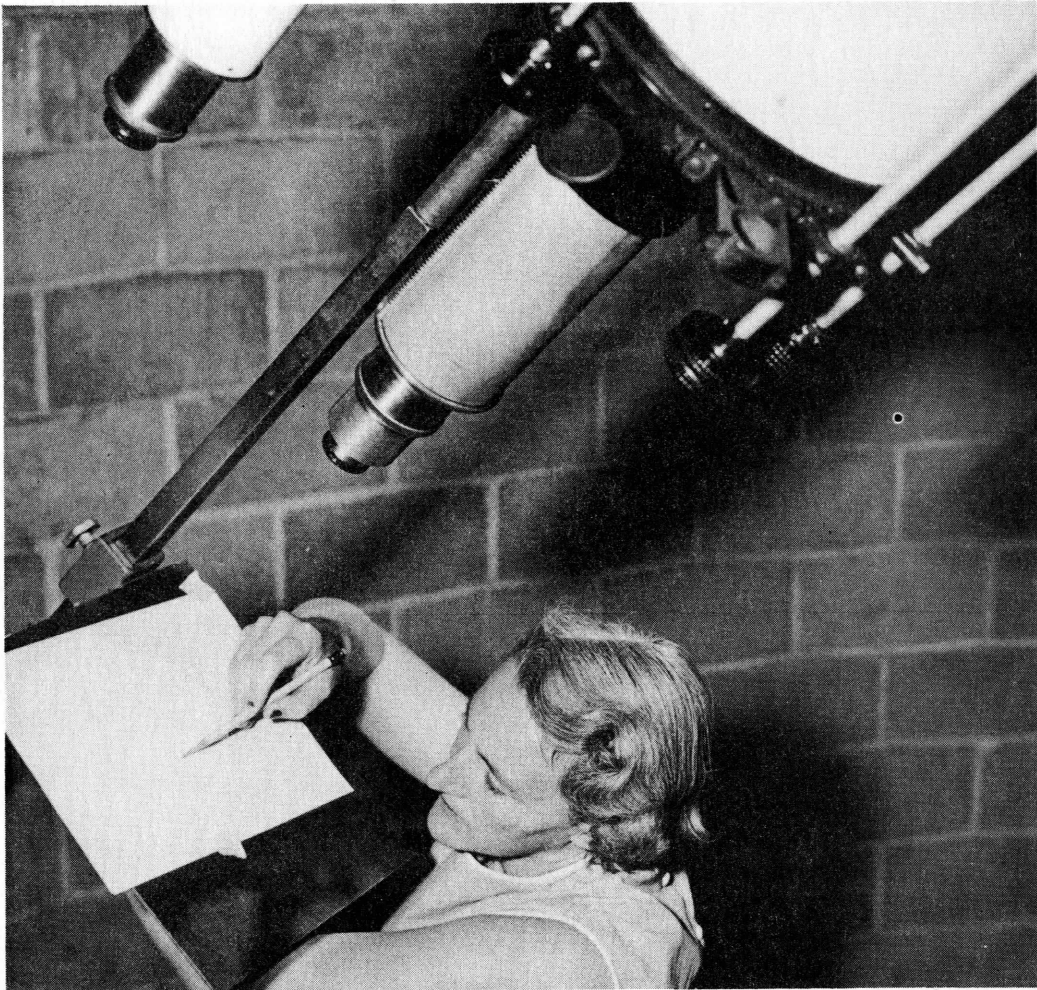


THE  
DIRECTOR'S QUARTERLY REPORT

1956-4

1 OCTOBER to 31 DECEMBER



*Sketching Sunspots\**

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

The High Altitude Observatory of the University of Colorado is a non-profit research and educational institution dedicated to the study of the sun and its effects on the earth.

\* Cover: Sketching sunspots. Centers of violent solar disturbance can generally be recognized from their associated sunspots. As a consequence, one of the oldest techniques of solar observing, shown here, takes its place beside the more complicated techniques of modern astrophysics. Miss Dorothy Trotter, who heads HAO's data reporting program, is shown making a pencil sketch of the location, size and type of sunspots visible by projection of the solar image with the 10 $\frac{1}{2}$ -inch Sommers-Bausch Observatory refractor at Boulder.

## SUMMARY

The sun's corona has long been considered a slowly-varying phenomenon, with just noticeable changes from day to day. When abrupt changes in a few hours have been reported, at rare intervals, we have even suspected errors of observation. New motion picture films of the corona taken at Sacramento Peak reveal, however, that on infrequent occasions abrupt changes in the corona do occur, and that they are sometimes very spectacular.

The sun's corona has two principal components: (1) the so-called emission-line corona, which we at HAO have observed spectroscopically since 1941, and which the Sacramento Peak staff now photographs regularly, in spite of the great difficulties of the technique; (2) the K-corona, made up of electrons. The two components do not always show the same distributions. Great scientific value can be derived from observing the degree and location of the differences. Thus, we have instituted, at Climax, a program of regular observations of the K-corona, to supplement the long-standing, continuing program of emission-corona observations. Valuable results came from this during the fall.

