INTERFEROMETRIC INVESTIGATION OF EMISSION LINES OF THE SOLAR CORONA DURING THE TOTAL SOLAR ECLIPSE OF 1958 OCTOBER 12

A. H. Jarrett and H. von Klüber

(Received 1960 November 4)

Summary

The total solar eclipse of 1958 October 12 was observed by a Cambridge Observatories expedition on the coral atoll Atafu, in the Tokelau Islands of the South Pacific. The solar corona was photographed through a Fabry–Perot interferometer, with a 0·35 mm spacer, using narrow-band interference filters for the green (λ 5303 A) and red (λ 6374 A) corona lines respectively. Several good photographs were obtained, standardized photometrically and showing very good interference fringes over the whole corona, in some position angles to more than 1·8 solar radii from the Sun's centre. Immediately before and after the eclipse, interference fringes were photographed in the light of the 5461 A line from a water-cooled mercury 198 isotope lamp, to check the instrumental adjustment and to provide an instrumental fringe profile. Many line profiles and half-widths, corrected for instrumental broadening, were determined for both the corona lines and temperatures derived from them. The mean temperature from the green line was about $3{\cdot}2 \times 10^6$ deg. K and from the red line $3{\cdot}5 \times 10^6$ deg. K, with an error of about 10 per cent in each case.

After many earlier attempts by other observers had failed, the present authors at last succeeded (**1, 2**) in obtaining Fabry–Perot interference fringes from the green corona line during the total solar eclipse of 1954. From this first attempt it became clear that with modern interference filters and with a suitable optical arrangement it is quite possible to obtain Fabry–Perot interference fringes of the brightest emission lines of the corona during a total eclipse, out to a distance from the Sun's centre which cannot be reached by the usual technique of daytime observations with coronagraphs. Line profiles of λ 5302·86 taken during an eclipse have also the advantage of being unaffected by the very disturbing iron absorption line λ 5302·309 which is present in the scattered skylight of all daytime observations and happens to be superimposed on to the violet wing of the corona line (**3**). The interferometric technique, when applied photographically, furthermore allows one to obtain line profiles with a fairly high resolving power over a considerable area of the corona simultaneously.

With the experience gained at the 1954 eclipse it seemed desirable to repeat interferometric observation of the solar corona during the total solar eclipse of 1958 October 12. This eclipse came near to the maximum (Epoch 1957·9) of the highest solar activity ever observed so far and also fell within the International Geophysical Year so that such observations could be assumed to be of special interest. The track of the 1958 total eclipse passed over the whole length of the Pacific Ocean and only eight tiny low coral atolls lay inside the belt of totality (**4**). Atafu, 172°30′W and 8°33′S, one of the Tokelau Islands, was chosen for the Cambridge Observatories eclipse expedition, mainly because flying boats could land right on the lagoon of the island (5) and could be used for the transport of instruments and scientists to and from the station. The coral reefs lying outside the island are a serious obstacle for ordinary landing operations and the island is seldom approached by vessels. The members of the expedition and most of the optical, photographic and electric equipment were flown by a Sunderland flying boat direct to the lagoon. The expedition lived in army tents on the outskirts of the small village of Atafu. The concrete pillars for the instrument and a temporary shelter of wooden planks and coconut mats over the coelostat and the optical equipment were erected, with the most efficient help of the Tokelau Islands Administration and of the local population, on the east shore of the lagoon in front of the small village hospital. In spite of the fact that the width of the heavily wooded island between the ocean shore and the lagoon was only about 300 metres, sea spray and wind gave little trouble during the seven weeks the expedition stayed on the island. The surfaces of the aluminium coated mirrors, the interferometer and the interference filters actually kept very well and so did the relative adjustment of the interference plates. Shade temperatures were remarkably uniform and were seldom higher than 30 °C.

Instruments.—The optical arrangement was a much improved version of the instrument used successfully in 1954 and of the one prepared for the 1955 eclipse in Ceylon which unfortunately was clouded out (1, 6).

In the new design fringes from the green and from the red corona lines respectively could be obtained on successive photographs during totality, merely by changing the interference filters. The Sun's image now had a diameter of 13 mm, compared with only 6 mm in 1954. Special 5 × 5 cm plates were used instead of 36 mm film, in a precision holder specially designed for a very rapid change of plates. Fig. 1 gives a general sketch of the optical arrangement. Using

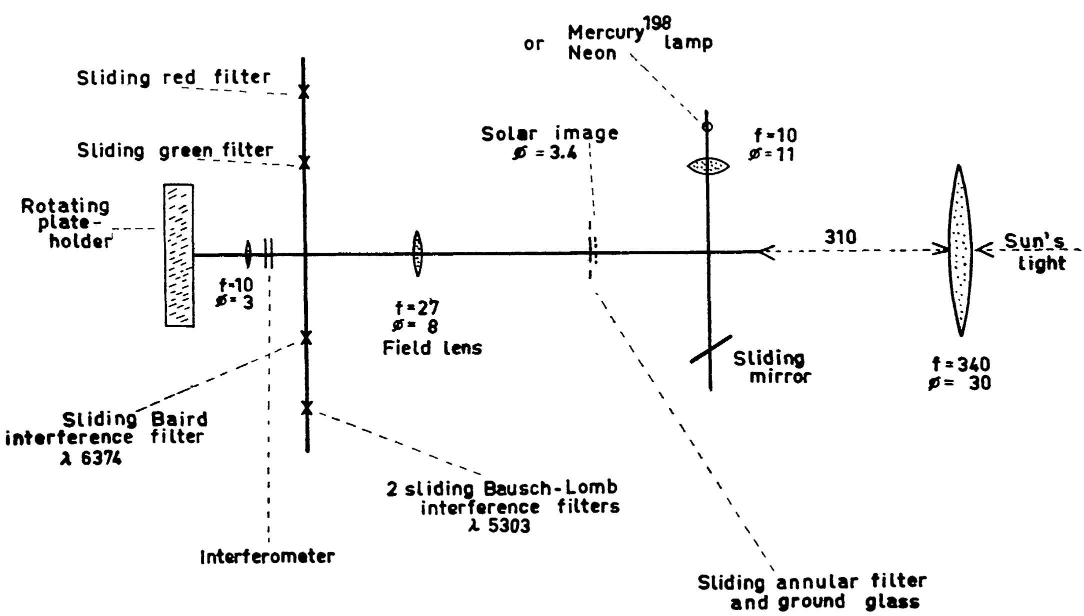

FIG. 1.—*General sketch of the optical arrangement. The symbol f gives the focal length and* ϕ *the aperture in cm.*

a coelostat and an auxiliary mirror, each having an aperture of 40 cm, the Sun's light was reflected on to an astrographic lens of 30 cm aperture and of 340 cm focal length. This lens formed a solar image of 34 mm diameter in the focal plane of a field lens of 27 cm focal length which, in turn, imaged the aperture of the

