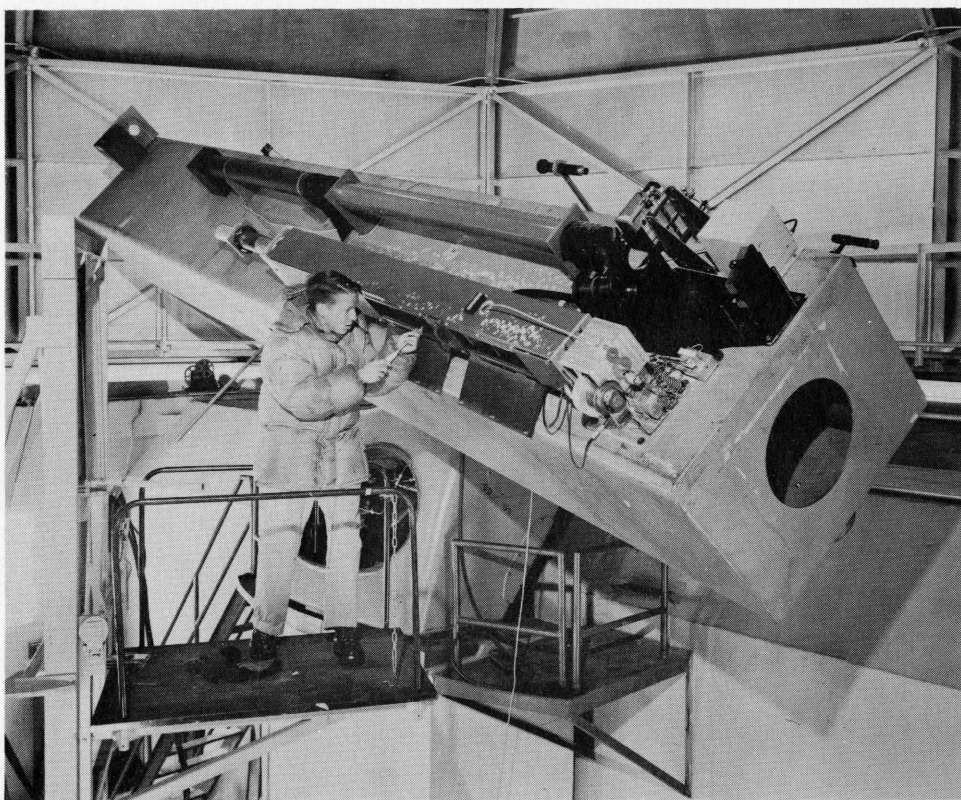


THE
DIRECTOR'S QUARTERLY REPORT

First and Second Quarters 1958

1 January to 30 June 1958



*Large Equatorial at Climax**

*High Altitude Observatory
of the
University of Colorado
Boulder and Climax, Colorado*

The High Altitude Observatory is an independent non-profit research and educational institution closely associated with the University of Colorado. Its major research objectives are study of the sun and the sun's effects on the earth.

*Cover: The 26-foot photoelectrically-guided equatorial spar in the large solar laboratory at Climax. Hobart is making adjustments on the K-coronameter which is mounted on the left of the upper face of the equatorial. Hobart is standing on the steerable elevator platform, some 15 feet above the floor of the Observatory. To the right of the K-coronameter is a special spectrograph constructed by Newkirk to observe the aurora on Venus (see page 12) during the planet's close approach to earth last winter.

SUMMARY

Science is moving at so fast a pace that every few years bring vastly improved means of measuring the physical phenomena of the upper atmosphere and of space. This means that every few years, when the sun suddenly unleashes an extraordinarily potent burst of radiation or matter to space, we have the means to make rather spectacular new discoveries. The dates of these events become important milestones in the progress of science. For example, here are just a few dates that have made astro-geophysical history:

- (1) 1 September 1859: A brilliant solar flare observed by R. C. Carrington in England by white light. It was followed by brilliant auroras and magnetic storms, and led to the association of specific solar outbreaks with these geophysical events.
- (2) 4 June 1946: The largest eruptive prominence ever detected--photographed at HAO, Meudon Observatory, McMath-Hulbert Observatory and elsewhere.
- (3) 25 July 1946: One of the largest flares in history, magnificently recorded at Meudon Observatory, and also detected at Climax by the late French astronomer, Dr. Bernard Lyot and me. Lyot, inventor of the coronagraph was, by chance, visiting the Observatory on this day.
- (4) 19 November 1949: A flare of large, but not outstanding proportions, that produced a sizeable increase of cosmic rays,

and greatly stimulated the search for similar events.

(5) 23 February 1956: Another flare with a cosmic ray increase, this time by tremendous proportions, with associated world-wide ionospheric effects, as described in our earlier reports.

A flare of large size, observed on the 22nd of August from Russia, Europe and America, produced extraordinary solar radio noise emissions. The event, described below under Highlights, will probably join the list of outstanding solar events of all time.

When equipment and observers succeed in obtaining detailed records of such events, it is only because long periods of unexciting vigil have preceded. It is the outstanding events, in part, that justify the long sequences of unspectacular and sometimes even "worthless" records that have preceded. This report chronicles another of these remarkable solar outbreaks, which I was fortunate enough to observe. I presume that in future periods there will be reason to make other comments on the implications of this event.

As once before, this report covers two quarters. During this period the HAO staff paid particular attention to problems of basic physics of solar flares, to preparation for the solar eclipse of October, and to interpretation of solar and satellite records with our new radio astronomical equipment. In particular, Warwick found a new method to calculate upper air densities from the declining spin rate of Sputnik I.

We also found some encouraging signs that our earlier findings on

the development of stronger cyclonic activity after geomagnetic storms was a real effect, and not just an accidental correspondence during a short period of analysis. This work, in the long run, may prove to be of considerable practical importance in long range forecasting, but for the present we are concentrating on establishing whether it is true, and on speculating about the possible means by which the apparent effects are produced.

The period also saw significant increases in the strength of the astro-geophysics graduate department. A growing student group is forming, and there is strong likelihood that we shall reach our full planned strength within a few years, if we can find adequate funds to aid worthy graduate students. Fellowship money from the Institute for Solar-Terrestrial Research is playing a highly valuable and stimulative role.

Needless to say, the IGY program occupied a major place in our observing schedule for the period. Moreover, the flow of information to our IGY Solar Data Center reached gratifying proportions. It will represent a major scientific resource in the years to come.

In January Venus came close to earth, and Newkirk made a strong effort to photograph the spectrum of its suspected aurora, with results that seem positive, and will encourage us to try vigorously again during the next and more favorable approach about a year from now.