Centers of great solar activity came in for intensive analysis during November and December. Rarely observed phenomena occurred and were well-covered simultaneously from Sacramento Peak and Climax, giving us unusually complete information from which we are making intensive studies.

Special 300 mb weather map studies, seeking a possible solar tie, began in December under the Institute for Solar Terrestrial Research.



Figure 1

The large solar dome of the Sacramento Peak Observatory in Sunspot, New Mexico. The basic instrument housed in this dome is a twin of the Climax instrument. The observing program at the Peak is closely coordinated with the HAO's Climax observational program. (Photo from Sacramento Peak Observatory.)

## I. HIGHLIGHTS OF THE QUARTER

### New Coronal Effect Discovered

At rare intervals in the progress of a science, entirely new effects are discovered. Phenomena like this are often found when a new method of observing evolves. Such a discovery came last fall from the Sacramento Peak Observatory. We believe the effect has never before been seen and there is no name for it in the scientific literature. The effect appeared on the artificial eclipse images of the sun taken in the coronagraph, with the light of the green coronal line, 5303A, and can best be described as a violent large scale disruption of the normally stable structural pattern of the emission line corona of the sun.

Pictures of this component of the corona are now regularly taken at the Sacramento Peak Observatory. They are of unprecedented quality, and reveal a wealth of structural detail in the corona. Many days of such motion picture runs in recent months have exhibited strange and interesting brightenings and delicate changes. Some showed strong surges of brightened coronal gas. Most runs, however, are notable because of the very unchangeability of the corona--a fact remarked many years ago by the French coronagraph pioneer, Dr. Bernard Lyot, from his early photos of the corona. But one day's run, last fall, revealed a gross and violent disruption of the entire structure of one portion of the corona. So far as I know, this is an entirely unparalleled observation.

The fact that such a gross structural change can occur, even if it is very rare, has far reaching significance. The film suggests that a fast-moving disturbance hurtled through the corona, tearing up its structure. Very probably, therefore, the magnetic field structure was likewise violently distorted. If so, the physical phenomena that depend on the sun's atmospheric magnetic fields may have been strongly affected. This includes such phenomena as the ejection of geomagnetic storm-producing solar corpuscles, cosmic rays, meter-wave radio signals, etc. This remarkable event, the other less spectacular coronal changes, and their relationships to the prominences and other solar phenomena are now under intensive study.

Credit for the extraordinary new films is due Mr. Richard Dunn, who made the necessary developments in the filter and observing techniques. These observations are far more difficult than the conventional spectroscopic observations. Credit is also due the members of the Harvard Observatory staff who made the film runs: Dr. Henry J. Smith, Mr. Harry Ramsey, Mr. George Schnable, Mr. Howard DeMastus, and Mr. Donald Cunningham.

The fall observations, moreover, reveal the basic soundness of the cooperative observing programs of the Sacramento Peak Observatory and

High Altitude Observatory. Much of the success of recent simultaneous measurements of the prominences and corona stems from the fact that the different telescopes of the two stations were able to explore simultaneously into different aspects of the regions of outstanding activity. In particular, as a result of overlapping coverage, we have observations that will enable us to know much more about the structure of the extraordinary regions at the sun's edge on 22 November, a date of outstanding coronal surge activity, than would ever have been possible previously. Some of the results of this cooperative observing program are described in more detail below.

## II. INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

### Analysis of the K-Corona

October and November brought great progress in our program to observe the K-corona, the sun's white light halo, which is scattered by free electrons in the sun's atmosphere.<sup>1)</sup> For about a month's period the instrument was operated continually, and values were obtained for the brightness of the light of the K-corona at various heights for a number of days.

Theoretical calculations indicate that the light from the K-corona should be tangentially polarized (electric vector), which means that a polaroid filter with its axis parallel to the sun's edge will reveal the maximum intensity of transmitted light. Observations made at eclipses have amply demonstrated that this is so. However, on 17 September 1956, Newkirk obtained an observation from one region of the corona that showed light polarized at an angle of over 30° from the tangential direction. This unexpected angle of polarization, he concluded, was due to polarized light from a faint prominence present at the position where the observation was taken.

This surprising observation suggests that the magnetic field effects in the sun's atmosphere are much stronger than we had previously thought. We expect, moreover, to find many similar instances when we have amassed more complete observational coverage. Interpretation of this previously unobserved phenomena has not yet been thoroughly worked out. There is every reason, however, to hope that further observation and study will give us information about the sun's magnetic fields that was unobtainable before the development of the K-coronameter.

Troubles with some of the mechanisms of the new solar laboratory plagued us a good part of the observing period, and they are not entirely

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<sup>1)</sup>See Director's Quarterly Report 1956-3, and earlier reports for a description of the role played by the K-corona in the sun's atmosphere.

cleaned up at the close. The large equatorial telescope mounting is working smoothly, but we are experiencing minor but irritating trouble with some of the electrical controls, the door opening electrical circuits, and we have had difficulties with the dome-rotation mechanisms. Problems like this are to be expected when so complex a new facility goes into operation, and we hope by next summer to have things well ironed out.

