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SOME RESULTS OF OBSERVATIONS OF THE SOLAR CORONA MADE
WITHOUT AN ECLIPSE AND THE OUTLOOK FOR THE DEVELOPMENT
OF A CORONAL OBSERVATION STATION

[Eekotoryye Resul'taty Vnezatmennyykh Nablyudeniy Solnechnoy
Korony I Perspektivy Razvitiya Koronal'noy Stantsii]

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SOME RESULTS OF NON-ECLIPSE OBSERVATIONS OF THE SOLAR CORONA AND

THE OUTLOOK FOR THE DEVELOPMENT OF A CORONAL STATION

by

M. G. Karimov

The first observations of solar prominences by the Astrophysical Institute were made on a non-eclipse coronagraph of Lyot's system in the hydrogen line H_{α} by the broad-band filter passing through a 50-Å band. With the filter at our disposal at that time the middle of the band passed through, did not coincide with the hydrogen line 6563 Å. The line H_{α} was located on the side area of the band transmitted ~~through~~ through the filter. Of all the light transmitted by the filter only 23% was on the H_{α} line. In this way our filter transmitted a continuous background of 77%. Notwithstanding this inconvenience ^{we} were were successful in getting a number of photographs of prominences.

With the acquisition in 1953 of a six-band interference filter prepared in the Institute of Crystallization of the Academy of Sciences by the engineer A. B. Gil'varg, the study of the solar prominences in the line H_{α} became more effective. The combination of the superior qualities of the filter with the splendid atmospheric conditions of our observatory made it possible to see the thin open structure of the prominences and the chromosphere. ^{As} ~~we~~ we went on accumulating observational material the most interesting prominences with the presence of motion of the centers were subjected to analysis (1). As has already been reported, G. M. Iddis proposed a system of analysis starting from some theoretical premises for the evaluation of the intensity of the magnetic fields connected with the prominences. Values were obtained for the intensity of the magnetic fields which were compared with the direct determinations in accordance with the Zeeman effect—the splittings of the lines in the magnetic field constructed by Babcock. The evaluation of the intensity

of the magnetic field, as obtained by us, amounted to 4—7 gauss \odot , and for Babcock practically on the same width on the edge of the sun where there were solar prominences the intensity of the magnetic field worked out as 2—4 gauss \odot .

Our observations on the coronagraph on the territory of the observatory of the observatory improved each time after precipitation when the atmosphere was cleared and there was no aureole around the sun. However, careful investigations of the same instrument showed the presence of some shortcomings. As the shortcoming that mattered most one should consider the circumstance that Lyot's basic idea, the introduction of the iris diaphragm for the cutting off of ~~the~~ diffraction from the edge of the basic object, was not sufficiently effective in our coronagraph (2).

Behind the lens of the field in the direction of the rays there is inserted a compound objective for the purpose of furthering the attainment of parallel light beams. Between the two legs of this compound objective there is located the iris diaphragm intended for eliminating the diffraction from the basic objective.

It turned out that with the correct disposition of the compound objective with relation to the lens of the field, the light beams with full opening of the basic objective were trimmed off by the edges of the rim of the compound objective. In using a wide-band filter the basic objective was diaphragmed by us up to 120 mm and the "vignetting" on the edges was not observed.

Due to the small transmitting capacity of the narrow-band filter we were forced to take out the diaphragm on the basic objective and use the full opening of the objective of 200 mm.

Keeping in mind that the image of the basic objective of the field lens did not coincide with the iris diaphragm, and with full opening of

the first objective the iris diaphragm did not perform its function, we had to shift it to a place ~~mm~~ where a sharp image of the basic objective was obtained. For this the compound objective of the old system together with the diaphragm was shifted almost to the double focus distance from the lens of the field (Ill. 1), ~~mm~~ and only with such an arrangement of the optics of the coronagraphy was one able to get an image of the basic objective on the iris diaphragm. By selecting a corresponding opening of

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diaphragm trimming off the diffraction of O_1



Ill 1. New system of the coronagraph. O_1 is the basic objective. O_2 is the lens of the field. O_3 is the compound objective which forms the image.


the iris diaphragm it was possible to eliminate completely the diffraction on the edges of the objective.


