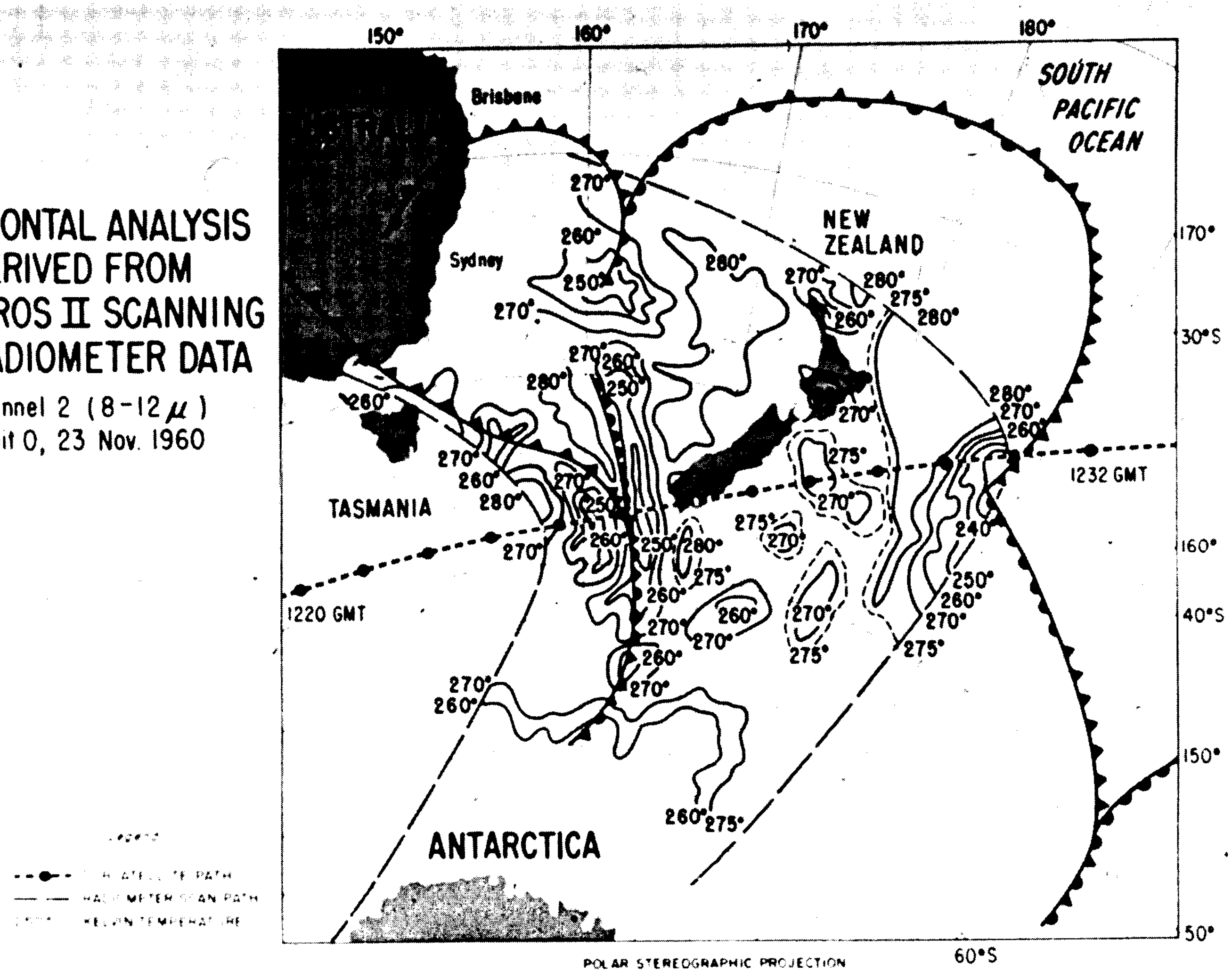
SLIDE #30


TYPHOON
NANCY
TYPHOON
PAMELA
REMAINS OF
HURRICANE BETSY
HURRICANE
ESTHER
HURRICANE
CARLA
HURRICANE
DEBBIE
GLOBAL
CLOUD
ANALYSIS
SEPT. 11
1961
F 62-10

SLIDE #31

FRONTAL ANALYSIS DERIVED FROM TIROS II SCANNING RADIOMETER DATA

Channel 2 (8-12 μ)
Orbit 0, 23 Nov. 1960



SLIDE #32