30 cm objective into the aperture of the interferometer, itself placed in a telecentric beam with respect to the Sun's image. A high quality Zeiss-Tessar camera lens of 10 cm focal length imaged the fringes of the interferometer as well as the corona, superimposed on each other, on the photographic plate. The image of the corona thereby was reduced in the proportion 10 : 27, i.e. the diameter of the solar image became now 13 mm. The plate holder was specially precision-made in the workshop of the Observatories so that by simply moving a handle from one mark to the next six plates 5 × 5 cm could be exposed in succession. The movement was controlled by precision ball bearings rotating against a large machined plate which itself was adjustable with respect to the optical axis by three push-pull screws. In this way all plates could be exposed within less than ± 0·05 mm of the best focus, a necessary requirement for obtaining good line profiles. The camera lens could be focussed by means of a special helical Zeiss mounting with equal accuracy. One interference filter for the green corona line λ 5303 and another one for the red line λ 6374 were arranged sliding on an optical rail perpendicular to the main optical axis in front of the interferometer. The change-over from the one to the other during totality controlled by pre-set stops, took about one second only. For adjustment and test purposes other ordinary glass filters could be moved into the main optical beam in the same way. Another short optical rail, again perpendicular to the main optical axis, was fixed a small distance in front of the primary image of the Sun. It carried the comparison light source, a condenser lens and a mirror which, when slid into the optical axis, reflected the comparison light on to a ground glass screen placed near the focal plane of the main objective. In this way, with the mirror inserted, comparison fringes could be imaged on the photographic plate in exactly the same way as were the fringes of the corona. The ground glass screen, resting against adjustable stops, had also the important function of providing a means of adjusting precisely the Sun's image and the fringe system on to each other. The mirror had, of course, to be shifted out of the optical beam during the actual eclipse observations.

It was to be expected that photometry of the interference fringes, superimposed on the background image of the corona, would be somewhat complicated by the well known steep intensity gradient of the corona near the limb of the Sun. With this in mind an annular filter had been prepared of dimensions and absorption gradient such that, when brought during the exposure of the corona near to the primary focal plane and adjusted concentrically with the corona, it would smooth out most of this unwanted steep intensity gradient. The filter was made according to given specifications by Messrs. Barr and Stroud, and worked very well during all tests before the eclipse. But obviously it had to absorb a certain amount of light and the feeling was that it should be used for the actual eclipse exposures only if the general circumstances and the transparency of the sky were such that this loss of light would be tolerable. Since some high cirri were still visible shortly before totality we eventually decided not to use this annular filter, for fear of under-exposure. Later, when the plated obtained during the eclipse were inspected, this decision was seen to err on the side of pessimism, for quite sufficient light had been available in the green line fully to justify use of the filter. But fortunately only some inconvenience, and no serious trouble was later encountered during the photometry from the steeper gradient thus obtained. For the long exposure (60 s) of the red line use of the annular filter would have given a more convenient gradient, whilst for the shorter exposure (20 s) of the red line, only a slight and probably tolerable loss in density in the inner corona would have occurred. The final verdict is that use of such an annular filter, in this and in other photometric problems dealing with the corona, might prove very helpful.

Interferometer.—We used the same interferometer as in 1954 (1), consisting of two flats of crystalline quartz figured by Messrs. Hilger and Watts to $1/40\lambda$. For spacer we again used balls from the Miniature Ball Bearing Co., in Switzerland, of 0·35 mm diameter, giving a range of 4·04 A which seemed well suited for our problem. But this time use of multi-coated dielectric layers on the plates seemed inadvisable because having only one interferometer we wanted to use it for the green as well as for the red corona lines. Both flats, therefore, were coated by Messrs. Hilger and Watts with an aluminium surface and we had to make a compromise between reflectivity which, once the spacer was fixed by the circumstances of the problem, controls the resolving power, and between the transparency which for increasing reflectivity decreases rather quickly. The resolving power actually used on this occasion was about 10,000. Since the actual instrumental profile could be measured very accurately with the help of the green Hg^{198} isotope line, 5461 A, and remembering that the corona lines have a half width of the order of 1 A, this resolution was considered quite sufficient. As will be seen below, the observed half widths of the corona lines could be corrected very reliably for the instrumental profile.

Filter.—For isolating the λ 5303 line we used two combined Bausch and Lomb interference filters manufactured in 1954. Each had a size of 5×5 cm, a half width of about 38 A and a peak transmission of about 75 per cent. The transparency curve of this combination, as used during the eclipse, is shown in Fig. 2,

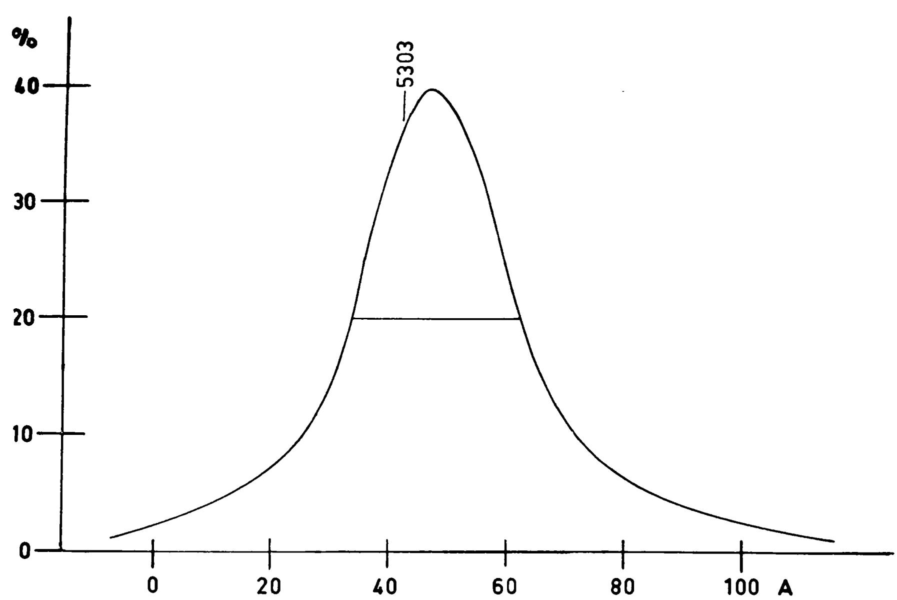

FIG. 2.—*Transmission of the two combined Bausch and Lomb interference filters used for observing the coronal emission* λ 5303.

from which we deduce that the effective half width was about 28 A. The peak transmission of about 40 per cent was found for perpendicular incidence to lie only 3 A to the red side of λ 5303 and could be brought right on to λ 5303 by tilting the

-4	-10	-17
+11	0	-10
+18	+13	+4

-32	+26	+28
-8	-2	+9
-7	+23	+26

FIG. 3.—*Deviations from* λ 5303 *of the wavelengths of peak transmission at different parts of the Bausch and Lomb interference filters, in Angstrom units.*

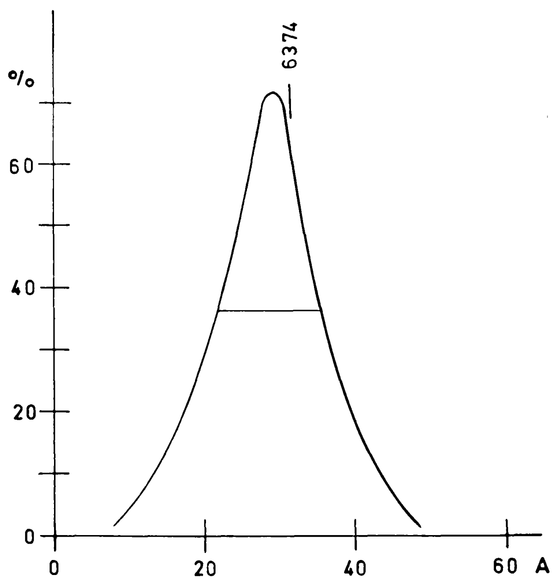

FIG. 4.—*Transmission of the Baird interference filter used for observing the coronal emission* λ 6374.