In this case the compound objective already performed the function of the objective forming the image. In this way one of the objectives of our coronagraph of the old system was completely eliminated from the coronagraph. The scale of the image remained as before and the equivalent focus of the coronagraph ~~was~~ ^{was} ~~mm~~ five meters long. Right behind the last object stands the turning prism and further in the slightly converging beam there is placed the interference-polarization filter. The convergence of the extreme beams amounts to 2.5° , and if one works in the central part of the frame then the divergence will amount to about 1.5° .


In case it is necessary to get a spectrum of the corona on the ocular part the spectrograph is attached.


Between the lens of the field and the iris diaphragm there are placed a number of auxiliary diaphragms for catching the dispersion of the light

from the highly convex surface of the  last compound objective. The high light from the second surface of the basic objective is removed by a screen placed in the center of the iris diaphragm.  Between the basic lens and the lens of the field there are placed supplementary diaphragms.



On the screen playing the role of an artificial moon, there is mounted  a reflecting screen at an angle of 45° to the incident rays for the purpose of transferring the basic light of the sun out of the tube of the coronagraph.

These enumerated extremely necessary improvements led to a considerable decrease in the scattered light inside the coronagraph  and made it possible, when it was raised to great height, to get right from the start a spectrum of the corona, and further on, the form of the corona in rays of 5303 \AA with the aid of a narrow-band interference filter.

For obtaining a spectrum of the solar corona, in the workshop of the Institute, there were prepared spectrographs of different design. The last model of the spectrograph (Ill. 2)  consists of two spherical mirrors and diffraction lattices with a concentration in the second order of 65% of the light.

In using a compartment mirror with a focal distance of 500 mm and a diffraction lattice in the second order  the dispersion of the spectrograph amounted of 14 \AA/mm .

On the grounds of the observatory we made trial observations of the spectrum of the chromosphere and the corona.

Along with the research of the solar prominences and the perfecting of the  coronagraph  in the Section

[Illeg. wording]

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Ill. 2. Spectrograph on the coronagraph. Dispersion 14 \AA/mm .

of Solar Physics of the Institute, beginning with the year 1951 much work was done in investigating the regions around the city of Alma-Ata for the building of a high-mountain corona station (3). In doing this one kept in mind the ~~the~~ altitude of the existing corona stations and, principally, the local conditions.

The elevation of our observatory is 1,350 m above sea level, ~~but~~ but the difference from that of the city is 600 m, and therefore the city smoke to a certain extent affects the coronal observation.

Our aim was to get away from the city as far as possible, so that the city would not affect us at all. In this we especially took into account the difficulties of mountain conditions. The steppe haze, in accordance with some observations, rises to a height of 2,000 m above sea level. Therefore our future station should ^{not} be situated lower than this height.

Our investigations of various regions of the mountainous ~~environs~~ ^{environs} of the city of Alma-Ata revealed a number of advantages of the Great Alma-Ata Lake region.

What are these advantages? In the first place, the existence of a road to an altitude of 2,600 m; in the second, the existence of electric current at a height of 2,600 m; and in the third, researches of the optical conditions at a height of 3,000 m (on an elevation suitable for the construction of a coronal station) showed that the region of the Great Alma-Ata Lake in comparison with the observatory has the ~~the~~ following advantages:

a) the transparency factor for all rays on the average is greater by 5 to 7% there—sometimes the transparency factor is 0.902, which shows the absence of dust;

b) the optical depth is less by 30%;

- c) the aerosole component of the optical depth is less by 35 to 40%;
- d) the solar aureole in the region of the Great Alma-Ati Lake is one half ~~as~~ as much in comparison with the observatory. It is an essential point that there is no systematic increase in the aureole around the sun in the afternoon. The sharp decrease in the aerosol component shows that the dust layer is lower than the elevation of the lake.

A determination of the twinkling of the edge of the sun gives a figure of $0.9''$, but by an evaluation of the twinkling of the stars a deviation from a straight line of $0.4''$, there being, cases, however, when a figure of ~~0.3''~~ $0.3''$ was obtained for the twinkling.

