XI. *On the Total Solar Eclipse of May* 17, 1882.

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[Plate 13.]

Part I. (Drawn up by Dr. Schuster.)

I.—*Introductory.*

The present paper contains an account of the photographic results obtained during the last total solar eclipse. The total number of photographs taken was six : three of these represent the corona itself, while on the three others photographic records of the spectrum of the prominences and the corona were secured.

The expedition left England on the 19th of April and arrived at Suez on the evening of May 3, where they were received on behalf of the Khedive by Esmatt Effendi and by the Governor of Suez. The following day was taken up with the journey to Cairo. The members of the expedition were welcomed at the station by Stone Pasha to whose foresight and energy, as well as extensive knowledge of the country, all the members of the expedition were much indebted throughout the time of their sojourn in Egypt. It was chiefly owing to the preparations which General Stone had already made that the expedition was able to leave Cairo on the following evening, arriving at Siout early on the morning of May 6. Owing to the low state of the Nile it was impossible for the expedition to reach the site which had already been chosen for the observatory the same evening, but they arrived there the next morning. The French expedition, sent out by M. Bischoffsheim, was already on the spot, and on them had fallen the burden of choosing the site; for as all the expeditions were to be the guests of the Khedive, a separation would have been inconvenient to our host, and would have had no advantages as the weather was safe within the belt of totality. We cannot help expressing our admiration for the excellent way in which the site of the observatory had been selected ; for not only did the result prove that the greatest length of totality had been secured, but local circumstances were well attended to, and the observatory was well protected against the dust, which formed the greatest danger to the success of the expedition.

Colonel Mokhtar Bey had accompanied the English party to the observatory by

order of the KHEDIVE, and was in charge of the joint expeditions during their stay at Sohag. Great thanks are due to his unremitting zeal and energy; his aid in erecting the observatory and telescopes proved of great value, and his mechanical skill helped the expedition over great difficulties.

ESMATT Effendi, also a member of the KHEDIVE's household, gave most valuable assistance, and to him, as well as to many others equally able and anxious to help, our thanks are due.

II.—*Preparations for totality.*

The observatory was built on a level piece of ground close to the banks of the Nile. It was surrounded by a double wall of sugar-canes, affording an efficient protection against the dust which occasionally was carried in large quantities along the river. The ground in the immediate vicinity of the observatory was, in addition, constantly kept wet by watermen, so that the danger to the instruments from the dust and sand was reduced to a minimum.

Half of the ground covered by the English station was taken up by Mr. LOCKYER's large equatoreal telescope, while the other half was reserved for the photographic instruments. The present report only refers to the results obtained with the latter. A double layer of bricks afforded a sufficiently firm foundation for the stand on which the cameras were mounted. The stand and clockwork had originally been made for the transit of Venus expedition of 1874, and on that occasion supported one of the photoheliographs, but during this eclipse it had to carry three cameras. An achromatic lens of 4 inches clear aperture, having a focal length of 5 feet $3\frac{1}{4}$ inches, was reserved for the photographs of the corona itself. The image of the moon taken with this lens during the eclipse had a radius of ·29 of an inch. The second camera, carried on the same stand, was on a similar principle to that first used during the Siamese eclipse of 1875, and then called a prismatic camera. It was an ordinary camera with a prism placed in front of the lens. The prism used on this occasion was of white and dense flint glass, and instead of an angle of 8° it had a refracting angle of 60°, and each face had a surface of 3 inches square. The corrected lens used with the prism had a focal length of 20 inches for the yellow rays. As the plates exposed in this camera were sensitive in the red as well as in the blue, it was impossible to obtain the whole range of the photographic spectrum in focus on the plate, but in order to obtain the best results the back of the camera which carried the sensitive plate could be tilted so as to bring a larger range of the spectrum into focus at the same time. Nevertheless, an inspection of the plates obtained in this camera shows that the parts extending from the green into the infra-red are the only ones which are properly in focus, and it is to these parts that our attention was chiefly directed with this instrument.

To the third camera was attached a complete spectroscope. A lens of 2 inches aperture and 11 inches focal length served to form an image of the corona on the slit.

Both collimator and camera had a focal length of about 9 inches; the prism had a refracting angle of 62°, and an aperture of 2 by $1\frac{1}{2}$ inches. The sensitive plate in this camera could be tilted with the axis of the lens in the manner already explained, and the spectrum is in fair focus throughout the range of sensitiveness of the plate. In fixing the time of exposure for each plate and camera we had to consider the probable intensity of the light, but we had also to take into account the loss of time involved in changing the plates. At first it seemed, indeed, as if 12 seconds would be required to change each slide, but after a good deal of practice the time thus lost was finally reduced to 7 seconds, though even this was a considerable proportion out of the total of 70 seconds during which totality was to last. It was therefore decided that only one plate should be exposed in each of the spectroscopic cameras; but that three photographs of the corona should be attempted with the large lens. A trial was also to be made to obtain an impression of the first flash of light at the end of totality with the prismatic camera. A detailed account of the times of exposure of the different plates actually obtained will be given under the head of "Results."

It was arranged that Mr. WOODS, who was the assistant for the photographic work, should, during totality, cover and uncover the different lenses at the proper times, whilst I undertook to change the slides. Mr. J. Y. BUCHANAN was kind enough to call out the time at intervals of 10 seconds during the whole of totality. An arrangement of this kind is absolutely necessary where plates have to be changed, and where each second is of importance.

The telescope was mounted and adjusted in the usual way; the adjustment for latitude was not perfect, and a firmer foundation would have been desirable, but as a very slight motion was of little consequence in the spectroscopic cameras, while the longest exposure for the corona was only to last 22 seconds, even a rough adjustment would have been sufficient; and the results were in no way affected by this want of adjustment or by any irregularity in the motion of the clock. The final adjustment of the clock was made only a few minutes before the beginning of totality, and its behaviour during the critical time was better than could have been expected from its previous performance.

In order to fix the position of the corona on the plate from its photographs, a platinum wire was stretched across the camera close to the sensitive plate. Before and after totality the clock was stopped, and photographs of the solar cusps were taken at an interval of 2 minutes on the same plate. In this way the position of the platinum wire could be ascertained relative to the sun's path directly before and after totality. The accurate orientation of the solar corona in the sky is a very important matter, and one which has been too much neglected in some of the recent eclipses.

