12*a*. SOUS-COMMISSION DES ECLIPSES DU SOLEIL

PRÉSIDENT: Professor R. O. Redman, Director of the Observatories, Madingley Road, Cambridge, England.

MEMBRES: Allen, Athay, Blackwell, Brück, Mlle Bugoslavskaya†, Cimino, Fujita, Mme Gossner, Houtgast, Kristenson, Menzel, Mulders, Mikhailov, Notuki, Parijsky, Righini, R. N. Thomas, Torroja, von Klüber, Vyazanitsyn†.

INTRODUCTION

Since the last report observations have been made at the two total eclipses of 1958 October 12 and 1959 October 2 respectively. Some expeditions were successful and are mentioned below, but clouds have caused much disappointment. In particular the 1959 eclipse was, like that of 1955, an occasion on which the majority of observers clustered together in what appeared to be the best region and obtained nothing, while a few others elsewhere had a clear sky.

Theoretical studies of the solar chromosphere etc., which are not specifically linked to eclipse observations, are in general not mentioned here. This is not to suggest that eclipse work can be separated from the widening field of research into the solar chromosphere and corona, of which indeed it must form an integral part. For the broader aspects of the subject the reader is referred to the main report of Commission 12.

EXTREME LIMB

N. A. Yakovkin (1) has measured the intensity of the photospheric continuum, $\lambda\lambda$ 3240–4340 Å, on slit spectrograms obtained in 1954. He found no darkening within 1″ of the limb.

CHROMOSPHERE

The general trend in theoretical studies of the chromosphere is towards more complicated, inhomogeneous and non-isothermal models, in which there may be considerable deviations from conditions of local thermo-dynamical equilibrium. The very limited opportunities offered by total solar eclipses make it difficult to produce adequate observational data to test these more complicated ideas. As far as the chromosphere is concerned, attention should be drawn to the possible use of partial and annular eclipses.

R. N. Thomas and R. G. Athay (2) have prepared a monograph entitled *Physics of the Solar Chromosphere*, due to appear at the end of 1960, which contains a compilation of 1952 eclipse data, together with analysis and theoretical discussion.

B. E. J. Pagel (3) has used H. Kristenson's measures (4) of the continuum in the neighbourhood of 6190 Å, based on a rapid succession of spectrograms obtained at the 1954 eclipse, to find the height distribution of temperature in the low chromosphere. He finds a temperature minimum between 4300° and 4400 °K, at optical depth τ_{6860} about 0·01, corresponding to a height probably less than 50 km above the limb.

S. R. Pottasch and R. N. Thomas (5) have re-analysed the continuous emission from the low chromosphere, taking account of deviations from local thermodynamical equilibrium, and find a substantially steeper gradient of the electron temperature, up to a height 1250 km, than has been deduced by earlier workers.

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R. N. Thomas has recommended that at future eclipses observations should be made of both the free-bound hydrogen Balmer continuum and the continuum above 4000 Å, attention being concentrated on heights −500 to +750 km, with a height resolution better than 50 to 100 km. He also urges that both slit and slitless spectrograms be taken simultaneously over the range 3000 to 10 000 Å, the slit being wide enough to include the whole chromosphere. A rapid succession of exposures should be made in such a way that intensities deduced from them can be differenced, to give the spectrum with a height resolution better than 100 km. B. E. J. Pagel, who supports these recommendations, is inclined to ask for somewhat greater height resolution than Thomas specifies. For the continuum he suggests using a radial slit and narrow band filters, rather than a spectrograph.

R. G. Athay, and H. R. Johnson (**6**, **7**) have shown that the electron temperature exceeds 40 000 °K in those parts of the chromosphere giving rise to the helium lines, with an upper limit 60 000° to 80 000°. This is sufficient to explain line profiles without any appeal to the 'turbulent velocities' of about 16 km/sec, which have so often been referred to in the literature.

G. I. Thompson (**8**), from spectrograms taken by D. W. Dewhirst at the 1954 eclipse, through thin cloud, has adduced evidence from the colour distribution in the spectrum which suggests that Rayleigh scattering may be an important mechanism in the chromosphere. R. G. Athay (**9**) has followed with arguments against Rayleigh scattering, but Thompson (**10**) in reply has pointed out that alternative explanations of the 1954 spectrograms are inadequate. He concluded that more spectrophotometric measurements should be made, in a good sky, to establish the chromospheric colour distribution beyond reasonable doubt.