### Solar Weather Studies

In December we asked Dr. David Woodbridge and Mr. Theodore Pohrte, of the Colorado School of Mines, to undertake some special studies on the patterns of motion of winds at high atmospheric levels. They tackled studies of the 300 mb level of the atmosphere (at about 30,000 feet elevation), using excellent new maps prepared and transmitted to us by the Department of Transport of the Air Services of Canada. These

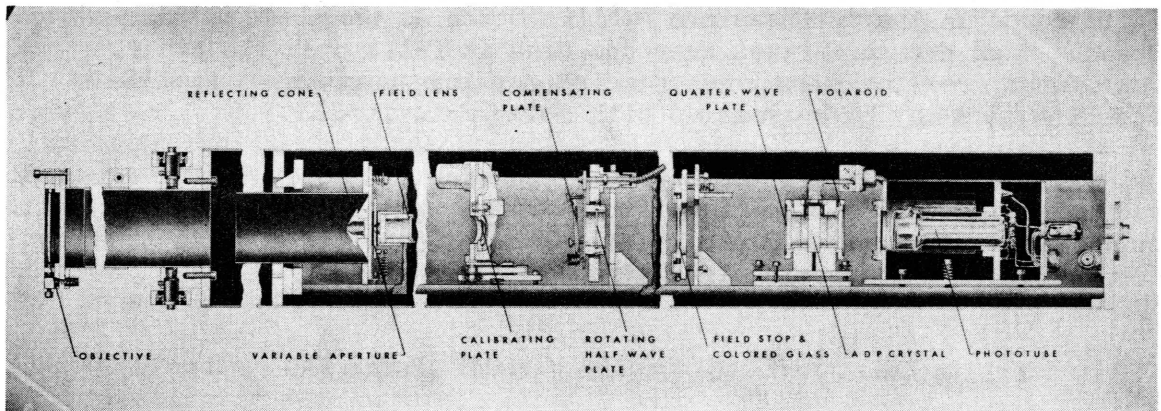


Figure 2

Schematic diagram of the new coronameter in operation at Climax. The instrument is a conventional Lyot coronagraph to which are added the elements of a sensitive photoelectric polarimeter. The coronameter detects the very weak polarized light scattered from the electrons of the solar corona. We hope later to use it also to detect flare and prominence polarizations.

maps exhibit wind flow trends for approximately half of the Northern Hemisphere, encompassing longitudes from 0° to 180° of the Western Hemisphere. On these we have studied the large high latitude pressure troughs that ultimately give birth to "closed" low pressure cells. There are preliminary signs that such troughs tend to be formed with unusual frequency some days after magnetic disturbances, with a maximum effect after about eight days. Technical Report No. 3 from the Institute for Solar-Terrestrial Research will give an interim progress report on this program. By the end of spring we expect to finish statistical tests of the supposed effect, and determine whether the leads are sufficiently promising to merit further pursuit in historical weather data.

Trotter carried forward our effort to develop new indices of overall solar activity based on the patterns of distribution and magnitude of centers of solar disturbance. About one year's solar maps were classified by two independent workers (Trotter, Klein) but the degree of correspondence between the ratings was disappointing, indicating that objective criteria of a more definitive sort are needed for the classification. Work will continue on this program.

Through oversight, I failed to mention in my last report that we invited Dr. I. Schell of Tufts University to visit HAO for a two day conference on the "southern oscillation" and its possible solar control. The term "southern oscillation" refers to complementary pressure effects found in the southeastern Pacific Ocean as compared to the Indian Ocean. When pressure rises over one area it falls over the other. Departures from the normal may persist for long periods, a fact that Schell thinks may be correlated with solar activity.

I have recently written a popular summary of the status of solar-weather research for the Scientific American, which will appear in the April 1957 issue. It deals particularly with possible effects of solar corpuscles on atmospheric circulation.

### III. OTHER RESEARCH PROGRAMS OF THE HAO

#### A. Staff

Mr. Fred B. Pearson, our optician, terminated his HAO appointment in the quarter to open his own business in Boulder. He will continue some work for the HAO. We do not plan to continue to make optical components in our own facilities now that he has left.

Mr. G. William Curtis returned to HAO after a year at the Institut d'Astrophysique in Paris. He will go to Climax the first of April as a member of the observing staff and will continue through the IGY.

In October I visited Alaska to confer on solar-terrestrial research



with the staff of the Geophysical Institute at College and to attend the Alaska Science Conference in Juneau.

Chapman was in Europe throughout the quarter. He worked principally in Göttingen, Germany with his long-time colleague J. Bartels. They are preparing a new edition of their monumental two-volume work "Geomagnetism." As international president of the IGY he was busy traveling and attending planning conferences.

He received an honorary fellowship from Imperial College in London and also an honorary award from the Accademia dei Lincei in Italy. A projected trip to Egypt in February 1957 was canceled because of the tense political situation. In March he goes to College, Alaska for three to four months.

