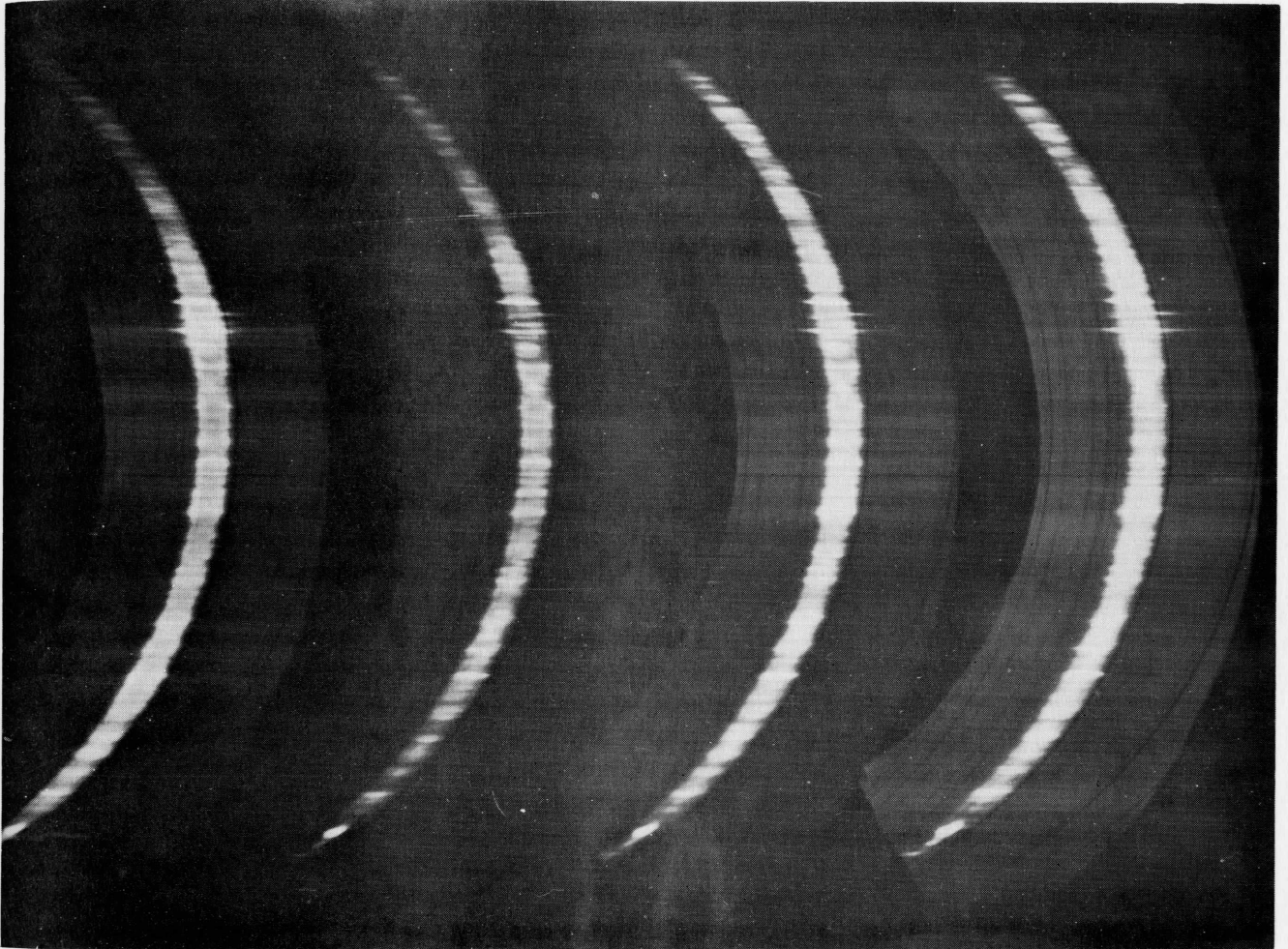


THE
DIRECTOR'S QUARTERLY REPORT

1956-2

1 APRIL to 30 JUNE



*Spicule Spectra**

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: A spectrum photograph from Climax, showing several successive images of the Balmer-alpha line of the spectrum of hydrogen gas in the sun's lowest atmospheric layer, the chromosphere. These are some of the first spectrograms from the new 5-inch coronagraph to exhibit the irregular internal details of the chromosphere. They reveal a complexity of structure never before defined spectroscopically (see Highlights, page 3). The different spectra shown are different exposures of the same region of the sun's edge taken in rapid succession. Analysis of such spectrograms will occupy a major portion of our effort in the months ahead, and should give us new insight into the temperature and density fluctuations of this critically important layer of the sun.

SUMMARY

The highlight of our quarter's research effort was the success of Richard Hansen's spectroscopic observations of the internal structure of the low-lying chromosphere of the sun. The chromosphere spectrum has previously been observed principally during eclipse. The significance of the new observations is described in some detail below.

The six-week seminar on solar-weather relationships, co-sponsored by the American Meteorological Society, began on June 18th, with a gratifying participation from other institutions. This seminar represents our first major push in the solar-weather field, and will be followed by continuing efforts in the field.

Professor Sydney Chapman rejoined us in June, to spend another three months. He continued his work on the physical and electrical properties of the corona, and his joint ionospheric and geomagnetic research with the National Bureau of Standards. During June Dr. R. G. Athay also returned to HAO after a year's leave of absence at Harvard College Observatory. He will continue his intensive research on the solar chromosphere. Dr. Malcolm Correll, head of the Department of Physics at De Pauw University, joined the Boulder staff for the summer, to undertake a continuation of his study of the magnetic field patterns

in the sun's atmosphere, as defined by prominence motion analysis from Climax and Sacramento Peak films.

