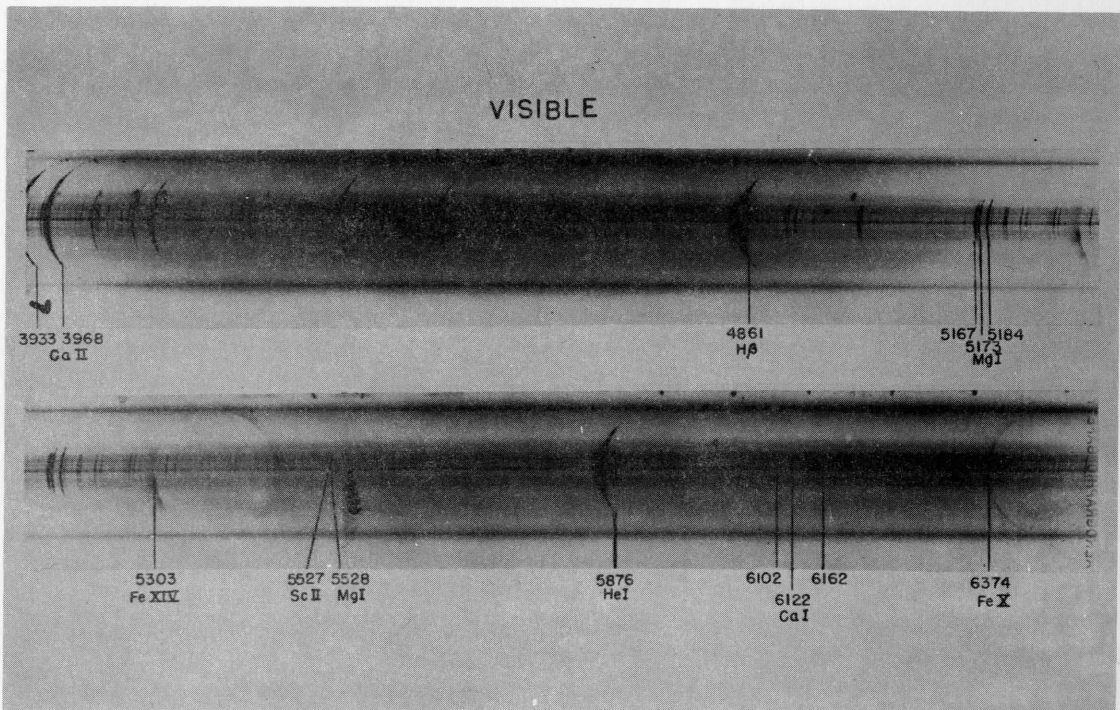


THE
DIRECTOR'S REPORT

1 January through 30 June 1961



Spectrum from 1952 Khartoum Eclipse*

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.

This issue of the Director's Report is dedicated to Captain Mary P. Converse, in affection and admiration. Her enthusiasm for our research and for the students and staff engaged in it was unbounded. Her memory is preserved at HAO, among other ways, in the "Captain Mary Room" where we hold frequent small conferences, and where the box-lunch contingent of students and staff meet each noon, for lunch and informal conversation.

***Cover:** The joint HAO-Naval Research Laboratory expedition to Khartoum, Sudan in 1952 obtained many spectrum photographs of the solar chromosphere, of which the cover picture is one example. These spectral photographs have served as the basis of extensive research on the chromosphere by many members of the HAO staff and others. A comprehensive discussion of these studies has been published by R. N. Thomas of the National Bureau of Standards and R. G. Athay of HAO. (See Highlights, page 2).

SUMMARY

Climax observer James, along with Hansen of the Boulder staff, developed a simplified and improved method of measuring the daily coronal spectrograms taken at the Climax station. The new system allows the Climax staff to make the final reductions of the observations within hours of developing the photographic plates. Previously the observers made only quick visual estimates of the intensities of the spectral lines and then sent the plates to the laboratory in Boulder for careful photoelectric measurement. The simplified process of measurement is proving as accurate as the older method and can be carried out at Climax without disruption of the observing program.

A book, "Physics of the Solar Chromosphere," by R. N. Thomas of the National Bureau of Standards and Athay of the HAO staff, was published early in 1961. This comprehensive analysis of problems of the solar chromosphere developed in major part from studies by Thomas, Athay and others of the data obtained at the 1952 Khartoun eclipse expedition. The authors describe in detail new methods of analyzing the physical state of the chromosphere. The methods are applicable to a wide range of astrophysical problems.

Roberts and Thompson continued development of the scientific program and recruitment of staff for the National Center for Atmospheric Research (NCAR). The State of Colorado appropriated funds to donate a 500 acre site south of Boulder for NCAR's new laboratory

and the citizens of Boulder voted a charter amendment to allow the city to deliver water to the site. Plans for merging the HAO with NCAR's management corporation, in order to bring HAO's and NCAR's complementary programs under integrated scientific direction, were described in a letter sent to HAO friends in November 1961. The merger was successfully accomplished in December 1961 and will be discussed in detail in the following report.

Chapman and Syun-Ichi Akasofu, a graduate student from the University of Alaska, jointly arrived at a new theory about the origin of certain auroral phenomena. The difficult problem of understanding the very high temperatures observed in the corona was approached in a number of new ways by Billings and several HAO visitors. Julian completed a study of streamflow records of the Colorado River and concluded; (1) that statistical forecasts of precipitation in the Colorado River Basin are not possible because the amount of precipitation is random from year to year; (2) that there is a small amount of persistence in the flow of the river making possible a small degree of predictability; and (3) that the probability of getting very wet or very dry years is underestimated by using historical records.