At the 1958 eclipse a Japanese party on Suwarrow Island (Cook Islands, S. Pacific) had clear sky for about half of totality, followed by cloud. Z. Suemoto and E. Hiei (**11**) obtained 300 slitless spectrograms of the chromosphere, dispersion about 2·3 Å/mm, covering two regions in the red and violet respectively. By using a grating near grazing incidence the chromospheric image projected on to the focal plane, and hence the effect of finite chromospheric height and of scintillation, was reduced in the direction of dispersion by a factor about five. It is estimated that a resolving power about 100 000 was attained. One of the problems now being studied is that of the transition from photosphere to low chromosphere. The density gradient of hydrogen in the low chromosphere appears to be the same as that of heavier elements.

Using spectrograms obtained by J. Houtgast in 1952 at Khartoum, Salmang has measured the emission wings of $H\beta$, $H\gamma$, $H\delta$, and Ca II H and K, and has shown the existence of 'inner' and 'outer' wings comparable with those obtained by G. Elste for the same lines in absorption. Spectrograms obtained by Utrecht observers at the 1954 eclipse in Gotland have been measured and results will soon be published. They give the absolute intensities of the Balmer lines $H\alpha$ to $H\delta$ and of Ca II H and K, between levels from about −1000 to +8000 km above the limb. The Netherlands expedition to the 1959 eclipse was stationed at Gran Tarajal, (Fuerteventura, Canary Islands), near the edge of the totality zone and obtained some results through fast moving clouds (**12**). Two large-dispersion spectrographs were used for the chromosphere, one a slitless grating instrument, the other a prism instrument with a semicircular slit. In addition a double camera was used to photograph prominences in the light of $H\beta$ and of the continuum near 6200 Å.

Chromospheric abundances of various atom and ions have been determined by N. V. Steshenko (**13**) from spectrograms obtained at the 1952 eclipse. N. V. Steshenko and E. N. Zemank (*loc. cit.*) have measured accurate profiles of the hydrogen Balmer lines and of H and K on slit spectrograms from the 1954 eclipse. They have deduced a turbulent velocity 16 km/sec at $T = 6000$ °K.

CORONA

Our general picture of the corona is of a gaseous K component, contributing chiefly by electron scattering and continuous with an interplanetary gas, plus an F (dust) component arising from diffraction or reflection of sunlight by small solid particles.

P. J. Kellogg and E. P. Ney (**14**) proposed, and subsequently themselves disproved, a new theory for the source of the K corona. Their idea was that a major contribution is provided by synchrotron radiation, from electrons trapped in the solar magnetic field (analogous to the van Allen radiation belt around the earth). D. E. Blackwell and D. W. Dewhirst (**15**) gave arguments against this view, one of the strongest being based on H. von Klüber's photographic measurements at the 1952 eclipse, which demonstrated that the corona shows only small deviations from radial polarization (and these chiefly where observational errors are expected to be highest), a result which could not be expected from synchrotron radiation. However, Kellogg and Ney (**16**) themselves organized three parties which were stationed at different points in the Sahara for the 1959 eclipse and measured the amount and direction of polarization photoelectrically. These observers were all favoured with clear sky and despite difficulties from high ambient temperatures the apparatus in every case worked satisfactorily. Results so far published fully confirm von Klüber's, the plane of polarization (magnetic vector) deviating from the radial direction by at most 1° or 2°. The conclusion is that the contribution of synchrotron radiation cannot be very great.

W. E. Felling and M. Witunski (**17**) have briefly reported polarization measures from photographs taken at the 1959 eclipse from an aircraft flying at 45 000 ft altitude. By flying at supersonic speeds the machine was able to stay in the umbral cone for about seven minutes, over twice the ordinary duration of totality. The measures, which should be much less affected by the Earth's atmosphere than are those from the ground, cover the region 2·5 to $5{\cdot}5R_\odot$ and what are considered by the authors to be significant deviations from radial polarization were found in equatorial regions. The authors also note, what many earlier observers have found, that the brightness of the lunar disk appeared greater than that in the outer corona (in this case beyond $3R_\odot$). Kellogg and Ney, following laboratory experiments, believe that in their own work this phenomenon is to be explained by light scattered in the optical train. There is undoubtedly in general also a contribution from earth-shine.

