The Total Solar Eclipse of June 19, 1936

Observations at Omsk

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THE expedition of the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies, and the University of Aberdeen, which was stationed at Omsk, had the good fortune to observe the total solar eclipse of June 19, 1936, under excellent conditions.

The expedition consisted of five members, namely, Prof. J. A. Carroll, professor of natural philosophy in the University of Aberdeen (leader); Mr. E. G. Williams, Solar Physics Observatory, Cambridge; Miss F. M. MacBain, Natural Philosophy Department, Aberdeen; and two volunteer observers, Mr. W. M. Alexander, Aberdeen; and Capt. S. I. Luck, London.

Our programme contained only three principal items, but as the instruments, methods and auxiliary equipment were in many respects quite novel, some detail of description will be of interest to readers of NATURE.

To deal first with the observing instruments themselves, and the results yielded by them:

(1) A very rapid objective prism spectrograph specially intended for exploratory work in the infra-red region of the coronal spectrum, but, of course, also used on the flash spectrum. Five 60° prisms were followed by an objective of two inches aperture and twenty inches focal length, giving a dispersion of about 100 A. per mm. at 9000 A., and covering the range from the *D*-lines of sodium to about 11,000 A. on several pieces of plate of different types. The plates used were (1) Ilford S.R. Panchromatic, (2) Agfa 800 Contrasty, (3) Agfa 950.

We were particularly concerned to detect the coronal radiation at about 9600 A. predicted by Rosenthal[1] on the supposition that the major coronal lines are due to excited helium atoms, and also to observe the line at 7896 A. observed by Curtis and Burns[2] in 1925 and recently observed by Lyot[3] at the Pic du Midi without eclipse.

Plates sensitive so far in the infra-red have in general poor keeping qualities, and the plates used were sent by air and by special messenger from Berlin as shortly before the eclipse as possible. We are much indebted to Messrs. Agfa for the prompt supply of fresh plates and to the British Embassy in Moscow and the Poulkovo Observatory for their rapid transit to Omsk, where we could keep them on ice. Thus our plates were in good condition, and thanks to the thermostatic control the instrument performed well.

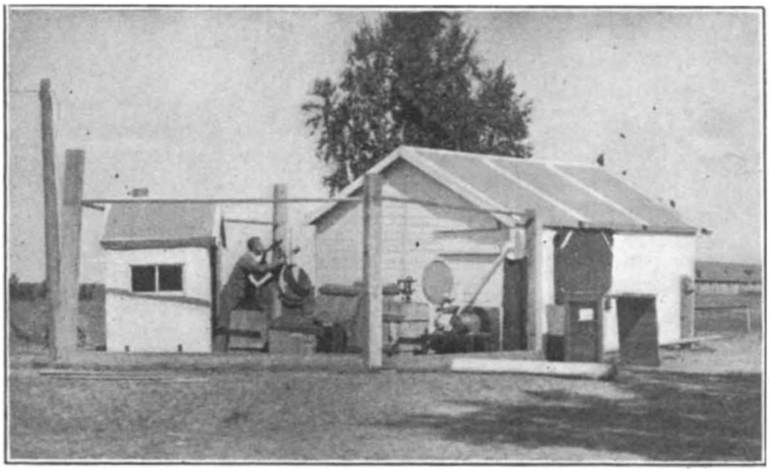

FIG. 1. Exterior of the cœlostat and experimental hut, looking east. The double-walled hut on wheels for sheltering the cœlostat is on the left. The larger hut is the double-walled, felt-lined hut for thermostatic sheltering of the instruments. At the nearest corner of the large hut can be seen the compressor for the refrigerator plant, and just above it the circular window to admit the horizontal beam from the cœlostat.