I. HIGHLIGHTS

Coronal Intensity Measurements at Climax

The High Altitude Observatory began its life in 1940 as an observing station at Climax making daily observations of the sun's corona. Since the day over 20 years ago when I took the first coronal measurement with the Climax coronagraph, we have taken many steps to improve the quality both of the photographic observations and of the reduction process through which photographic data are translated into numerical values for our scientific staff and others around the world. During the period of this report an important innovation, developed by Hansen and James, contributed greatly to the speed of this processing.

Climax was the third observing station in the world to undertake day-to-day observations of the strength of the emissions of the green and red solar coronal spectrum lines from point to point along the sun's artificially eclipsed edge. For two decades, now, observers at Climax have carried out a daily survey of these coronal radiations. The sequence of observations has been interrupted only by weather and by the occasional periods when the station has been closed down for repairs or for major improvements to the instruments.

In the early days the observations of the corona were very crude. They consisted, first, of simply taking a look through the eyepiece of the spectrograph at the coronal line, and guessing its relative brightness on an arbitrary scale of some thirty or so steps carried in the observer's memory of the brightest emissions he had ever seen.

Later, the visual estimates were supplemented by holding a tiny fly-swatter-shaped film carrying a previously prepared set of images of coronal lines of different intensities next to the unknown line. A matching intensity was then selected and recorded.

As the years went by, more accurate techniques were demanded. These requirements finally caused us to move the locus of coronal measurement from Climax, where the films were taken, to Boulder where we had fancier measuring devices of automatic photoelectric character. But the price was a delay of some weeks in getting accurate absolute intensity data, and a loss of quality control at Climax. It also meant that the observers at Climax couldn't maintain as good touch with the day-to-day changes of coronal intensity and activity as was desirable.

To get around all of these difficulties, a new measuring procedure was completed and instituted the first months of 1961. It was developed principally by Hansen, an alumnus of the Climax and

Sacramento Peak stations, and by James, now at Climax. The new method gives us the accuracy of the Boulder measuring scheme, on a time-scale that keeps the reductions current on a 48-hour time basis. The speed and accuracy of reduction contributes greatly to the daily use of the data by the National Bureau of Standards for radio prediction and geophysical research purposes, and improves the quality of the weekly maps of coronal activity widely distributed from Boulder by Trotter.

The method involves projecting the coronal spectrograms to large scale and then probing inside the image of the line with a sensitive photoelectric photometer whose scale deflections are compared with those produced by photometric standards. This is all carried out with considerable dispatch in the spectrograph wing of the large solar laboratory at Climax.

Cooper makes systematic spot checks on the Climax intensities using the microphotometer in Boulder. The intensities determined from the same film by the two methods of measurements agree to a gratifying degree. Different observers obtain closely comparable results, and the rapidly reported data appear to be of accuracy equal to the substantially more cumbersome older methods. Moreover, the Climax observing team has been able to handle this reduction procedure with no sacrifices in the regular research program there.

Comprehensive Book on the Solar Chromosphere

Early 1961, saw the publication of the book, "Physics of the Solar Chromosphere," by R. N. Thomas of the staff of the National Bureau of Standards, and for many years a Research Associate of the HAO, and by Athay of the HAO. The book presents the most complete discussion of problems of the solar chromosphere in existence.

The volume is based in part on the data taken by the High Altitude Observatory expedition in 1952 to observe the solar eclipse in Khartoum, Egypt. In a sense it summarizes ten years of effort to understand the measurements made at Khartoum and to devise theoretical techniques that can handle the complex problems of stellar atmospheres.

The attempt to deal with problems of hot gases that are not in thermodynamic equilibrium goes back at least to the work of D. H. Menzel and his colleagues in the 1930's, but considerable progress has been made recently in this field under the leadership of Thomas. In dealing with physical systems that can be considered isolated from the rest of the universe, in which most of the radiation generated in the region is absorbed in the same region, many simplifications of the laws governing the system are possible. For example, for a region deep inside a star, we may discuss the

relations between certain quantities, such as temperature and radiation density, without knowing the detailed atomic processes involved. On the other hand, for the case of an extremely thin gas, such as the outer solar corona, practically all of the radiation escapes and additional kinds of simplifications are possible in the formulas used to describe such a region.

For a wide range of astrophysical problems, the solar chromosphere being a good example, neither kind of simplification is possible. Here, one must face up to the difficult problem of dealing with the detailed atomic processes occurring in the region being studied. To do this one must devise mathematical methods and make necessary approximations to yield useful results, thereby increasing our understanding of portions of the universe.

The Thomas-Athay book is more than just a description of the chromosphere. It is a guide to useful methods in dealing with these kinds of problems, and employs these methods to proclaim models of the chromosphere that will certainly be the basis of many other studies.

II. NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

In a letter which came to you in November, with the last issue of this report, I described the establishment of NCAR, the relationships of its scientific goals to those of HAO and our plans to merge HAO with the University Corporation for Atmospheric Research, the management corporation for NCAR.⁽¹⁾ The merger was successfully accomplished in December 1961 and will be fully reported in the next issue of the HAO Director's Report.

We anticipate that the next report will be the last in this form, after which we will begin the issuance of newsletters or reports embracing the work of both research groups.

