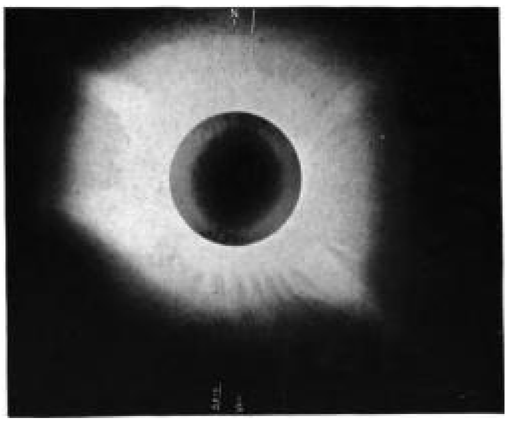
The Indian eclipse, 1898: report of the expeditions organized by the British ...

By Edward Walter Maunder, British Astronomical Association

Exposure, H seconds.



Exposure, 9 seconds.

THE CORONA, 1898, JANUARY 22.

(As photographed at Talni, by Mr. C. Thwaites.)

The following table gives a list of the photographs obtained by members of the expeditions arranged in order of their equivalent exposure; all the photographs being reduced to the standard of a camera with its focal length fifteen times that of its aperture:—

No.	Photographer.	Aperture.	Equi- valent Focus.	//A.	Exposure.	Equivalent Exposure //15.
		In.	In.		Sec.	Sec.
1,2	Capt. Molesworth	1.67	96	57	1	0-067
3	Mr. COUSENS . . .	2-1	32.5	15	i	0.25
4,5	Capt. Molesworth	1.67	96	57	5	0-33

6	Miss Bacon	1-2	26	22	1	0-46
'7	Mr. COUSENS . . .	21	32 .5	15	i	0.50
8	Miss Bacon	1.2	26	22	2	0.93
9	Mr. Oakes	ro	11	11	i	0-93
10	Mr. COUSENS . . .	21	32.5	15	1	I.O
11	Mr. F. Bacon . . .	41	60	14$	1	1.04
12	Air. Thwaites . . .	4 .25	71	16-7	1*	1.20
13, 14	Capt. Molesworth	1.67	96	57	20	1-32
15	Miss Bacon	1.2	26	22	3	1-4
16	Miss Bacon	1.2	26	22	4	T9
17	Mr. COUSENS . . .	2.1	32.5	15	2	2.0
18	Mr. F. Bacon . . .	41	60	14f	2	2.2
19	Mr. Lys Smith . . .	0-3	55	16	3	27
20, 21	Mr. COUSENS ...	2.1	32 "5	15	4	4.0
22,23	Mrs. Maunder . . .	re	9	6	1	6.2
24	Mr. Thwaites . . .	4.25	71	16-7	9	7.25
25	Mr. Lys Smith . . .	0.3	5.5	16	25	22.2
26	Mr. Thwaites . . .	4.25	71	16.7	30	24-2
27, 28	Mrs. Maunder . . .	1.5	9	6	5	31.2
29, 30	Mrs. Maunder . . .	1.5	9	6	20	125-0

Plates Nos. 1 and 2 gave no result, and Nos. 21 and 23 were spoiled by the return of sunlight.

In the above table no allowance has been made for the rapidity of the plates used.

The above photographs were handed for examination to Mr. W. H. Wesley, who has most kindly prepared the diagram which appears as frontispiece to this volume from the photographs, and who has supplied the following report of the appearance of the corona of 1898 from the photographs.

H. KEATLEY MOORE.

SPECTROSCOPIC RESEARCH AT FUTURE ECLIPSES.*

AMONG the numerous questions which present themselves for solution at future eclipses perhaps the most vital is that relating to the distribution of the gases in the Flash spectrum layer. Although the entire thickness of the stratum subtends an angle of but one or two seconds of arc, and consequently appears to us at the moments of second and third contact as an extremely fine thread of light, yet it will have to be examined in much greater detail than heretofore if an advance is to be made in our knowledge of the relation which its bright-line spectrum bears to the dark-line Fraiinhofer spectrum. The

* By J. Evershed, F.R.A.S.

lower depths in which the photospheric clouds are suspended must be separated from the higher levels, to determine the order of succession of the various constituent gases in passing outward from the photosphere through the 800 miles or so of incandescent gases.