One should note that there was no increase or decrease noted for the dependence of the twinkling on the ~~distance from zenith~~ ~~of the sun or stars~~ of the sun or stars.

If one takes into ~~consideration~~ consideration that the main dust layer lies below 2,000 m above sea ~~level~~ level, then 2,600 m already can fully satisfy coronal observations, and 3,000, it stands to reason, is a still more favorable elevation.

The considerations pointed out above served as a basis for the possible construction of a high-mountain station. The ~~planning~~ ^{planning} of the station was in two stages. At the present time there is a final plan for the construction confirmed by the Presidium of the Acad. of Sc. of the USSR at the cost of one million seven hundred thousand roubles of which four hundred thousand roubles have been spent for the obtaining of a chromosphere telescope. In the estimate about seven hundred thousand roubles are earmarked for the building of a road about 2.5 km long from the Great Alma-Ati lake to the site selected. Although the construction of the coronal station was not begun on the elevation first chosen of 3,000 m above sea level, in the autumn of 1954 the Astronomical ^{physi}cal Institute prepared a base for this station at an elevation 2,600 m. The need for the preparation of such a base became urgent in connection with the obtaining of

the chromosphere telescope and in view of what was learned about the possibility of observing the solar corona. We appealed for assistance to the administration of the Alma-Ata ~~hydroelectric~~ hydroelectric works who very willingly came to our assistance. We obtained four standard houses, ^{two} of which represented an exchange for one two-dwelling ^{and} stand house, and two were by ~~least~~ until April 1, 1955, when the laboratory and living quarters for the observers were built. Two houses, obtained as property of the Institute, were ~~converted~~ converted into pavilions with wings which can be opened up. In one of the pavilions the chromosphere telescope is set up, and in the other one there is the eclipse coronagraph. In this way already by the beginning of the construction of the coronal station the Astrophysical Institute had organized a base for observation of the ^{solar} corona. ~~Beginnin;~~ Beginning with December 1, 1954 regular observations have


been carried on of the red coronal line 6374 Å, and from December 25, 1954 observations have been made of the green coronal line 5304 Å (Ill. 3).

Along with the obtaining of the lines 6374 and 5303 Å ^{on} ~~the~~ January 6, 1955 (4), regular observations were begun of the form of the corona in the line 5303 Å with the aid of the narrow-band interference filter (Ill. 4). The absence of good-quality fresh film some-

Ill. 3. Corona line 5303 Å
1/25/1955



what slowed down our observation work. The Commission for Observation of the Sun has done ~~considerable~~ considerable work in ~~supplyin;~~ supplying stations of the network of the sun service. I have in mind the ~~photoheliograph~~ photoheliograph, the chromosphere-photosphere telescope, and other things. There has developed an urgent necessity for supplying ^{ed} need fresh photographic film

to all stations, including our observatory. The lack of film interrupts the carrying out of our program of the sun service.

The initial material received by us at the coronal station underwent adaptation. In this regard, on the table of the spectroprojector there was attached a photographic element  with a slit which was shifted by a micrometer screw. The measuring was done with an enlargement of the

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Ill. 4 a) Structure of the corona in the line 5303 Å 1/25/55.

negative by fifteen times. The reading of the line and the background was done with the aid of a mirror  galvanometer. Later on, contours were constructed for the line 5303 Å and equivalent widths were obtained of the lines in ^{Å, ström} units of  the continuous spectrum of the sun.

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Ill. 4 b) Structure of the corona in the line 5303 Å 1/25/55.

Our observations are being made at a distance of 40° from the edge of the sun, and therefore we can construct the course of the brightness of this line at the distance indicated from the edge of the sun as depends on the position angle.

Besides, we were able to make the  measurements of the filter observations of the course of the brightness of the inner corona as depends on the  position angle at a distance of 40° from the edge of the sun

and attached to the sun in the area of the continuous spectrum of 5303 Å and compare them with spectral observations. As an example, in Ill. 5 we present a graph for one of the days of observation (2/20/55).