The NCAR staff and research program rapidly took shape during the first half of 1961. Thompson, who was named associate director in 1960,⁽²⁾ helped Roberts in formulating broad outlines of research programs and policies, and assumed vigorous control of the staff recruitment program even before his arrival on the scene full-time in July.

(1) See Memorandum to Friends of the High Altitude Observatory, 28 November 1961.

(2) See Director's Report, July to December 1960, page 3.

NCAR is building a research program that takes into account the following considerations:

1. The principal research purpose for which NCAR was designed: namely, to mount a cross-disciplinary attack on large, fundamental problems of the atmosphere which are beyond the resources of single universities or research groups to treat in a comprehensive way.

2. Proper preference for problems of a fundamental, rather than secondary or incidental, nature.

3. The proper "mix" of problems of varying difficulties, so that certain desirable goals are sure to be met, while other, more difficult problems of a fundamental nature may nevertheless be tackled.

4. Due regard for the relative value of the practical benefits that will accrue from expected or potential results in various basic research areas.

Much of NCAR's work will deal with or lead up to problems of interaction and feedback, usually involving a variety of physical processes and requiring competence in a number of disciplines to solve them.

The scope of NCAR's Theoretical and Experimental Program is encompassed by the following four main categories:

1. Dynamical Aspects

- a. Dynamics of atmospheric motions on all scales: dynamical factors in the general circulation and long-period variations of the atmosphere's large-scale state. (connected with 3)
- b. Dynamical coupling between the "upper" and "lower" atmosphere.
- c. Cloud dynamics and atmospheric electricity; interaction of droplets in convective flows.
- d. Dynamics of ionized gases in a magnetic field.

2. Thermodynamical, Physical and Chemical Aspects

- a. Absorption, radiation, and scattering: thermodynamical factors determining the quasi-equilibrium state.
- b. Physics and chemistry of phase changes of water.

- c. Distribution and budget of particulates and chemical constituents of the atmosphere. Eddy transport and diffusion on all scales of motion.
 - d. Chemistry of irradiated or bombarded gases and mixed gases.
3. Interaction between the Atmosphere and the Underlying Ground or Ocean Surface (connected with 1.a)
- a. Exchange of atmospheric constituents across the surface.
 - b. Eddy transport of heat, momentum and energy through the turbulent boundary layer.
 - c. Ocean currents and wind-generated waves: dynamical factors determining the distribution of sea surface temperature.
 - d. Atmospheric influences in plant growth, erosion and other changes of surface properties or conformation.
 - e. Hydrological factors in the interaction between earth and atmosphere.
4. Interaction between Terrestrial Atmosphere and Astrophysical Phenomena
- a. Cosmic and meteoric dust.
 - b. Radiational inputs to atmosphere.
 - c. Ionized particle interactions: auroras, stratospheric ionization, role of terrestrial magnetic field.
 - d. Physics of the solar atmosphere: coronal and chromospheric energy balance, hydromagnetic phenomena, conduction and radiation outputs, corpuscular emission, cosmic ray generation, radio noise output, synchrotron radiation.

When it was decided to locate the National Center for Atmospheric Research in Boulder, the State of Colorado, under the leadership of Governor Stephen L. R. McNichols, offered to provide a 500-acre site for the laboratory on the southern edge of the city, just at the foot of the mountains. Funds for the purchase of the land were appropriated by the 1961 Legislature and the State began the process of acquiring the land.

The site contains an irregularly shaped mesa on which we plan to build the first increments of laboratory construction. (See picture page 8.) From the mesa there is a spectacular view of the Flatirons, the high rocks which jut above Boulder, and also a wide overlook of the plains and the City. The location will provide the NCAR staff with isolation and quiet; yet it is only a ten-minute drive from downtown Boulder, eight minutes from the University of Colorado and the HAO, and abuts the site of the National Bureau of Standards.

To provide water for NCAR on the mesa site the citizens of Boulder voted overwhelmingly, at a special election held in February, to make an exception to a city charter provision that prohibits the delivery of water above a certain elevation and that would have precluded the use of city water on the mesa. The mayor, the city manager and many civic groups have given us wholehearted cooperation in our plans for development of the NCAR laboratory and the mesa site.

III. INSTITUTE FOR SOLAR-TERRESTRIAL RESEARCH

As mentioned in the last report, the Institute for Solar-Terrestrial Research has carried on its work at a reduced pace during recent months. The principal sponsor of work in this area was the Association of American Railroads.

We have undertaken planning for a new program of work oriented towards solution of the pressing problem of the origin of solar flares and their generation of solar corpuscular streams and solar radio noise emission. This program will involve both an instrumental development phase and an analysis phase. We plan in the instrumental phase to complete a high-resolution spectrograph and coronagraph at Climax, with newly-developed techniques of data acquisition. The development of the apparatus is already well along, having been supported in past years by the first four-year program of the Institute, by a grant from the National Science Foundation, and by funds provided in unrestricted gifts from a generous and very close friend of HAO.

Our new program will require funds of the order of \$200,000 to be spent over approximately five years. We shall be looking soon to help of old friends and associates to assist in gaining for us private industrial and foundation support for this activity.

IV. THE DEPARTMENT OF ASTRO-GEOPHYSICS

Nothing could be more gratifying than the past four years of progress of the Department of Astro-Geophysics under the guidance

of Zirin, Warwick and, now, Billings. The complement of the graduate department is at approximately twenty, all candidates for the Ph.D. degree. We have about four to five times as many applicants for admission as we have seen fit to accommodate. Our first fully home-grown "crop" of doctorates has reached harvest time, with successful Ph.D. thesis defense by H. R. Johnson and J. M. Malville. Three other candidates are nearing the threshold.