The plates show many flash lines and a number of coronal rings. Four exposures were given, (1) 5 sec. on the first flash, (2) 20 sec. on the corona, (3) 90 sec. on the corona, (4) 7 sec. on the second flash. Timing was good, and both flashes are satisfactory. In the flash spectrum, the Ca II triplet at 8500 A. is strong, the usual features show in the visible region and there are several strong lines in the region 9000 A.–10,000 A. not yet certainly identified, probably including a line due to helium. On the coronal exposures 6374 A. is strong and also the line near 7890 A. There is no strong radiation in the expected region near 9600 A., though later examination may reveal traces. The plates were good enough to show strong lines down to 10,000 A. It is interesting to note that at mid-totality prominences show, in $H\alpha$ and the *D*-lines, on both sides of the solar disk.

(2) An objective interferometer of 13 cm. aperture and 105 cm. focal length for the study

of the corona in its own monochromatic green radiation at 5303 A. The aim of this instrument is not, as some seem to have thought, to obtain accurate wave-lengths of the coronal green line. As this line is about 1 A. wide, the use of an interferometer for such a purpose is futile. The point is that by introducing a Fabry-Perot etalon into the optical train of a suitable objective spectrograph, one obtains a spectrograph working in all directions simultaneously as it were, and can obtain at all points of the corona the sort of information given by a powerful prism instrument, with a slit, over a small region only. Thus the variation in wave-length, strength, profile, and width of the line selected may be observed, and rotation and internal motion of the coronal material measured.

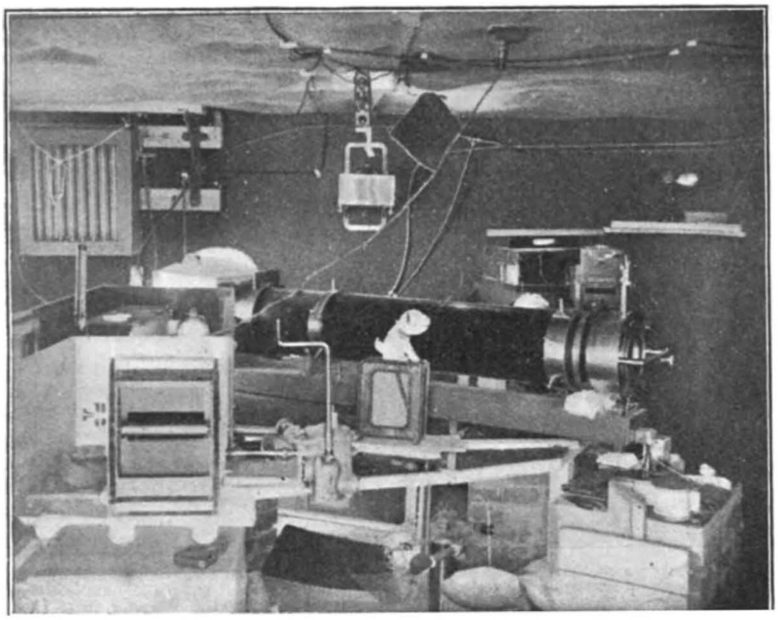

FIG. 2. Interior of experimental hut, showing echelon spectrograph, interferometer and infra-red objective prism spectrograph, with roof and sides of inner thermostatic chamber removed. One of the cooling coils of the refrigerator plant can be seen just above and to the left of the window admitting light from the cœlostat. In the opposite corner is one of the fans of the heating elements. In the centre of the ceiling are two thermostats controlling the cooling and heating elements for hut temperature. In the foreground is the heater element (surmounted by the Expedition's mascot) for fine control of instrument temperatures.

Two 6-inch 45° prisms dispersed the continuous spectrum sufficiently to allow the green ring to show by contrast, and the Ilford Astra VI plates were used, as these have a narrow maximum of sensitivity at 5300 A. with good resolving power and contrast. The plates of the étalon were separated by 1 mm. and were coated with aluminium *in vacuo* in an apparatus specially constructed in the Natural Philosophy Department at Aberdeen, so that the coating was uniform to a fraction of one per cent and the density could be exactly controlled. Thus the greatest resolving power obtainable for the loss of light allowance was secured.