+ 3.6	− 0.9	−0.9	+2.7
+ 1.8	− 3.6	−4.6	−0.9
− 3.6	− 3.6	−3.6	−3.6
− 3.6	− 6.3	− 5.4	− 0.0

FIG. 5.—*Deviations from* λ 6374 *of the wavelengths of peak transmission at different parts of the Baird interference filter, in Angstrom units.*

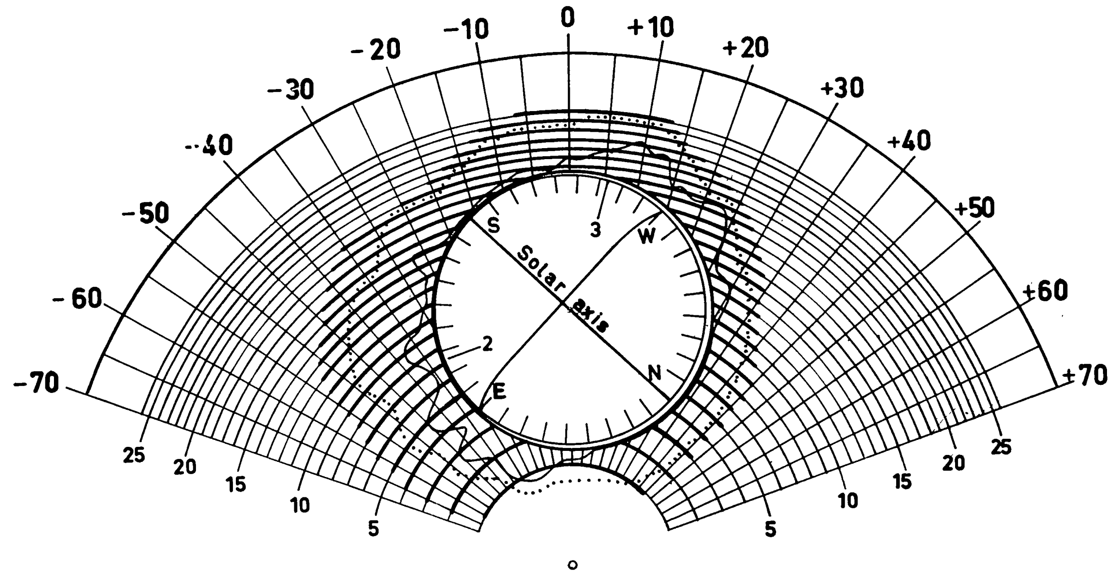

FIG. 8.—*Sketch showing the system of interference fringes of λ 5303, on plate 2, with respect to the solar coordinates. The Nos. 2 and 3 denote the second and third contact. The Sun's position is inserted into the circle of the moon for about the middle of exposures of plate 2. The heavily drawn parts of the concentric circles indicate all interference fringes clearly visible on the original plate. The dotted line indicates the contour of the corona background as visible on the plate and the thinly drawn curve the intensity estimations for λ 5303 carried out with the Climax coronagraph about one hour after the eclipse. The system of straight lines, originating from the centre of the fringe system but otherwise arbitrarily orientated, indicates the lines along which as far as possible photometry has been carried out.*

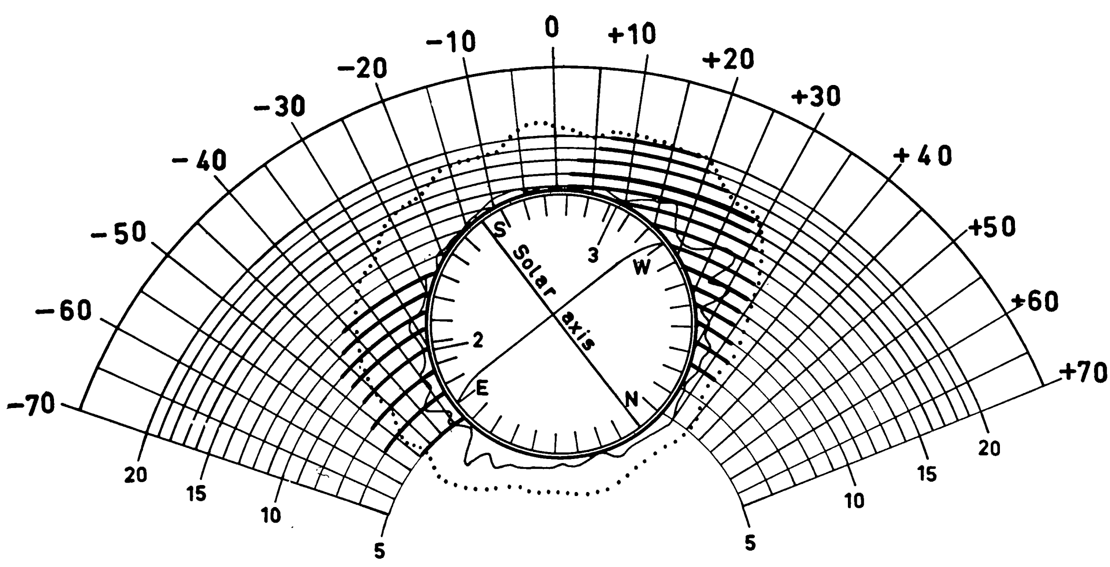

FIG. 9.—*Same as Fig.* 8 *but for* λ 6374 *on plates* 3 *and* 4. *The system of straight lines along which photometry has been carried out and originating in the centre of the fringe system is, for technical reasons, again arbitrary and not quite identical with the similar system in Fig.* 8.