The HAO and the University of Colorado invited the National Academy of Sciences to give consideration to the qualifications of the Boulder scientific community as the permanent IGY "World Data Center" for several of the geophysical disciplines that will be aggressively pursued during the IGY. Drs. Harry Vestine and G. F. Schilling, representing the National Academy visited Boulder and the HAO in late June as the first step in their efforts to find suitable sites for sections of the World Data Center. It seems particularly logical to locate in Boulder the ionospheric and solar activity disciplines. Already major archives of basic data in these and related fields exist at the National Bureau of Standards and the HAO. The University and the HAO have now agreed to provide substantial support in the form of a new building to house a part of the IGY Data Center facility and to provide new facilities for the HAO, now spread out in three locations in Boulder. The balance of the Boulder Data Center will be located at the NBS if the present joint proposal is accepted.

I. HIGHLIGHTS OF THE QUARTER

Spicule Spectra

One day back in the fall of 1943, when the Climax coronagraph station was still new and the whole HAO staff consisted of two people, me and a secretary-assistant, the sun confronted us with an unusual problem. Its rim was practically bald. Nowhere along its entire periphery was there a solitary eruption in progress, nor did it exhibit a single large or interesting-looking prominence.

The normal routine on a usual morning in those days, was to make a careful visual scrutiny of the sun's periphery before settling down to a motion picture run on the prominences or a series of coronal spectrograms. This survey served to locate the largest and most complex of the solar prominences, which we would then follow in hopes of capturing a flare, an ejection, or a series of fast-moving prominence knots.

In those days we used to do a good deal more visual observing than is the custom today—and in this visual observing I had noted a fact that many other solar observers have also lamented: that fine structural details of prominences that are quite evident to the eye are nevertheless impossible to photograph. The reason apparently is smearing produced by the jiggle of the telescope and the atmospheric shimmer, both of which make a dancing solar image instead of a stable one.

The sun's baldness was the more distressing that November morning because the sky was beautifully clear, and the atmospheric shimmer at a minimum. My assistant and I, therefore, decided to do a careful visual scan of the sun's edge, working closer to the rim than usual, to see whether we might find unusually faint or small scale features that could go entirely overlooked on days with more excitement brewing.

We found just such a phenomenon—to which we later gave the name "spicule." The whole solar edge, particularly in the regions of the sun's north and south poles, was furry with faint spike-like jets of gas.* Moreover, their pace was lively. A few minutes took them from tiny blisters, to suddenly elongated jets, to rapidly fading spikes. We made some careful pencil drawings, seeking to illustrate their typical appearance. Figure 1 is one of these first drawings, showing how the spicules looked to me in the eyepiece of the coronagraph fitted with a filter centered on the Balmer-alpha line of the hydrogen spectrum.

* Later I found that the spicules had been seen on 1930 eclipse photos by Marriott of Swarthmore, but not analyzed in detail, and that some of their characteristics had been reported much earlier still by the famous visual solar observer, Father Secchi of the Collegio Romano.

Better still, we succeeded in photographing the spicules, even though much of the wealth of eye-view detail was lost. The virtue of the photos was that we could study them in the warmth of the Observatory shop-darkroom-office during the leisure of the long, bitter blizzards that often plague Climax in winter. From the very first film, a few hundred frames in length, we measured the average spicule's height, width, lifetime, and abundance. A typical spicule, it turned out, reaches at fullest development a size about 2,000 miles by 6,000 miles¹⁾—a small feature at the sun's distance of 90,000,000 miles, or compared to the sun's diameter of 864,000 miles.

On the average, spicules reach an upwards thrust velocity, at the post-blister stage, of about 20 miles per second, and have lifetimes of about four minutes. At any given moment one to two spicules can be seen for every degree of sun's edge. Near the poles of the sun they are straighter, taller, and simpler in appearance; at low latitudes on the sun they are less well defined or regular. At best their small size makes them difficult to observe; but their abundance, and their ubiquity makes us realize that they are a fundamentally important feature of the sun's lowest atmosphere.

Subsequent years of research have confirmed the sketchy early observations, and extended their scope.²⁾ Nowadays, they are called upon by the theoreticians to explain many of the properties of the sun's chromosphere.³⁾

It may be that the chromosphere is but a fine interlacing of such jets—denser and more luminous lower down. Their kinetic energy may be sufficient to heat the corona by dissipation of the supersonic shock waves that result from their up-thrust.⁴⁾ These and many other theoretical possibilities now seem at least worth considering.

As we have mentioned before, the temperature and physical properties of spicules are still matters on which opinion is divided (Report 1955-2). As a consequence, spectrum-line analysis, using large dispersion spectrographs to obtain the detailed shape, the profile, of the spectrum line is a most important goal. A great deal more information on motion and temperature can be gotten from spectrograms than from photographs alone—but adequate spectrograms are very much harder to get, even than photographs.

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- 1) Roberts, *Astrophysical Journal*, 101, 136, 1945.
 - 2) Rush and Roberts, *Australian Journal of Physics*, 7, 230, 1954.
Lippincott, *Astronomical Journal*, 61, 8, 1956.
 - 3) For example, see van de Hulst, page 212, The Sun, ed G. Kuiper, Univ. of Chicago Press, 1953.
 - 4) Thomas, *Astrophysical Journal*, 108, 130, 1948.

Recently Dr. Raymond Michard of the Meudon Observatory in France, working at the famous Arcetri Astrophysical Observatory in Italy, succeeded in obtaining about ten spectrograms showing some 35 spicules at the sun's edge.⁵⁾ From the Doppler effect, he concluded that the typical spicule had a substantial velocity towards or away from the earth of about 12 miles per second, and that its temperature was under about 18,000°F. He admits quite frankly that the observations were difficult and their interpretation may therefore be subject to errors.