The objective was a triplet of 6-inches aperture specially computed and made by Messrs. Adam Hilger, Ltd. The instrument worked excellently, and comparison fringes obtained during eclipse show exquisite definition at the full aperture.

Most unhappily, the light from the sun was cut off from this instrument during the total phase by a trivial accident, and only the comparison fringes remain to show the excellence of its performance. These are, however, not without interest in view of the remarks later on the need for, and benefits of, thermostatic control of eclipse instruments.

(3) An echelon spectrograph with automatic camera giving successive exposures of about 1·5 seconds for the study of the flash spectrum. It is of great interest to obtain accurate measures of the shapes of the chromospheric emission lines and of the changes in their shapes with height in the chromosphere. As these lines are only some 0·5 A. or so in width, very high resolution and dispersion are needed. An echelon spectroscope, crossed by, say, a pair of prisms, is almost the only instrument satisfying the necessary conditions for this type of observation, but so delicate an instrument is hard to use under eclipse conditions, and further, no echelons of large aperture exist.

The Natural Philosophy Department at Aberdeen possesses a very fine transmission echelon of 33 plates, each 1 cm. thick, height of step 1·1 mm., width 37 mm. This is still a very small aperture, but in view of the great interest of the observations and the great expense of a larger echelon, it was decided to attempt the observation of the flash spectrum with this instrument despite its small aperture. The information obtained would in any event be of vital importance in showing the practicability of the method and the size of instrument needed for accurate measurements, even if the flash spectrum turned out to be under-exposed.

As ordinarily used in air, the instrument had too small a separation between successive orders for use on the chromospheric lines, and the expedient of using the echelon immersed in oil of suitable refractive index was tried. Fortunately, the plates of the echelon turned out to be sufficiently homogeneous to permit this, and the main difficulty was due to the now abnormal sensitivity of the instrument to temperature changes. Liquids all have a temperature coefficient of refractive index some ten or more times that of glass, and to maintain homogeneity to a small fraction of a wave-length in a column of liquid 40 cm. long by some 8 cm. square proved a formidable task. Success was ultimately attained by careful thermostatic control, combined with the use of concentric tnick-walled chambers of good conducting material (brass or copper) separated by air spaces or lagging, so that the echelon and its oil were surrounded by three such 'tunnels', and uniformity of temperature was satisfactorily obtained. The optical and mechanical details of the instrument are far too elaborate to describe in a short article. In essence, the appropriate portion of the chromospheric arc is picked out by a specially designed image rotator and achromatic collimator, and the light dispersed horizontally by two flint prisms and vertically by the echelon. The resulting spectrum is received on a film in a camera automatically operated to expose for about 1·5 sec., then move the film forward in about 0·2 sec. and expose again as often as desired.

The spectra obtained at eclipse proved too faint for useful measurement of flash lines, but the spectrum of the disappearing limb of the sun is well exposed for a study of darkening towards the limb in the last minute of arc over the region 4000–5000 A. It is of interest to note that the Fraunhofer lines seem to have almost completely disappeared by 10 seconds before second contact. The results given by this instrument suggest several possible avenues for exploration at future eclipses, and give accurate data enabling the design of a larger instrument to be undertaken with confidence in its adequacy and practicability.

Perhaps the most interesting and striking feature of our programme was the temperature control of the apparatus.

Modern eclipse observing requires the utmost of the optical performance of the instruments, and it is quite idle to set up spectrographs of any size with prisms and lenses, etc., figured to the last fraction of a wave-length, and expect any but mediocre results if they are subject to the ambient diurnal temperature changes. Still more is this so if interferometric apparatus is used. In Omsk the diurnal range of temperature was some 11° C., and this fluctuation was about a mean temperature that varied every few days from about 10° C. to 25° C. Ordinary lagging and screening by temporary shelters is hopelessly inadequate to deal with this, and it was decided to attempt complete and accurate temperature control as practised in the laboratory.