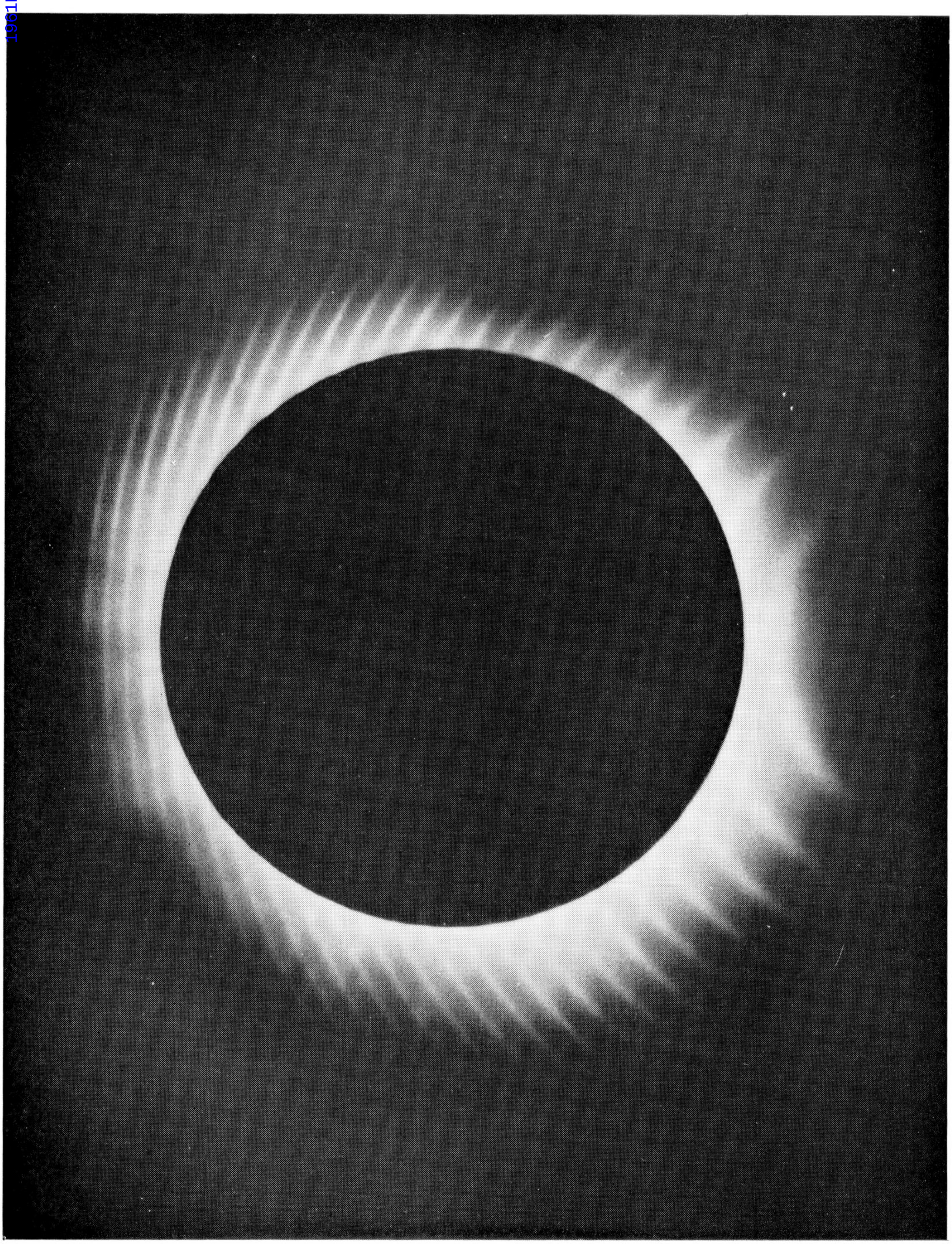

FIG. 6.—*The corona with superimposed interference fringes in the light of λ 5303, (plate 2). Exposure time 20 seconds, range of the interferometer 4·04Å.*

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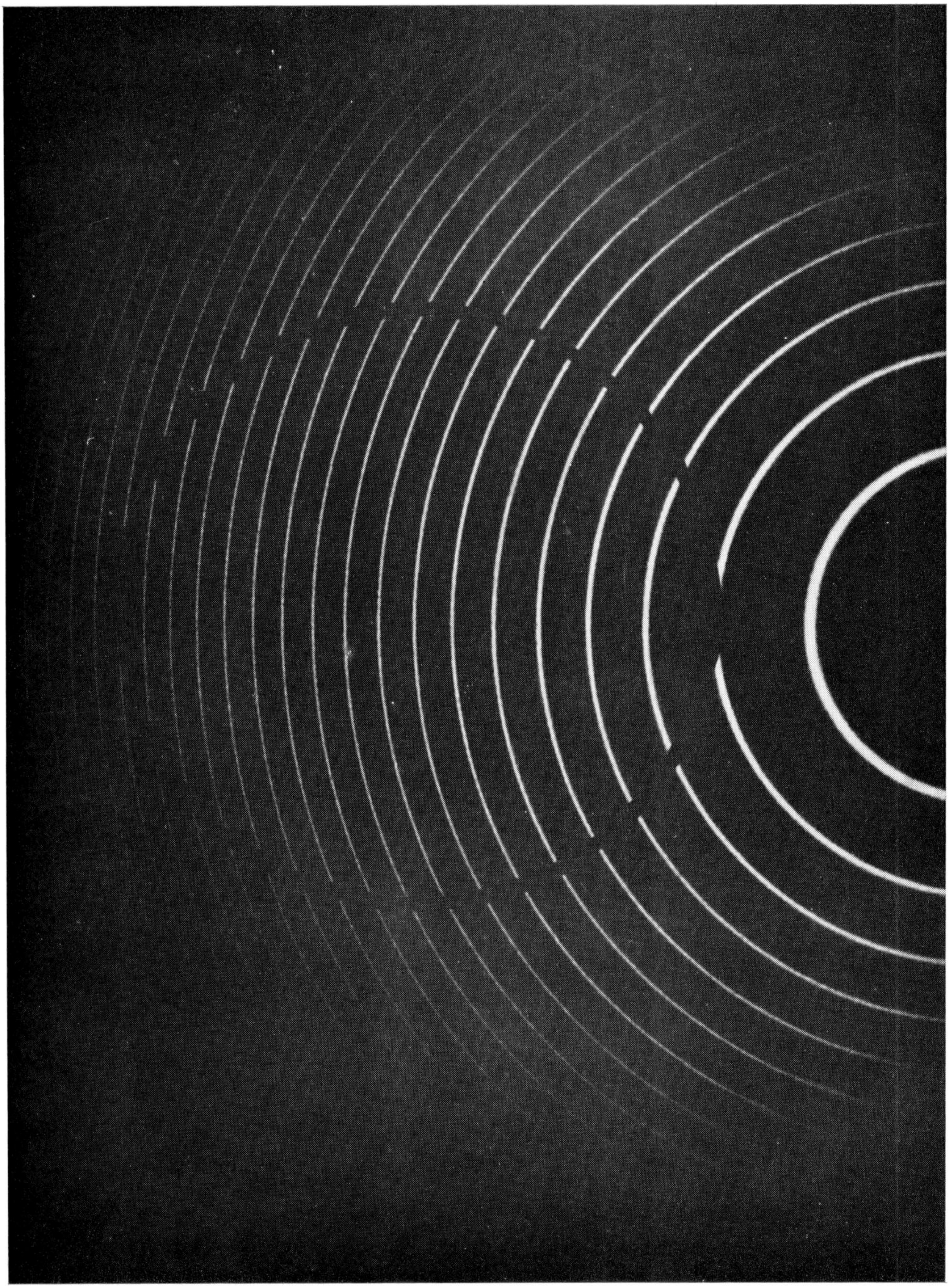

FIG. 7.—*Fabry-Perot test fringes at λ 5461 from a mercury 198 water-cooled isotope lamp, photographed a few minutes after totality (plate 5). Exposure time 15 seconds, range 4·04Å.*

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filters slightly. This combination possessed another broad maximum around λ 4400 which could be removed by an additional OY6 Chance glass filter. Another very weak maximum near λ 6300 was placed well beyond the colour sensitivity of the photographic plates. The homogeneity of the two filters was satisfactory as one can see from Fig. 3.

For the red line λ 6374, a specially excellent filter was made by Baird Atomic Inc., Cambridge (Mass.). Its properties, as measured photometrically with the large Cambridge spectrograph, are shown in Fig. 4. It had a half width of only 14 A and a peak transmission of well over 70 per cent. Unfortunately its maximum transparency was displaced about 3 A to the violet beyond λ 6374 and could therefore not be corrected by tilting the filter, so that a slight loss of transparency and therefore of contrast had to be taken into account. With such a small band-width the uniformity of the filter over its surface is quite important and very often not well attained. This particular filter was found to be very uniform over its whole area, as can be seen from Fig. 5. The filter was cemented together with a coloured cover glass to remove the other unwanted transmission maxima. A weak transmission on the violet side of the main peak was easily removed by an OR2 Schott filter.