As can be seen from this graph, the change in the course of brightness of the green corona is repeated in both cases. In some of the position angles the numerical values of the

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Ill. 5. Comparison of the course of the intensity of the line 5303 Å in accordance with the position angle, 2/20/55. 1. filter; 2. spectrum

brightness do not coincide. We did not take into consideration the contour of the part passed through the filter and its superimposition on the contour of the emission lines. If we take into consideration that the width of the green line 5303 Å, in accordance with a number of authors (Lyot, Waldmeier, A. A. Kalinyak) (1), fluctuates within the limits of 1.4 Å and 2.2 Å, and the band passed through the filter amounts to 2 Å, then it becomes quite clear that one needs to know the width of the lines ~~in the separate instances~~ in the separate instances in order to get the full intensity in accordance with the position angles with the filter device.

In the case of observing the spectrum of the corona we had to take into consideration instrumental error introduced by the instrument into the observed contour. For the preliminary evaluation of the instrumental contour we made use of some ~~Fraunhofer~~ Fraunhofer lines the true contour of which it was possible to obtain from Minnaert's atlas. Although such a computation of the instrumental contour is not very strict (It is necessary to keep in mind the effect of the residual intensity of the Fraunhofer lines), we were successful in obtaining the first evaluation of the instrumental contour and to get its true width from the observed contour

of the green line of the corona 5303 Å. ~~Q. Q. Q.~~ An estimate of the temperature of the corona in accordance with the ratio between the half-width and the temperature by our measurements ~~Q. Q. Q.~~ for January 21, 1955 was obtained for various parts of the corona: $3.28 \cdot 10^6$, $1.54 \cdot 10^6$, $1.96 \cdot 10^6$, and $2.06 \cdot 10^6$ degrees. With the chromosphere-photosphere telescope ~~Q. Q. Q.~~ because of the absence of the interference filter, up to ~~this~~ time ~~Q. Q. Q.~~ no photograph of the chromosphere has been obtained, but observations are being made of the photosphere. Preliminary winter observations show that the images of best quality are ~~Q. Q. Q.~~ around noon. Such were our preliminary results.

Let us consider for a moment the problems ^{of} and the outlook for the development of a coronal station. In the first place, as has already been noted by the academician V. G. Fesenkov, at this session we have to consider the question as to where the coronal station is to be built.

The elevation of the initially chosen area for the construction of the coronal station differs from the elevation of the base of the coronal station by 385 m. As has been reported at the base of the station observations of the solar corona are already going on, both with the spectrograph and the narrow-band filter. This means that the basic aim—the observation of the solar corona is already being realized. If one ~~Q. Q. Q.~~ speaks of ~~Q. Q. Q.~~ improvement ⁱⁿ the observations, clearly it is necessary to go up to a much higher elevation than the region of the the Great Alms-Alta Lake. Our ~~Q. Q. Q.~~ experience in the operation of the base of the station in the winter period ~~Q. Q. Q.~~ has shown that when there are great snow drifts the most accessible place is our base, but the area at the elevation of 3,000 m is quite ⁱⁿ accessible. Besides, in the winter period there is difficulty there in the water supply. In taking into ~~Q. Q. Q.~~ consideration the difficulties of the operation we at the same time should not forget the

difference in the atmospheric conditions. There should not be any considerable difference in the factor of transparency and the magnitude of the aureoles between the lake and the chosen site. If there is such a difference, however, it would be possible to detect it with photoelectric devices. Consequently, one can only talk about the difference in the quality of the images. Our initial parallel observations conducted at the end of 1954 at ~~the~~ ^{the} elevations of 3,000 and 2,600 did not show a considerable difference in the twinkling. But such observations should be continued until the problem of the microclimate of one or another place is cleared up. This is the most important.

Our observations conducted ~~in~~ ^{from} the region of the lake for the chromosphere by means of the prominences through a filter with the aid of a ~~coronagraph~~ coronagraph showed a comparatively good quality of the images. The problem of the place of the construction of the coronal ~~station~~ station should be subjected to special observation and the existing station should be ~~strengthened~~ strengthened. In the second place, in the scientific-research plan of the station there is provided for conduct of research in the following directions.

1. Spectrophotometric researches of the solar corona and determination of the true contours of the separate emission lines, the obtaining consequently, of the temperature and density in the different parts of the corona, and research of the shifting of coronal lines.