The spring semester's courses of instruction involved lectures by Newkirk and Warwick, staff members and by John T. Jefferies, Franklin E. Roach and Thomas E. Van Zandt, members of the staff of the Boulder Laboratories of the National Bureau of Standards. All of those who taught this semester hold appointments in the University as professors adjoint.

The program of support afforded by the Ford Foundation has played a critical role in getting the department going so well. This grant has supported fellowships at the pre-doctoral level and at the post-doctoral level, and has given us the opportunity of inviting visiting senior scientists to HAO and the department. We have made less than anticipated use of the senior scientists provisions, but the pre-doctoral fellowship and loan provisions have facilitated the whole program.

We must note with distress, here, the passing of a dear friend of the HAO, Captain Mary P. Converse, to whom this issue of the Director's Report is dedicated. And we recognize this sad event in this section of our report because of Captain Mary's long and intense interest in our students. She created our "Student's Emergency Fund," which we insisted should bear her name. This fund makes entirely free emergency grants to our students in times of pressing special needs, without formal repayment clauses or other provisos, to meet medical bills, hardships, or any other situations meriting extraordinary measures of help. We anticipate in future years that students who have been aided by this fund may wish to return contributions to it, and so lend a helping hand to a new generation of scientists. Administration of this fund is at the sole discretion of the chairman of the department. Many of Captain Mary's friends contributed to the "Captain Mary P. Converse Student's Emergency Fund" at her death. HAO will long remember her devotion. And her name has been given to our excellent conference room in the HAO building made possible by her generous gift.(3)

(3) Director's Report, July - December 1960, page 4.



FIGURE 1

The 500 acre site donated by the State of Colorado for the laboratory of the National Center for Atmospheric Research is shown in the upper left-hand of this aerial photograph. The laboratory building will be on Table Mesa (A), a high, relatively level area outlined by trees. A portion of the City of Boulder is shown to the right and bottom of the photograph. The site abuts the National Bureau of Standards (B) and is only a short drive from the HAO (C) and the University of Colorado (D).

V. CLIMAX

The improvements effected in the coronal emission line intensity patrol are described under HIGHLIGHTS, above. The regular staff, James, Richey, Eddy and Sanchez, continued under the direction of Watson. Roger A. Kopp, an astronomy major from the University of Michigan, came to Climax as a summer assistant. He planned to commence work on an advanced degree at Harvard in the fall.

Design and construction work was well under way throughout the winter and spring, aimed towards completion of the 16-inch coronagraph and the large spectrograph that will be associated with it. Lacey and the staff of the instrument shop were at work on this. When finished, this instrument will be HAO's most important observing facility.

Improvements were made also to the large dome at Climax, to the flare patrol, and steps were taken towards installation of an infrared image tube for observation of the strong coronal lines at 10,747 and 10,798 angstroms, where photographic emulsions are too slow for practical observations. The image tube development is being supervised by John W. Firor, of the Carnegie Institution of Washington, and the research on the infrared lines is a joint effort between Firor and Zirin.

We ran into one severe disappointment in development of the Climax station. We had expected to be able to acquire an additional house from the Climax Molybdenum Company, which is dismantling all family residences at Climax and transferring them to Leadville, 14 miles to the south. Through a generous gift to the HAO, we obtained funds sufficient to purchase one of the houses, and at a great bargain. However, the house proved necessary for Company employee housing at Leadville, and we were not able to acquire it. Next summer we must endeavor to work out some satisfactory solution to this problem, so that we can continue to reserve the "Yale Shack" for Boulder and other transient scientific visitors.

The dismantling of the Climax mining community is going to present the Climax station with severe problems. The coming winter, for example, will probably be the last one during which the public school there will be maintained. Fortunately, there will be no diminution of the scale of mining operations at Climax, so we can count on the usual superlative support that we receive from the Climax Company.

VI. OTHER RESEARCH ACTIVITIES

This section contains our usual somewhat scattered highlighting of certain of the research activities in progress at HAO.

1. Research on Aurora and Geomagnetism

For many years, now, Chapman has oscillated between the Geophysical Institute of the University of Alaska and the HAO, not to mention various other research institutes in other parts of the globe. We have particularly valued the close ties he has brought us with Dr. Elvey's group in Alaska.

One of the recent products of this fruitful joint effort has been Chapman's collaboration with Syun-Ichi Akasofu, of the University of Alaska who has accompanied Chapman to Boulder on several extended visits. Akasofu and Chapman have jointly developed a new explanation for some of the principal features of the aurora. Their theory involves the effect of an arriving cloud of charged solar particles that impinge upon the magnetic lines of the earth's magnetic field, some earth-diameters out into space. The distortion of the earth's field on the sunwards side of the earth produces regions on the dark side where the magnetic field lines "cross," dropping to a null value at the intersection, which they call a neutral point. In their theory, when charged particles pass near neutral positions, the process can provide a continuing stream of radiation belt particles that have the energy to penetrate the atmosphere down to the levels of some hundreds of miles, where they produce visible auroras.

Akasofu and Chapman, during recent months, have been further studying the magnetic fields in space surrounding the earth in an effort to understand the changes that occur during times of geomagnetic storms, when field fluctuations occur at earth, when auroras spread southwards, and when ionospheric radio propagation is upset.