During October he obtained records of a very interesting tropical aurora that was observed on September 8th when two British ships in the Indian Ocean bound from Australia to Africa saw the same aurora from places hundreds of miles apart and in different latitudes. One was in latitude  $29^\circ$  and for ten minutes the aurora ascended to a  $40^\circ$  elevation, so that it must have been visible in the tropics. Chapman is quite pleased by this because it means that this sunspot cycle has already provided a pre-IGY tropical aurora -- something previously considered very rare. However, there has been no report of this aurora actually received from the tropics.

He and Bartels devised a simple instrument, which they call a "comb elevometer," for reading the elevation of an aurora or other celestial feature in the dark without the reading of circles. A photograph of this and description will soon appear in various popular journals distributed internationally to encourage people to build and use these for recording tropical auroras during the IGY.

## B. Research in Progress

Once again, I touch on those programs that passed significant milestones, skipping over others.

### 1. Active Region Analysis -- Corona and Prominences

The full benefits of our new 5-inch coronagraph at Climax (Figure 4, Page 12) were evident in the observing program for November and December. We had the fortune to have excellent observing conditions on several days of outstanding solar activity. And on one in particular, November 22, we had coordinated simultaneous observations of extraordinary solar activity from Sacramento Peak and Climax. On this occasion we were able to tie down the association of rapid aurora-like fluctuations in the sun's corona with the occurrence of strong line of sight Doppler effects in the coronal spectrum, and also with the motion of surge and streamers of a

violently active prominence region. Members of the Sacramento Peak Observatory staff, together with C. Warwick and Newkirk of our staff, are now spending a considerable part of their time in efforts to interpret the complex interrelationships.

In December the Climax observers obtained a series of spectrograms that exhibit the yellow coronal line with such strong intensity that we shall be able to determine its line-width with great reliability, and also its intensity relative to the companion spectrum line at about 5446A. This companion line, theoretical research indicates, should be not less than half the intensity of the 5694A yellow line, if we are correct in identifying the lines as Ca XV. These are calcium atoms with 14 electrons detached, the highest ionization state of any atoms yet observed by man. Our identification as Ca XV, done over two years ago,<sup>2)</sup> has recently been criticised by Waldmeier, of Switzerland, on the grounds that we have not shown conclusively that the two yellow spectrum lines (5694A and 5446A) are of comparable intensity. His own research led him to believe that the 5446A line was about one-sixth as strong as the 5694A line.

The December spectrograms are not fully analyzed yet, but they clearly indicate that the fainter line is more than half as bright as the stronger, confirming our earlier work. We find, moreover, an explanation for the negative result of Waldmeier. The fainter line lies in a fortuitously bad place in the spectrum, directly on an absorption line of normal sunlight, which thus masks its true brightness. Our success was made possible by the new instrumental arrangements at Climax that allow us to obtain spectra in rapid succession, at a closely spaced range of heights.

A still further result of vast importance is that we have discovered, in the same region, the 4086A line of Ca XIII (12 detached electrons). (See Figure 3, Page 9.) This practically clinches the calcium identification and confirms the extraordinarily high temperatures we have previously suggested for these regions. The new spectra will, when analyzed fully, also give us far better temperature values than before. We will use the methods we have described earlier.<sup>3)</sup> Preliminary runs on the microphotometer, using this method, suggest temperatures above five million degrees (Kelvin).

Billings, Zirin and Bretz are doing the main portions of this active region coronal analysis under HAO programs supported by the Office of Naval Research and the Geophysics Research Directorate of the Air Force.

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<sup>2)</sup> Described in Quarterly Report on Research Program of HAO, October 1954-December 1954, Page 5.

<sup>3)</sup> Director's Quarterly Report: 1955-4, Page 3.

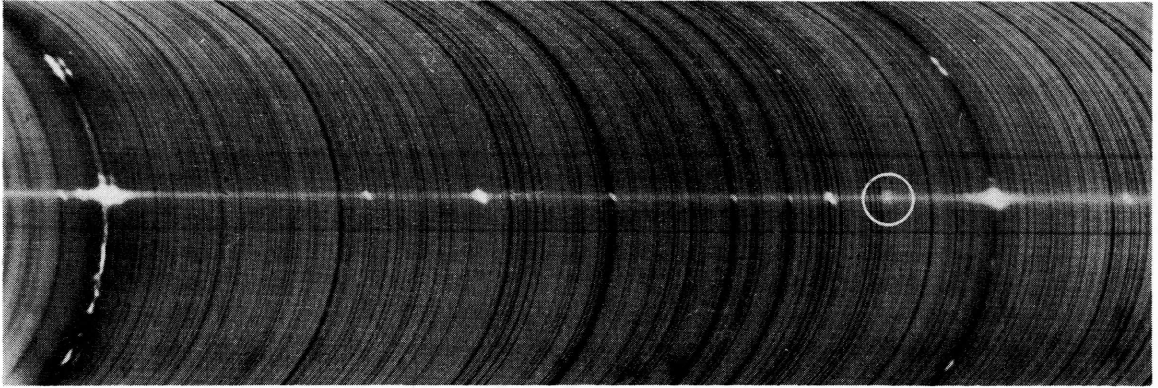


Figure 3

Spectrogram of December 18, 1956, showing strong prominence emission lines and, as circled in white, the diffuse emission line of twelve-fold ionized calcium at 4086 Å. This is the first time such observation has been made outside of eclipse.