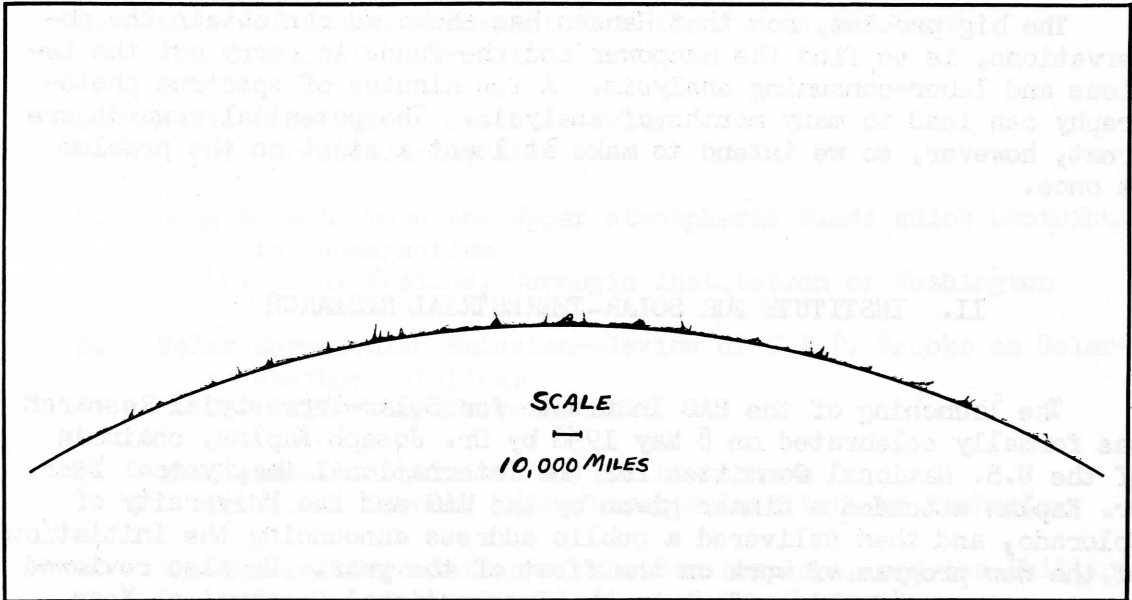


Figure 1

Drawing showing general character of the polar region of the sun. This sketch of the chromosphere was made from visual observations in H-alpha with best seeing conditions and sky purity.

In June, however, Richard Hansen and the other observers at Climax turned their attention to the problem of obtaining spectra of individual spicules. Their success was outstanding. The cover illustration shows the astonishing complexity of the profile of the Balmer-alpha spectrum line of hydrogen. Several different exposures at the same points along the sun's edge are shown. The color-dispersion is from left to right. Lines that are grossly spread out in this direction arise in gases that are either very dense or very hot. Lines that are narrow, left to right,

5) Michard, *Annales d'Astrophysique*, 19, 1, 1956.

must be relatively cool. By "cool" I mean under 20,000°F. and by "hot" I mean two or three times that value.

We haven't yet had time to analyze these spectra, but we hope that their quality will permit us to make temperature and motion analysis more reliably than Michard could do. We intend, therefore, to repeat immediately the sort of analysis he has done, and to extend similar observations to other lines of the spectrum arising in atoms of different atomic weight from hydrogen. By so doing we have a chance to unravel the intricately intermeshed physical properties of temperature and density.

The big problem, now that Hansen has shown we can obtain the observations, is to find the manpower and the funds to carry out the tedious and labor-consuming analysis. A few minutes of spectrum photography can lead to many months of analysis. The potential rewards are great, however, so we intend to make at least a start on the problem at once.

II. INSTITUTE FOR SOLAR--TERRESTRIAL RESEARCH

The launching of the HAO Institute for Solar--Terrestrial Research was formally celebrated on 8 May 1956 by Dr. Joseph Kaplan, chairman of the U.S. National Committee for the International Geophysical Year. Dr. Kaplan attended a dinner given by the HAO and the University of Colorado, and then delivered a public address announcing the initiation of the new program of work on the first of the year. He also reviewed the importance of this effort to the International Geophysical Year.

During his three-day visit, Dr. Kaplan examined the research goals of the HAO with the scientific staff, and discussed with us more generally the problems of solar influences on the upper atmosphere, with emphasis on upper air chemistry, a field to which he has made very significant contributions.

Seminar on Solar-Weather Research

The second quarter of work under the HAO Institute program is completed. Principal preoccupation for the period was the intensive program planning that was necessary to the success of the Six-Week Solar-Weather Seminar, which began on the 18th of June with a distinguished list of visitors. Athay and I carried out this planning work, and Athay served as general chairman for the seminar.

The seminar threatened for awhile to outgrow our plans, and we were forced, with regret, to place limitations on further attendance.

We did not do so until well over 25 participants had signified a wish to attend. A list of the topics of the Seminar follows:*

Session No.

1. General Features of the Sun
Dr. Donald E. Billings, HAO
2. The Inter-relation of Phenomena on the Sun and the Time Relations of Solar Activity
Dr. Gordon A. Newkirk
3. Modes of Energy Transport from the Sun to the Earth
Dr. James W. Warwick
4. Basic Theories of Solar Activity
Dr. Harold Zirin, HAO
5. Some Effects upon the Upper Atmospheric Winds which Contribute to Geomagnetism
Dr. E. H. Vestine, Carnegie Institution of Washington
6. Solar Corpuscular Emission—Review of C.E.P. Brooks on Solar-Weather Relations
Dr. Walter Orr Roberts, HAO
7. The General Circulation of the Atmosphere
Dr. E. N. Lorenz, Massachusetts Institute of Technology
8. The General Circulation of the Stratosphere, and the Phillips' Theory of the Circulation of the Troposphere
Dr. H. A. Panofsky, Pennsylvania State University
9. Climatic Changes
Dr. H. C. Willett, Massachusetts Institute of Technology
10. Meteorological Evidence for Solar Control of Weather
Dr. H. C. Willett, Massachusetts Institute of Technology
On Geomagnetic Indices Responsible for Solar Particles
Dr. S. Matsushita, Kyoto University and HAO
11. Stability of the Atmosphere: The Dishpan Experiments
Dr. Ralph Shapiro, Geophysics Research Directorate, Air Force Cambridge Research Center
Stability of the Atmosphere
Dr. Edward Lorenz, Massachusetts Institute of Technology

* Corrected for changes in program after the seminar got under way.