All the plates were gelatine plates, specially prepared by Captain ABNEY for the occasion. Those used in the prismatic camera, as before stated, were sensitive in the red as well as in the blue. From calculations made, it appears that all the plates used

had a sensitiveness for the blue end of the spectrum between fifty and sixty times greater than an ordinary wet plate. This is a matter of no slight importance when it is remembered that in comparison with photographic observations made during all other eclipses, except, perhaps, that of 1878, this exquisite sensitiveness has in effect turned seconds of time into minutes, thus enabling much more to be done in a short totality than could be accomplished in a much longer one when using the older process.

III.—*The totality.*

During the present short eclipse it was of special importance that the signal at the beginning of totality should be correctly given. If given too early, the plates would be spoiled by the presence of the last gleam of the sun, while if too late valuable time would be lost, and there would be the danger of exposing the plates beyond the end of totality, and thus again destroying their value. Experience during the last two eclipses had taught me that the corona was distinctly visible four or five seconds before totality, and I therefore determined on giving three signals: the first when the rapidly waning crescent showed that the critical moment was approaching; the second when I could see the corona against the dark limb of the moon; and finally when totality had set in. Mr. BUCHANAN undertook to measure the interval between the two last signals. In order to make sure that all the lenses were covered at the end of totality, it was decided to utilise only 65 seconds out of the 70 we hoped to have. Proceedings during totality were carried out strictly according to the programme laid down. My time and attention were so much occupied in looking after the slides and cameras that I had only a few seconds to spare for eye-observations, and no value can be attached to impressions gained in so short a time. I did not, indeed, notice any striking difference in the appearance in this and the two previous eclipses, except the presence of the prominences which I now saw for the first time, and which seemed to colour the greater part of the inner corona with a tint which appeared to me to be much more of a light orange than of a red colour. The photographs show, however, a very considerable difference between the outline and distribution of the corona in this and the three last eclipses. In the short time at my disposal I did not notice the comet, to which reference will be made, though it was very conspicuous to the majority of the party.

IV.—*Time observations.*

It was not part of the regular programme of the expedition to take any regular time observations, and the following results have therefore little value, except, perhaps, so far as the duration of totality is concerned.

The longitude and latitude of the place of observation was determined by M. TREPIED: the former by means of four lunar culminations, the latter by means of a

meridian passage of the sun observed with a small meridian circle. The results obtained were :

Latitude : 26° 33′ 21″
Longitude : 1° 57′ 40″ east of Paris, or
2° 07′ 01″ east of Greenwich.

M. TREPIED considers these values as provisional only.

I observed the first contact through the finder belonging to Mr. LOCKYER's equatoreal (aperture 3 inches). As I was, however, not accustomed to use that instrument, I forgot that there was a reflecting mirror in the eyepiece, and therefore looked for the contact at the wrong place. I first noticed the moon on the solar disc at

$7^h\ 20^m\ 14^s$ (L.M.T.).

The first contact was observed by M. TREPIED at

$7^h\ 20^m\ 09^s$ (L.M.T.).

The observation for the last contact was, of course, much better. I gave the signal at

$9^h\ 54^m\ 46^s$ (L.M.T.).

M. TREPIED gives for this contact

$9^h\ 54^m\ 57^s$ (L.M.T.).

At the beginning and end of totality the whole party was naturally so much occupied with their special work that nobody was available to mark down the time of the signals. Mr. BUCHANAN, however, by means of a stop-watch, measured the time intervening between my two signals, which meant respectively that I saw the corona and that totality had begun. That time was 4 seconds, and though with suitable instruments the corona might, perhaps, be seen sooner, I feel confident that with the naked eye my observation gives a fair estimate of the time of visibility of the corona before totality. The time agrees well with that determined by me during the eclipse of 1878 in Colorado, where I had measured it as 5 seconds. Mr. BUCHANAN also started a pendulum clock when I gave the signal for totality, and stopped it again at the end of totality. The time of duration of the eclipse was thus determined, and I have considerable confidence in the accuracy of the results to within one or two seconds. Owing to the brilliancy of the chromosphere and the inner parts of the corona it is by no means easy to fix the beginning of totality with absolute accuracy, especially if the observer has never previously witnessed an eclipse. The experience gained during previous eclipses gives me confidence, however, as to the duration on this occasion. The calculated time of totality was 72 seconds, the interval between my signals was 74 seconds, being probably too long, though not by more than one or two seconds. As the question of duration of totality has some interest, and as different observers differed considerably in their estimate, it may be well to give the opinion of some

of the other observers within hearing of my signals as to their accuracy. Mr. BAILLIE, who had joined the expedition, and to whose excellent sketch of the corona we shall have occasion to refer, wrote directly after the eclipse as follows: "I was seated at my table just before totality, and, being unable to look upwards, kept my eye on the watch in my hand, waiting for SCHUSTER'S signal. Immediately upon hearing his voice I looked up at the sun. Totality was complete . . . . ."

Mr. LAWRANCE, Mr. LOCKYER'S assistant, who was looking through Mr. LOCKYER'S finder, writes as follows: "The moment Dr. SCHUSTER gave his signal of commencement of totality, I still saw BAILEY'S beads and a thin crescent of the sun still uncovered. I think, however, that totality commenced within a second or two. . . . . ."

It appears from Mr. LAWRANCE'S statement that my signal could not have been given too late, while the photographs give conclusive proof that I could not have been too early by any appreciable amount. For as I called out I drew the slide of the spectroscopic camera, and Mr. WOODS, on hearing me give the signal, removed the cap from the prismatic camera. The plate in this camera would have been spoiled had any sunlight been allowed to fall on it. I may have been a little late at the end of totality, as Mr. BAILLIE remarks, but when a signal is given by calling out, a good fraction of a second must necessarily intervene between the time that a phenomenon is seen and the time that the signal is actually given and realised by another observer. On the whole, it may be said that the calculated time of totality was as nearly realised as possible.

PART II.—(Drawn up by Captain ABNEY and Dr. SCHUSTER.)