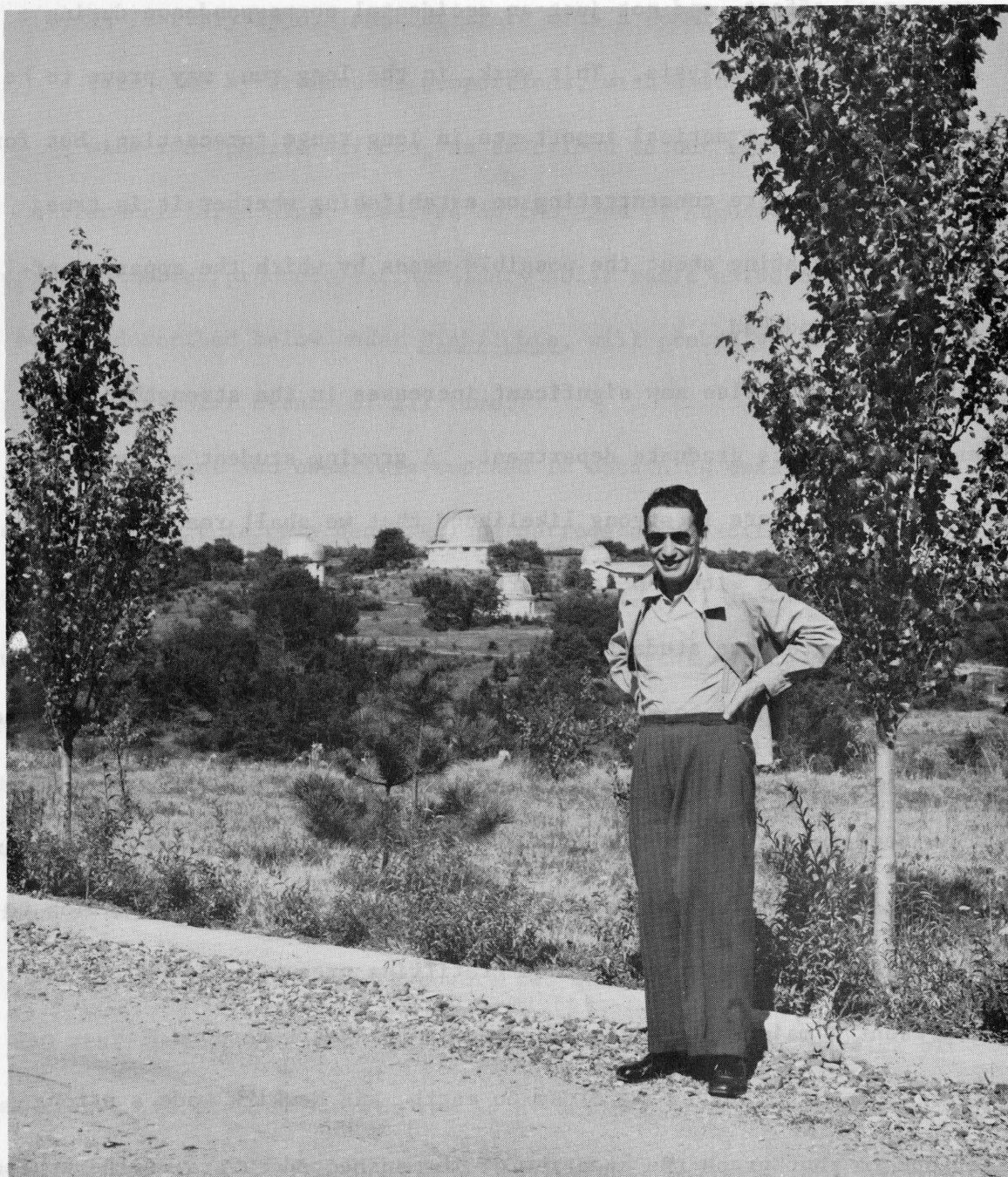


FIGURE 1

Dr. A. B. Severny, Director of the Crimean Astrophysical Observatory, U.S.S.R., standing on the drive to the solar tower of the Observatory. In the background are domes of several stellar telescopes. The picture was taken by Roberts during his stay in the Crimea.

I. INTRODUCTION

A. Made in the U.S.S.R.

The first pages of this issue of the Director's Report are written from within Russia. As I dictate these pages on my portable tape recorder, I am sitting on the balcony of a guest room in the main building of the Crimean Astrophysical Observatory, deep in the south of the Soviet Union, near the town of Partisanskoe, Crimea, U.S.S.R.

It is a beautiful sunny morning, this 23rd of August, and my balcony overlooks a garden of flowers, then out past the homes of the scientific staff of the Observatory, and to the very beautiful, densely wooded hills lying beyond. The nearby landscape has already turned brown except where it is watered; almost no rainfall occurs here at this time of year.

Off to the right are hills with chalk-like white stone on the steeper slopes, and the low sparse vegetation characteristic of arid regions. Beyond are sharply rising cliffs, surmounted by a level mesa. It could easily be New Mexico.

Far to the left the large solar tower shimmers brilliantly in the sun, and I can see by the open aperture that the observers are at work. This tower and associated instruments, which I used myself for a time yesterday, is well designed and executed, and of adequate size for high resolution solar work. The image quality that I saw yesterday morning was excellent. Clearly this is an outstanding solar observatory.

Behind me I can hear the tractors and air hammers working on a new administration building and research laboratory. More housing and other new facilities are also going up rapidly. The total population of this isolated observatory is already over 250, and judging by the rate of progress of construction, the scientific potential of the station may well be doubled within a few years. Up on a hill east of this building I have just visited the foundation work for a 106-inch nighttime telescope that is under construction. The site also includes five or six other astronomical domes, an ionospheric station, a cosmic ray laboratory, a geomagnetic station, and a solar radio noise observatory.

My visit to Russia was to attend two scientific meetings, and to visit this station, the principal solar observatory of the U.S.S.R. My first three weeks were devoted to the International Geophysical Year planning committee meetings and the International Astronomical Union meetings, both held in Moscow. I am planning to write a separate report

on my trip for distribution to those interested, so I won't describe it further here.

B. Case History: A Large Flare Detected at the Crimean Observatory.

Solar flares are among the most spectacular and most important of the sun's phenomena. Only yesterday, as I write this, I saw a graphic demonstration of some of the things that happen during a solar flare.

I spent yesterday morning in the solar tower of the Crimean Astrophysical Observatory. For awhile I used the telescope myself, and scanned with the spectroscope across a very complex sunspot region about 20° north of the solar equator. This region had a tremendous number of small sunspots in it. As Dr. Severny, director of the Observatory, and I looked at the region with the new magnetic field measuring instrument, we found places with extremely steep magnetic field "hills." The spot group had grown rapidly on the disk, and seemed like an excellent one to be the seat of major flares. Later, as I sat in Dr. Severny's office discussing the spectra of solar flares, the loudspeaker brought in reports of minor flares in this region, detected in the coronagraph and flare patrol in the adjacent building. Nothing spectacular let go, however.

About 5:30 in the afternoon, while the sun was still about one and one-half hours above the horizon, I was in the radio astronomy building of the Observatory looking at the equipment. I had just started to leave when one of the observers called excitedly to say that the solar radio noise telescope recorder had started to climb. We rushed to the instrument and watched the needles rise to an extraordinarily high level, indicating strong activity on two different radio receivers, one on a wavelength of 10 cm, and one on a wavelength of $1\frac{1}{2}$ meters. A suddenly excited region was emitting powerful radio signals. I shot a picture of the meters, shown in Figure 1. The signals mounted, until both instruments went completely off the ends of the recording paper, and the amplification of the instrument had to be changed to bring them back on scale. We knew by then that a major flare was in progress. While we were watching, in came an excited call (all Russian telephone calls sound somewhat excited to me, but this one was more so than usual) and the news that the flare was Importance 3, as seen at the solar tower. This is almost as large as they come, and spectra were being taken.

We then rushed across to another portion of the building to an instrument that detects flare effects in the earth's ionosphere. It, too, showed violent reactions indicating that the radio reflectivity of the bottom layers of the earth's ionosphere had abruptly increased for long

wave radio signals, and we were picking up the 25 kilocycle radio noise of far distant thunderstorms, probably in the tropics, reaching us by reflection here in the Crimea at 45° latitude. These were the so-called SEA's, sudden enhancements of atmospheric radio noise. The flare continued at a very high level for 15 minutes or so, and then began its steady decline. It was late enough in the afternoon here in Russia, that the same flare may well have been observed at Climax or Sacramento Peak. If so, it will be interesting to compare the effects, and the radio influence should be known over a wide range of stations. Very possibly, it will produce an aurora this evening.