12. The Radiation Budget of the Troposphere and Stratosphere
Dr. Julius London, New York University
13. Carbon Dioxide Theory of Climatic Control
Dr. Julius London, New York University
Alternate Theories of Climatic Change
Dr. H. C. Willett, Massachusetts Institute of Technology
Comment on Solar Emissions at Different Levels of Solar Activity
Dr. Walter Orr Roberts
14. Some Correlations of Atmospheric Parameters with Solar Activity
Mr. Glenn Brier, U.S. Weather Bureau
15. Short-Term Correlations
Mr. Glenn Brier, U.S. Weather Bureau
16. Persistence Correlations and Geomagnetism
Dr. Ralph Shapiro, Geophysics Research Directorate, Air
Force Cambridge Research Center
17. The Simultaneous Pressure Oscillation of Barometers Along the
Equator
Dr. C. E. Palmer, Institute of Geophysics, University of
California
18. Upper Level Cyclonic Circulations in Equatorial Regions
Dr. C. E. Palmer, Institute of Geophysics, University of
California
19. Specifications of Circulation Features Resulting in Low
Persistence Correlation
Dr. Ralph Shapiro, Geophysics Research Directorate, Air
Force Cambridge Research Center
20. Generalized Harmonic Analysis
Dr. H. A. Panofsky, Pennsylvania State University
21. Long Range Climatic Forecasting on the Basis of Solar Variability
Dr. H. C. Willett, Massachusetts Institute of Technology
22. Weather Changes Associated with Coronal Activity
Mr. E. D. Farthing, Trans World Airlines
23. Radio Fading Techniques of Ionospheric Wind Measurement
Dr. Donald G. Yerg, Michigan College of Mining and Technology
Relations Between Geomagnetic Activity and 100 mb Temperature
and Height
Mr. Irwin Ruff, New York University
- General Remarks
Mr. Loren Crow, Consulting Meteorologist, Denver, Colorado

24. Possible Linkages Between the Mesosphere and Troposphere
 Dr. C. E. Palmer, Institute of Geophysics, University of California
 An Approach to a Theoretical Study of a Solar-Weather Relationship
 Dr. Edward Lorenz, Massachusetts Institute of Technology
 Comments
 Dr. Julius London, New York University
25. High Level Temperatures and Solar Activity
 Mr. Frederick Ward, Geophysics Research Directorate, Air Force Cambridge Research Center
26. Research, Proposed or Completed
 Mr. Jack Nordf, Massachusetts Institute of Technology
 Dr. C. E. Palmer, Institute of Geophysics, University of California
 Dr. Ralph Shapiro, Geophysics Research Directorate, Air Force Cambridge Research Center

To this program a substantial number of additional informal discussions were added, for which notes were not kept. The informal sessions were probably in many ways the most important part of the entire seminar, for they allowed the different participants to gain closest familiarity with each other's work.

A limited number of copies of the full notes of the Seminar will be available from the HAO early in September.

We are deeply indebted to the American Meteorological Society for co-sponsoring the Seminar, and to the National Science Foundation for a grant that covered a part of the expenses of the Seminar.

Detection and Analysis of the K-Corona

As we have described in numerous earlier reports, the only convincing short-term solar-weather relationship thus far discovered is that of Dr. R. Shapiro of the Air Force Cambridge Research Center. The solar emission involved is of electrified corpuscles--mostly protons and electrons--that stream from sun to earth in one to three days. These corpuscles are also responsible for important radio-communications interruptions, and for other earth effects, such as the auroras, geomagnetic storms, and earth currents.

The mechanisms by which the solar clouds are emitted remains a mystery, and the prediction from solar observations of the time of arrival of the corpuscular clouds is still an uncertain business. For example, some active sunspot regions seem to cause great increases in corpuscular emission; others appear to inhibit the same kinds of clouds. We at HAO believe that the unravelling of this mystery has become a central



Figure 2
Axtell (left) and Wlérick (right) are shown here checking the operation of the K-coronameter outside the Sommers Bausch Observatory in Boulder. Immediately above Axtell's hand is the Lallemand multiplier photocell that detects the light from the electron corona. It gives a signal that is graphically recorded on an Esterline-Angus recorder located inside the building.

problem of sun-earth research, and for this reason are aiming a substantial part of our effort towards the problem.

One part of our attack on this problem is being carried forward by a University of Colorado graduate student, James C. Axtell. A fellowship supported by the Institute permits him to endeavor to locate the corpuscular streams near the sun, on a day to day basis, and therefrom to ascertain the space shape of the brightest of these particle streams. His work will, if successful, constitute his Ph. D. thesis subject. Axtell's thesis study was supported by Radio Corporation of America. The development of the new "K-coronameter" that Axtell will use has been supported by the U.S. National Committee for the International Geophysical Year, through a National Science Foundation grant. (See Figure 2) We will give more details about this work in our next report.