V.—*The photographs of the corona.*

Across all the photographs of the corona is a transparent line, which is the shadow of a platinum wire stretched immediately in front of the slide placed there to enable us to fix, with accuracy, the position of the corona. Before and after totality the clockwork of the telescope was stopped, and the solar cusps were photographed at fixed intervals. The position of the platinum wire could thus be referred to the line of the sun's motion. On a paper print of these photographs the position of the centres of the solar images was determined as accurately as possible, and it was found that a line joining these centres made an angle of about 45 minutes with the image of the platinum wire. Thanks to the courtesy of Mr. WHIPPLE, we had an opportunity of measuring our photographs with Mr. DE LA RUE'S instrument, which is now deposited at Kew. The photographs taken previous to totality showed a sufficient part of the sun uncovered to enable us to draw a tangent, and thus to determine with great accuracy the direction of the sun's motion. This method gave an angle of 49 minutes between the wire and the circle of declination, a result practically identical with that previously obtained. The angle between the lines joining the cusps and the wire are slightly different, but this is due to the moon's motion over the solar disc. Owing to

the rapid change in the lunar parallax, the calculation of the angles which the line of cusps should make with the circle of declination is rather tedious, and would not repay the trouble, and without it the orientation of the photographs possesses all the necessary accuracy. In adopting 45 minutes as the angle between the shadow of the wire and the declination circle, we shall certainly not make an error greater than half a degree, and most probably not more than a quarter of a degree. The image of the wire lies in the quadrant between the east and the south.

The backs of the plates in all the cameras were coated with asphaltum, in order to prevent photographic irradiation as far as possible, but the prominences and inner parts of the corona sent out such a strong light that in spite of this precaution the photographic effect encroaches on the disc of the moon. One of the prominences appears even reversed on one of the plates which was exposed for about 22 seconds. The images of the prominences themselves appear, however, perfectly defined. The different times of exposure could not be measured exactly for want of sufficient attendance. A very fair idea of the exposures can, however, be obtained from Dr. SCHUSTER's notes made immediately after the eclipse. He wrote :—" After drawing the slide of the spectroscopic camera at the beginning of totality, I immediately did the same for the large camera, and called on Mr. WOODS to remove the screen, which he held up in front. This he did, noticing that Mr. BUCHANAN called out '60' at the time. At the time signal '50' the screen was to be replaced, thus giving an exposure of 10 seconds. Mr. WOODS was, however, a little late in answering to the signal, and I believe that 11 seconds would not be a bad estimate for the exposure of this plate. There was no record made of the time at which the second plate was actually exposed, but experience had shown that it took about 7 seconds to change a plate in this camera, and as the exposure ended at the time signal previously fixed upon, I think we may take the exposure of this plate to have been 23 seconds within one second of error. The third plate was to be exposed for 3 seconds; these were estimated by Mr. WOODS, and as he has had much practice in exposing photographs, this time was probably correct within narrow limits."

The body of the moon appears on the photographs bordered by a well-defined black line, out of which the prominences are seen to rise. It must be borne in mind that the radius of the moon during the last eclipse was only slightly larger than that of the sun, so that even in the middle of the eclipse the brightest parts of the corona, and perhaps even the upper layers of the chromosphere, were visible. The inner parts of the corona, and especially the prominences, are over-exposed in all the photographs, but in that one which had three seconds' exposure all the details up to the body of the moon are well shown.

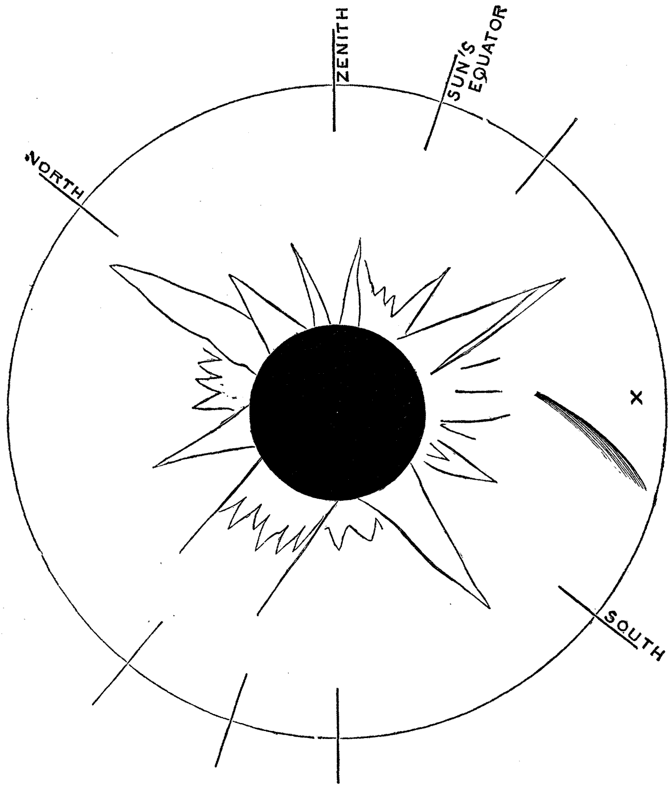
As regards the corona, we are especially struck with the irregularity of its shape. A close connexion between the outline of the corona and the state of the sun's surface is now placed beyond doubt. The corona, as seen in Colorada during the summer of

1878, may be taken as a type of what is seen at a time of few sun spots. We notice a great extension in two opposite directions. Unfortunately it has never been properly decided whether this direction agrees with the ecliptic or with the direction of the sun's equator, or does not accurately agree with either. There is, however, a probability that the direction of greatest extension varies somewhat in different eclipses. This equatoreal extension (for we may so call it, without implying any hypothesis as to its cause) has, as a rule, a form which the Siamese in 1875 not inaptly likened to a fishtail, and for this reason the longest streamers of the corona are found not near the solar equator, but symmetrically at some distance from it. Another remarkable feature of the corona of the time of sun-spot minimum are the generally short and curved polar rifts. They are found on all good drawings and photographs of the corona, when the eclipse took place at periods of small solar activity, and have often been compared to the rays of our aurora borealis. In our photographs we look in vain for the equatoreal extension and for the polar rifts. Streamers are seen to stretch away in all directions from the moon's edge, but there is no regularity whatever. The extent to which the corona can be traced in the photographs depends, of course, on the time of exposure and the sensitiveness of the plates; and considering the great progress which has lately been made in the science of photography, it is not, perhaps, astonishing that our photographs show a greater extent of corona than any of those previously obtained. One of the streamers reaches, indeed, to a distance of 44 minutes of arc from the sun's limb, that is about 1·4 solar diameter. The details shown on the different photographs are very interesting, but they cannot be described, and are only shown on a good drawing. Two points, however, deserve a special noticc. One is the remarkable curvature of some of the coronal rays. It has long been known that these are not straight, but their general curvature shows more regularity than it did on the last occasion. The rays seem in many cases to start almost tangentially from the sun's limb; they are as a rule wider near the sun's limb, and contract as their distance from the sun increases, while others are spread out in fan-like shape. The second point to which we wish to draw attention is the transparency of the streamers: in two instances at least we can trace structural details through the luminous streamers. The distinction which has been drawn between the outer and the inner corona appears to us to be justified, the inner corona being decidedly more compact and luminous. The corona, as seen during this eclipse, does not seem to bring us any nearer to any plausible and scientific theory as to its causes. Two theories especially have been brought forward and discussed, and both of them seem to become less and less likely. The corona of last May is conclusive against any theory of meteor streams as far, at any rate, as its streamers are concerned, and the rival theory of a much disturbed solar atmosphere seems open to equally conclusive objections. It is only by means of continued observations that we may hope to solve the coronal mystery; and these we are likely to have before long, thanks to Dr. HUGGINS' important discovery.

