ON SOME RESULTS OF PHOTOGRAPHING THE SOLAR CORONA

WITHOUT AN ECLIPSE

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Last December (1882) I had the honour of presenting to the Royal Society a note on « A Method of Photographing the Solar Corona without an Eclipse. » In that paper I say:— « If by screens of coloured glass or other absorptive media the region of the spectrum between G and H could be isolated, then the coronal light which is here very strong would have to contend only with a similar range of refrangibility of the light scattered from the terrestrial atmosphere. It appeared to me by no means improbable that under these conditions the corona would be able so far to hold its own against the atmospheric glare, that the parts of the sky immediately about the sun where the corona was present would be in a sensible degree brighter than the adjoining parts where the atmospheric light alone was present. It was obvious, however, that in our climate and low down on the earth's surface, even with the aid of suitable screens, the addition of the coronal light behind would be able to increase but in a very small degree the illumination of the sky at those places where it was present. There was also a serious drawback from the circumstance that although this region of the spectrum falls just within the range of vision, the sensitiveness of the eye for very small differences of illumination in this region near its limit of power is much less than in more favourable parts of the spectrum; at least such is the case with my own eyes. There was also another consideration of importance; the corona is an object of very complex form, and full of details depending on small differences of illumination, so that even if it could be glimpsed by the eye, it could scarcely be expected that observations of a sufficiently precise character could be made to permit of the detection of the more ordinary changes which are doubtlessly taking place in it. These considerations induced me not to attempt eye-observations, but from the first to use photography, which possesses extreme sensitiveness in the discrimination of minute differences of illumination, and also the enormous advantage of furnishing a permanent record from an instantaneous exposure of the most complex forms. »

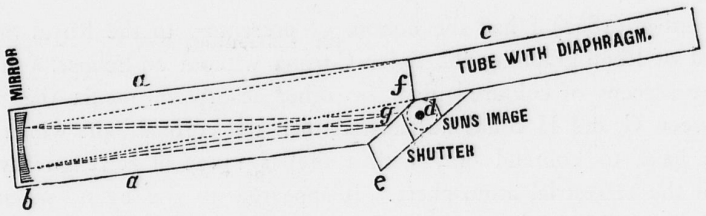
The photographs described in that paper were obtained with a reflecting telescope of the Newtonian form by Short, and the restriction of the light to the small range of refrangibility from about G to H was effected by the use of screens of coloured glass,

(1) A Paper read at the Southport Meeting of the British Association for the Advencement of Science 1883. (London 1884).

or by a cell containing a solution of potassic permanganate. The photographs showed distinctly coronal appearances around the sun, and I was permitted by Captain Abney, F.R.S., who made a careful examination of the plates, to say that, in his opinion, the solar corona had been photographed on my plates with an uneclipsed sun.

I purpose in this paper to give an account of some further experiments founded on the same method made during the spring and summer of the present year.

I am indebted to Miss Lassell for the loan of a seven-foot Newtonian telescope made by the late Mr. Lassell. The speculum, which is seven inches in diameter, possesses great perfection of figure, and still retains its original fine polish. I decided not to use more than $3\,^1/_2$ inches of the central portion of the speculum, partly for the reason that a larger amount of light would be difficult of management, and partly because this restriction of the aperture would enable me to adopt the arrangement which is shown in the diagram.