Other Institute Programs

Several other programs of study under the HAO Institute program are getting under way. One is a modest study of the relationship of light-scattering particles in the earth's atmosphere, and their possible relation to solar corpuscular emission. Several research workers believe that when there are abnormally strong solar corpuscular beams there are also greater numbers of scattering particles in the earth's atmosphere. Newkirk is taking a critical look at these questions. He and Dr. Paul MacCreedy of the Munitalp Foundation engaged in detailed discussions in April of the possibilities of light-scattering particles as agents to trigger large-scale upper atmospheric changes.

We believe that the Climax coronagraph, which is highly sensitive to atmospheric light-scatter may provide some additional basic observational data on the matter of the amount of such material at high altitudes. Billings and Newkirk are investigating the possibility of obtaining systematic measures of the scatter from the 1942-56 archives of daily corona spectrograms taken at Climax and Sacramento Peak. The data are also of interest to Mr. Glenn Brier of the U.S. Weather Bureau, who would like to find out if new observational data will bear on the question of atmospheric dust, possibly from volcanoes, which might, in turn, produce natural "cloud-seeding" effects.

Early in April Mr. E. D. Farthing of Trans World Airlines visited Boulder for conferences on his program of solar-weather research. We discussed particularly the problems of intercomparison of Climax and Boulder coronal indices, which are showing discontinuities with respect to each other. Mr. Farthing subsequently sent a list of seriously discrepant values, which Trotter and Billings analyzed in some detail. Most of the serious discrepancies were on days of poor observing conditions and were in preliminary data, which emphasizes the need for more reliable preliminary reporting. We have instituted procedures that should, we believe, greatly lessen these troubles. During the visit we

authorized Mr. Farthing to distribute his computed indices in whatever way would stimulate the most widespread research use.

We intend also to enter into a modest scale study of 300 mb. mid-latitude synoptic maps to see whether responses of any sort can be recognized qualitatively that might bear some relation to solar activity. This work will be done jointly with Mr. Robert Curtis, Department of Meteorology, Continental Air Lines.

Indices of Solar Activity

During the quarter we began preliminary thinking on a method of developing a new type of solar activity index or indices that will measure not only the degree of activity, but the nature of the latitude and longitude distribution of solar centers.

It is apparent that the solar activity distribution can be very drastically different for identically similar average monthly sunspot numbers, depending on whether the activity is concentrated sharply into a few intense regions, or whether it is dispersed rather uniformly into many. Moreover, it is also evident that the solar radiational and corpuscular emissions can be expected to be very different in the two cases, and their terrestrial impacts to differ also. Such indices may be useful also in deriving solar "analog" months from past solar data, and such analog months may be of use in solar-weather research.

III. OTHER RESEARCH PROGRAMS OF THE HAO

A. Staff

We mentioned in the SUMMARY the return of Chapman and Athay, and the summer visit of Correll. The other major personnel change is the appointment of Mrs. Mary L. Andrews to the post of assistant to the director to succeed Mrs. Kathryn Virnelson Shapley, who will leave the Observatory after managing the administrative details of the Solar-Weather Seminar.

B. Research in Progress

1. General

As before, we describe some programs in just a few words, reserving details for times when especially important advances are completed.

2. Active Region Analysis

The observational facilities of Climax and Sacramento Peak are now poised for completion of far more complete active region data-taking than ever before. Analysis of the outstanding February-March activity (See Report 1956-1) is in progress.

3. Solar Effects in the Ionosphere

Warwick's observational facilities are gradually being put into shape for preliminary operation with temporary antennas. Some measures may be possible within a few months.

4. Solar Effects in Geomagnetism

Forecasting of geomagnetic disturbances continues as a joint HAO-NBS program. Further research is also being done on the basic relations involved.

Roberts and Matsushita have looked over magnetograms for the 22 February cosmic ray rise and flare (see 1956-1 HIGHLIGHTS, p. 3). Strangely enough there appears to be a minor geomagnetic disturbance at the same time as the cosmic ray increase (03:45 UT on 23 February 1956) at farthest north stations. (Resolute Bay 83° N geomagnetic latitude and Baker Lake 74° N geomagnetic latitude), inside the auroral zone, but none lower (College 64° N geomagnetic latitude or Agincourt 55° geomagnetic latitude). This suggests that solar corpuscles traveling with a large fraction of the velocity of light arrived about 10 to 15 minutes after the flare, and produced magnetic effects within the polar cap. Perhaps a careful search should be made for similar polar cap flare effects on other dates, using dark hemisphere stations (to avoid confusing effects of radiation) and instances when geomagnetic conditions were generally very quiet.

5. Observations of the Electron Corona (see mention under INSTITUTE program above)

6. Solar Activity Observing

The recent studies of Zirin and the examination of the relative levels of recent active regions suggests that we have undervalued the criteria determinable from the motion of limb prominences, as new active regions come over the east edge of the sun in its 27-day rotation. Consequently, we have given high priority at Boulder to the development of a new prominence motion-observing and flare-locating coronagraph to be added to the observing facilities at Climax. We will have it in operation by next quarter.

Solar activity has leveled off, or even declined a bit, from the very spectacular levels of February and March. However, the long-term trend shows that solar activity has moved a large part of the way towards a maximum-type.

The regular corona-observing program has recently been improved in several regards. First, we have worked out techniques to improve the position angle determinations on coronal spectra, which have sometimes been subject to errors of several degrees. We have also worked on techniques for improvement of the zero height determination in graded height series. Finally, the intensity calibration schemes have been carefully cross-compared, and our measures now appear to be in good correspondence with the Pic du Midi in the Pyrenees, the only station using absolute calibrations.

7. Temperature and Motions in the Corona

8. Temperature and Radio Emission in Prominences

Special new sets of observations of outstanding quality were made by David Dodgen, observer at Climax, which will be the subject of special analysis by Zirin, who hopes to have results to report before the end of the next quarter.