Thus it will be of the greatest interest to learn whether in the lowest depths, where the pressure and temperature are greatest, the emission spectrum becomes more nearly the counterpart of the Fraiinhofer spectrum. Or whether, on the other hand, the dissociating effects of higher temperatures in these regions give rise to a simpler spectrum differing materially from the dark-line spectrum, as well as from the emission spectrum of the higher regions.

In the photographs recently obtained the bright lines of the Flash represent the integration of the entire 800 miles of depth, and it is not easy to discriminate between high levels and low levels, which may, and probably do, differ very considerably, seeing that the range of temperature and pressure through this depth is likely to be very great.

At first sight it would seem almost hopeless, with instruments of any reasonable dimensions, to perform this detailed analysis of an object subtending so minute an angle; particularly when it is remembered that under the ordinary conditions of *sm* eclipse the advancing edge of the moon traverses the entire depth of the layer in two or three seconds of time, and only a fraction of a second would be available for photographing the lowest strata.

I think nevertheless that it will be possible at future eclipses to get fresh evidence bearing on this question, which should show, at any rate, which way the tendency lies with regard to the lowest strata.

If observing stations were selected, not on the central line of the eclipse, but only a few miles within the north or south limits of totality, it is probable that some important results would be secured. A calculation of the conditions which would obtain at the eclipse of 1900, May 28th, at a station near the limits of the shadow zone, indicates that although totality itself would be a matter of some twenty or thirty seconds only, the duration of the flash spectrum would be many times prolonged, and the covering up and uncovering by the moon would be a very much more deliberate process.

At a station situated so far from the central line that the duration of totality was reduced to one-third the value it would have on the central line, it would probably be possible to observe the Flash spectrum during the whole time of totality—that is, for about thirty seconds at stations in Spain and Portugal. Under these conditions the bright crescent giving the Flash spectrum would be seen to rapidly shift round the limb from second to third contact, these two points being separated by an angle of 39 degrees only. The lowest strata of the layer would of course only be revealed at the moments of the contacts, while at mid-eclipse only the highest limits would be seen. But the comparatively slow rate at which the excessively thin flash spectrum layer would be occulted by the moon and then again uncovered, would evidently afford an excellent opportunity for obtaining a long series of photographs of the spectrum at the various stages; those taken at mid-eclipse giving high-level spectra only, whilst photographs taken fifteen seconds earlier and later would give high- and low-level spectra combined.

But even under these favourable conditions it will still be difficult to separate the high- and low-level spectra unless instruments of great focal length and considerable aperture are employed. The radiation coming from a stratum at the base of the layer, say within 100 miles of the photosphere, may be very intense, yet it will be difficult to photograph on account of the extreme fineness of the spectrum lines; and small apertures would probably entirely fail to get anything but the spectra of the more extensively diffused gases.

At all stations in the Spanish peninsula where the duration is one-third that on the central line, it will happen also that one of the contacts occurs at, or very near, one of the poles of the sun. If north of the central line, third contact will be at the north pole ; and if on the southern border of the shadow track, second contact is at the south pole. In either case, therefore, the spectrum of the polar regions would be obtained, and it would be of interest to learn whether the flash spectrum at the poles differs in any way from that at low latitudes hitherto observed; or whether it has the same composition in all parts of the sphere. It would be important from this point of view to carefully compare the spectra obtained at second and third contacts, since these points being separated by 39 degrees would give this range in latitude.