Photographic plates.—For the green line a Kodak emulsion similar to Kodak IIa J but specially prepared for this purpose (Code V 1008 on 5×5 cm plates), was used, while for the red corona line the Kodak emulsion IIaE was found very suitable (7). Both emulsions are only of moderate speed but were chosen after a long set of tests as giving a good compromise between resolving power, contrast, colour sensitivity and speed. We are obliged to the research laboratories of Kodak Ltd., Wealdstone, Harrow, for preparing several test emulsions according to our specifications and for supplying eventually all the plates used by us during the eclipse.

Observations.—The weather, somewhat doubtful in the early morning, became quite good during eclipse. Local time of mid-totality was $8^{h}\,7^{m}\!\cdot\!5$. Soon after first contact, apart from a few drifting cumuli clouds, there was only faint irregular high cirrus disappearing slowly in the neighbourhood of the Sun, and, if present during totality, seems not to have interfered at all with the observations. But, as mentioned above, the cirrus was the reason for not using the annular filter, an unnecessary precaution as appeared later. The observations were carried out in the following sequence:

1: about 5 minutes before second contact test fringes of the green Hg 198 line were taken with 15 seconds exposure time.

2: the green mercury filter was then replaced by the Bausch and Lomb interference filters for the green corona line. This change took only about 2 seconds and no other part of the instrument was touched.

3: a few seconds after second contact the fringes of the green corona line were exposed for 20 seconds (Fig. 6).

4: the green interference filters were then replaced by the Baird λ 6374 interference filter and 2 exposures of 60 and 20 seconds respectively were taken of the red fringes.

5: about 2 minutes after third contact another test exposure of the green Hg 198 line was taken in exactly the same manner as at the beginning (Fig. 7).

The change of plates with the rotating plate holder operated by the observer inside the hut required about 1 or 2 seconds. The actual exposures were made by a shutter operated by Mrs von Klüber in front of the 30 cm lens near the coelostat, so that the instrument was never touched during these operations.

After the eclipse a set of intensity marks from a Hilger rhodium step filter was printed on separate 5×5 cm plates which came out of the same boxes which had provided the eclipse plates. The exposure times were in each case identical with the exposure times of the eclipse plates with which they were to be combined. These exposures were made in a separate, small, electric standardising equipment through filters which separated the λ 5303 or the λ 6374 region in the same way as during the eclipse. Each eclipse photograph was developed together with its standardised companion, in a specially made plexi frame, ensuring that the whole sequence of processing was carried out for both plates absolutely identically. In this way the fundamental condition of photographic photometry, *viz*, equality of emulsion, exposure time, wavelength and processing could be easily and strictly fulfilled.

Since temperatures often reached, and sometimes surpassed, the 30°C limit, Kodak tropical developer DK 15 and a Kodak tropical hardening stop bath SB4 containing potassium chromalum were used for all photographic processing, and proved very satisfactory (**8**). There was a plentiful supply of rainwater for all solutions and for washing purposes.

The fringes of λ 5303 came out with remarkable contrast and quality all over the corona, as can be seen from Fig. 6. The intensity ratio of corona background to the fringes is on the average about 1 : 1·6. This contrast is much higher than found in 1954 and doubtless to a great extent is due to the much greater intensity of the green line during this eclipse. Solar activity had its highest maximum on record (**9**) in 1957 December, while the Zürich relative number during the month of the eclipse was 181 (**3**). In contrast the 1954 eclipse showed a typical minimum corona with a relative number as low as about 0·2 and with the green line hardly visible with the usual coronagraph.

On the day of the 1958 eclipse good observations were obtained at the Climax station of the High Altitude Observatory of the University of Colorado with a Lyot coronagraph. Since the corona lines on our plate extend far beyond the distance covered by the usual routine corona observations it is of interest to show in Fig. 8 our λ 5303 fringe system superimposed on the intensity contours of the Climax station. One must keep in mind that these contours are not isophotes but relate to intensities only, observed at a distance of about 0·03 radii from the centre of the Sun. On the average our fringe intensity follows the coronagraph limb observations fairly well. Our greatest intensities and, as we will see below from Table I, our greatest fringe widths are found around position angle 80°–120°, obviously in connection with the active centre near the spot group Zürich No. 28 and 21 of rotation 1406.

The two exposures of λ 6374 show the fringes in the vicinity of the equatorial belt very well but, as to be expected and in agreement with the Climax observations of the same day, with much lower contrast than for the green line. Our drawings, of fig. 8 for λ 5303 and Fig. 9 for λ 6374, show the orientation of the fringe system with respect to the solar corona and to the solar coordinates.

Reduction.—Our main aim was to derive a number of line profiles and a greater number of line half widths (and therefore temperatures) for as much of the corona

TABLE I

Half widths in angstroms of the green corona line λ 5303 A as measured on plate 2. The uppermost row gives the readings of the radial lines originating in the centre of the fringe system as shown in the sketch of Fig. 8. The first column left indicates the number of the interference fringes as given in the same sketch.

Fringe	−65	−60	−55	−50	−45	−40	−35	−30	−25	−20	−15	−10	−5	0	+5	+10	+15	+20	+25	+30	+35	+40	+45
1	0·93	0·92	0·92	0·77	0·86	0·82	0·85	0·75	0·63	0·65	0·82						0·80			0·80	0·80	0·91	
2	1·20	0·82	0·81	0·99	0·90	0·92	1·10														0·93	0·97	1·00
3	1·00	0·92	0·81	0·94	1·05	0·91	1·19														0·87	0·97	0·95
4		0·75	0·96	0·80	0·86	1·09	1·30														0·89	0·89	0·82
5		0·80	0·89	0·85	0·89	1·03	1·32														0·91	0·85	0·90
6		0·94	0·91	0·88	0·94	1·07	1·12														0·92	0·96	
7			1·08	0·87	0·97	1·08	1·36														0·88	0·79	
8			0·86	0·85	0·92	1·01	1·20														0·82	0·79	
9				0·73	0·86	1·26	1·17														0·80		
10				0·76	1·17	1·01	0·96													0·90	0·71		
11				0·77	1·04	1·03	0·93	1·10												0·79	0·66		
12				0·75	1·08	0·93	1·12	1·07												0·85	0·82		
13					1·10	0·94	1·05	1·05											0·97	0·90	0·64		
14					1·03	1·12	1·18	1·46	1·20										0·95	0·87			
15							1·10	1·02	1·27	0·78									0·76	0·93			
16								1·00	1·43	1·00								0·89	0·91	1·08			
17								0·99	1·31	0·93								0·92	0·98				
18								1·09	1·11	—	1·01						0·99	0·97	0·80				
19										0·99	0·95	0·83				0·82	0·82	0·88	0·85				
20											0·85	0·93	0·90	0·92	1·30	0·87	0·86	0·96					
21											0·80	0·98	0·98	0·89	1·24	0·87	0·77	1·04					
22												0·90	0·99	0·85	1·22	0·95	0·70	1·10					
23												0·88	1·04	0·86	1·24	0·90	0·76	1·08					
24													1·04	0·81	1·23	1·00	0·78						
25													0·95	0·94	1·19	0·99							

as was imaged with sufficient intensity on our plates. The procedure was the following:

1. The two Hg 198 test plates, taken immediately before and after totality were carefully examined. Both are of excellent quality and prove that adjustment of the interferometer during totality must have been very good.
2. A number of microphotometer tracings were made in different directions through the whole fringe system of the mercury plates using the same adjustment and slit widths (0·06 × 0·016 mm) as were later used for the photometry of the corona fringes themselves. Using the intensity calibration of the plates the line profiles for the mercury fringes were then drawn for different parts of the fringe system. As to be expected from the good quality of the lines as shown in Fig. 7 these profiles could be determined easily and with great accuracy. Since we know from previous interferometric observations (**10**) that the line widths produced by our water-cooled mercury isotope lamp are of the order of 0·007 A, the observed line profiles as derived here, give the instrumental profile of the interference fringes including the effects of the microphotometer, with all the accuracy we need. All the line profiles for the mercury fringes normalised to unity were found to be very similar, as one might expect. Their form as finally adopted for the subsequent reductions, is shown in Fig. 10a. It could be approximated most satisfactorily by a Voigt function (**11, 12**) with $\beta_1/h = 0{\cdot}25$ which is very nearly a pure Gaussian curve. On the other hand from the well-known intensity formula of the Fabry–Perot interferometer (**13**) one can also calculate a theoretical line profile as a function of reflectivity. Fig. 10 shows such a profile, calculated for reflectivity = 0·80; it is nearly a pure dispersion curve and shows fairly extended wings at the lower intensities. These well-known wings are one of the reasons why we have chosen to use the interferometer with the rather large range of about 4A. The observed mercury fringe profiles and the theoretical profiles for a reflectivity slightly below 80 per cent fit each other very well over a large range, small differences becoming perceptible only at low intensities. This, of course, is to be expected since the lowest part of the wings in our mercury exposures approach the threshold of the photographic plates. A similar situation occurs for the corona lines as well; their fringes are superposed on a background formed from an image of the corona, so that photometrically the lowest part of their wings also becomes increasingly uncertain by merging into the corona.
3. The next step was to determine the centre of the fringe system on each eclipse plate, which could be done very accurately, since many fringes are observable. Microphotometric tracings were then carried out along straight lines radial to the fringe system and at intervals of 5°, or 2°·5 as indicated in Figs. 8 and 8(*a*). Each intersection of such a straight line with one of the concentric fringes gave a record of a line profile. With the help of the intensity calibration for each plate these records were then reduced to intensities in the usual manner. From the observed profiles true profiles and true half widths were then calculated by correcting for the instrumental profile we have already discussed. By half width we always mean the full width of the line at half peak intensity. For this purpose both profiles were represented by Voigt functions and the corrections were

calculated in the manner explained in (12). This could be done quite reliably; Voigt functions represent both the intensity profile and the observed profile very satisfactorily, as can be seen from some examples in Fig. 10.

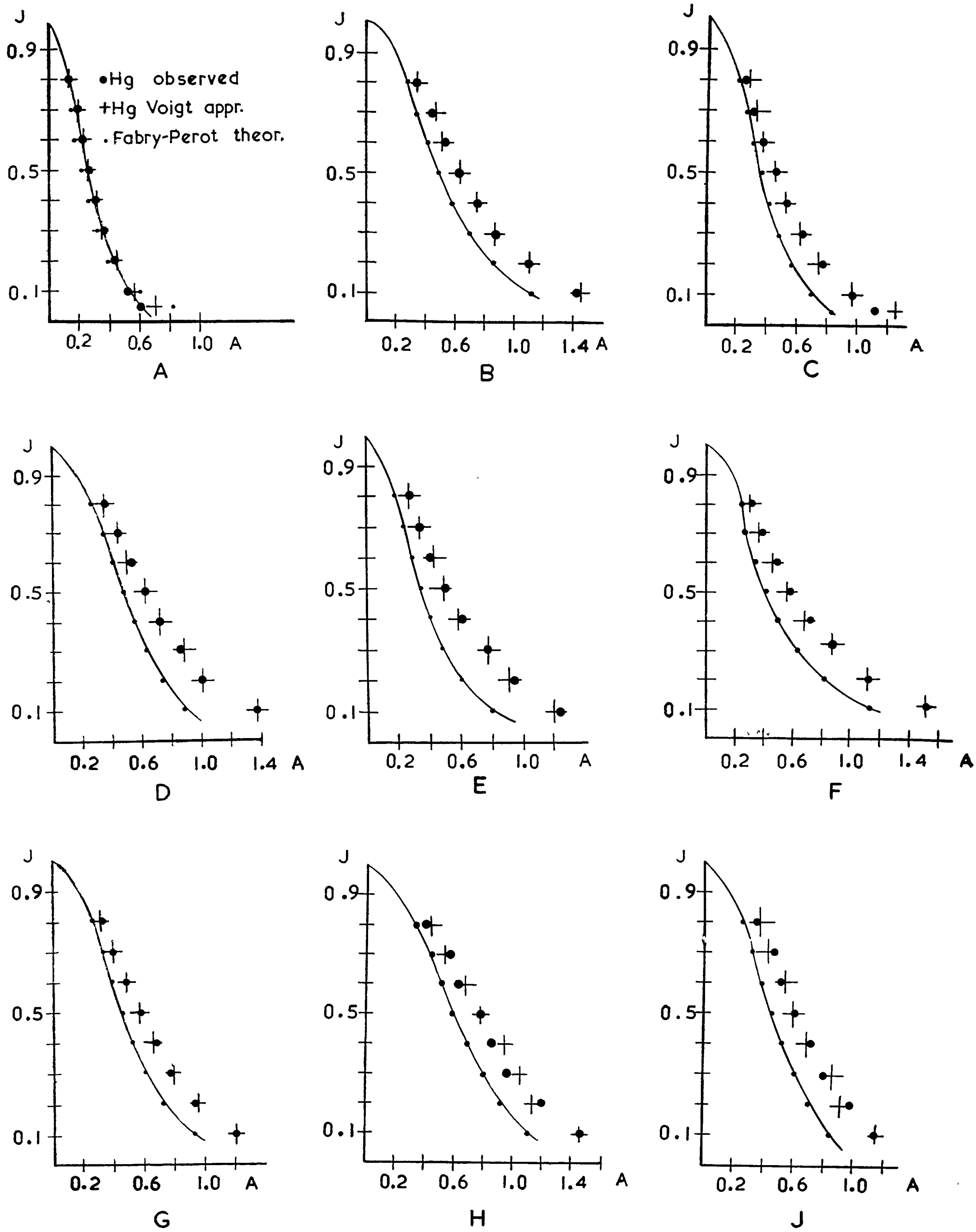

FIG. 10.—*Examples of different line profiles.*

A. *The large dots indicate the observed instrumental line profile for the mercury fringes (including the contribution of the microphotometer), the crosses its representation by a Voigt function and the small dots the profile to be expected from the theory of the Fabry-Perot interferometer (for instance* (13)) *accepting a reflectivity of* 80 *per cent.*

B–G. *Examples of true line profiles for the coronal emission* λ 5303 *(see Fig.* 6). *The large dots indicate the observed profiles (including the contribution of the microphotometer), the crosses their representation by a Voigt function and the small dots represent the true line profile expressed also by a Voigt function, after correction has been applied by using the instrumental profile of Fig.* 10A *according to* (12).

H–J. *Same as for* B–G *but for the corona line* λ 6374.