Mr. BAILLIE'S *drawing of the corona.*

Mr. BAILLIE accompanied the expedition and undertook to make a drawing of the corona during totality. Though little attention has been paid of late to pencil sketches made during eclipses, we yet venture to lay the present one before the Society, as it shows how much can really be done in so short a time by a skilled

Fig. 1.



Mr. BAILLIE'S drawing of the corona.

draughtsman, who aims less at an artistic production than at the correct representation of what he sees. Mr. BAILLIE'S drawing is of value as showing the relative extent of the corona as seen with the naked eye and as shown on the photographic plates. We can trace on Mr. BAILLIE'S drawing all the more important streamers, and they agree in length as well as can be expected with our photographs, thus showing that there was no perceptible difference in the extent of the visible and the photographic corona. This is confirmed by the remarks made by Professor TACCHINI on the extent of the visible corona.

The comet.

Some of the observers noticed during totality a luminous streak of light presenting exactly the appearance of a comet, which our photographs prove beyond doubt

to be the case. The nucleus is exceedingly well and sharply defined, the tail is somewhat curved; it did not point towards the sun's centre, but in a direction nearly tangential to the limb. The extent of the tail was roughly two-thirds of a solar diameter.

Our photographs allow us to fix the position of the comet. It appears that the nucleus was at a distance of 45′ 50″ from the sun's centre during the middle of the eclipse, and that the line joining the comet to the sun's centre made an angle of 16′ 27″ with the circle of declination towards the west. Professor TACCHINI (C.R., xcv., p. 896, 1882; Memorie della Società degli Spettroscopisti Italiani, vol. xi., 1882) gives slightly different values. According to him the comet's position was: Dec. 18° 30′ 17″ N., R.A. $3^h\ 35^m\ 16^s$. This would give a distance of 52′ 26″ from the sun's centre, and a position angle of 68′ 09″, 21′ 51″. According to our measurements the position of the comet at $18^h\ 24^m\ 36^s$ G.M.T. was—

Dec. 18° 34′ 59″ N.
R.A. $3^h\ 34^m\ 43^s$.

An examination of our different photographs shows a slight but progressive change in the comet's position. This is in part accounted for by the moon's motion over the solar disc during the eclipse, for the position of the comet had of course to be referred to the dark lunar disc. The change in the distance of the comet from the moon's centre is however slightly larger than can be accounted for by the motion of the moon, and is probably in part due to the proper motion of the comet, which in that case must have moved away from the sun during the eclipse. The motion, if it exists, must however have been very small, and as the matter presents very little importance we have not investigated it further, especially as the comet in all probability will not be heard of any more. The different eclipse parties present at Sohag decided at a joint meeting after the eclipse to give the name of TEWFIK to the comet, in recognition of the KHEDIVE's generous hospitality.

Results of the prismatic camera.

This instrument consisted, as has already been explained, of a camera the lens of which had an aperture of 3 inches, and a focal length of 20 inches in the yellow. The prism, which was placed directly in front of the lens, had a refracting angle of 60°. The line of dispersion projected on the celestial sphere ran nearly north and south, the less refrangible side being towards the south. Only one plate was exposed, and that for 65 seconds. The first impression gained by an inspection of the photograph thus obtained would lead one to believe that sufficient care was not taken in focussing the camera. As before stated, however, it was quite impossible to have the whole of the spectrum in focus at the same time, and as special attention was directed to the less refrangible part in this instrument, it is obvious that

the violet and ultra-violet in which the strongest impressions occur could not be in proper focus. The solar line F, and everything which is below, are well defined.

It is clear that with this instrument we obtain a series of rings corresponding to the different rays sent out by the prominences. We are at once struck by the intensity of two of these rings lying close together near the boundary between the violet and ultra-violet. A comparison with the photographs obtained in the spectroscopic camera leaves no doubt that these rings are due to calcium, and are in fact coincident with the solar lines H and K. They may serve therefore as a starting-point for the determination of other wave-lengths. Measurements of the distances between the different prominence rings, and comparison with a photograph of the solar spectrum, taken with the same prism, renders it easy to identify the hydrogen lines, $H\alpha$ (C), $H\beta$ (F), $H\gamma$ (near G), and $H\delta$ (h), and these may again stand as reference lines for the other images.

Three prominences especially are noticeable by their great intensity. We shall designate them by the numbers I., II., and III. I. and II. were close to the east point of the sun, III. was a little more towards the north. Next in intensity came a prominence (V.) near the west point of the sun. I., II., and III. show all the hydrogen lines in the visible part of the spectrum, V. shows all but C. A series of prominences towards the southern edge of the sun show F strong and $H\gamma$ very distinctly; a prominence on the northern edge (IV.) shows $H\gamma$ faintly, and only a trace of F. The prominence III. shows a number of lines in the ultra-violet. Want of focus renders them difficult to measure on this plate, but as the slit of the spectroscope camera happened fortunately to cut the same prominence, the want is fully supplied. It is found that these lines are in part due to the same hydrogen lines which Dr. HUGGINS has photographed in several star-spectra. The prominences I. and II. show these lines also, but not so markedly. It ought to be mentioned that the prominence which we have called III. is by far the strongest in the direct photographs of the corona, and is that which we have already stated to be centrally reversed in one of the plates. The results of the prismatic camera show that the intensity of III. as compared with I. and II. was most marked in the most refrangible part of the spectrum. The same relation of relative intensity holds in the line coincident with C, but is reversed with F, I. and II. being here the strongest. This points to the conclusion that I. and II. were cooler than III., for we know that on cooling $H\beta$ (F) becomes the strongest hydrogen line, while other lines gain in relative intensity on heating. The prominence IV. gives an anomalous result, showing $H\beta$ (F) and $H\gamma$ (near G), but the latter with greater intensity. It was perhaps a hot, but thin and therefore black prominence.