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## 2. Solar Effects in the Ionosphere

Work is nearing completion on Warwick's antennas for studying radio noise partially absorbed in the ionosphere as it comes from distant stellar sources. Erection will be under way in April.

Meanwhile, Zirin and Warwick are studying the distribution of the electrons responsible for absorption in the D-region of the ionosphere. They are using measures from our indirect SCNA (Sudden Cosmic Noise Absorption) flare detectors built for the IGY, which we have been test-operating for nearly a year. This result is an unexpected "bonus" from the program. The daily variation of cosmic noise, induced by the ionosphere, makes the analysis feasible. Final results will come later.

## 3. Solar Effects in Geomagnetism

Our level of activity here is curtailed. However, Dr. M. Sugiura joins us in late spring, and Dr. Matsushita rejoins us. So that activity will commence again in the summer. Dr. Sydney Chapman will then be here also and will take a part in planning the program on solar-geomagnetic work.

C. Warwick, working with members of the sun-earth group of NBS, is planning to program part of this solar geomagnetic study for the use of the NBS 650 electronic computer.

#### 4. Observations of K-corona

Newkirk worked on the theory of the polarization of light in the K-corona, with a view to finding under what conditions departures from the radial direction in the corona could be produced. He concluded that magnetic fields of a few hundred gauss (higher than usually presumed) would permit "synchrotron" radiation at odd angles from very fast-moving electrons possibly associated with the ejection of cosmic rays from the sun. However, there are no clear indications that such polarization effects show up in the K-corona, although we will search for them. The one well observed example of a departure of polarization angles from the expected came, we believe, from a prominence (as described above, under the Institute program).

#### 5. Solar Activity Observing

This program continued with excellent quality data being obtained by Dodgen and Watson, who deserve special commendation for doing such a thorough job despite being short-handed at Climax.

#### 6. Temperature and Motions in the Corona

See Highlights, and also Active Region Analysis, above. Schwartz, in pursuit of his Ph. D. thesis goals, has been concentrating heavily on calculation of the ionization processes in the corona, and investigating the possible role of turbulence in the coronal gases in explaining its heat.

#### 7. Sunspot Spectra

J. Warwick made an extended trip to Sacramento Peak to observe sunspot spectra of high quality, from which he hopes to pursue the physics of the formation of absorption lines in spots. In particular, he will study the role of thermal emission and "noncoherent scattering" according to theoretical views he published two years ago.<sup>4)</sup> He also plans to investigate the effects of sunspot magnetic fields on the formation of certain spectrum lines that are magnetically sensitive, using observations of the Zeeman effect on these lines.

#### 8. Chromospheric Spectra and Spicules

Spectroscopic study of spicules continues, with particularly valuable results coming from the large spectrograph at Sacramento Peak. Athay is doing our principal work on this.

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<sup>4)</sup> James W. Warwick, *Astrophysical Journal*, 121, 190, 1955.

9. Measurement of Older Coronal Spectra

Work is moving ahead well on this program.

10. Guide Book on Solar Activity

This project was, unfortunately, nearly static during the quarter.

11. Eclipse of 12 October 1958

12. Venus Aurora

The ONR astronomy program has agreed to support our work on the observation of the possible aurora of Venus. We are starting to assemble the parts for the test late in 1957.

#### IV. RELATED PROGRESS AT OTHER INSTITUTIONS

##### A. Solar-Weather Research

An important paper appeared in the fall by Pemmaraju S. Pant, of New York University.<sup>5)</sup> The paper gives a summary of all available evidence of high altitude winds, including some new data of the authors. From all this he derives average circulation patterns for very high atmospheric wind flow (above about 12 miles altitude) at different seasons. He suggests, for example, that there are easterly winds in summer at all latitudes, in the region above 12 miles where the atmospheric temperature is rising. Above this he suggests the atmosphere is turbulent, in the region where temperatures again fall (the so-called "meso-decline") surmounted still higher (50 to 200 miles) by a large scale circulatory system with rising air over the equator and intermediate high latitudes, with descending air over the pole and the intermediate low latitudes. Still higher, he presumes, the winds become easterly at all times, as the air viscosity becomes very low, and the air-sphere begins slipping with respect to the gases of interplanetary space.

Definite seasonal changes occur, for example, after the fall equinox, affecting direction and level of various kinds of dynamic behavior. The circulation model, while decidedly speculative and preliminary, has great importance for research on atmospheric stability, and on the physical likelihood of disruptions by transient solar outbreaks.

A recent paper by Gilbert N. Plass<sup>6)</sup> suggests that the steady warming of Eastern U.S. weather since 1900 results from increases of the

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<sup>5)</sup>Pemmaraju S. Pant, Journal of Geophysical Research, 61, 459, 1956.

<sup>6)</sup>Gilbert N. Plass, American Scientist, 44, 302, 1956.