For this purpose the cœlostat mirror was of pyrex glass, and instead of the usual temporary canvas shelter a well-ventilated double-walled wooden hut, on wheels, was used to prevent undue fluctuation of mirror temperature. The performance of the mirror showed these precautions to be adequate so far as the cœlostat mirror is concerned, though a fused quartz mirror would be worth while. As the cœlostat must necessarily be uncovered in use, more accurate thermostatic control of it is impracticable.

The spectrographs themselves were very elaborately housed and controlled. Steady thermal conditions were obtained in two stages. First of all, a coarse control of the interior of the experi-

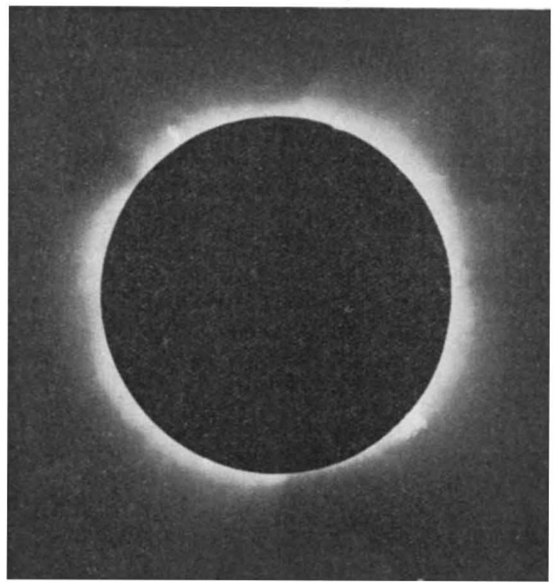

FIG. 3. Photograph of the corona taken by Mrs. Balanovsky, of Poulkovo Observatory, at Omsk. Lens, 5 m. focus; 10 cm. aperture; exposure, 1 sec. on Ilford Special Lantern Plate. By courtesy of Prof. B. P. Gerasimovic, director of Poulkovo Observatory.

mental hut. This hut was of wood, double-walled and felt-lined, with canvas screens (kindly supplied by the Willesden Paper & Canvas Works, Ltd.) for roof and walls. The mean temperature inside was maintained at about 15° ± 1° C. by means of a 1½ h.p. compressor and refrigerating coils (air conditioning units) lent by International Refrigerators, Ltd., and also by two 1 kw. low-temperature heating frames interlocked with the refrigeration control and regulated by a thermionic relay. Within the hut the instruments themselves, supported on masonry piers, were further enclosed in a lagged wooden chamber maintained at 1° C. ± 0·01 above mean hut temperature by thermostat and thermionic relay operating a low-temperature heater only. Tests of heat transfer in Aberdeen showed this system to be practicable and able to deal with the variation of external conditions expected in Omsk.

It is very gratifying to be able to report that the installation, despite its elaboration, worked excellently. Some sixteen separately wired and fused circuits drawing currents of from ½ ampere to 20 amperes were needed and were required to operate smoothly for a fortnight or more before the eclipse ! Some troubles avoidable on a future occasion were experienced, but nothing disastrous, and the vagaries of electrical supply usual in remote districts were nobly reduced by the Omsk Electrical Supply Authorities despite our being some 8 km. from the generating station, on a line supplying heavy loads *en route*. Without the willing co-operation and special provisions of the supply authorities our efforts would have been nullified, and the way in which this unusual demand was met was typical of the treatment our Expedition received in the U.S.S.R.