As this is the first time that it has been possible to measure profiles and half widths of corona lines over the whole corona in all position angles simultaneously and to a reasonable distance from the Sun, we believe the results to be valuable enough to be given in some detail in Tables I and II. The location with respect to the corona and to the solar coordinates of each point for which a measurement was obtained can easily be found by combining Tables I and II with Figs. 8 and 9.

The interference fringes could be traced with the naked eye easily to a distance from the Sun indicated by the dotted contour in Figs. 8 and 9. But since photometry gets increasingly unreliable when too low a density on the plate is approached records of the weakest parts of the line have not been used. Photometrically the fringes could be traced to their greatest distance from the Sun's centre near position angle 120°, for 5303 A to a maximum distance $1{\cdot}8\,r$ and for the red line 6374 A to $1{\cdot}7\,r$.

Discussion.—From the half width h given in Tables I and II temperatures T could be derived by the well known formula

$$T = \frac{2\,.\,10^{12}\,.\,h^2\,.\,\mu}{\lambda^2} \qquad (1)$$

where μ is the molecular weight (here 56 for iron) and λ the wave length. These temperatures are found from the half widths of the green line to lie between $1{\cdot}6 \times 10^6$ and about $3{\cdot}2 \times 10^6$ deg. K and in a few cases of obviously high excitation (as near position angles 155° or 250°) rise even to about 8×10^6 degrees. If one excludes some of these exceptionally high values the overall mean value from the present measurement is found to be about $3{\cdot}2 \times 10^6$ degrees. The red line gave temperatures between 2·0 and $3{\cdot}5 \times 10^6$ with some values up to about 6×10^6 degrees and an overall mean value near about $3{\cdot}5 \times 10^6$ degrees. We do not consider the small difference between the overall means for the green and for the red line as being significant. Some of the fringes arise from a corona background with quite steep intensity gradient. Also there is in several regions a good deal of structure in the corona, e.g. near position angle 230°. As is known in other line profile work, there is necessarily some additional uncertainty where the lines are superposed on a rapidly varying or otherwise uncertain continuous background. Although most fringes have been measured on two or more different recordings and in spite of the fact that the internal accuracy usually was very good, we would assume the general accuracy of half widths of these rather broad and diffused lines would be of the order of $\pm$ 10 per cent. Since the contrast for the green fringes is much higher than for the red the results for λ 5303 must be considered as much more reliable than those for λ 6374. But on the whole temperatures derived from both lines for the same region agree quite well.

It is of course of special interest to investigate if the line widths or relative intensities depend upon the distance from the centre of the Sun as this would throw some light on the general physics of the corona. For this purpose we have determined the peak intensity of the fringes relative to the coronal background J/J_0. But it must be kept in mind that these intensities are only relative. Further, the corona background in this case is a rather arbitrary one, produced in a somewhat complicated way by the transmission function of the interference filters and of the interferometer. For this reason it appears impracticable to reduce them to absolute intensities.

TABLE II

Half widths in angstroms of the red corona line λ 6374 A *as measured on plates* 3 *and* 4. *The uppermost row gives the readings of the radial lines originating in the centre of the fringes system as shown in the sketch of Fig.* 9. *The first column left indicates the number of the interference fringes as given in the same sketch.*

Fringe	−47·5	−45·0	−42·5	−40·0	−37·5	−35·0	+15·0	+17·5	+20·0	+22·5	+25·0	+27·5	+30·0	+32·5
5			1·39	1·15	1·35	1·15								
6		1·08	1·20	1·20	1·45	1·25								
7	1·07	1·08	1·14	1·25	1·16									
8	1·10	1·15	1·22	1·20	1·16									
9				1·05	1·25									
10		1·01	1·10	1·10	1·37									
11		0·96		1·30	1·44						1·17			
12										1·05	1·25	1·20		1·20
13										1·05	1·12		1·10	1·10
14									1·15	1·28	1·21		1·15	1·15
15							1·05			1·20			1·16	
16							1·10	1·15		1·17				
17							1·12	0·93		0·90				
18										1·05				

Unfortunately because of the curvature of the fringes for most position angles there are only a few points available along a radial line passing through the centre of the Sun. For several typical position angles where sufficient points were available we have nevertheless plotted line widths in Fig. 11 and relative intensities J/J_0 in Fig. 12 for λ 5303 against distances from the Sun's centre. The measurements show hardly any change in the line width with distance, indicating a rather uniform temperature through the region of the corona covered by our observations.

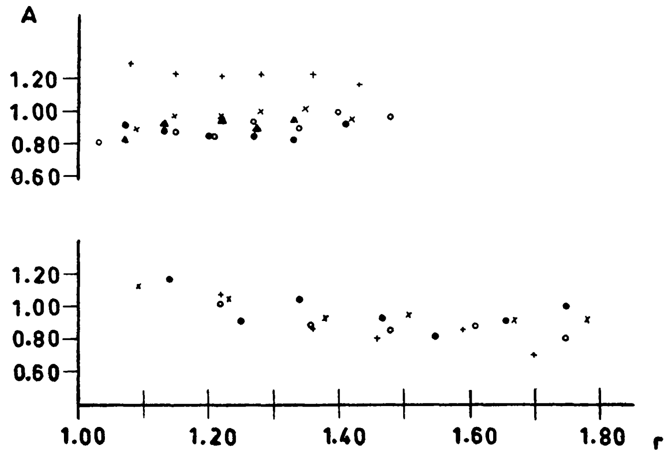

FIG. 11.—*True line half-widths of* λ 5303 *against distance r from the centre of the Sun.*

Upper sketch: half-widths along 5 *radii between* −10° *and* +10° *in our arbitrary scale of Fig.* 8, *i.e. around position angle* 230°.

Lower sketch: Half-widths along the fringes 3 *to* 6, *i.e. around position angle* 90° (*equator east*).

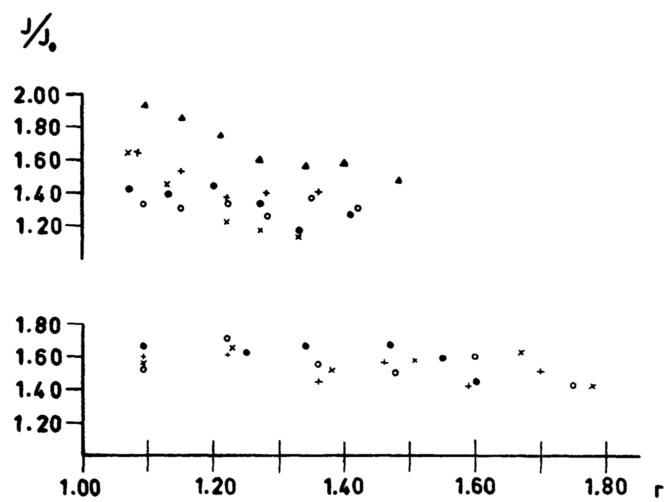

FIG. 12.—*Peak intensities* J/J_0 *of some fringes for* λ 5303, *relative to the coronal background* (*plate* 2), *against distance r from the Sun's centre.*

Upper sketch: Intensities along 5 *radii between* −10° *and* +10° *in our arbitrary scale of Fig.* 8, *i.e. around position angle* 230°.

Lower sketch: Intensities on fringes 3 *to* 6 *near position angle* 90° (*equator east*).