We may turn now to the lines due to other substances. The wave-lengths were determined by measuring the distance of the image of any prominence to the corresponding image of one of the hydrogen lines. A first approximate result is obtained by employing the ordinary interpolation formula which is based on the

supposition that differences in the refractive indices of two lines are proportional to the differences of the inverse squares of the wave-length. Owing to different circumstances, and amongst others to the fact that the distances measured are not quite proportional to differences of the refractive indices, we obtain in this way approximate results only; but by taking a photograph of the solar spectrum with the same prism in the same position, we can easily determine the correction which has to be applied in order to arrive at the most satisfactory result. For instance, the distance of one image was measured from the corresponding image of C and F, both with a micrometer and directly with a finely divided scale. The interpolation formula gave 5889 by the first method of measurement and 5893 by the second, the mean being 5891. This brings us near D, and if a similar calculation is made in the reference spectrum, interpolating D between C and F, a wave-length 5907 is obtained. The true wave-length being 5882, we see that we have to apply a correction of — 15 in this part of the spectrum. We thus find finally 5876 for the wave-length of the unknown line, agreeing almost exactly with the wave-length (5875) of D_3. The prominences I. and II. gave results which are practically identical.

Similarly we find for a very faint image of the prominence II. a wave-length 5315, which is evidently the well-known corona line (K 1474), which has a wave-length 5316. The image, however, is exceedingly faint. The prominence I. shows also two lines in the infra-red which are difficult to identify. One of them is very likely $\lambda=8240$; the other has a wave-length which is certainly above λ 10,000, but by how much we cannot tell. Two lines, $\lambda=4471$ and $\lambda=4394$, are seen in the blue; 4471 is the line f which is always present in prominences, but what 4394 is we do not know. YOUNG, in his catalogue of chromospheric lines, notes that he saw 4394·6 fifteen times out of 100 observations.

Besides these well-defined prominences the photograph shows two rings, which are evidently due to the lower parts of the corona, and therefore correspond to true coronal light. The wave-length of one of these rings was measured to be 5315. It is due to the green corona line (K 1474); the second is coincident with D_3. The ring in the green is particularly strong in the south-western quadrant, and hardly visible at some of the other points of the sun's limb. The yellow ring is much fainter on the whole, but more uniform all round the sun. In addition to the rings and prominences we observe on the photograph at places a certain striped appearance, which is due to continuous spectrum belonging to the prominences or to intense parts of the solar corona round the sun's limb.

A curious and rather puzzling point remains to be noticed. The prominence V. in the F ring seems to be duplicated. Two distinct impressions appear, one above the other. This cannot be due to a shift in the camera, for the other prominences, some of which are more intense, do not show the duplication. The only possible explanation which has occurred to us is, that one of the images is due to the comet, and that it is only by accident that it appears so close to an image of the prominence.

An instantaneous photograph taken in the prismatic camera about 5 seconds after the end of totality presents one or two peculiarities which are worth noticing.

In the first place, the prominences still appear, except at the places at which their light is overpowered by that of the sun. The continuous spectrum of the sun is broken up into three or four parallel bands—an appearance no doubt due to the irregularities on the moon's surface. We have here BAILEY's beads drawn out into bands. At the solar cusps traces of rings are seen which are due to the lower parts of the chromosphere extending beyond the cusps. The two brightest of these rings correspond apparently to the solar lines F and G.

We give in conclusion a table showing the lines which are seen in different prominences. The numbers indicate the order of intensity for the same line in different prominences. Thus, for instance, it is seen that in I., C is fainter than in the prominence II.; while the order is reversed for the line F.

RELATIVE intensities of lines in the prominences.

Prominence =	I.	II.	III.	IV.	V.	VI.	
Below λ 10,000	Faint						
8240 (?) ..	Distinct	..	..	..	..	..	Probably a hydrogen line.
6562 (C) ..	3	2	1				
5875 (D_3) ..	3	2	1				
5315 (1474*) ..	Very faint						
4861 (F) ..	2	1	3	Very weak	5	4	
4471 (f) ..	3	2	1				
4394	..	..	1				
4340 (Hγ) ..	3	2	1	Weak, but stronger than F	4	5	
4101 (h) ..	3	2	1	..	4		
3968 (H) ..	3	2	1				
3933 (K) ..	3	2	1	..	5	4	
	Many lines in ultra-violet	..	..	..	..	..	

Results of the spectroscopic camera.

The slit of the spectroscope had a direction approximately north and south, but it did not accurately pass through the centre of the solar disc, and we have no data to fix accurately on the regions of the corona through which it passed, although its approximate intersection of the image can be guessed, as will be seen further on.

The photograph shows, in the first place, a strong continuous spectrum. This is neither equally strong nor equally extended on both sides of the moon's disc. On the northern side the spectrum can be traced to a wave-length of about 3490 towards the ultra-violet; but on the southern side it reaches further and almost as far as the solar

* KIRCHHOFF's scale.

spectrum, which had before and after the eclipse been photographed on the same plate as a reference. Towards the less refrangible side, the solar line E forms the approximate boundary, though on the southern side the continuous spectrum reaches a little further. The continuous spectrum extends from the moon's limb on both sides with great intensity up to a certain height, then there is a sudden falling off in intensity, decreasing steadily on the southern side from this point up to a height at which it cannot be traced any more; but on the southern side there seems to be a slight increase again in intensity as we go towards greater distances from the sun's limb; then there is again a sharp boundary at which a sudden decrease in intensity is noticed. From that point the continuous spectrum gradually vanishes.