In association with Joseph C. Cain of the National Aeronautics and Space Administration, they have made calculations of the currents and magnetic fields in the Van Allen belts in normal times, and during disturbance. Their calculations suggest that when the "ring current," some six earth radii above the equator, grows strong enough (during solar particle storms) it reverses the magnetic field in limited strips of the equatorial plane on the dark side of earth, and these are the places where the aurora-producing effects are generated. The magnetic field configurations predicted are subject to experimental check with artificial earth-satellite measurements and preliminary comparisons look most promising.

Peter C. Kendall, a visiting scientist at HAO from Bedford College, London, worked with Chapman this spring on the study of the paths of trapped particles in the vicinity of the neutral lines.

Results of these fruitful collaborations are being presented in some dozen scientific papers published or in preparation by Chapman and colleagues. Those of us who are in the supposed primes of our scientific lives wish that we could attain the productive output Chapman exhibits in this, his retirement.

2. The Coronal Temperature Problem

For a quarter-century astronomers have struggled with the coronal temperature problem: how is its high temperature produced and what is the source of heat that sustains it?

The very existence of highly-ionized atomic species like Fe XIV (the iron atom stripped of 13 electrons) implies that the coronal gases must be of the order of a million degrees C.

This problem has run like a central theme through the research programs of HAO. We have concerned ourselves, for example, with detailed studies of the profiles (detailed measurements of the spectrum line shape) of the green, yellow and red coronal lines. We have described many of our results in previous issues of the Director's Report. We have noted time and again that the line profiles of these coronal emissions are not only generally very broad, but also that the profiles are smooth and of such a shape as to lead us to suspect they are widened by thermal processes (Doppler profiles) and not by the kinds of irregular line-of sight velocity distribution that so generally characterize prominence spectra in regions of strong coronal intensity.

Billings, in particular, has worked intensely on this problem in the last year, with most intriguing progress. A number of results have turned out:

(a) Billings and a 1960 summer visitor, Robert Lehman, measured profiles for a large number of coronal red (Fe X) and green (Fe XIV) spectrum lines. They concluded that there was a significant systematic excess of breadth to the green line. The profiles translated into coronal temperatures, suggest that the Fe XIV atoms responsible for the green line are at a temperature of 2.5 million degrees C. and the Fe X atoms producing the red line are at 1.8 million degrees. This result is encouraging in the sense that the more highly stripped green line, which requires higher ionization to be produced, seems on the average to be at a hotter ion kinetic temperature, as physical intuition suggests it should be. But both values are higher than the theory of atomic collisional cross sections predicts, and so the source of the heat and the details of the process are not revealed in this result.

(b) Billings, working with Charles M. Fullerton and Nathan K. Williamson (both 1960 summer visitors), tackled quantitatively the often-noted diminution in intensity of the coronal emission near brilliant large quiescent prominences, for which we are pretty sure the temperatures are much below a million degrees. Their work did indeed confirm the reality of the diminution of intensity and indicated that when he happened to look along the length of an extended prominence the weakening was greater. (Prominences can be located on flare patrol films as dark filaments on the face of the sun.) The conclusion of Billings and his colleagues was that cooling near the prominence cannot extend very far beyond the actual confines of the prominence itself, and that beyond a short distance the corona was at its characteristic high temperature and emission.

(c) This work led to the supposition that ion temperatures (measured by the coronal line profiles) may markedly exceed electron temperatures in the same regions of the solar atmosphere. Billings, therefore, undertook to study several possible mechanisms by which an electron gas could lose its temperature more rapidly than the heavier ions. In particular he calculated that heat loss by two different mechanisms for typical situations. The first of the mechanisms tried was the loss of heat by radiation of X rays. This mechanism was suggested by the fact that some X rays have been detected by the Naval Research Laboratory rocket observatory of the sun. The second mechanism examined heat conduction to cooler prominences (as suggested above) and to the cooler solar chromosphere that underlies the corona.

X-ray radiation might explain a difference as large as 100,000 degrees C., and if X-ray rocket data are in error by more than a factor of two, as might conceivably be the case, perhaps the observed temperature discrepancies can be explained, but it is not a very convincing result.

Conduction near the chromosphere and near large cool prominences, on the other hand, can be quite significant. But it cannot explain the bulk of the observed differences through different parts of the corona. If conduction does play an important role, it can do so only near prominences and the chromosphere; X ray production must account for the temperature differential elsewhere. We are still far from a completely satisfactory solution, and only future work will answer the basic problem, but at least we have our teeth well into it.

(d) The resolution of the coronal temperature problem (i.e. deciding what the electron and ion temperatures really are) has critically important bearing on the problem of the magnitude of the "solar wind" so important in space physics and aeronomy. Billings

has, therefore, looked into the question of fitting various "solar wind" models into the coronal temperature data. It may turn out before long that new artificial satellite data will materially assist us in solving the coronal temperature problem.

(e) Billings has found quite convincing evidence that the two yellow coronal lines (5446 angstroms and 5694 angstroms) arise from the same atomic species (presumably Ca XV). This has been regarded as a moot point by many. He has found, moreover, that the ratio of intensities of these lines appears to depend quite strongly on the coronal density in the region from which they originate. This result was predicted by I. S. Shklovsky of the USSR, more than 10 years ago, but it has never previously been possible to obtain adequate coronal data to study it quantitatively. The dependence, Billings finds, appears to be stronger than that predicted by Shklovsky.