* * * * *

Since the above lines were written, I've returned to Colorado, and not without relief to be back home where news is freely available, and one is not caught in the grinding inefficiency of bureaucracy. The great flare of the 22nd of August was indeed visible in U.S.A. And there was a strong geomagnetic storm and a moderate aurora associated with the flare. The event was a "textbook example" of the wide range of phenomena that accompany a solar flare. It exhibited powerful bursts of radio emission, a short wave radio fadeout, increases in long-wave ionospheric reflectivity, and the ejection of electrified particles that struck the earth's atmosphere, about 35 hours later, to produce a brilliant aurora and a strong magnetic storm.

There are still other effects that may be picked up during flares. I am not yet sure whether they occurred during the 22 August flare. For example, we occasionally find evidences for sudden changes in cosmic rays. It is also possible that there were effects extending to the weather, though such effects, when they appear to occur are difficult to pin down for certain; the evidence to date is entirely statistical, and somewhat speculative.

Most important of all, from the purely scientific standpoint, flares represent a highly energetic high temperature phenomenon capable of emitting X-ray and ultraviolet emission that can change the physical conditions of the very high atmosphere. How these changes are produced, and in fact, exactly why a flare suddenly pops out when it does, are matters still unknown. A major objective of the work of the High Altitude Observatory, as of the work of the Crimean Observatory and many other solar research centers, is to understand these problems. Careful observations, particularly spectroscopically, of flares like the 22 August one greatly advance our knowledge of these important events.

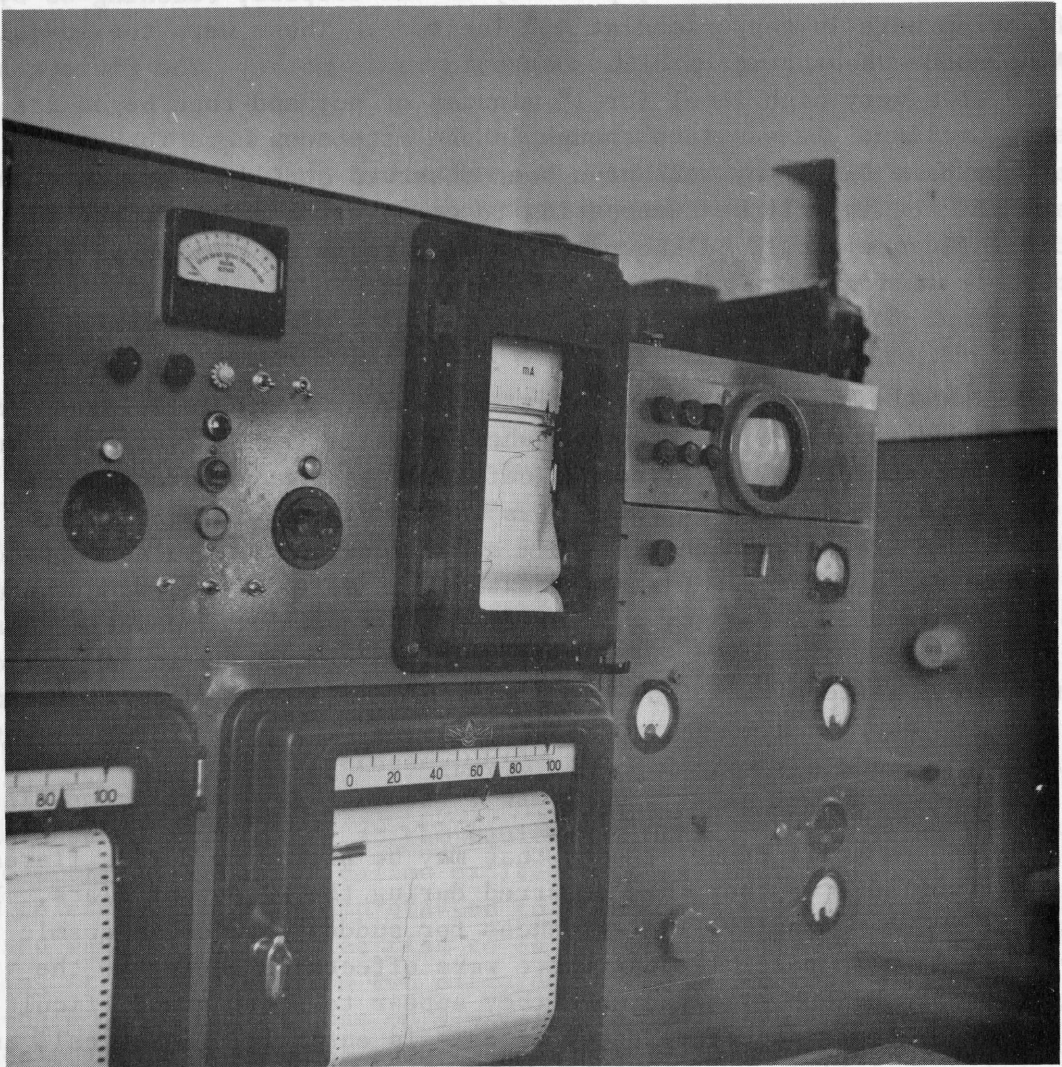


FIGURE 2

Recorders on the solar radio telescope of the Crimean Astrophysical Observatory showing the 10 cm. radio noise peak produced by the large flare of the 22nd of August. This picture was shot by Roberts who had the good fortune to be near the equipment as the spectacular rise of the needle began (see text). As here shown, the flare has still not reached its full maximum. It is interesting, by the way, to note the close similarity of the Russian recorders to Leeds and Northrop and to Esterline-Angus recorders made in U. S. A.

C. Scope of this Report

As once before, when I was delayed by the pressure of other work, I am combining two Quarterly Reports into one. Thus, this report covers the first half of 1958.

II. HIGHLIGHTS

A. A Symposium on Flare Processes

Because our theoretical understanding of the processes in flares is still so meagre, the interconnections between the different effects of flares are obscure. As one small step to improve this situation, the HAO and the NBS joined forces in mid-February to sponsor an informal symposium on flare processes for the purpose of trying to piece together, from all of the new observations now made, some fresh clues about the processes involved. We invited Drs. Goldberg and Mueller from the University of Michigan, Drs. Friedman, Chubb and others from the Naval Research Laboratory who are attempting to observe flare radiation from rockets, and a Sacramento Peak contingent.

Many problems of the flares received a thorough discussion, including such questions as (1) how high the temperatures go, (2) how good the evidence is that X rays are responsible for upper atmosphere effects rather than ultraviolet light, (3) the role played by the magnetic fields in the solar atmosphere in producing a flare, (4) the related problems of opacity, spectrum line formation, "source functions," etc.

The conference was organized by R. N. Thomas of the NBS and Warwick of HAO. One of its aims was to emphasize physical theory. The importance of theoretical studies in guiding the work of observation is often overlooked, especially in popular accounts like these. The contesting theories are often very hard to explain in simple language, and even then, it is evident that they are grossly inadequate. But without imaginative and thorough theoretical research, it is very difficult to know what observations are the most important to take, and it is very difficult to know just how the interrelationships among the various things observed are to be interpreted. In fact, interpretation usually is theory. But when one is seeking the way to find new relationships in a field so complex as this, it is often important to bring in people who have worked on these problems in independent ways. Thereby one gains a cross-comparison of knowledge to break seeming deadlocks and to guide future observing programs more intelligently. These were the purposes of our informal conference.