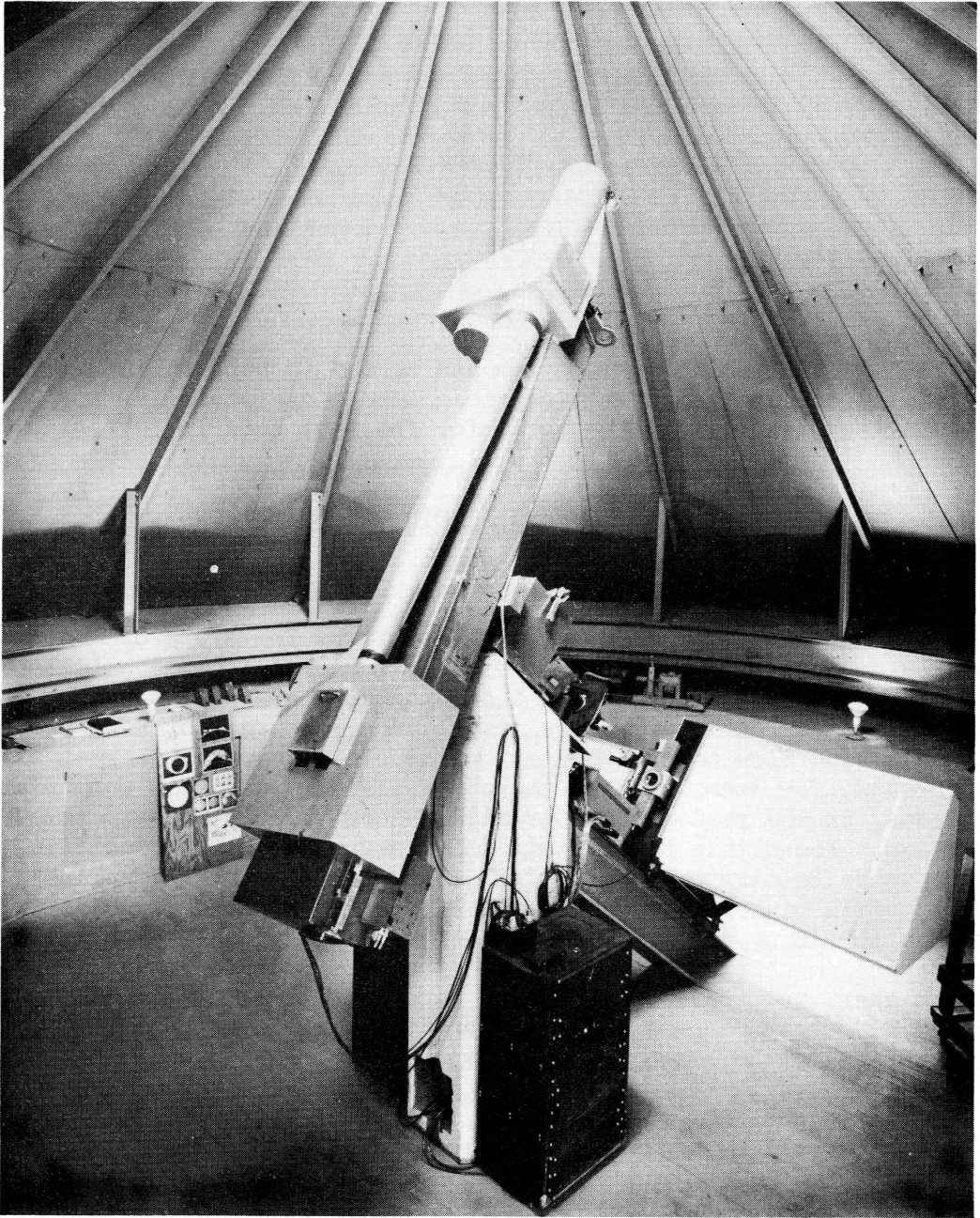


Figure 4

A new picture of the 5" coronagraph at Climax. The spectrograph, shown at the right and below the telescope, permits us to make rapid sequence observations at closely spaced heights at the edge of the sun's eclipsed face. (Photo by Alan McClure.)

carbon dioxide put into the air by man with increasing industrialization and mechanization. This theory argues directly against solar activity as a major control. If average eastern U.S. temperatures fall in coming years, it will be strong evidence against the carbon dioxide theory, since the injection of more and more carbon dioxide is likely to continue.

A novel study of long term climatic trends was recently done in Japan. Arakawa pointed out<sup>7)</sup> that ever since the 9th Century records have been accurately kept of the date of the Japanese Emperor's festival held of the day of the fullest bloom of the cherry trees in Kyoto. These records were kept until 1868, when Kyoto was no longer the capital. They reveal long term trends in the earliness of spring. From the 11th to 14th centuries, the records reveal, and again in the 16th century, the spring was later and cooler. Unfortunately, however, no direct solar activity records go back that far. Indirect data from frequency of auroras may possibly bear on this, however.