Other approaches to problems in solar physics have been made at HAO recently. T. L. John, a visiting scientist from University College in London, has done theoretical calculations of the absorption by the negative hydrogen ion which is an important constituent of the lower solar atmosphere. His preliminary results suggest that earlier calculations by Chandrasekhar and Breen yield cross sections about 30% too high.

Still another approach has been made by Kin-aki Kawabata, who was on a visiting appointment from Tokyo Astronomical Observatory in Japan. Kawabata tied microwave radio bursts of emission from flare regions to thermal radiation and concluded that electron temperatures in flares may reach 10 million degrees. He studied particular solar events, especially the flares of 31 August 1959. Related to the microwave radio bursts on this date he found increased ionospheric radio signal absorption, which he attributed to thermal X rays from this extremely hot electron gas. And for one event there were rocket X-ray measures made by the Naval Research Laboratory. He attempted to build specific models for the flare region fitting all the observed data.

His conclusion was that X rays in the spectrum from 2 A.U. to 8 A.U. may result from thermal emission, but that the observed X rays of 0.6 A.U. and shorter wavelengths must arise from a non-thermal process.

There seem to be grave difficulties with considering that the electron gas can reach such extremely high temperatures. The question is still an unresolved one.

3. Water Resources of the Upper Colorado River

Julian finished up an extended research on the Colorado Streamflow project, and wrote the final report encompassing his conclusions. These are summarized as follows:

(a) There is no hope of making statistical forecasts of precipitation amounts in the Colorado River Basin, because these amounts fluctuate in random fashion.

(b) There is a slight amount of year-to-year persistence exhibited by the flow of the Colorado River enabling a very small degree of predictability to be gained.

(c) Such persistence is introduced into the streamflow values by essentially three processes: storage of water from previous years, a persistence in evaporative processes, and inhomogeneties in the records caused by increased activity of man and his usage of water.

(d) The natural variability of the streamflow is probably greater than our present historical records indicate. Thus the probability of getting very wet or very dry years is underestimated by using historical records.

Of purely scientific interest was the emphasis the project placed on the application of new statistical tools to historic weather and streamflow records. Also of scientific interest was the inquiry into the basic physical relationships of the hydrological cycle and how predictable these processes might be.

The resulting probability analysis was, however, of immediate practical use. For example, the analysis resulted in knowledge from which we can make statements such as this: There is a 67 per cent probability that the future 5-year average flow of the Colorado River at Lee Ferry will be between 11.3 and 15.0 million acre feet. Knowledge of this sort is of value to planners of large river-basin economics.

4. The Gegenschein or "Counter-glow"

A highly mysterious feature of the night sky most noticeable from the high altitudes in the tropics is the gegenschein or "counter-glow." It is a faint glow in the sky, more or less concentrated to directions of the sky opposite from the sun, as mentioned in our last Director's Report (page 13). It has been suggested that the gegenschein is a faint comet-like "tail" appended to the earth and repelled by sunlight or the solar wind.

Dr. H. Tanabe, a visitor from the Tokyo Astronomical Observatory, extended his earlier studies of this phenomenon at Fritz Peak near Boulder, where Franklin E. Roach operates the National Bureau of Standards' night sky research site.

Tanabe's work does not explain the gegenschein at all, but it does suggest that it has minima near the spring equinox (March-April) and near the fall equinox (September-October). This behavior is just opposite to that of auroras and geomagnetic activity, both of which are strongly related to activity on the sun. However, its brightness does not appear to correlate with sunspot activity. Further work will be done on the matter. Data are taken on every clear night in the dark of the moon.

5. A Research Visit to the USSR

Dr. and Mrs. Zirin spent a good part of the period on an extended research visit of about six months to the Crimean Astrophysical Observatory near the Black Sea. There they lived at the Observatory, ate their meals with the staff, and worked elbow-to elbow with them at the telescopes and in the laboratories.

Their experiences, both scientific and otherwise, were most interesting, and I hope they will write a detailed story of their journey.

Zirin, while there, made extensive studies of the magnetic fields of active-region solar prominences and found them to possess, even at significant heights, magnetic fields as large as 150 gauss. Quiescent prominences, he found, were magnetically weaker, around 50 gauss. These were the first direct measurements, I believe, of the actual field strengths within solar prominences. We hope to develop an instrument here capable of similar researches. Zirin has started plans for such an instrument.

6. The Solar Chromosphere

We are not going to review, in this report, the excellent progress being made in research on the chromosphere by Athay and others. However, the publication of a monograph on the chromosphere by Athay and R. N. Thomas has been reported above under Highlights.

7. Other Programs

We will leave to future reports discussion of the ionospheric researches of Matsushita, the research on atmospheric dynamics of Haurwitz, the radio noise emission results of Warwick, which include most interesting results on the nature of Jupiter's atmosphere, the