Another important point which future eclipse work will determine is the composition of the flash spectrum with reference to the sun-spot cycle. A comparison which I have made between the flash spectrum photographed by Mr. Shackleton in August 1896, and that obtained by me in January 1898, shows that in the visible part of the spectrum between D and H the two spectra are identical. The former does not extend far enough in the ultra-violet to make the comparison complete, but below H I can find no line on the one which is not also indicated on the other, and *vice versa*; and the relative intensities seem to be the same. But it may well be that photographs taken at opposite phases of the spot cycle would show differences. Judging by the changes which seem to take place in the coronal spectrum, we should expect the flash to be richest in lines at a time of maximum sun spots. It is well known, too, that when spots are numerous the chromosphere gives many more bright lines than are seen at times of minimum activity, the eruptive action which so frequently takes place in the neighbourhood of spots elevating for the time being the low- lying metallic vapours.

A chance photograph of one of these metallic eruptions taken during the moments when the flash spectrum is visible would be of the greatest interest, as it would probably give valuable information as to the constitution of the very lowest strata. Such a favourable chance is perhaps almost too much to hope for, at any rate until an eclipse occurs at a time of very great solar activity. The observation could only be made at a station near the central line of the eclipse, as eruptive prominences are never seen in high solar latitudes.

The experience gained at the recent eclipse with regard to photographic plates is in one respect of great value to the spectroscopist. The advantages attending the use of triple-coated plates was clearly demonstrated by the successful photographs obtained by Mrs. Maunder; and in particular by the coronal photograph taken forty seconds after the sun had reappeared.

Now, in the series of spectrum plates exposed by me, the first was an ordinary single-film isochromatic, whilst the last was a Sandell triple-coated plate: both received two images of the cusp spectrum with exposures of about half a second, the single- film plate just before second contact and the triple just after third contact. Comparing the two results, it is evident that there is a marked difference in favour of the triple-coated plate. The final exposure on the latter was some twenty seconds ajfter the sun had reappeared, the full blaze of the brilliant cusp falling upon the plate; yet no halation effects obscure the delicate fringe of bright lines bordering the spectrum, and I feel confident that longer exposures might have been made without any ill effects, whilst the finer details would have been more strongly impressed. Probably exposures up to two seconds or more on these plates would give excellent results under the same conditions.

In prismatic camera work these oufc-of-totality photographs are especially valuable, if only on account of the beautifully defined Fraiinhofer spectrum which is impressed. This, in effect, forms a most convenient wave-length scale, which greatly facilitates the reduction of the bright-line spectra, and in all future eclipse work with the prismatic camera it is most desirable that these cusp spectra be obtained both before and after totality.

3. EVERSHED.

ON THE PROPER EXPOSURE TO BE GIVEN FOR PHOTOGRAPHS OF THE CORONA.*

ONE of the most interesting features in the observations of the late eclipse is the enormous variation in the length of the exposures given. To take the two extreme cases, Prof. C. Michie Smith, with an objective of 6 inches aperture and 40 feet focal length, that is with //80, exposed one of his plates for half a second. Mrs. Walter Maunder, with a lens of l| inch aperture and 9 inches focus, *i.e.* //6, exposed two plates for 20 seconds each, If we take it that the equivalent exposure varies inversely as (^)a, then in the second instance the exposures were more than 7000 times as great as in the first.

Since both these extreme exposures were successful for the respective purposes for which they were designed, it would seem, at first sight, as if any exposure between these two extreme limits might serve. And there can be no doubt that a really skilful photographer, having a clear idea of the practical exposure which he had given, and of the special features which such an exposure was well calculated to bring out, might even succeed in producing a negative not without value with any exposure within this wide range, possibly within a range even wider still; provided always, of course, that the sky was really clear, and that there was an absence of anything like overwhelming atmospheric glare.

In the Indian eclipse of 1898, the weather conditions were everywhere so favourable that this condition was fulfilled throughout. The question, therefore, was one of pure photography, and we may ask whether we have any indications as to what are the suitable exposures to be given in order to secure certain definite pictures of the eclipse.