B. Sputnik Spin and the Density of the Upper Air

One of the most interesting features of the behavior of Sputnik I was the way in which its spin slowed down. On the night of launching, October 4th, its spin rate was about $5 \frac{1}{2}$ seconds per spin, but it rapidly slowed down to about $8 \frac{1}{2}$ seconds per spin on the 7th, and thereafter the slowing down was more gradual, so that on October 24th it was still about $9 \frac{1}{2}$ seconds per spin. Figure 3 shows the changing speed of spin, as determined from records of the rate of fading of the satellite radio signals picked up by Warwick and his colleagues with the large HAO corner-reflector interferometer, measuring the 20 Mc/s signal of the satellite.

The cause of the abrupt spin-fading in the first days is still a matter of some conjecture. Probably it resulted from the reorientation of the axis about which the satellite was spinning. One might expect such a reorientation to occur, until the satellite was spinning in such a way that maximized its rotational inertia. Or it might have been the result of a slowly progressive opening to full extension of the antennas, over the first few days.

Thereafter, however, the slower spin decay, which was very uniform from the 7th to the 24th, suggests the damping due to air friction on the extended antennas. This spin decay is accurately enough determined to permit a reasonably accurate estimate of the amount of air drag, or thus, of the amount of air present at the satellite's altitude. To do this, of course, requires assumptions about the dimensions of the antennas of the satellite. In the absence of any exact information from the Russians, Warwick has made what seem like reasonable guesses. From these he has derived an estimated air density of 220 kms altitude (3.8×10^{-13} grams/cc), which agrees well with the determinations of Sterne and Schilling (1) derived entirely independently, from the change in the orbit of the satellite as a whole. These values are substantially greater than the expected values.

An alternative interpretation of the spin decay imputes it to the electrical drag of an electrically charged satellite, passing through the ionized plasma of the ionosphere. If such be the case, then the satellite must possess a charge of about 10,000 volts. Possibly both effects are at work. The method of analysis seems new and potentially valuable for future satellite research. A paper on this will appear soon,

(1) Sterne and Schilling, Special Report No. 3 IGY Project No. 30.10, Smithsonian Astrophysical Observatory, Cambridge, Massachusetts.

and was presented in outline form at the Moscow IGY meetings in July.

III. PROGRESS ON NEW HAO RESEARCH BUILDING

Real progress towards financing of the HAO's critically needed new research building has occurred. Pledges towards our building now stand this way:

Boettcher Foundation	\$17,500
S. S. Kresge Foundation	25,000
Max C. Fleischmann Foundation	25,000
Smaller pledges (approximately)	<u>3,000</u>
Total pledged	\$70,500

Most of the pledged funds are conditional on the completion of the financing for the entire construction, which the planning staff of the University has carefully estimated at \$250,000. One of the pledges expires at the end of December. For this reason, I am putting a major part of my coming months of work to finding the needed funds, and I welcome suggestions and advice from any and all of HAO's friends.

IV. PROGRESS IN THE INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

A. Solar-Weather Studies

Our work during the half-year has led us to an independent confirmation, in 1957-58, of the relationship we found a year earlier between geomagnetism and the development of strong cyclonic storm troughs at high altitudes. The effect is most pronounced when a sustained zonal flow pattern has prevailed for some time before the magnetic storm. This adds a great deal of confidence to our belief that we have discovered a real relationship between a phenomenon that is under solar activity control, earth magnetism, and day-to-day weather changes. These results have come entirely from our privately sponsored work under the Institute for Solar-Terrestrial Research. Dr. David D. Woodbridge, who now is located at the Army Ballistic Missile Agency, also found the same result, independently examining the 1957-58 period. Woodbridge, of course, participated in our first work on this affect.

The new results show that the locations of the troughs at high wind levels for October-April 1957-58 do not fall into the same patterns as those of 1956-57, the "discovery period." But the timing and apparent

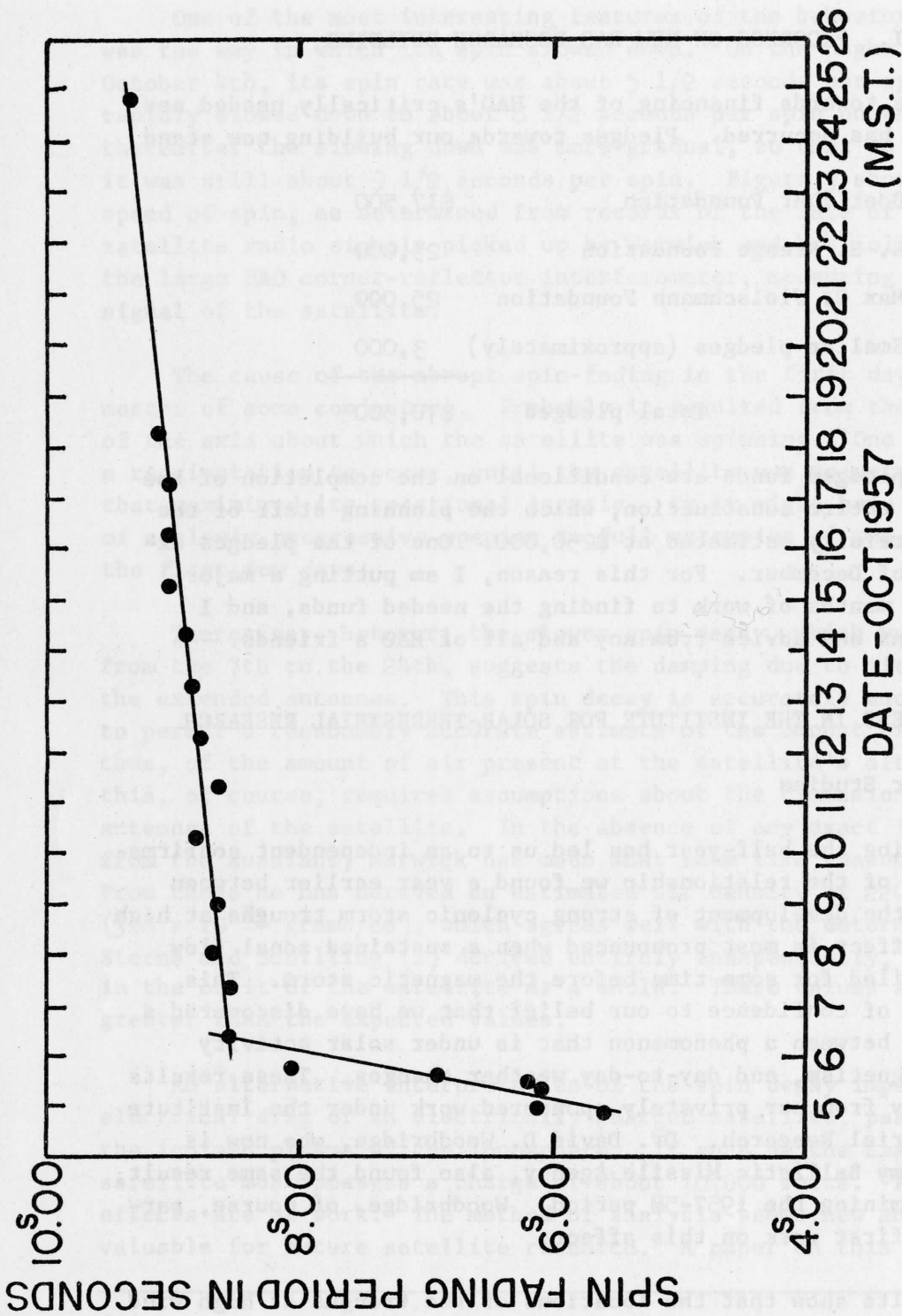


FIGURE 3

The slow-down of the spinning Sputnik I proceeded in a most unusual fashion, as shown above. We were able, from Warwick's interferometer records, to determine accurately the spin rate from the first day of flight onwards, and thus found that after a rapid decay in the first two days, the spin rate changed more gradually. The exact cause of this apparently abrupt change is still somewhat of a mystery, but the very steady decline from the 7th of October, shown above, has permitted a reliable and independent study of the drag of the atmosphere on the satellite antennas, and thus of the air density at the satellite's altitudes.