Cosmic cloud-seeding by meteor dust has previously been suggested by E. G. Bowen of Australia as a cause of rainfall peaks on the same calendar days, year after year. We have described Bowen's hypothesis previously in these reports.<sup>8)</sup> For the most part Bowen's ideas have been greeted with scepticism. Bowen's most recent paper,<sup>9)</sup> however, brings impressive evidence to bear in support of the novel view. Bowen suggests that 300 years of records of the date of the first snow to cover the ground at Tokyo (another clever use of old records to derive climatological information) exhibit peaks that agree in detail with those shown in 10 years of records of cirrus cloud sky cover in Western Australia and also with those shown in freezing nuclei measured in Western Australia for one winter. These dates are also peaks, he maintains, of world rainfall. The principal dates of the peaks are:

6 December  
18-20 December  
29-31 December  
11-13 January  
21-23 January

Bowen's results are emphatic support for the notion of a cosmic influence on terrestrial weather, and may well be related to such well-known weather phenomena as the recurrent "January thaw" and similar discontinuities of weather that seem to occur about the same date of each year.

Bowen even suggests that the year to year data for the 29-31 December rainfall show the 6.6 year periodicity of the Bielid meteor shower, which occurs about 30 November. Bowen estimates the probability that his association is accidental as less than one in a million.

7) H. Arakawa, Journal of Meteorology, 13, 599, 1956.

8) See, for example, Director's Quarterly 1956-1, p. 15.

9) E. G. Bowen, Australian Journal of Physics, 2, 545, 1956.

Another paper by Bowen, in the same journal,<sup>10)</sup> shows that the formation of freezing nuclei in widely separated parts of the globe, for three successive years, tends to occur on dates when his previous work has indicated that world rainfall peaks occur. Other papers in the same issue of the journal discuss freezing nuclei counts from Pretoria (South Africa), from Carnarvon (Australia) and Palo Alto (U.S.A.). The over-all picture is one of definite support for the Bowen hypothesis, but with suggestions that other influences may also be partially responsible. Bowen's suggested effect, though not solar-weather is, however, an astro-geophysical interaction, and will be of equal interest to solar-weather effects if it is borne out.

## B. Solar Effects on Upper Atmosphere

Dr. Eugene Parker, frequent HAO visitor, offered a new and most intriguing argument<sup>11)</sup> for the effect of solar corpuscles in distorting ionospheric layers and simultaneously producing a geomagnetic disturbance. Using reasoning based on hydromagnetic theory, he proposed that ionospheric and geomagnetic effects come about from the heating effects of solar corpuscles on the ionosphere, and the attendant displacements of the earth's magnetic field force lines. Working with the NBS research group, we hope to make some direct observational checks on this soon.

A report from Australia by J. B. Gregory<sup>12)</sup> presents evidence, based in E-layer ionospheric reflections, for a solar ionizing cause, presumably the corona, that varies from day to day in intensity and penetrating ability, but may also preserve its identity for several days in succession. The cause, however, is not yet pinned down in any detail. Gregory also speaks suggestively of "ionospheric meteorology" suggesting that the time is ripe for us to examine air motions in the ionosphere for phenomena similar to meteorological ones in these higher layers. Such phenomena might go far towards explaining the less-than-perfect solar control of certain ionospheric disturbance effects that are nonetheless statistically under clear solar influence.

## C. Solar Research

I plan to defer the consideration of solar research at other institutions until a later report.

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10) E. G. Bowen, Australian Journal of Physics, 9, 552, 1956.

11) E. N. Parker, Journal of Geophysical Research, 61, 625, 1956.

12) J. B. Gregory, Australian Journal of Physics, 9, 324, 1956.