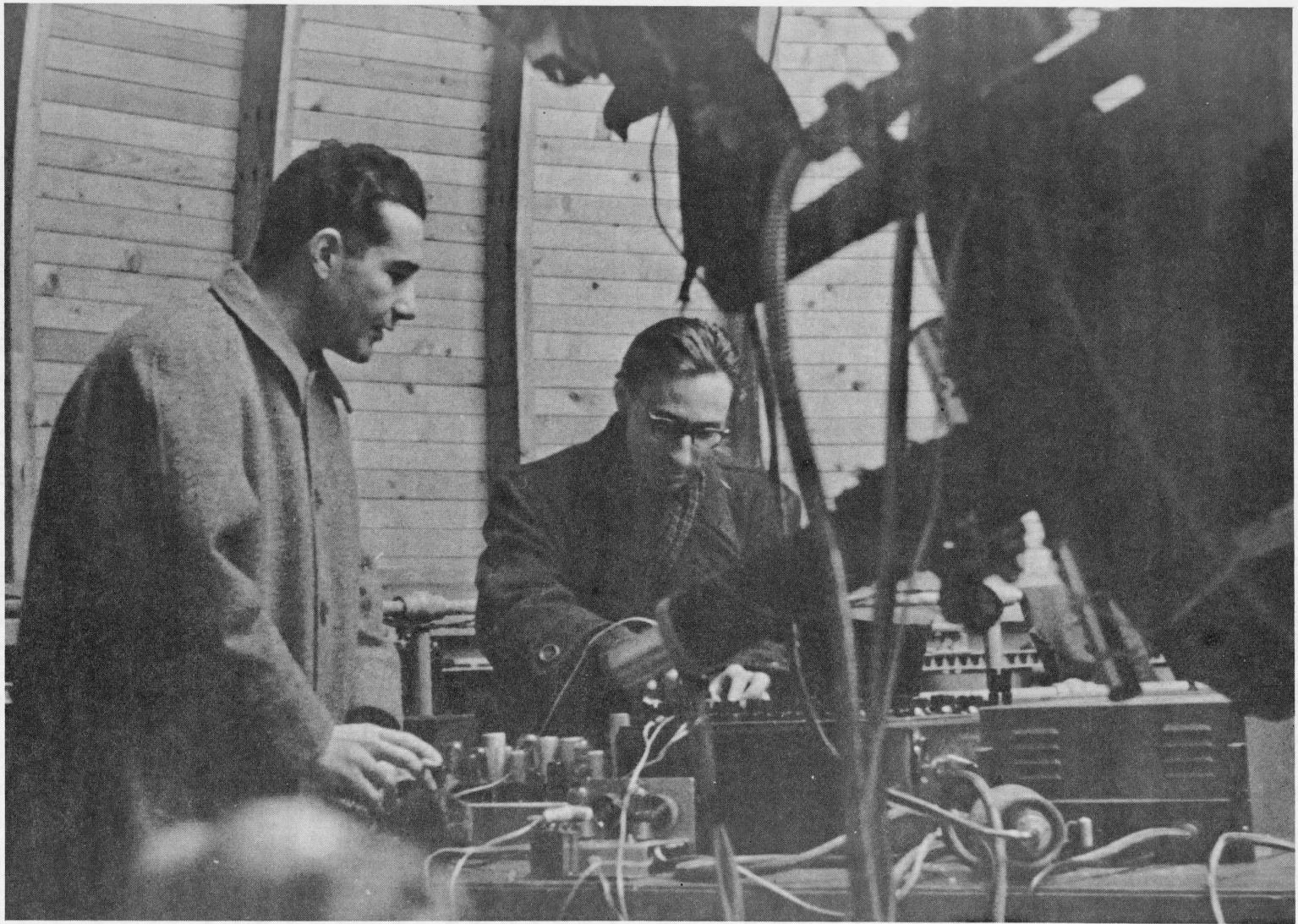


FIGURE 2

Zirin, (left) of the HAO staff is shown here working with Nikolai Shakhovskoy at the Crimean Astrophysical Observatory, U.S.S.R. where he spent six months as an exchange visitor. While there he joined with Shakhovskoy and Yura Efimov of the Crimean Observatory staff in an effort to measure the polarization of light from the corona during the eclipse of February 15, 1961. The eclipse path passed directly over the Observatory but unfortunately clouds obscured the sun at the moment of eclipse. The telescope in the picture is part of a twin 16" astrograph used in the experiment. The picture was printed from a clip from a newsreel presented to Zirin by the staff of the Ukrainian newsreel service.

K-corona researches, the balloon studies of atmospheric particulates, and several other areas of work-in-progress. These will, however, be described in future reports.

VII. PERSONNEL

During this period Chapman was elected a foreign fellow of the Accademia Nazionale der Lincei in Rome, an honor we are proud to report.

David Burnett joined the staff in May for a one year appointment under our Henry T. Ford Foundation senior post-doctoral program. Burnett had been at Rhodes University in South Africa. His interests are in mathematics and gas dynamics and he has undertaken a joint research program with Chapman on problems of ionized gases.

Another visitor, for six months, was Stefan F. Smerd from the Commonwealth Scientific and Industrial Research Organization in Australia who came to Boulder in early June for the purpose of making some preliminary statistical studies of the solar radio emission data gathered during the International Geophysical Year.

Robert A. Duncan, also from the Commonwealth Scientific and Industrial Research Organization, Australia, joined the staff in March with a one year appointment to study Antarctic and Arctic F-region of the ionosphere.

Other new staff members during the period included Mrs. Diane Hackett and Philip S. Kuhn, research assistants, and Mrs. B. Laurel Rokala and Mrs. Janice C. Kaufman, office staff. Mrs. Rosanna M. Camps, who had been working for the University of Colorado on HAO business affairs, transferred to the HAO staff.

Mrs. Anna Jo Murrow, Mrs. Deborah G. Bouboulis and Mrs. Diane R. Gordon left the staff to return to full time housekeeping for their families.