causal mechanism seem the same. We feel, nevertheless, that it is still necessary to treat the result with caution and to seek further entirely independent verification. Analysis is now under way on winter seasons for the earlier years, 1953 to 1956. So far, the winter half-year has been studied exclusively, but we hope soon to examine the summer circulations also.

We are continuing the study of hurricane path distributions with different patterns of geomagnetic activity. If the relationships we have found for the winter seasons of 1956-58 are general, and apply during the hurricane season, it would not be surprising to find a hurricane-steering influence that responds to solar activity changes.

During the period Macdonald completed and we issued a Local Forecasting Handbook for Denver, sponsored by the Institute. Most of the work on the handbook was done under other auspices, before Macdonald joined the HAO staff and during tours of duty in Naval Reserve. The handbook summarizes the rules of local weather forecasting, taking into account the interaction of local topography on larger-scale phenomena. Copies are available on request from HAO.

During September we plan to co-sponsor an intensive three-day informal national conference of fifteen to twenty meteorologists interested in long-range forecasting. This will be jointly sponsored with the Munitalp Foundation, and will be held at an isolated ski-lodge near Dillon, Colorado.

In June, Dr. Jerome Spar, of New York University, joined the HAO staff for the summer, with Institute support. He will make a study of physical processes involved in possible solar-weather relationships, and this will later appear as an Institute technical report. (2)

Dr. Bernard Haurwitz, head of the Department of Meteorology and Oceanography also joined the HAO summer staff to pursue research on atmospheric tides, atmospheric radiation balance and related circulation problems. Haurwitz will join HAO permanently, in 1959, as Professor of Astro-Geophysics.

On March 6 and 7, Dr. Herbert Riehl of the University of Chicago visited HAO for an intensive two-day conference on atmospheric dynamics and to review and advise in the circulation studies pursued by Macdonald.

(2) Technical Report No. 5 from the Institute for Solar-Terrestrial Research, "Meteorological Models for the Study of Atmospheric Responses to Anomalous Solar Emissions" (in press).

B. Second Sponsors' Seminar

HAO will hold the second seminar for sponsors of the Institute for Solar-Terrestrial Research on January 12th and 13th. The seminar will describe research in solar-terrestrial relations done here and elsewhere since last year's conference. One of the most important sessions will be devoted to discussion of mutual research interests among the HAO staff and the sponsor's representatives, an area we touched on in last year's meeting but did not fully explore. On the day following the conference we plan to take all those who would like to go on a visit to our Climax observing station.

C. Research on Ionospheric Effects from Sputniks I and II

Gratifying progress was carried on during the half-year, in interpreting satellite records with the HAO radio interferometer and by Doppler studies with a simple receiver. (See Highlights, above, and the last two Director's Quarterly Reports.) We have now obtained special funds for research on satellites, and did not dip into Institute funds for the work. However, the freedom to use such funds, if necessary, gave us the cushion of security without which it would have been difficult for us to do a thorough job of satellite tracking in the early and critically important days last October.

V. ASTRO-GEOPHYSICS

The first doctoral degree in astro-geophysics was completed in June by Dr. Stuart R. Pottasch. Pottasch began his Ph.D. candidacy at the Harvard College Observatory and completed his program at HAO and the University of Colorado in June. His thesis was supervised by Zirin, Thomas and Jefferies, and deals with the physical processes in nova-type stars (3).

Mr. Oran Richard White joined the department at mid-term. Mr. White graduated from the University of Colorado in 1955, with a B.S. degree in Engineering Physics. From then until the end of 1957, he was the Project Officer for a research group in the Air Force.

In the spring we awarded from HAO funds four fellowships for the

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- (3) S. R. Pottasch, "The Nova Outburst," A Thesis from the High Altitude Observatory and the Department of Astro-Geophysics, University of Colorado, 22 May 1958.

academic year 1958-59. These were given to:

- (1) Mr. Lewis L. House, comes to us with an M.S. from Rensselaer Polytechnic Institute, which he received under the General Electric graduate school program. Mr. House and his wife, Helen, lived in Colorado previously, and Mr. House obtained his B.S. in 1955 from the Colorado School of Mines.
- (2) Mr. Jerry L. Weinberg, from St. Lawrence University, where he received a B.S. in physics in June.
- (3) Mr. William R. Simmons, who received his B.S. in Engineering Physics from the University of Colorado in June of this year; his wife, Claire, has been on the secretarial staff for several years.
- (4) Mr. Rakesh K. Bhatnagar from Bangalore, India. Mr. Bhatnagar completed work on his M.A. in mathematics at St. Stephen's College in Delhi in June.

Because of my heavy load of duties the duties of department head were assumed by Zirin in capacity of "acting head of the Department of Astro-Geophysics" until the close of the summer semester.

VI. OTHER RESEARCH PROGRAMS OF HAO

A. Staff

In June Dr. Bernhard Haurwitz accepted an appointment as Professor of Astro-Geophysics at the University of Colorado and member of the research staff of HAO. Haurwitz, a distinguished meteorologist, author of several books on meteorology, and past vice-president of the American Meteorological Society, has long had an interest in upper atmospheric dynamics, radiation balance, and, to a lesser degree, in problems of possible solar-weather connections. He will resign as Head of the Department of Meteorology and Oceanography at New York University to join us either in February or June of 1959, depending on his academic duties there.

Dr. Constance Warwick left the HAO staff in January, to join the closely associated NBS program on sun-earth relations, under the direction of Mr. Alan Shapley. It is fortunate that her close association with the Observatory will continue in her new position.

Mr. Kenneth Durbin joined the Climax observing staff, accompanied by his wife, Lou, and their first child, a son, was born soon after his arrival. They are living in the converted quonset home at Climax. Alfred Hobart terminated his Climax stay in May, and will return to college this fall.

Chapman spent a brief stay in June at HAO, and will return again in early fall for several months. Part of his coming stay will be spent at Sacramento Peak. Dr. Joseph Cain, of the Geophysical Institute, University of Alaska, began an indefinite stay as a guest worker at HAO, occupying himself in interpretation of the fast-run magnetometer networks in Alaska and Colorado. He is attempting to determine the scale and speed of the currents associated with short-term magnetic fluctuations and will be closely associated with Matsushita in this work.

Miss Betty Prescott joined HAO in June, to assist Miss Dorothy Trotter in the solar activity reporting program, and to replace Mrs. Mary Fleming Zirin who left in June. Several summer appointments were also made at the secretarial and research assistant level.