Research of the structure of the internal corona with the aid of interference-~~polarization~~ polarization filters. Especial interest is afforded by the clarification of the nature of the ~~chromosphere~~ chromosphere material.

2. The continuance of the research work on the solar prominences in connection with the possibility of clarifying the tension of the magnetic fields. As has already been reported, at the end of 1954 at the observatory, in accordance with formulas developed by G. M. Idlis, the magnetic

fields in the prominences were determined on the basis of research of their internal movements in the picture plane. There appeared in the course of about a year and a half altogether ^{only} a few examples of the characteristic prominences with great systematic motion among those photographed by the Section of the Physics of the Sun on the corona, to which prominences all five of the ~~worked~~^{out} estimates were applied. However, for these all the evaluations agreed well with each other, mutually checking each other, and the correctness of the intensity of the field obtained is confirmed by the data of the corresponding magnetogram by Babcock for the disk of the sun.

An analysis of the kinematographic material published by Larmor showed that the precision of the evaluation of the field meanwhile remains the same as with the ordinary consecutive photograph with the regular film camera.

In these circumstances, when the movements in the prominences have a completely irregular, chaotic character, from the five developed formulas for the evaluation of the intensity of the magnetic field, only one remains as applicable (parity of the magnetic and turbulent energy), but this evaluation can be relied on completely since it corresponds well with the others when the others are physically applicable. In this connection E. Ye. Durov at the Crimean Observatory determined the average value of the magnetic field in a typical prominence right on the basis of this evaluation and got a result about of the same order as we did for the individual prominences.

One of the five developed formulas leads to the same value of the field as do the others, for the coronal prominences (formed in the corona), and to zero for the chromosphere prominences (ejected from the chromosphere). This creates a good ~~possibility~~ possibility for classifying the prominences as coronal and chromospheric, observing them in any state of development,

but not, necessarily, from the very beginning.

If the movement in the prominence finds itself at the limit of precision, then it is possible to give at least a superficial evaluation of the magnitude of the field.

It is desirable to have a large amount of material covering many years for statistical research of the dependence of the tension of the magnetic field on the phase of the solar cycle, the geographic latitude, and the elevation above the surface of the sun.

To obtain such material it is necessary to organize systematic photographing of the prominences, taking pictures ^{within} ~~each~~ each series every 20 to 30 seconds. It would be very desirable for such a program to be included in the Sun Service and carried on at all the respective observatories, and the data on the speeds of motion of the prominences in the picture plane, and thereby also ^{on} the magnetic fields to be found there, such as present ^{to} interest for the study of solar activity, ^{to} be concentrated at our coronal station.

The procedure suggested for the determination of the magnetic fields on the sun substantially supplements the procedure based on Zeeman's effect, but ~~is~~ is not ~~is~~ overlapped by it, since the latter is applicable only within the limits of the solar disk. If a turbulent motion of this structure were observed in the corona, then ~~then~~ analogous determinations of the magnetic fields could be made also outside of the prominences in the corona. This would be a substantial addition to the determination of the magnetic field at the respective level of the corona with the aid of the measurement of the circumferential polarization of the radio emission of the sun.

3. With the aid of the chromosphere telescope research of the chromosphere flares.

In recent years a great deal of attention has been paid to the research of chromosphere flares—brief phenomena in the lower strata of the sun's atmosphere accompanied by the emission of a considerable amount of energy.

Radioastronomical observations show that in the corona there occur rather frequently sporadic phenomena of great power. Along with the rather rare large ^{splashes} accompanying the chromosphere flares and excited by corpuscular streams which are radiated from the regions of the flares, there are observed "isolated flares" of radio emission excited by relativistic particles. The frequency of the isolated splashes is ten times that of the great splashes (several hundred during a thousand hours). Their duration is 2 or 3 sec.

A very attractive idea is that of developing a procedure which would make it possible to follow the sporadic effects in the corona in the optical range. It is clear that as a basis for such a procedure one should use spectro-electrophotometric principles. One should keep in mind the two variants of the coronal electrophotometer.