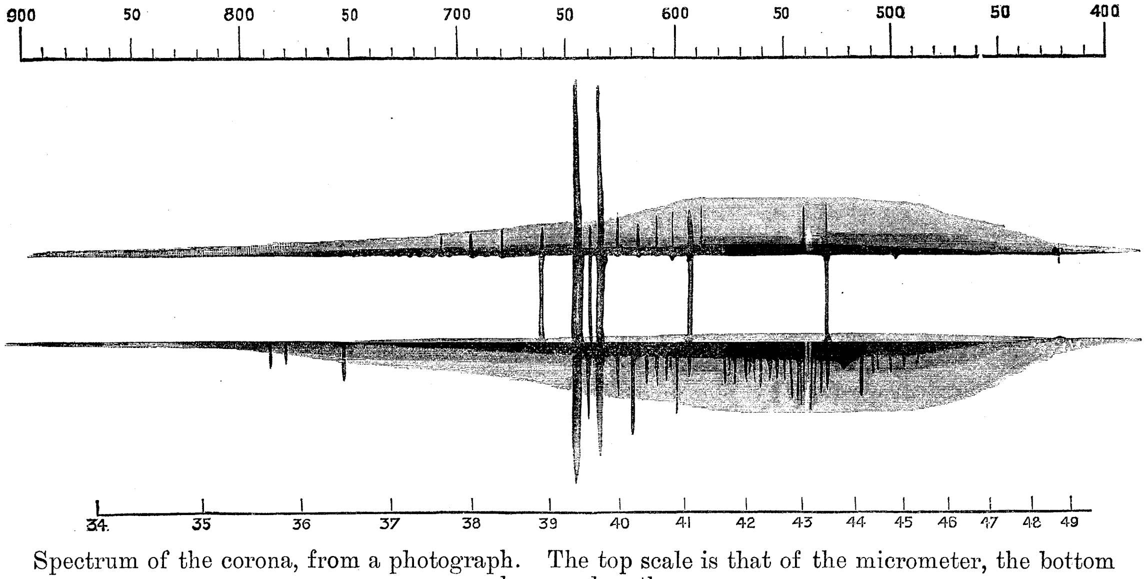
The following numbers will give an idea of the extent to which the continuous spectrum reaches at different points on the southern side:

	Height of continuous spectrum in terms of a solar radius.		
Near F	. .	. .	·2
For λ=4489	·37	·53	1·23
Near G	·29	·60	1·47

The first column refers to the first sharp decrease in brightness; the second column to the second falling off in intensity; and the last column gives the limit to which the continuous spectrum can be traced. On the northern side the spectrum does not reach as high, thus near G it cannot be traced further than ·9 of a solar radius.

In the lower regions the spectrum appears perfectly continuous, but in the upper regions the solar line G appears reversed.

Fig. 2.



Spectrum of the corona, from a photograph. The top scale is that of the micrometer, the bottom scale wave-lengths.

The prominence spectrum.

Close to the solar limb, on both sides of the photograph, bright lines are seen which evidently belong to the prominences. On the northern limb these are most numerous and brightest. It seems certain, in fact, from a comparison with the photograph obtained in the prismatic camera, that the slit must have crossed the prominence 3, which, as has already been mentioned, was rich in ultra-violet light. On the same plate above and below, the solar spectrum had been photographed after the eclipse, and we had, therefore, no difficulty in identifying the principal lines. We see in the first place the calcium lines H and K. These two lines are, indeed, the great feature of the photograph. Being of great intensity they do not confine themselves to the prominence regions, but appear as bright lines through the corona and over the body of the moon. The light which is due to them must, in fact, have been so strong that the scattered light was sufficiently intense in our atmosphere to give the appearance and to be conspicuous everywhere in the neighbourhood of the moon, or else that the lens forming the image on the slit was so illuminated as to give this result. It can, indeed, be traced to a distance of quite three solar radii. In addition to these lines the hydrogen lines must, of course, be expected to be present; and, indeed, their identification presents no difficulties. The full series is present, including those photographed by Dr. HUGGINS in the ultra-violet spectra of stars. Once these lines had been traced, and their characteristic distribution identified, the work of mapping was rendered comparatively easy, as they could be used as reference lines, and thus the wave-lengths of the remaining lines determined. The result is given in the following Table. The first column gives the intensity of the lines as they appear in the prominence, 1 denoting the greatest and 6 the smallest intensity. The second column gives the wave-lengths as determined by means of the hydrogen lines. In the third column the origin of the lines is identified as far as possible. In the last column we have added the numbers given by Dr. HUGGINS for the lines seen in α Aquilæ; and it will be noticed how, in the ultra-violet especially, many of the lines which we have not been able to identify are common to our photograph and to the spectrum of α Aquilæ. This correspondence was so striking that we felt justified in bringing it forward. The relative intensities of the less refrangible lines cannot be given, as their own light is so much overpowered by the continuous spectrum that even a strong line can only be traced with difficulty.

Intensity.	Wave-length of prominence lines.	Comparison.	Dr. HUGGINS' spectrum of α Aquilæ
	4861	Hβ (E)	
	4473	4471 (f)	
	4340	Hγ	
			4230
			4172·5
			4131
			4120
	4076	4077 (Ca)	4072
	4049		
6	4025	. .	4022·5
	. .	. .	4000
	. .	. .	3997
6	3989		
1	3968	H	3967·9
4	3955	Ca	
1	3933	K	3932·8
	. .	. .	3915
2	3888	Hϰ	3862·5
6	3859 ± 6	. .	3854
3	3834	Hβ	3834
6	3816	. .	3816
			3807·5
4	3795	Hγ	3795
4	3768	Hδ	3767·5
3	3757	. .	3757·5
5	3746	Hε	3745·5
6	3730	Hζ	3730
6	3718	Hη	3717·5
6	3708	Hο	3707·5
5	3699	Hι	3698
6	3693	. .	3690
4	3680	. .	3677·5
6	3674		
6	3667		
6	3658 }	. .	3656
	3653 }	. .	3654
	3635	Ca (?)	3637·5

The line 3859 was entered as a band, terminating sharply at 3865 and 3853; similarly the two lines 3658, 3653 appear on our photograph as joined together. The line 3955, which appears between H and K, is very likely the representative of a calcium triplet, photographed by Professors LIVEING and DEWAR, and having, according to them, a wave-length of 3972·3, 3956·0, 3947·9. The most refrangible of the lines appearing in the prominence seems also likely to be due to calcium; for there is a calcium triplet marked as very strong, diffuse at 3644, 3631, 3623·5. We are obliged to Professors LIVEING and DEWAR for their information respecting these lines.

The line spectrum of the corona.