Dr. Marianne Bretz terminated her HAO stay in June. She has been here nearly two years on a visiting scientific staff appointment from Germany. She will go to Lick Observatory for the coming year. Mrs. Arloa Kupilik also resigned in May to accompany her husband who graduated from the University. Her duties in the business office will be assumed by Miss Clara Gebura.

Zirin was honored by winning a two-year Alfred P. Sloan Research Fellowship. His appointment at HAO under the fellowship will start in September. The fellowship frees him of specific research program duties for entirely undirected basic research for the two year period, and provides him a great opportunity to undertake a speculative and sustained effort to solve problems of the physics of coronal gases. He will spend the first four to five months of the appointment exploring relevant research work in various Russian and Western European centers engaged actively in coronal research, including the Sternberg Institute in Moscow, the Crimean Astrophysical Observatory, the Swiss Federal Observatory in Zürich, the Max Planck Institute in Göttingen, the Meudon Observatory in France, and elsewhere.

Roberts was awarded an honorary degree of Doctor of Science at Ripon College in Wisconsin in June, and had the opportunity of viewing a beautiful aurora from the college campus on the evening of the baccalaureate address.

B. Research in Progress

The winter-spring period often proves to be a time when results of sustained programs seem to bear the fruit of efforts begun in summer and fall. This year was no exception, and several programs, in addition to those described above under Highlights, resulted in significant conclusions. The principal advances are singled out below.

1. Active Solar Region Analysis

Several separate programs of intense study of active region phenomena are in progress using spectroscopic observations from the 5-inch coronagraph-spectrograph at Climax. From these studies, three papers have already been submitted for publication and one presented at a scientific meeting.

A study was carried out by Curtis and Watson, involving the comparison of the ultraviolet spectral lines $\lambda 3888$ of ionized helium, and $\lambda 3889$, of hydrogen. They found the ionized helium line to be much broader than the hydrogen line, indicating that it came from a hotter region of the prominence. Their results were presented at the spring meeting of the Colorado-Wyoming Academy of Science.

A second study by Zirin, Watson and Curtis involved a comparison of line profiles of spectral lines in highly active prominences with those in quiescent prominences. These results have been submitted to Publications of the Astronomical Society of the Pacific.

Two further papers, one by Tandberg-Hanssen and Zirin, and another by Zirin, have been submitted to the Astrophysical Journal. These deal with the physical conditions in highly active regions and consider the spectroscopic evidence for the interaction between prominences, flares and corona in these regions. In the former of these two papers, temperatures and velocities in active region prominences are computed. In the latter, further evidence for the Ca XV identification of the yellow coronal line is presented and mechanisms for its excitation are suggested.

Billings and Cooper continued their studies of the profiles and height gradients of the green and red coronal lines of iron. From these studies they hope to get a picture of the motion and structure in the corona.



FIGURE 4

Dorothy Trotter (left) and Mary Zirin receiving and recording measurements of the sun from Climax over our radio station and relaying these on to a rocket-firing team of the Naval Research Laboratory off the California coast. With the radio equipment shown here we also receive frequent regular messages from Sacramento Peak Observatory for transmission on to the IGY World Warning Center at Fort Belvoir, Virginia. Miss Trotter is operating the transmitter with which we communicate to the Naval Research Laboratory up to the minute solar observations so that they may fire research rockets above the earth's atmosphere shield in order to measure X-ray and ultraviolet emission from the sun during solar flares. National Academy of Sciences—IGY Photo.

2. Solar Effects in the Ionosphere

The night on February 10-11 brought one of the outstanding auroral displays of the twentieth century. Unfortunately for the HAO staff, the skies at Climax and Boulder were totally cloudy; Sacramento Peak and many other American centers, however, had clear weather and a magnificent view of a strong reddish aurora of diffuse character, as well as numerous other auroral phenomena.

The 18 mc/s cosmic noise recording equipment at HAO's radio site north of Boulder was in full operation, however, and obtained outstanding records of irregular fading of signals from cosmic sources throughout a good part of the night. Warwick analyzed these in some detail (4), and found several striking effects. For example, there were two sudden fades during the night when signal strength dropped abruptly to very low values (5% in one case). The evidence was strong that these fades were exactly simultaneous over a large area of at least 1,000 miles diameter. Magnetic and balloon X-ray records suggest, moreover, that the areas were considerably larger, and that the earth at these moments collided with a giant cloud of solar corpuscles that affected a major part of the earth's atmosphere simultaneously.

The HAO radio interferometer, moreover, showed evidence of a small area of complete cosmic noise obscuration, which may possibly have been related in some way to the auroral arch that often can be seen in the north sky during diffuse auroras. Perhaps during the strong fadeout the auroral particles were especially numerous in a small part of the sky well to the north of us. The interpretation, however, is still speculative.

HAO, again with Warwick's guidance, has undertaken another study of great interest dealing with the relationship of solar flares to absorption of cosmic noise. The new program is supported by the Army Ballistic Missile Agency in Huntsville, Alabama. The program director there is Dr. David D. Woodbridge, formerly associated with our solar-weather research as a consulting member of the staff of the Colorado School of Mines.

We will build a new cosmic noise recorder like that now at HAO, Sacramento Peak and McMath-Hulbert Observatory to be operated from Hawaii. The instrument will permit examination of the flare effects of a given flare at widely differing angles of incidence of the flare radiation onto the earth's atmosphere. It will be installed

at the University of Hawaii, with the cooperation of Dr. Walter Steiger, after we carry it to the October eclipse at Puka Puka.

3. Solar Effects in Geomagnetism

For several years, a joint research effort of HAO and the Sun-Earth Relations Section of the National Bureau of Standards has been to attempt to predict geomagnetic storms from observations of solar activity. Many studies had been made during the past several decades relating separate, individual solar parameters to geomagnetic fluctuations. However, these were generally for short time periods and covered various phases of the solar cycle. Dr. C. Warwick, Miss Marion Wood, of NBS, and Hansen recently completed a larger scale superposed-epoch correlation analysis using punched card techniques of a great many optically observed solar phenomena and their geomagnetic associations in an attempt to shuffle out those solar-geomagnetic relations which might be of practical use for forecasting. The most reliable sun-geomagnetic association was reaffirmed to be with large solar flares. However, it is becoming increasingly clear that further progress in forecasting will probably come only by careful consideration of the radio noise characteristics of solar events.

4. Solar Activity Observing

The intensive IGY patrol efforts of HAO continue in full swing. Some modest reduction of the scale of routine coronal observations was made in June to facilitate special region studies. However, these changes will, we hope, permit an improvement in the interpretative efforts possible from the observational materials.

5. Temperatures and Motions in the Corona

Excellent progress on this work went forward during the half-year, and has led to the formulation of intriguing new results that will be discussed in the next report. Zirin, Schwartz, Billings and Tandberg-Hanssen all participated in the work. Happily we received additional ONR sponsorship for this work, and the financial bottleneck mentioned in the last report has thus been broken.

6. Chromospheric Spicule Studies

Athay succeeded in making additional spicule spectra, extending

his studies to the H-beta and H-gamma spectrum lines of the Balmer series. The virtue of going to other higher-order Balmer lines than H-alpha, as described in the last report (4), is that the greater transparency of the gases permits a more straightforward interpretation of the temperatures of the gases involved. The new results reached essentially the same conclusion as the more limited studies, and led, again, to very high temperatures for the gases comprising the spicule jets.