Accepting the principle that with different instruments the duration of exposure should vary inversely as (//a)2, in order to produce the same result, we have before us three series of negatives that may give some definite information. The first we will call the Waters series, as it was taken with the tele- photographic camera bequeathed by the late Mr. Sidney Waters to the Royal Astronomical Society. Here the equivalent *f/a* was 57, and the exposures given were 1, 5, and 20 seconds. The second series was intended as a continuation of this, and was taken by Mrs. Walter Maunder with the Dallmeyer stigmatic lens of //6, the exposures being the same as in the Waters series. This we will call the Dallmeyer series. The third is a set of five plates taken by Mr. Henry COUSENS, which we will call the COUSENS series. The *f/a* in this series was 15, and the exposures were £, |, 1, 2, and 4 seconds. The yalue of a given exposure in the Waters series was double that of the same exposure given by Prof. Michie Smith in his great 40-foot telescope, whilst an exposure with the COUSENS or with the Dallmeyer instruments were equivalent respectively to 15 or 90 times that exposure with the Waters, and 30 or 180 times that given by Dr. Michie Smith.

Now as to results. The i-second exposure given with the great 40-foot telescope " shows the very beginning of the eclipse with a range of small prominences round nearly half the sun's limb." The Waters 1-second plate, which was therefore four times the one just mentioned, shows not merely the prominences, but a distinct ring of corona, some two or three minutes in height. We may take it, then, that if the object be to secure the prominences alone with little or nothing of the corona, it will not be safe to exceed greatly the exposure of £ second with//80, or ^ second with//15; the plate being supposed of maximum sensitiveness, like the " Wratten and Wainwright drop shutter" employed by Dr. Michie Smith. This exposure will be sufficient, and anything much longer will be undesirable.

The next plate in order of light efficiency is the first of the COUSENS series, and the estimated exposure was £ second, equivalent to fifteen times that of the i-second exposure with the Madras 40-foot lens, which we will take as our unit. Here the exposure of the lower corona, up to 3' of arc from the limb, is full. The prominences are seen, but are much over-exposed, and the brightest begins to eat into the limb of the moon. The fainter parts of the corona are also coming out distinctly, and the roots of the three great coronal rays can be traced to a full radius from the limb.

The 5-second Waters, which corresponds to 20 units, and therefore is ^ as efficient again as the COUSENS first plate, shows a very considerable development of the corona. The next two COUSENS plates and the third Waters have the values of 30, 60 and 80 respectively, but do not greatly extend the dimensions of the corona beyond that of the 5-second Waters. Exposures, therefore, of from 20 to 30 units, or from *jj* to £ of a second with *f*/\ 5, are sufficient to bring up satisfactorily nearly the whole of the corona as ordinarily shown on photographs. The gain in extent by increasing these exposures, with//15, to 1 second and 1^ second, does not appear to be of any important amount, whilst the risk of entirely losing the detail in the lower corona by over-exposure increases rapidly with the prolongation of the time.

The five splendid photographs obtained by Mr. Thwaites and Mr. Fred Bacon fully confirm these conclusions. Mr. Thwaites employed an o.g. of 4.25 inches aperture and 7.1 inches focus ; Mr. Bacon had a similar aperture but a focal length of 60 inches. The *f/a* was therefore 16.7 in the first case and 14§ in the second. Mr. Thwaites' exposures were 1|, 9, and 30 seconds, corresponding approximately to 1'2, 7-2o and 24-2 seconds with //15. Mr. Bacon's exposures were 1 second and 2 seconds, his //« being almost 15. But both observers used Ilford ordinary plates, not extra-rapid. The exposures are therefore equivalent only to one-fourth or one-fifth of what an ultra-sensitive plate would have given. Mr. Thwaites' second plate is very fully exposed, one of the coronal streamers at least reaching the edge of the plate; and though it shows a great wealth of detail, yet over-exposure is beginning to show itself near the limb. Mr. Bacon's two plates are both amply exposed, whilst Mr. Thwaites' third plate is evidently not at all the equal of his second.