9. Solar Granulation Analysis

Wlérick will complete his work in this area during the next quarter, and we shall briefly present his conclusions in Report 1956-3.

10. Chromospheric Research (See HIGHLIGHTS above)

11. Electronic Flare Pickup

After a frantic last-minute "crash program" to meet the deadline for the sailing of the USS Colonial, from which ten or twelve balloon-borne rockets were fired in July, we delivered to Dr. Talbot Chubb what we believed to be a fully operating flare detecting device for use from shipboard. We added to the pickup instrument in our "crash program" a spectrograph of low dispersion to improve the rejection of wavelengths far from the ultraviolet wavelength (K line of Ca+) used for the flare detection. We also added several elements of a birefringent filter lent us by Mr. R. B. Dunn of the Sacramento Peak Observatory. We shall describe the results of the rocket firings in the next report.

12. Measurement of Older Coronal Spectrograms

This program made good strides during the quarter.

13. Guide Book on Solar Activity.

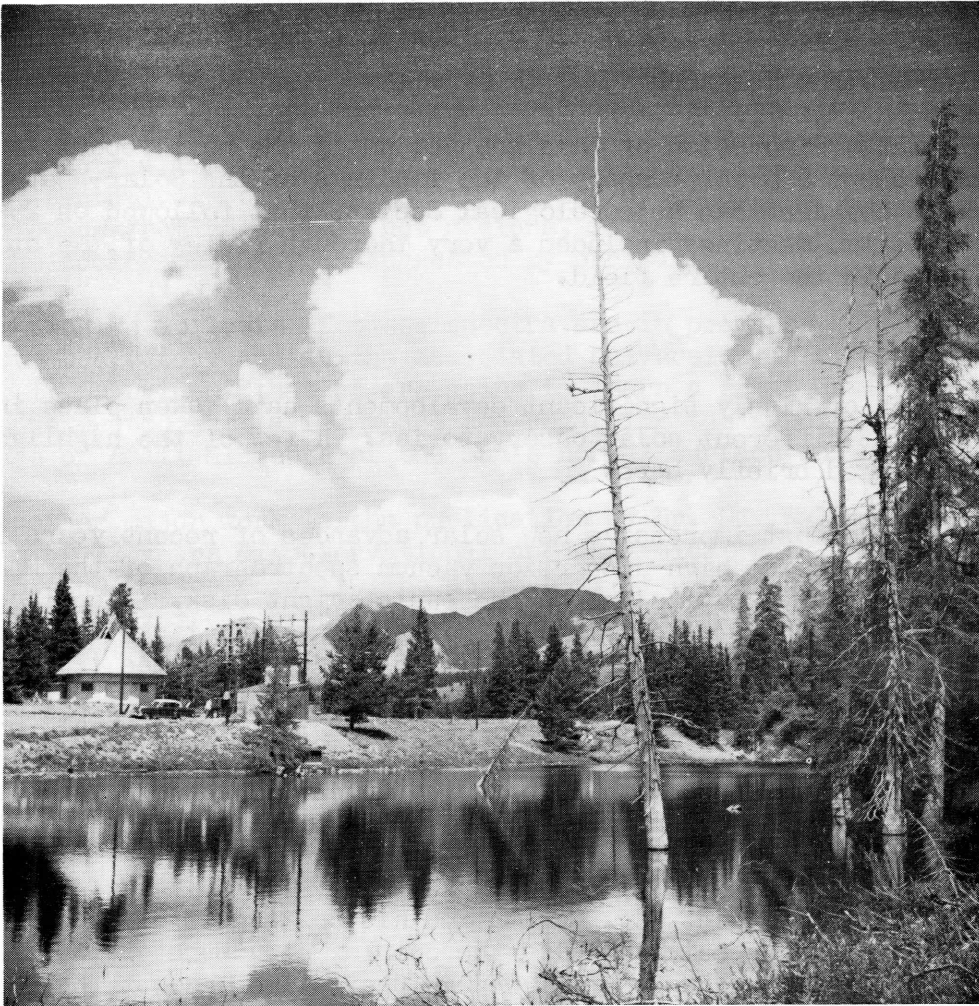


Figure 3

New picture of the small dome at Climax showing typical summer afternoon clouds. The best summer observing is in the early morning when the sky is usually clear.

14. Danger Island Eclipse, October 1958.

Plans are definitely proceeding for a joint Sacramento Peak Observatory-HAO expedition to Danger Island (latitude 10°S , longitude 170°W) about 400 miles north of Pago Pago in the Samoa Islands. The program will be supported by the Air Force Cambridge Research Center.

IV. RELATED PROGRESS AT OTHER INSTITUTIONS

A. Solar-Weather Research

We defer a discussion of this subject until the next report, when we shall present a brief summary of the findings of the Solar-Weather Seminar and the American Meteorological Society that followed on 25-27 July. These two meetings included a very thorough review of the status of knowledge in the entire field.

B. Solar Research

A number of highly significant developments have taken place in recent months at different solar observatories. A few of the highlights will be reviewed briefly here.

One of the most impressive new solar advances of recent years is the completion of the high-dispersion vacuum spectrograph of the McMath-Hulbert Observatory and its use on the sun's bright disk.⁶⁾ The large spectrograph, which is placed in a 52 foot long vacuum tank to eliminate air turbulence, has a maximum dispersion of nearly 100 times (28 mm/A) that of our "high dispersion" coronal spectrograph at Climax, with correspondingly high resolution of spectroscopic detail. (We should point out that for coronal research, where the available light is very limited, a spectrograph like the McMath-Hulbert instrument would operate at a tremendous disadvantage, and would probably require exposures that are impossibly long.)

With this instrument, Dr. McMath and his colleagues have obtained, for the first time, spectra showing the complex structure of the Balmer-alpha line of hydrogen gas when viewed in projection against the solar disk, and thus when the spectrum lines are seen in absorption.