It has been mentioned that close to the sun's limb a strong continuous spectrum hides any lines which might be present in these regions. We have reason to believe

that there are indeed a number of lines in this region. Over the fainter portions of this continuous region lines can be distinctly traced. A few of them are sufficiently strong to be seen with the naked eye, but most of them require the use of a magnifying glass. The lines are no doubt very faint, but we have succeeded in showing them even to some whose eyes were not specially trained to examine faint photographic impressions, and there cannot be the slightest doubt as to the real existence of these lines. It is more difficult to say to what extent our measurements can be considered as accurate. They have been taken with a measuring microscope, but it was only when the light was good, and when the eyes were in their best condition, that satisfactory results were obtained. We give the wave-lengths as being as exact as we can hope for with the small dispersion employed. Four or five of the lines can be easily seen under ordinary circumstances. These are one line less refrangible than G, of very peculiar appearance. At its base it is a broad band, then contracting quickly it fades away into a sharp point; close to it is a sharper and longer line. A little less refrangible than H is an easily recognised line reaching to a good height away from the sun (more than a radius). Two or three lines in the ultra-violet are also easily recognised.

The following list of lines does not pretend to be complete. There are some lines, especially in the ultra-violet, which have not been included, but they are so faint that their measurement would have been very difficult. As it is, even some of the lines given in the table can only be seen under specially favourable circumstances. On the northern side only a few of the principal lines can be traced. We have sometimes thought that a different set of lines appeared there, but the measurement and interpretation of the northern line present some difficulties. In the first place the spectrum of the corona is much fainter, and secondly the spectrum of the prominences is much stronger. Most of the prominence lines, like H and K, stretch across the moon's disc, and therefore also across the corona. Amongst the number of lines we have measured it would not be difficult to point to some coincidences with the lines of spectra of known bodies, but other equally strong lines of the same bodies seem to be wanting, and we do not feel ourselves justified in suggesting any more than accidental coincidence.

Another feature of the photograph is the fact that the FRAUNHOFER (dark) lines about G are clearly distinguishable in the coronal spectrum. About this region of the spectrum the photographic action attains its maximum, and it is in this locality that we should naturally first look for evidence of reflected solar light. That a small fraction of the coronal light is reflected light of this nature is now without doubt established, the photographic evidences being complete. We may remark that the lines are of greatest intensity a little distance from the moon's track, though at the best they are extremely faint.

LINES seen in the corona.

4526	4212
4501 double (?)	4195
4473	4179
4442	4173 short
4414	4168
4401 short	4101 h
4395	4085
4370 short and winged	4067
4340 Hγ	4057
4289	4044
4267	4015 comparatively strong
4252	3992
4241	3948
4224	

Conclusion.

In conclusion we may briefly review the principal results we have obtained.

The direct photographs of the corona are chiefly of interest in connexion with previous and future eclipses, and we believe that those obtained will be found of value, as they have been taken during a time of sunspot maximum; as they extend further than any photographs previously obtained, and as the position of the corona has been fixed by their aid to within a fraction of a degree.

The photograph taken with the prismatic camera is of importance when we come to compare spectra of different prominences, which are found to give lines with different relative intensities, caused no doubt by differences of temperature. Two prominence lines in the ultra-red have been discovered. It is also proved that the green line of the corona is a line specially belonging to the corona, forming a distinct ring round a large part of the solar disc, whilst it is only very faintly present in the prominences. A faint ring corresponding to D_3 is also seen.

The photograph of the spectrum of the corona and prominences has yielded an abundant harvest. Twenty-nine lines of one prominence have been photographed, and the great importance which the metal calcium plays in the solar eruptions has been brought to light. Other lines, well known hitherto as chromospheric lines, but not traced in the prominences, are now shown to belong to them also, and a number of unknown lines, especially in the ultra-violet, has been added to the list.

As regards the corona, we may perhaps point out that hitherto the position of only one true corona line had been fixed, though two other lines had been suspected. The corona, during the late eclipse, seems to have been especially rich in lines. THOLLON observed some in the violet without being able to fix their position, and TACCHINI could determine the position of four true corona lines in the red; from the photograph we

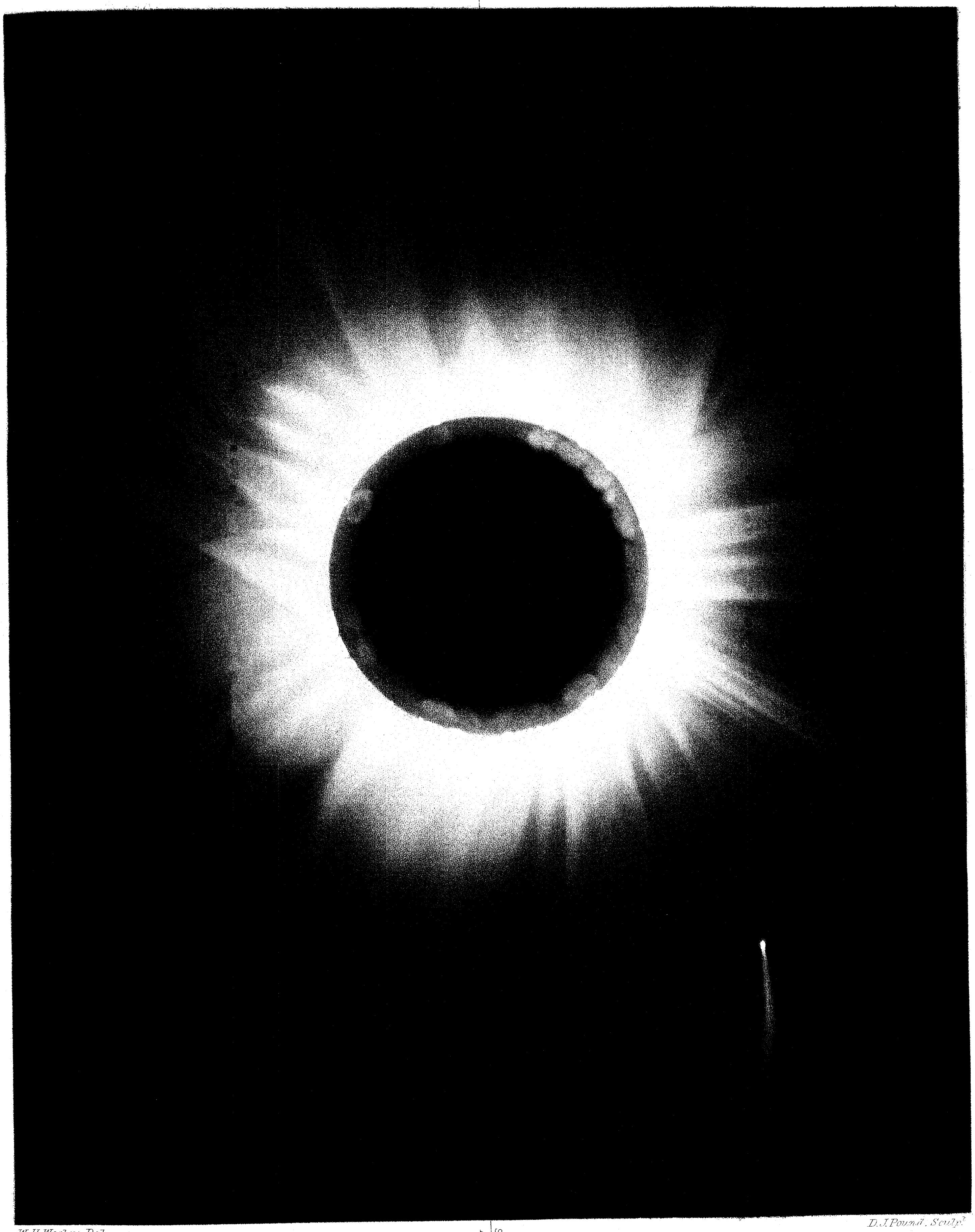
have been able to measure about thirty additional lines, thus increasing the number considerably.