It may be remarked that the two observers were well advised to use slow plates ; for where there is no urgent need to cut the exposures very short, there can be no doubt that it is the wiser course to use a plate of normal sensitiveness, rather than an extra-rapid, and to lengthen the exposure in proportion. The slower plate is easier to manage and safer to handle ; in other words, a restrained and prolonged development can be better employed upon it, and it is less liable to accidental fog ; whilst the grain of the deposit is usually finer. Certainly the five plates in question leave nothing to be desired as to detail and beauty.

The fourth and fifth of the COUSENS series show a very real development of the coronal rays: so far as we are aware, the greatest development shown on any photographs obtained during the eclipse, except the three which we secured with the Dallmeyer. These two COUSENS plates had exposures of 2 and 4 seconds respectively, equivalent to 120 and 240 units. The first of the Dallmeyer series would have been 360 units, but it is spoiled by bad shake. The second and third had exposures 1800 and 7200 on the same scale, or 31 seconds and 125 seconds with //15. The advantage in extension of the second Dallmeyer over the fifth COUSENS is small, when it is borne in mind that the equivalent exposure is 7| times as long. The two plates representing the third stage in the Dallmeyer series carry the rays very considerably further, but their exposure was 30 times that of the fifth COUSENS, and they were taken on the Sandell triple- coated plates.

It is precisely in these extreme exposures that the value of the Sandell plate becomes apparent. The problem of photographing the coronal extensions has three elements. The first, the extreme faintness of these rays, can, of course, be overcome by increasing the equivalent exposure in each or all of three different ways, that is by increasing the actual duration of the exposure, by increasing the ratio of aperture to focal length, or by increasing the sensitiveness of the plate. The second element is the presence in close contiguity to these faint rays of an exceedingly brilliant light. To increase the equivalent exposure, therefore, and to do nothing else, is simply to secure the fogging of the plate before the development can bring up the faint lights. The third element is the amount of atmospheric glare present in the immediate neighbourhood of the faint extensions. With a large amount of such glare, or if it diminishes in brightness with distance from the sun more slowly than does the corona, it is clear that a limit will soon be reached-beyond which these rays cannot be photographed. Otherwise the problem is to give an exposure sufficient to show the ray, but not long enough to bring up the general glare, and to use plates so prepared that the intense action set up by the inner corona shall not spread far enough to interfere with the outer.

The evidence before us does not enable us to decide whether the limit of exposure in a fine eclipse has yet been reached. It would certainly appear to be a duty to attempt on the next occasion to increase the exposures given this time as far as possible ; although it is perfectly likely that the result of such an experiment will only be to prove that the limit was nearly reached on the present occasion.

There is, however, some ground for hope that if favoured with skies as clear as we had in India, the present record exposures may be greatly increased with success. The attempt to photograph the corona during the partial phase is photographically but a special case of the same problem. The difficulty was not, indeed, to give a long enough exposure, but to avoid the fogging of the plate from the brilliance of the returning sunlight and from the consequent general illumination of the atmosphere. The success of the attempt was most remarkable, and could only have been obtained on a plate possessing the characteristics of the triple-coated Handell. When it is borne in mind that the exposure given was equivalent to 9 seconds with *fj*\ 5, or 540 units; that carefully backed plates exposed during mid-totality for periods corresponding to this are strongly halated, and that, surface for surface, the sun is something like 100,000 times as bright as the corona, it is indeed a remarkable result to find that the coronal ring can be traced round practically to meet the cusps of the returning sun, and that the limb of the moon is seen sharply and distinctly denned black against its bright background. With no other plate that I know of would it have been possible to develop a photograph with any hope of success upon which the image of the sun had come out deep, distinct and black before ever the developer touched it, Mr, COUSENS, for example, exposed a sixth plate, carefully backed, which was caught by the first ray of returning sunlight. The flood of sunshine made it impossible to fully develop the plate without entirely fogging