The K and F coronas have hitherto been separated chiefly by means of the assumption that the measured polarization is entirely due to the electron corona. D. E. Blackwell and M. F. Ingham (**18**) have shown that this is false in the case of the zodiacal light, which means that the entire question of separating K and F must be reconsidered, using some other method. M. F. Ingham (*loc. cit.*) has attempted this, supposing K and F have been separated satisfactorily near the Sun, in part on spectroscopic evidence, and that the electron density can be represented by a smooth interpolation function out to the zodiacal light region, where again spectroscopic evidence sets an upper limit to the electron density. The dust contribution can then be deduced, and also some of the properties of the dust particles.

But even with the usual assumptions the separations hitherto made between K and F may need correction. M. Waldmeier (**18a**) has shown that account should be taken of the depression of the K continuum by numerous smeared-out Fraunhofer lines, especially in shorter wavelengths. After doing this he finds that spectroscopic and polarization analyses are brought into better agreement.

A number of practical attempts to make a better separation of K and F coronas have been frustrated by clouds. For example, in 1958 K. Takakubo and N. Sato again tried the method, mentioned in the last report, of photographing the corona through a birefringent filter centred

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on a strong Fraunhofer line. In 1959 H. von Klüber and M. F. Ingham attempted to photograph the spectrum simultaneously in both polar and equatorial regions, and in two planes of polarization.

S. Chapman (**19**) has extended and revised his computations of temperature and density distribution in a hydrostatic corona and finds $T = 100\,000$ °K and $N = 500$ cm^{-3} at about one astronomical unit from the Sun. This density exceeds Blackwell and Ingham's maximum value by a factor 4.

At the 1958 eclipse, Y. Yamashita and M. Shimizu, under the supervision of K. Saito, used two quadruple cameras, each photographing the sky simultaneously in different planes of polarization, in red light. Absolute calibrations were made after the eclipse, using the Sun. The longer exposures were affected by thin clouds, but measurements could be made to $15R_\odot$.

M. Waldmeier has discussed the white light corona as photographed at the 1954, 1955 and 1958 eclipses (**19a**). Some of the photographs were made from aircraft. In the case of the 1954 corona, photographed practically at sunspot minimum, he has compared the polar rays to the lines of force of a bar magnet having poles about 0·6 solar radii from the centre, or of an equivalent system of electric currents, but points out that the strong equatorial rays cannot be fitted into this picture. In the 1958 corona he found the electron density in a prominent coronal ray to exceed that of the undistributed corona by about 3·3 times at 2·0 $R_\odot$ and 9·1 times at 2·5 $R_\odot$.

I. D. Gitz (**20**) has published accurate measures of the degree of polarization out to $4{\cdot}5R_\odot$.

I. K. Koval (**21**) measured the integrated light of the corona at the 1954 eclipse and found it to be $0{\cdot}56 \times 10^{-6}$ of that of the Sun.

J. M. Kumsishvili (**22**) from radiometric observations found that the corona has an infra-red colour excess 0·16. Also at the 1954 eclipse V. A. Mikhailov, K. N. Kuzmenko and V. Ch. Pluznikov (**23**) determined isophotes and the distribution of intensity with distance from the limb, in six colours. Another six-colour photometry ($\lambda\lambda$ 6580, 6200, 5310, 4170, 3960, 3640 Å) was carried out by V. P. Konopleva and a two-colour photometry by J. T. Kapko. A summary of results dealing with the structure of the inner corona at the 1952 and 1954 eclipses has been published by G. M. Nikolsky (**24**). N. Owaki measured white light isophotes of the inner corona in 1958.

The surface brightness distribution of the corona in the light of the green 5303 Å line has been measured at the 1952 and 1954 eclipses by V. A. Fedoretz and V. I. Ezersky (**25**), while E. I. Mogilevsky, G. M. Nikolsky, and K. I. Nikolskaja (**26**) have measured the degree of polarization in the green and red coronal lines, and have calculated the effective cross-section of excitation by electron impact. P. M. Poloupan has published measures of the green coronal line from slitless spectrograms obtained in 1952.

A. H. Jarrett and H. von Klüber (**27**) have completed measurements of photographs of the corona obtained by them at the 1958 eclipse, the photographs being taken through a Fabry-Perot interferometer and through narrow-band filters restricting the light to either the 5303 or the 6374 Å line. The instrumental fringe shape was determined immediately before and after totality, with a Hg-198 isotope lamp. The measures cover 1·1 to 1·75 $R_\odot$. Attributing the line widths to thermal motions, 5303 Å gave temperatures between 1·6 and 6×10^6 °K, with most values near a mean $3{\cdot}2 \times 10^6$ °K, while the 6374 Å line gave values approximately 10% higher. In view of the experimental accuracy no great weight is attached by the authors to this difference. (It is in the opposite sense to the difference found by D. E. Billings from coronagraph measures relatively near the limb). The Jarrett and von Klüber 1958 temperatures, measured near the maximum of solar activity, are about 30% higher than the temperatures they obtained by the same method in 1954, when solar activity was exceptionally low.