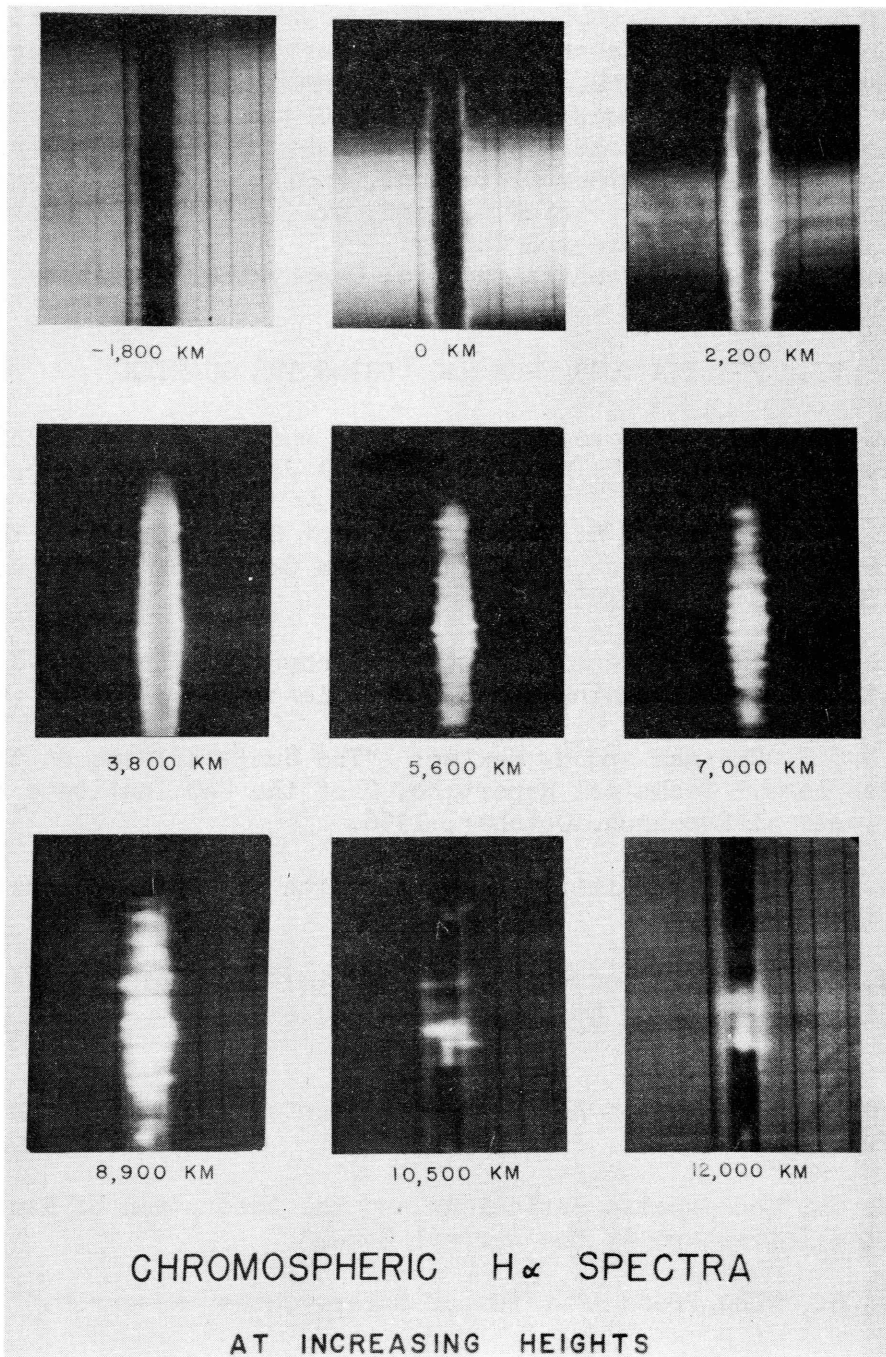


Figure 5

A series of chromospheric hydrogen spectra at increasing heights from the sun's edge, showing the irregular spicule structure under high spectroscopic resolution. (From Sacramento Peak Observatory.)

## V. RECENT SCIENTIFIC VISITORS AT HAO

|                |   |
|----------------|---|
| 26-28 October  | Dr. Richard N. Thomas, Harvard College Observatory  |
| 5-12 November  | Dr. J. H. Piddington, Commonwealth Scientific and Industrial Research Organization, Australia |
| 8-9 November   | Dr. Richard N. Thomas, Harvard College Observatory  |
| 16 November    | Dr. Arthur D. Belmont, McGill University, Canada  |
| 3-7 December   | Mr. Frederick W. Ward, Jr., Air Force Cambridge Research Center                               |
| 26-30 December | Dr. Masahisa Sugiura, Geophysical Institute, Alaska   |

## VI. PUBLICATIONS FROM HAO DURING THE QUARTER

- Athay, R. G. and R. N. Thomas: "Lyman-alpha and the Structure of the Solar Chromosphere," *The Astrophysical Journal*, 124, 586, 1956.
- Axtell, J., G. Wlérick and R. H. Lee: "Recent Observations on the Solar Electron Corona," *Journal of the Colorado-Wyoming Academy of Science*, 4, 31, 1956 (abstract).
- Cooper, Robert: "Reconstruction of the Monochromatic Corona," *Journal of the Colorado-Wyoming Academy of Science*, 4, 31, 1956 (abstract).
- Evans, J. W., S. Chapman and H. Wexler: "The Sun's Effects on the Earth's Atmosphere," Technical Report No. 2 of the HAO Institute for Solar-Terrestrial Research, October, 1956.
- Roberts, W. O.: "A High Altitude Solar Research Station," *Weatherwise*, 2, 155, 1956.
- Newkirk, G.: "Photometry of the Solar Aureole," *Journal of the Optical Society of America*, 46, 1028, 1956.
- Papers given at the Seventh Alaska Science Conference, September 27-30, 1956, at Juneau, Alaska:
- Matsushita, S., "Geomagnetic Variations and the Absorption of Radio Waves in the Ionosphere at the Auroral Zone."
- Roberts, W. O., "The Present Status of Solar-Weather Research."
- Papers given at the American Astronomical Society meeting, December 26-29, 1956, at New York:
- Billings, D. and H. Zirin: "Some Observations of the Yellow Coronal Line," (abstract).

Newkirk, G., J. Axtell and G. Wlérick: "Studies of the Electron Corona,"  
(abstract).

Warwick, J. and H. Zirin: "Cosmic Noise Absorption in the Upper Atmosphere," (abstract).

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