Athay also completed some work on the numbers and limiting heights of spicules from observations by Dunn made at the Sacramento Peak Observatory. The principal conclusions were that the number of spicules covering the whole solar disk is about 90,000, rather than about a million, which is approximately the number of individual solar granules (5) that can be observed in ordinary white light under good conditions of atmospheric seeing and telescopic resolution. It was previously an open question whether the number of spicules increased with increased telescopic resolution, and with techniques that allow one to see lower and lower into the solar chromosphere. The present result says no, and thus strongly suggests that spicules are not simple extensions of the solar granule mechanism, but must be explained by physical processes of the chromosphere only indirectly related to the behavior of individual granules.

7. IGY Pilot Studies

Two principal efforts have been undertaken under the new IGY pilot study program. The first was carried on by Matsushita, and involved interpretation of the rapid run magnetic field networks in Alaska and Colorado. Matsushita made a preliminary approach to the problems of the current systems in the atmosphere (or in the earth) that produce the observed magnetic field fluctuations.

One of the first results found from examination of original records was that the sensitivity of the instruments used in the networks is appreciably too high for optimum interpretation during the most interesting periods of magnetic upsets. However, our discussions with the Coast and Geodetic Survey personnel who operate these instruments reveals that the sensitivity cannot be altered without

(4) Director's Quarterly Report, 1957, Fourth Quarter, page 14.

(5) See discussion of solar granules, Director's Quarterly Report 1957, Second and Third Quarters.

factory modification of the instruments, and is impossible during IGY. Very interesting results will, nonetheless, be available in less disturbed periods.

A second area of pilot studies is under Billings's guidance and involves an effort to interpret spectra of flares observed with the Climax coronagraph-spectrograph against the differing backgrounds of solar disk, sunspots, chromosphere, and sky in an effort to evaluate the opacity of flares. Results will be discussed later.

8. Older Coronal Spectrum Analysis

Billings and Bretz completed their analysis of old coronal records and spectrograms. This study began as a result of Waldmeier, in Switzerland, reporting a peculiar jump in the red coronal line during the years 1942-44. His report was based on sparse and uncertain observations made at Arosa, Switzerland. Since we had in our archives, old, unanalyzed spectrograph plates containing the only other coronal data for those years in existence, we decided that it would be most worthwhile to take a look at them.

Billings determined from the density of the lines on the old plates how bright the corona had been. Bretz then incorporated these results into an extensive study of how both the red and the green coronal lines varied in intensity during the years 1942-1956. Her summary of almost 100,000 coronal intensities will be useful for many solar-terrestrial studies. Moreover, her results failed to confirm the peculiarity found by Waldmeier. They indicated, also, that both temperature and density in the corona increase with the sunspot cycle, but that density is the more important factor in determining how bright the lines will be.

9. Eclipse Research

The pace of eclipse preparation reached the frenzy level, and a preview of the next quarter shows that all of the necessary equipment and people did get off for Puka Puka and reached the atoll successfully at the start of September. Details later. Copies of Low's summary of the eclipse planning story in Sky and Telescope are available at HAO on request.

10. Analysis of Sunspot Spectra

11. Solar Activity Guide Book

12. Aurora of Venus

Newkirk obtained several good quality spectra in January of the light from the dark crescent of the planet Venus. These reveal that Venus has an airglow or aurora of intensity vastly greater than the earth's aurora. The spectrum lines were recorded on several spectra on different nights, and could be obtained with exposures of only a few minutes' duration. Newkirk speculates that the strong Venus aurora may be the cause of the often-reported "ashen glow" that outlines the dark disk of Venus in visual observations made by amateurs, particularly those of the British association of amateur planetary observers. These observers reported, for example, that the ashen glow was visible in January.

The results confirm the apparent auroral lines of Venus reported by the Russian worker Kosyrev, though our spectra are of lower dispersion and do not reveal the many fainter lines reported by Kosyrev. The main spectrum lines seem to be from nitrogen and oxygen appears to be absent.

The March tries at the Venus spectrum photography were made from Boulder, because of the poor Eastern horizon at Climax, but were uniformly unsuccessful, reassuring us that a high altitude astronomical site is worth the trouble!

The experiments should be repeated at Venus's next approach in late summer of 1959, and the spectrum extended to the red, where it is possible that some considerably stronger spectrum lines will be found.

13. Solar Data Center

A principal data center activity has been directed towards the intercomparison of coronal observations from different stations. The Center has also published data summaries of surge prominences and other limb prominence features.

14. K-Coronameter Observations

Newkirk has extended the interpretation of coronal density distributions from K-corona observations. About 50 days of observational data have been obtained with the instrument to date, though some are of marginal quality. Very excellent sky quality conditions are needed for this work.

Several exciting discoveries have resulted from the comparison of the K-coronameter results with high resolution "pictures" of the sun made by radio telescopes. The K-coronameter tells us the density of coronal electrons along the line of sight. We find that the regions of high electron density are just the same regions which appear bright in the radio pictures such as have been made by Christiansen in Australia. Newkirk has carried out an analysis to show that the long lived "hot spots" seen on the sun by radio telescopes are due to the thermal radiation from the extensive regions of increased density in the corona. The results of this study by Newkirk were presented by Dr. Gérard Wlérick at the Paris International Astronomical Union-International Scientific Radio Union Symposium on Radio Astronomy in July. Dr. Wlérick of the Meudon Observatory developed the K-coronameter during a two-year stay at HAO as reported earlier. (See Figure 5.)

13. Solar Aureole Studies

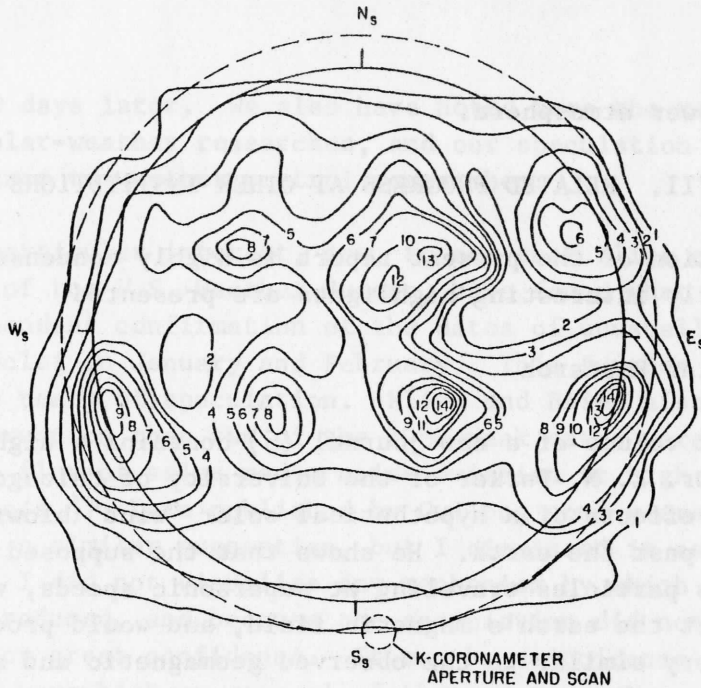
The halo produced by dust and ice crystals in the terrestrial atmosphere is a matter of considerable scientific interest. The techniques for observing it are similar to those for the solar corona. Newkirk, thus, undertook a new program of ONR-supported research to devise and operate instruments for atmospheric analysis from high altitude balloons, a program associated with Project Stratolab headed by Cdr. Malcolm Ross. Flight to about 45,000 feet altitude are planned from Colorado in late 1958.