These temperatures are kinetic temperatures of iron ions. They are higher than the temperatures, mainly electron temperatures, given by other methods. C. W. Allen has drawn attention to these differences as probably giving a significant clue to physical conditions within the corona.

ROCKET OBSERVATIONS

The 1958 U.S. expedition to the Danger Islands used a remarkable number of new technical devices. Unfortunately clouds prevented any optical observations being made from the ground. However under the direction of H. Friedman (**28**) a number of rockets were fired successfully from shipboard to altitudes ranging from 90 to 245 km, during both partial and total phases, to measure Lα and also X-rays in the wave-length bands 8–18 Å and 44–60 Å. Preliminary results indicate that the Lα radiation almost disappeared during totality and is therefore mostly confined to the solar disk. On the other hand more than 25% of the X-ray flux near 50 Å persisted throughout totality. The X-rays show strong limb-brightening and in their distribution over the corona resemble radio radiation in decimetre wave-lengths. These measures came near sunspot maximum. Friedman has pointed out the desirability of repeating the experiments near sunspot minimum.

RADIO OBSERVATIONS

The 1958 annular eclipse was observed in China in cm wave-lengths (1·63, 3·2, 5·1, 10 and 50 cm), by a combined Sino-Soviet expedition. Sources of polarized radiation were localized, some coinciding with sunspot umbrae, and their dimensions measured (**29, 30, 31**).

Records made by I. G. Moisseiev (**32**) of radio emission at 1·5 m, have shown irregular intensity variations attributed to prominences and filaments.

EINSTEIN DEFLECTION

In the 1959 George Darwin lecture, A. A. Mikhailov (**33**) discussed the problem of the deflection of light in the gravitational field of the Sun. A general review of the same problem has also been published by H. von Klüber (**34**).

FUTURE ECLIPSES

Mrs S. D. Gossner (**35**) has continued to publish predictions for the circumstances of future eclipses. Data are now available up to and including 1970. It should be noted that the radii of umbra and penumbra in future will be computed with a new value of k, the quantity defined by

$$\sin(\text{semi-diameter}) = k \sin(\text{horizontal parallax})$$

The new value is $\kappa = 0{\cdot}27248\,07$. However, the computed duration on the central line of total eclipse will still be based on the old value $k = 0{\cdot}27$, which is retained in order to avoid approximate limb corrections.

The predictions cited are based on the old k. Predictions in national ephemerides will use the new k, starting with the volume for 1963. The position of the central line does not depend on k.

If desired, the published Besselian elements may be easily adapted to other values of k. Suppose k_0 is the value used in the calculated table and l_0 is the tabulated value of the radius of umbra or penumbra. For any other $k = k_0 + \delta k$

$$l = l_0 + \delta k \text{ (penumbra)}$$
$$= l_0 - \delta k \text{ (umbra)}.$$

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A. A. Mikhailov (36) has published detailed predictions for the total eclipse of 1961 February 15. Local information relating to the 1962 and 1965 eclipses has been collected by H. von Klüber and has been circulated to members in typescript.

Coming total eclipses

Date	Max. duration (minutes)	Where visible
1962 February 4	4·1	New Guinea, Solomon Is., Palmyra I.
1963 July 20	1·7	Alaska, N. Canada, Quebec, New England.
1965 May 30	5·3	New Zealand, Cook Is., W. Peru.
1966 November 12	2·0	Peru, Bolivia, Argentina, S. Brazil.
1967 November 2	not central	North of Weddell Sea.
1968 September 22	0·7	W. Siberia
1970 March 7	3·5	Mexico, S.E. United States.

Coming annular eclipses

Date	Max. duration (minutes)	Where visible
1962 July 31	3·5	S. America, W. and Central Africa.
1963 January 25	1·0	S. Argentine, S. Africa, Madagascar.
1965 November 23	4·1	Himalayas, Indo-China, Celebes, New Guinea
1966 May 20	0·9	W. Africa, Algeria, Libya, Turkey, South U.S.S.R.
1969 March 18	1·2	E. Indies.
1969 September 11	3·2	Peru, Bolivia.
1970 August 31—September 1	6·8	S. Pacific.

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President of the Sub-Commission

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