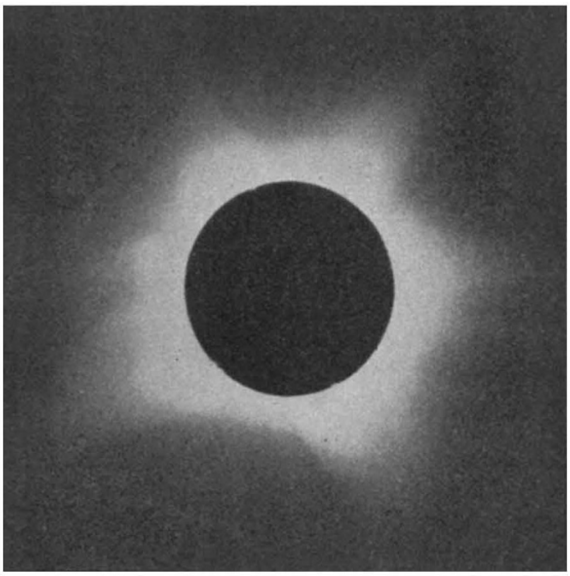

FIG. 4. Photograph of the corona in ultra-violet light taken by Dr. G. Tikoff, of Poulkovo Observatory, at Sara. Lens, 1·5 m. focus; 8 cm. aperture; exposure, 36 sec. on Ilford Special Rapid Plate. By courtesy of Prof. B. P. Gerasimovic, director of Poulkovo Observatory.

It would have been idle to take such elaborate precautions to ensure perfection of optical performance if the photographic materials had not been equally carefully prepared, tested and selected. The resolving power of many suitable emulsions, as well as their sensitivity, was carefully measured in Aberdeen, and the equipment so designed that the optical resolution attainable could be fully utilized. We are much indebted to the Research Department of Messrs. Ilford, Ltd., for the willing preparation of special materials and samples for this work and to Mr. Olaf Bloch for much time spent in valuable discussion.

One point of anxiety that was difficult to relieve by tests made in advance was the question of the correct temperature of stabilization for the instruments. Any desired temperature could be maintained, but clearly the desideratum is to have the instruments as near as possible to the actual temperature of the outside air at mid-totality. The expected temperature, based on mean diurnal records and calculations of temperature drop during the partial phase, was 15·5° C. The eclipse day itself was cooler than average, and the actual temperature was only 13·5° C. at mid-totality. The light was admitted to the instruments through a hole in one end of the hut, and a corresponding hole in the interior casing. These apertures were fully opened some five minutes before second contact and all temperature controls disconnected, the aperture into the hut being opened and the coarse controls suspended some 15 minutes earlier. The definition during totality proved excellent and the trouble feared from air currents did not arise.

The general 'seeing' was very good, and as the down-coming beam from the sun had to pass over the roof of the hut, this was covered for the greater part of the partial phase by a Willesden canvas sheet, removed shortly before totality and leaving the roof itself in good temperature equality with the surrounding air.

It is with great pleasure and gratitude that we can say in conclusion that no praise is too high for the arrangements made for us and facilities given for ourselves and our apparatus. On all sides we met with cordial co-operation, and a willingness to cut through routine procedure to expedite or to simplify our task. The special committee appointed by the All Union Academy of Sciences made excellent arrangements, which were well carried out, and the Government of the U.S.S.R. granted us exceptionally favourable rates for transport and housing, so that it was possible to take out sufficient equipment and personnel to execute this elaborate programme in the middle of Siberia. To Dr. B. P. Gerasimovic, director of Poulkovo Observatory, in particular, we are especially indebted for his personal attention to the hundred and one points of detail, as well as for the major planning of the arrangements made for us in the U.S.S.R. By his courtesy, two excellent photographs (Figs. 3 and 4) of the corona obtained by the Poulkovo expeditions at Omsk and at Sara are reproduced here. The main Poulkovo station was near us at Omsk, on State Farm No. 54, and its observers and the staff of the State Farm rendered us much assistance for which we are deeply grateful.

[1] A. H. Rosenthal, *Z. Ast.*, **1**, 115 (1930).

[2] Curtis and Burns, *Pub. Alleg. Obs.*, **6**, 95.

[3] B. Lyot, *C.R.*, **202**, 1259 (1936). Lyot gives 7891·6±0·2A. as a new line. The observations of Curtis and Burns in 1925 do not seem to be recorded in any of the more recent lists of coronal lines. I assume provisionally their line at 7896 is the same as Lyot's, allowing for the relative inaccuracies of the measurements made in 1925.