The fact that part of the outer corona shines by reflected light has been once more proved by the presence of the dark FRAUNHOFER lines near G, and if any doubt previously existed respecting the presence of dark lines in the corona spectrum, that doubt is now completely removed.

The results have amply proved the value of the photographic method employed, and it has been shown how an eclipse of only 70 seconds' duration can be made to yield important information.

We cannot conclude this paper without a reference to the energy and zeal displayed by Mr. C. R. WOODS, the assistant told off for the photographic operations. His careful development of all the plates has largely contributed to the success of this branch of the expedition. A six months' practice in South Kensington with the particular plates employed for the observations made him thoroughly master of the manipulations required, and to his mechanical skill in the preparation of some of the pieces of apparatus we are indebted. Mr. LAWRANCE, Mr. LOCKYER's assistant, also gave valuable aid in the photographic work at the observing station.

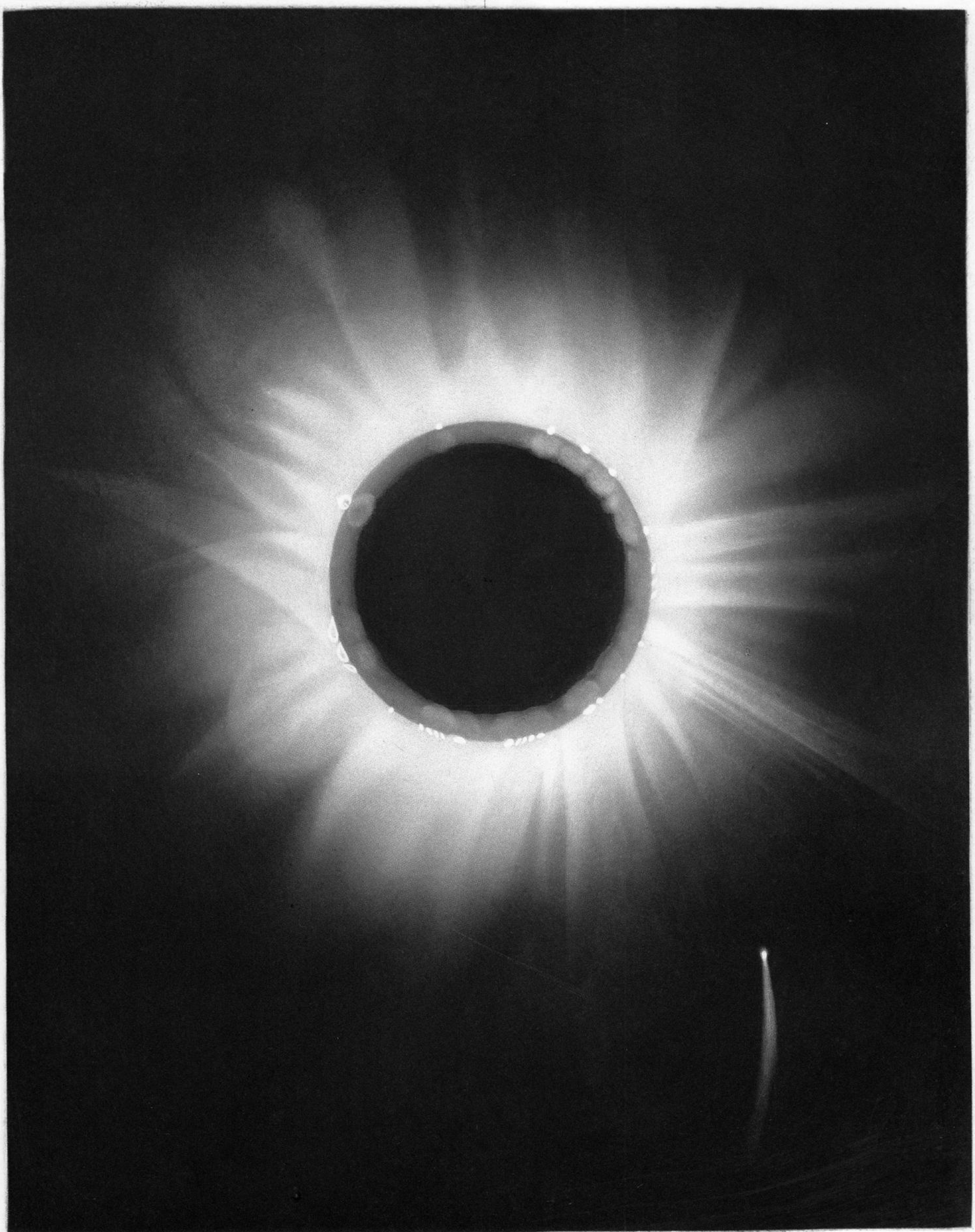
N. SUN'S AXIS.



W. H. Wesley, Del. D. J. Pound, Sculp.

SUN'S AXIS. S.

N. SUNS AXIS.



SUNS AXIS. S.