The results are directly relevant to the chromosphere emission spectra that we are now able to take at the solar edge (see HIGHLIGHTS, and also show that there are large variations in the profiles of the solar face from one point to another, implying a complex temperature-pressure structure. The size of the structural elements revealed in the McMath-Hulbert spectrograms is larger than the conventional "granulation" of the solar face, which is not evident in the spectra. The smallest features have an average thickness about five times that of the ordinary solar granules.

Another remarkable result revealed in the McMath-Hulbert spectra is the structure shown by very narrow absorption lines arising from other elements in the sun, such as chromium and barium. These lines show "wiggles" apparently produced by the up and down movements of the small

6) McMath, Mohler, Pierce and Goldberg, *Astrophysical Journal* 124, 1, 1956

irregular cells of the sun's face--some rising, some falling, in apparently chaotic fashion, with velocities of about 0.5 miles per second.

The hydrogen line is too broad to reveal these velocities so clearly, but exhibits fluctuations from point to point in the breadth of the spectrum line, symptomatic of temperature effects. The authors suggest tentatively that a good part of the hydrogen gas in the chromosphere comes from relatively hot regions, rather than predominantly from the cooler regions, as suggested by our earlier work (1955-2, page 3).

Intensive analysis of these spectra are in progress at the McMath-Hulbert Observatory and at the associated University of Michigan Observatory. It is evident that we are going to learn a great deal that was quite unexpected just a few years ago regarding the fluctuations of temperature of small elements of the sun's normal surface and atmosphere.

Another major work is the publication by Dr. Max Waldmeier of the results of 12 years of observational and analytical work on the occurrence of the yellow coronal line at 5694 A.⁷⁾ During the years 1944 to 1955 Waldmeier observed the relatively rare yellow coronal line on 345 different occasions. This is a far larger number of occasions than the more complete observing schedules of Climax and Sacramento Peak have revealed, attesting the quality of the coronal observations of Waldmeier, and also reflecting the fact that his coronagraph and spectrograph are somewhat better suited to the detection of faint coronal lines.

Waldmeier compared the type of sunspot found in active regions of the sun with the probability of occurrence of the yellow coronal line above the region, and discovered that for the very complex, active sunspots (Classification F) there is essentially a 100% probability of finding the line. He confirmed, also, the earlier and less thorough-going conclusions reached here and elsewhere that the yellow coronal line always corresponds to greatly enhanced solar activity. Waldmeier expressed some doubt, however, about the HAO identification of the yellow coronal line with Ca XV, discussed earlier in these reports.⁸⁾

The resolution of this problem will be in the further study of the relative intensities of the coronal lines 5694A and 5446A. These both arise from Ca XV, if the identification is correct, and theory indicates that their intensities must be about the same. Waldmeier considers their intensities significantly different, while HAO's only measurement has indicated them similar in one instance.

7) Waldmeier, Zeitschrift fur Astrophysik, 39, 219, 1956

8) Pecker, Billings and Roberts, reported in full in Astrophysical Journal, 120, 509, 1954

Another major work bearing on the significance of the yellow coronal line is the voluminous Ph. D. thesis by Dr. P. Simon, now issued in full from the Paris Observatory. This very complete study compares, among other things, yellow line occurrences with geomagnetic and ionospheric data. It reveals that the regions exhibiting yellow coronal emission are relatively certain to produce substantial geomagnetic effects at their central meridian passage, and that they have a strong association with ionospheric disturbance and with solar radio noise emission at meter wavelengths. The work suggests that systematic yellow coronal patrol observations, in spite of their great difficulty, are of high importance. It also suggests that use of a photoelectric coronal