While it is known (14, 15) that for larger numbers of observations there is statistically a tendency for the equivalent width of the emission lines to decrease with increasing distance from the Sun our measurements show hardly any such effect, presumably because it is masked by the general scatter of the individual values.

As is well known, the intensities and also the widths of the corona lines can vary appreciably for different position angles around the Sun. In Fig. 13 we have plotted our half widths of λ5303, for three different distances from the Sun's centre, as a function of the position angle. From this figure it becomes clear that there is a good deal of variation of the widths with position angle. The high values between 80° and 180° are certainly connected with the active area around the large spot group mentioned above and similarly the maximum at position angle 240 is probably connected with another photospheric disturbance indicated by a large prominence visible there on the day of the eclipse. It can also be seen from Figs. 11 and 13 that there is hardly any alteration in the width of the line with increasing distance from the Sun.

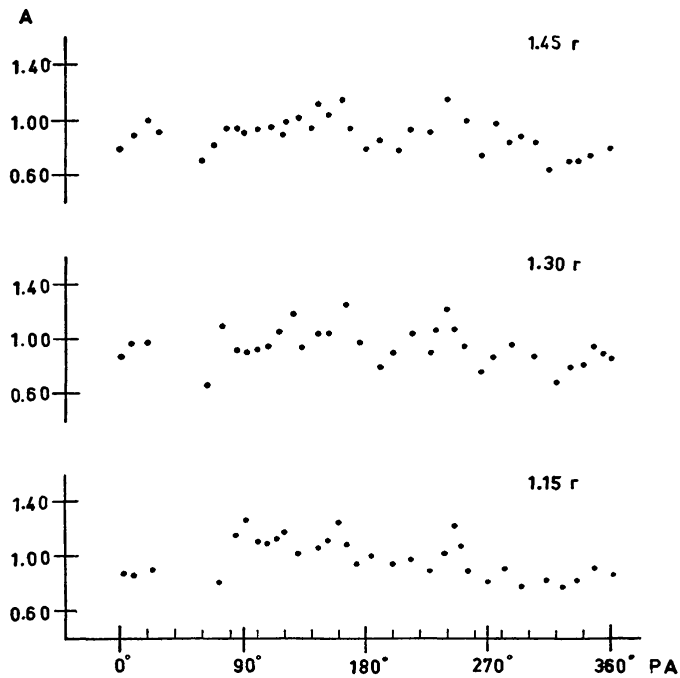

FIG. 13.—*True half-widths of* λ 5303 *plotted against position angle for different distances r from the Sun's centre.*

Further outlook.—The experience gained in this work shows that it is quite possible during a total solar eclipse to obtain a large number of line profiles for λ5303 over the area of the corona by using modern interferometric techniques. This holds also for the λ6374 line, if very narrow band filters can be used and if the line at the moment of the observations happens to be not too weak. In our case, admittedly during a period of unusually high solar activity, fringes of λ5303 could be traced up to 1·8 solar radii from the Sun's centre. This was achieved with an equivalent focal ratio of 5·6, a peak transmission of the interference filter of 40 per cent, a reflectivity of the interferometer of 70 to 80 per cent and with an exposure time of about 20 seconds only. It would be of great interest to obtain line profiles to still greater distances from the Sun's centre and with special equipment this could probably be done quite well. In principle it should be possible to work with special optical equipment at a focal ratio of about 1 : 2. Furthermore one could avoid or reduce the loss of light at several surfaces of the auxiliary filters and lenses and could make use of the full maximal transparency of 70 to 80 per cent of

TABLE III

Line half width in A.U. and in brackets corresponding temperatures using formula (1) in 10^6 deg K.

Number	Year	Author	λ 5303	λ 5694	λ 6374	Res. Power in A.U.	Instrument	Reference
1	1931 1936	Lyot	0·8–1·2 (2·5–5·7)		~1·0 ~(2·8)	0·6	Pic du Midi Coronagraph	20
2	1941 1947	Waldmeier	1·3 (6·8) 0·56–1·08 (1·2–4·5) 0·8–1·3 (2·6–6·8)			0·8	Arosa Coronagraph	21
3	1953	Lyot/Dollfus			0·91–0·97 (2·2–2·5)	0·23	Pic du Midi Coronagraph	22
4	1954	Pecker, Billings, Roberts	0·92–1·19 (3·2–5·7)	1·19–1·48 (3·5–5·5)	1·11–1·47 (3·3–6·0)	0·5	Climax Coronagraph, old	23
5	1955	Jarrett, v. Klüber	0·7–1·1 (2·0–4·8)			0·21	Interferometer during eclipse 1954	1
6	1956	Billings, Hirsch, Varsavsky	~0·6–1·0 ~(1·4–4·0)		~0·7–1·2 ~(1·4–4·0)	0·5	Climax Coronagraph, old	24
7	1957	Billings		1·32 (4·2)		0·15	Climax Coronagraph, new	25
8	1959	Billings	0·78 (2·4)		0·94 (2·4)	0·15	Climax Coronagraph, new	26
9	1960	Jarrett, v. Klüber	0·6–0·9 (1·6–3·2)		0·9–1·2 (2·0–3·5)	0·50	Interferometer during eclipse 1958	present publication

modern interference filters. Furthermore, special plates could give gain in speed by perhaps a factor of 2, and if one is prepared to devote the whole duration of totality, say 200 seconds, to one exposure a further factor of about 10 should be gained. If one takes further into account that the intensity gradient of the corona becomes less steep with increasing distance from the Sun but that the intensity gradient for the corona emission lines seems to be steeper than for the continuum (**16**) we estimate that it should be possible under favourable circumstances and depending upon the properties of the filter, to obtain fringes up to about 2·5 solar radii from the Sun's centre.

If one restricts oneself to a few fringes only photoelectric observations of high accuracy should well be possible with a Fabry–Perot device. Actually such arrangements have alrady been designed elsewhere (**5**).

As has been observed for some time, temperatures within the corona derived from spectrographic observations either with coronagraphs or during a total solar eclipse have a quite obvious tendency to be higher than temperatures derived by other methods (**17, 18, 19**). Table III gives a short summary of most of the spectroscopic temperature determinations available so far, using the simple relation (1) for converting line widths into temperatures. Since different authors have reduced and presented their results in somewhat different ways only average mean values could be given in the Table and to obtain accurate figures the original publications, as quoted, should be consulted. Some local and exceptionally high values are excluded from the Table.

Acknowledgments

The expedition to Atafu Islands was sponsored by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society. We are also indebted to Dr B. H. Billings of Baird Atomic Inc., Cambridge, Mass. for the production of the narrow band interference filter for λ 6374 and to the research laboratory of Kodak Ltd., Harrow, for providing several photographic test emulsions as well as the emulsions actually used for our observations. The preparations for our expedition and our work on Atafu Island received much support from Mr G. W. Markham of D.S.I.R., Wellington, N.Z., J. L. Thomsen, Director of the Carter Observatory, Wellington and from the Tokelau Islands Administration in Samoa. The Royal New Zealand Air Force stationed at Lauthala Bay, Suva, Fiji, and its Commanding Officer, then Group Captain A. S. Agar, provided us with transport between Fiji and Atafu by Sunderland flying boat. We should specially thank the Faipule and our many friends of Atafu village for their most friendly hospitality and for their constant helpfulness, given despite the inconvenience and trouble which our presence in their small community must have caused.

The Observatories,
Madingley Road,
Cambridge:
1960 *November*.

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