In June, Robert J. Bessey of the University of Wyoming, Alan Burgess of University College, London, and Thornton L. Page of the Van Vleck Observatory, Wesleyan University, came to the HAO for the summer. John M. Malville, who received his doctorate from the Department of Astro-Geophysics in June, also served on the HAO research staff during the summer. Lawrence B. Kilham, Frank D. Haurwitz, Dugald E. Christie, Gerard A. Roach, Harold L. Petrie and Ann M. Silverman worked in Boulder as research assistants during the summer months and Roger A. Kopp and J. Scott Shaw assisted the Climax staff.

Raymond Michard and M. Khairy Aly joined the HAO visiting research staff during the period and worked at the Sacramento Peak Observatory. Jerome T. Loomis, Ute E. Strahl and Wolfgang G. K. Lehmann also went to Sacramento Peak as HAO staff members.

VIII. HAO VISITORS DURING JANUARY - JUNE 1961

9 January	Christian E. Junge, Air Force Cambridge Research Laboratory, Bedford, Massachusetts
7 February	Frank J. Kerr, Commonwealth Scientific and Industrial Research Organization, Radiophysics Laboratory, Sydney, Australia
21 February	Gerard P. Kuiper, University of Arizona, Tucson, Arizona
2 March	Pembroke J. Hart, National Academy of Sciences, Washington, D. C.
3 March	J. Howard Dellinger, First Chief of Central Radio Propagation Laboratory, Washington, D. C.
8 March	John C. Simons, Jr., National Research Corporation, Cambridge, Massachusetts
13-15 March	Robert B. Hunter, Sacramento Peak Observatory, Sunspot, New Mexico
15 March	R. W. Nicholls, University of Western Ontario, Canada
20-21 March	Martin Schwarzschild, Princeton University Observatory, Princeton, New Jersey
20-22 March	A. A. Boyarchuk, Crimean Astrophysical Observatory, Crimea, USSR
3-15 April	Audrey E. Robbins, University of Cambridge, Cambridge, England
13-17 April	Hans U. Dütsch, Zurich, Switzerland
18 April	V. A. Sarabhai, Physical Research Laboratory, Ahmedabad, India
21-24 April	Edward P. Todd, National Science Foundation, Washington D. C.

16 May	Richard A. Miller, Manila Observatory, Phillipines
12-15 June	Eleanor Trefftz, Max-Planck Institut, Munich, Germany
15 June-August	Thornton Page, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut
16 June	Harold Glaser, Office of Naval Research, Washington, D. C.
16 June	H. K. Bourne, United Kingdom Scientific Mission, Washington, D. C.
26 June	Tom Gehrels, Indiana Observatory, Bloomington, Indiana
27 June	S. H. Herzfeld, Office of Naval Research, Chicago, Illinois
28-30 June	Takakiyo Kikinuma, Tokyo Astronomical Observa- tory, Tokoyo, Japan

IX. PUBLICATIONS FROM HAO DURING PERIOD

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- Chapman, S., "Magnetic Storms: Their Geometrical and Physical Analysis and Their Classification," presented at the Post-IGY Conference, Prague, pp. 30-50, 1961.
- Chapman, S., "From Polar Years to Geophysical Year," presented at the Post-IGY Conference, Prague, pp. 313-329, 1961.
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- Chapman, S., "The World Magnetic Survey," New Scientist, 11, pp. 32-34, 1961.
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- Julian, P., "Remarks on 'The Disturbed Circulation of the Arctic Stratosphere,'" Journal of Meteorology, 18, No. 1, pp. 119-121, 1961.
- Macdonald, N. J., and W. O. Roberts, "Effect of Solar Corpuscular Emission on the Development of Large Troughs in the Troposphere," Journal of Meteorology, 18, No. 1, pp. 116-118, 1961.
- Malville, J. M., "Excitation of Helium in the Aurora," Journal of Atmospheric and Terrestrial Physics, 21, pp. 54-64, 1961.
- Munch, Guido, and Zirin, "Interstellar Matter at Large Distances from the Galactic Plane," The Astrophysical Journal, 133, No. 1, pp. 11-28, 1961.
- Newkirk, G., "The Solar Corona in Active Regions and the Thermal Origin of the Slowly Varying Component of Solar Radio Radiation," The Astrophysical Journal, 133, No. 3, pp. 983-1013, 1961.
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- White, O. R., "A General Solution of the Statistical Equilibrium Equations," The Astrophysical Journal, 134, No. 1, pp. 85-90, 1961.
- Williamson, Fullerton and Billings, "Coronal Emission in the Vicinity of Quiescent Prominences," The Astrophysical Journal, 133, pp. 973-977, 1961.

X. DATA REPORTS AND SPECIAL PUBLICATIONS FROM HAO

A. World Data Center Publications

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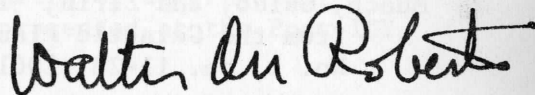
IGY Solar Activity Report Series No 15, June 26, 1961, "McMath-Hulbert Observatory Working List of Flares and Daily Flare Index For IGC-1959."

B. Solar Activity Reports

Trotter, Dorothy E., Betty Tanner, and R. Grant Athay, Solar Activity Summary I, Report No. HAO-51, 15 March 1961.

Trotter, Dorothy E., Walter Orr Roberts, Solar Activity Summary II, Report No. HAO-52, 15 June 1961.

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