HAO has also made some plans to consult in planning several other high terrestrial atmosphere programs of research.

16. Airglow Cells

Dr. Franklin Roach of the NBS has made extensive studies of the terrestrial airglow that illuminates the sky on clear moonless nights. This glow resembles a permanent aurora, save that it is not concentrated to the polar regions, and may have entirely different dynamic properties from the usual aurora.

Tandberg-Hanssen joined Dr. Roach in studies of the properties of this airglow motion. They will be described in a later report. A striking fact suggested by the preliminary analyses is that the air motions at the great altitudes of the airglow (about 60 miles) carry a large amount of kinetic energy--perhaps amounts beginning to be significant when compared with cyclonic storms in the much



21 CM. WAVELENGTH
 6 JAN. 1958
 0200 U.T.
 CONTOUR BRIGHTNESS UNIT = $0.62 \times 10^5 \text{K}$.

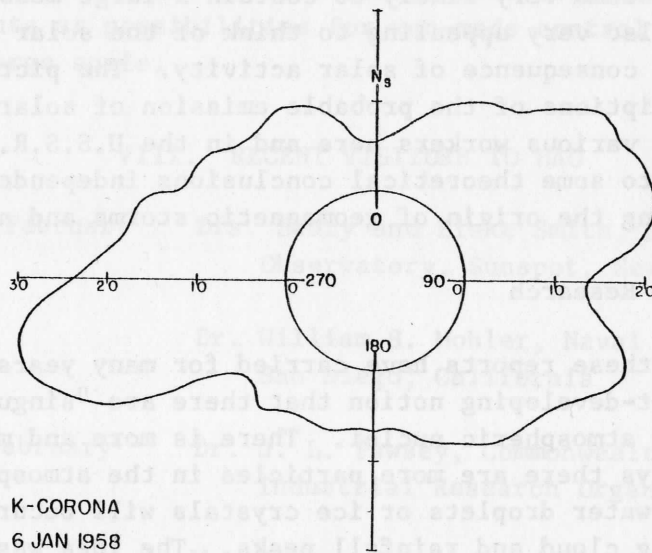


FIGURE 5

The upper figure shows a map of the corona as deduced by Christiansen of the Radio-physics Laboratory in Australia from measurements of the strength of solar radio emission at 21 cms. wavelength. The dashed circle shows the position of the scanning circle of the HAO K-coronameter operated by Newkirk the same day at Climax. It is interesting to note that the coronameter measurements, shown in the lower figure, correspond very closely to the radio map, lending confidence to the supposition that the K-corona may indeed be the source of the radio emission detected at these wavelengths.

denser lower atmosphere.

VII. RELATED PROGRESS AT OTHER INSTITUTIONS

This section of the present report is highly condensed. However, a few particularly interesting highlights are presented.

A. Basic Solar Research

The first volume of a new journal (6) contains a highly important new paper by Dr. E. N. Parker of the University of Chicago. In it Parker discusses the effects of a hypothetical solar "wind" blowing outwards from the sun, past the earth. He shows that the supposed wind, made up of ionized gas particles traveling at supersonic speeds, would impinge upon and affect the earth's magnetic field, and would produce effects of a nature very similar to the observed geomagnetic and auroral effects. The acceleration of ions for deep penetration into the atmosphere, and the changes of the earth's magnetic field during a magnetic storm both seem to fit quantitatively with the new Parker idea.

The new work seems very likely to contain a large measure of the truth, and it is also very appealing to think of the solar "wind" as a more or less usual consequence of solar activity. The picture fits well with various descriptions of the probable emission of solar corpuscular energy advanced by various workers here and in the U.S.S.R. It also has a close relevance to some theoretical conclusions independently derived by Warwick regarding the origin of geomagnetic storms and auroras.

B. Solar Weather Research

The pages of these reports have carried for many years a running account of the fast-developing notion that there are "singularities" in rainfall-producing atmospheric nuclei. There is more and more evidence that on certain days there are more particles in the atmosphere on which condensation into water droplets or ice crystals will occur and that there are resulting cloud and rainfall peaks. The idea was first advanced by E. G. Bowen of Australia, who noted that these dates of abnormally abundant particles and of increased rainfall tended to occur on the same calendar dates year after year. It was for this reason, primarily, that Bowen concluded that meteor dust must be the initiating cause. He suggested that the earth intercepts dense meteor streams on the same calendar dates each year, and that the meteor dust has a cosmic cloud seeding

(6) The Physics of Fluids, Vol. 1, page 171, 1958.

effect about 30 days later. We also have noted here the relevance of this work to solar-weather researches, and our speculation about the possible relevance to weather control researches.

It is of particular interest, now, to see that Kline and Brier, meteorologists of the U.S. Weather Bureau, have found what appears to be strong independent confirmation of the dates of unusually dense condensation nuclei in January and February. This further removes the effect from the realm of speculation. Kline and Brier also make the intriguing observation that two of the 1958 peak dates were also peak dates of a high flux of solar radio noise emission at high frequencies (about 10,000 Mc/s.). Data published by Cwilong some years ago also indicated to me a similar suggestion, but I dismissed it as improbable, in part because I did not visualize any mechanism by which such an effect could be produced, and because the association did not appear to be strong enough for great confidence. It may be coincidence that the solar radio emissions were high on several of these dates. However, this new observation suggests the merit of a more careful search for such an effect at various radio frequencies. It also underlines the need for a diligent effort to understand how the Bowen astro-geophysical effect can be produced. Inherent in this work, moreover, are yet dimly-understood hints at possibilities for man-made control of weather processes on a large scale.

VIII. RECENT VISITORS TO HAO

16 January-18 February	Drs. Henry and Elske Smith, Sacramento Peak Observatory, Sunspot, New Mexico
16 January	Dr. William S. Mohler, Naval Electronics Lab., San Diego, California
31 January-7 February	Dr. J. L. Pawsey, Commonwealth Scientific and Industrial Research Organization, Australia
7 February	Mr. Walter Garstka and Mr. Robert Clark, Bureau of Reclamation, Denver
14-15 February	Dr. John Winckler, University of Minnesota, Minneapolis, Minnesota
25-26 February	Dr. John W. Evans, Sacramento Peak Observatory, Sunspot, New Mexico
6-7 March	Dr. Herbert Riehl, University of Chicago, Chicago, Illinois



FIGURE 6

The IGY Data Center for Solar Activity located at HAO in Boulder. Hansen who directs the data center program is checking over a 35 mm solar flare film from Sacramento Peak Observatory, with Arloa Kupilik (center) taking notes. Karen Chalonge (right) is filing flare reports, which are received from 36 stations around the world.

31 March-1 April	Dr. Bernhard Haurwitz, New York University
31 March	Dr. David Woodbridge, Army Ballistic Missile Agency, Huntsville, Alabama
16-18 April	Dr. Eugene Parker, Enrico Fermi Institute, University of Chicago
17 April	Dr. Vincent Schaefer, Munitalp Foundation, New York, New York
21-25 April	Dr. Hurd C. Willett, Massachusetts Institute of Technology, Cambridge, Massachusetts
13-15 May	Mr. C. I. H. Aspliden, WMO, Desert Locust Control, East African Weather Department, Kenya
9 June	Dr. Arthur Adel, Lowell Observatory, State College, Flagstaff, Arizona

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Walter Orr Roberts

Walter Orr Roberts
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