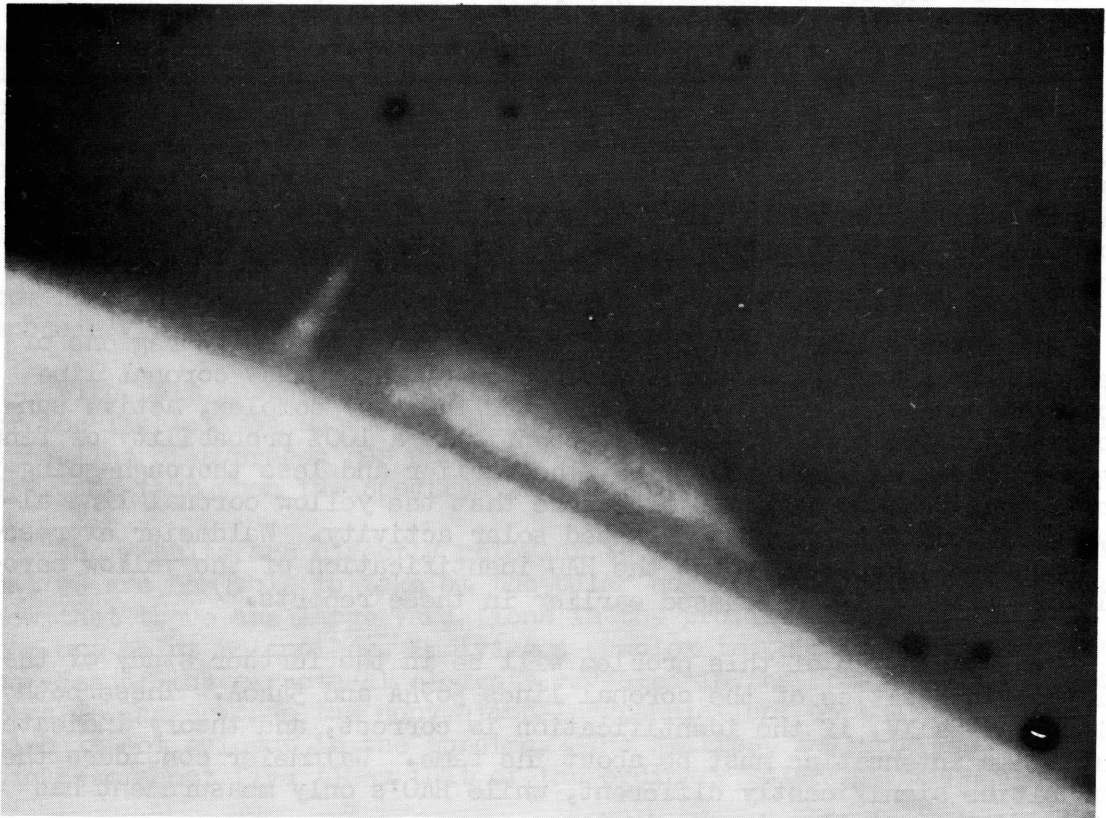


Figure 4
The chromosphere seen in projection against a prominence.
Picture taken at Sacramento Peak Observatory.

line-emission photometer to heighten the detectability of the line might be justified.

Mme. M. d'Azambuja, one of the greatest living solar observers, published a short, provocative note recently⁹⁾ suggesting that twice as many solar active regions form in the sun's east hemisphere, viewed from earth, as are found in the west. This report, following the long history of observations of east-west asymmetries, is a further perplexing fact in the list suggesting, with various degrees of reliability, that more sunspots, prominences, and other active solar phenomena have their birth in the east than the west of the sun.

Various explanations have been offered, none appealing. Some workers doubt the reality of the effects. (In this case, Mme. d'Azambuja finds the effect large.) Others frankly assume it represents an earth-effect of some sort of another, perhaps tidal. This is very hard to believe, because the earth's influence should be very small compared, for example, to Jupiter. Still others explain it as an apparent effect only, arising from systematic tilts in the plane of the active regions, so that visibility is greater in the eastern hemisphere.

There is a division of view about the effects here at HAO. I, for example, am simply perplexed and regard it as a curious and challenging relationship that seems reasonably well established; J. Warwick, representing the other extreme, believes that the results are probably entirely spurious, and come from some sort of systematic observing error.

The Harvard Observatory staff at the Sacramento Peak Observatory, using the large scale height-resolution coronagraph for prominence photography, recently succeeded in observing an effect that has never before, so far as I am aware, been recorded photographically, though both Lyot and I have mentioned it from visual observations. The Sacramento Peak photograph demonstrates the effect more clearly, however, than I have seen it visually. The effect is that of viewing the sun's thin chromospheric layer, a mere 5,000 or so miles thick, by the shadow it casts on a bright, uniform solar prominence that is located past the edge of the sun, but which stands up high enough so that it shows behind the chromosphere.

Figure 4 shows the prominence, with the edge of the sun unclipped, and the chromosphere visible in projection as a dark band. Such photographs have an important scientific justification; from them it should be possible to gain additional knowledge of the degree of opacity of the chromosphere. Such information will help unravel the tangled threads of the temperature-density problems of corona, prominences and chromosphere.

9) d'Azambuja, Comptes Rendus, 241, 1712, 1955

V. RECENT SCIENTIFIC VISITORS AT HAO

A partial list of the scientific visitors to HAO during the quarter included:

- Mr. Richard B. Dunn, Sacramento Peak Observatory, 5-6 April
Dr. John W. Evans, Sacramento Peak Observatory, 5-6 April
Dr. A. Lallemand, Paris Observatory, 4-7 June
Dr. Donald Packer and Dr. J. D. Purcell, Naval Research Laboratory, 16 May
Dr. J. J. Raimond, Director of the Zeiss Planetarium, The Hague Netherlands, 3-6 May
Dr. G. Righini, Director of the Astrophysical Observatory of Arcetri, Firenze, Italy, 31 May-2 June
Dr. Martin Schwarzschild, Princeton University Observatory, 16-17 April
Dr. Richard N. Thomas, Harvard College Observatory, 5-7 April
Dr. Lloyd White, Office of Naval Research, 27 June

VI. RECENT PUBLICATIONS FROM HAO

- Zirin, H: "The Helium Equilibrium in Prominences and the Chromosphere," *Astrophysical Journal* 123, 536, 1956.
- Billings, D. E., S. Hirsch and C. Varsavsky: "Coronal Temperature Determination from Emission Lines," *Astrophysical Journal* 123, 532, 1956.
- Roberts, W. O: "Some Coronagraph Spectra of the Chromosphere," *Astronomical Journal* 61, 189, 1956 (abstract).
- Wild, J. P. and H. Zirin: "On the Association of Solar Radio Emission and Solar Prominences," *Astronomical Journal* 61, 193, 1956 (abstract).
- Roberts, W. O: "Solar Coronal Temperature and Emission," *Journal of Geophysical Research* 61, 409, 1956 (abstract).
- Matsushita, S: "Ancient Aurorae Seen in Japan," *Journal of Geophysical Research* 61, 297, 1956.
- Newkirk, G. and L. M. Lowenthal: "Temperature Anomalies Aloft and Their Correlation with Solar Activity (1952-54)," *Bulletin of the American Meteorological Society* 37, 293, 1956 (abstract).

Athay, R. G: "Variable Solar Emission in Ultraviolet and X-ray Regions and Possible Implication for the Upper Atmosphere," Bulletin of the American Meteorological Society 37, 293, 1956 (abstract).

Newkirk, G: "Photometry of the Solar Aureole," Bulletin of the American Meteorological Society 37, 293, 1956 (abstract).

Zirin, H: "Indices of Solar Coronal Radiation," Bulletin of the American Meteorological Society 37, 295, 1956 (abstract).

Walter Orr Roberts

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High Altitude Observatory
Boulder, Colorado
14 September 1956

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