The first is a monochromator connected with a coronagraph. ^{to} On the second slit of the monochromator there is projected the region of the green line. By means of a jointed little mirror or a plane-parallel plate, the line is periodically shifted along the focal plane. Behind the second slit there is located the photomultiplier. A signal from the photo multiplier after amplification passes to the cathode oscillograph, the horizontal scanning of which is synchronized with the shifting of the green line in the focal plane. In this way on the screen of the oscillograph one can observe the contour of the green line. By rapidly contouring the input slit of the monochromator around the limb the observer is able to seek out the regions with an anomalous contour character study ^{them} in detail.

The second variant of the electrophotometer is the electrophotometer with the interference-polarization filter. It may be designed so that on the screen of the oscillograph (cathode-ray or loop-type) there will be formed an image of the full intensity of the green corona in some section parallel to the radius of the sun.

If we make the slit automatically go around the limb then one ^{can} practically make a continuous recording of the change in the form of the corona. It is clear that such an electrophotometer would enable one quickly to obtain ^{the} results required for the surface of the sun.

The composition of such equipment is quite realizable for the mountain observatory. At the present time an electrophotometric ^{attachment} ~~is~~ is being made which will enable one to test ~~the~~ experimentally the possibility of the creation of the first variant.

4. The chromosphere and the corona prove to be the sources of the radio irradiation of the sun in the centimeter and decimeter ranges, and the corona in the meter range. Researches of recent years have shown that the region of radiation of high intensity in the decimeter range coincides apparently with coronal condensations (see, for example, the work of Kristiansen with the interferometer on the 21-cm wave [Australia] ~~and~~ and that of Covington with the wave-guide linear antenna on the 10-cm wave ~~from~~ [Canada]). The study of the spectrum of the radiation of the disturbed sun in the meter range (Wild-Murray and Row) convincingly points to the fact that the anomalous optical and ^{radio} emission are genetically connected. The study of the spectrum of the disturbed sun made it possible to reveal the existence in the solar crown of powerful sporadic corpuscular streams, ^{both of the} comparatively slow ones (correlating with the "great splashes" the sources of which have a speed of $\sim 10^3$ km/sec), and of relativistic ones (sources of isolated splashes). In this way radio astronomy proves to be a new, powerful method of making non-eclipse studies of the corona.

It appears to be completely unquestionable that ^{for} the conduct of non-eclipse research of the corona it is necessary to use both of the existent methods—the optical and the radio-astronomical. It is clear also that it would be ~~very~~ of great value to locate at the same spot the observation with the coronagraph and that with the radio-astronomical apparatus. For this purpose it is necessary to set up the proper radio-astronomical equipment, a list of which we shall make up soon.

The radio telescope on the 10-cm wave for the continuous automatic recording of the full emission of the whole radio-emitting disk. The width of the lobe of the diagram of the ~~directivity~~ ^{directivity} between the points of the half power should be from 1 to 3°. For such a radio telescope one may make use of the receiving and antenna part of the special unit obtained by the Institute. In doing this some modifications will be required, which can be accomplished by the observatory force. The setting up and the utilization of such a radio telescope proves to be a comparatively simple problem, and this problem in the development of the radio-astronomical projects should be solved first. Its solution will enable one to research systematically the dependence of the increased emission on the 10-cm wave on the total intensity and other properties of the coronal condensation.

With a more distant perspective one can foresee the need for the following equipment:

a) Radio telescope on waves 8 mm to 20 cm in length with high directivity (5'—15' between the points of the half power of the diagram of directivity). For such a unit the most difficult part proves to be the antenna, which should have a great aperture. One may make use of the interference method. If the length of the wave is chosen sufficiently short (21 cm) it will be very essential to have beside it a chromosphere telescope.

b) The radio spectrograph for the range $\lambda > 50$ cm. The most feasible, apparently, is the panorama design of the receiver in conjunction with the system of wide-field antennas. The most difficult part for building proves to be the receiver. For this instrument it is of importance to have at hand not only the coronagraph, but also the chromosphere telescope.

Our coronal station already in the current year 1955 may be included in the All-Union program of the Service of the Sun for the observation of the prominences in the solar corona.

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