It will be seen at once from an inspection of the diagram that in this arrangement the disadvantage of a second reflection by the small mirror is avoided, as is also the mechanical inconvenience of tilting the speculum within in the tube as in the ordinary form of the Herschelian telescope. The speculum *b* remains in its place at the end of the tube *a*, *d*. The small plane speculum and the arm carrying it were removed. The open end of the tube is fitted with a mahogany cover. In this cover at one side is a circular hole *f*, $3\,^1/_4''$ diameter, for the light to enter; below is a similar hole over which is fitted a framework to receive the « backs » containing the photographic plates, and also to receive a frame with fine ground-glass for putting the apparatus into position. Immediately below, towards the speculum, is fixed a shutter with an opening of adjustable width, which can be made to pas across more or less rapidly by the use of india-rubber bands of different degrees of strength. In front of the opening *f* is fixed a tube *c*, six feet long, fitted with diaphragms, to restrict as far as possible the light which enters the telescope to that which comes from the sun and the sky immediately around it. The telescope-tube *a*, *a*, is also fitted with diaphragms, which are not shown in the diagram, to keep from the plate all light, except that coming directly from the speculum. It is obvious that, when the sun's light entering the tube at *f* falls upon the central part of the speculum, the image of the sun will be formed in the middle of the second opening at *d*, about two inches from the position it would take if the tube were directed axially to the sun. The exquisite definition of the photographic images of the sun shows, as was to be expected, that this small deviation from the axial direction, two inches in seven feet, does not affect sensibly the performance of the mirror. The whole apparatus is firmly strapped on to the refractor of the equatorial, and carried with it by the clock motion.

The performance of the apparatus is very satisfactory. The photographs show the sun's image sharply defined; even small spots are seen. When the sky is free from clouds, but presents a whity appearance from the large amount of scattered light, the sun's image is well-defined upon a uniform beckground of illuminated sky, without any great increase of illumination immediately about it. It is only when the sky becomes clear and blue in colour that coronal appearances present themselves with more or less distinctness.

In my earlier work with this apparatus I used cells containing potassic permanganate in solution, which were placed close to the sensitive surface, and between it and the shutter. I was much troubled by the rapid decomposition of the potassic permanganate under the influence of the sun's light. When apparently clear to the eye, a lens revealed minute particles which precipitated themselves upon the glass plates of the cell, and gave an appearance of structure to any coronal appearance which was on the plate. Besides, any diminution of the transparency of the solution, by the presence of minute particles would produce scattered light on the plate.

I then tried a solution of iodine in carbon disulphide, but the same inconvenience presented itself. Very soon under the sun's light the solution was found by examination with a lens to show signs of commencing decomposition.

Even when the solution was sensibly clear, there was some disadvantage from unavoidable imperfection of polish of the surfaces of the plates which reveals itself under the strong light in which they are placed. If, however, the violet (pot) glass which I used at first could be obtained annealed and free from the imperfections usually present in it, it would serve most usefully as a selective screen.

For these reasons, after some months' work, I decided to give up the use of absorbing media, and I came to the conclusion that the advantages they present, which are doubtless considerable, are more than balanced by the possible false appearances which they might give rise to if the solutions were not in a condition of perfect transparency.

As, for the reasons stated above, it seemed desirable to avoid placing media of any kind before the sensitive surface, the selective power upon the light had to be sought in the nature of the sensitive surface itself. The suggestion of staining the film presented itself, but after consultation with Captain Abney, I decided to try an emulsion containing silver chloride only. Captain Abney kindly prepared some silver chloride emulsion for me, and the plates were developed with a solution of ferrous-citro-oxalate.

The silver chloride film, according to Captain Abney, is strongly sensitive to light from *h* to *H*, and hardly at all beyond *H*.

Since the middle of July these plates have been used as well as the ordinary silver bromide gelatine plates. A comparison of the two kinds of plates, when used under similar conditions, shows a decided advantage for this work in favour of the silver chloride.

All the plates were backed with a solution of asphaltum in benzole.

For the purpose of screening the sensitive surface from the intensely bright image of the sun, small circular disks of thin brass were turned about $^1/_{50}$ inch larger in diameter than the sun's image. The brass disk was held close before the sensitive surface by a fine metal arm when the sun was taken in the middle of the field, and attached to the inner edge of a circular diaphragm when the sun's image was placed towards the side of the field.

A comparison of photographs taken under similar conditions with and without the

disk showed less advantage in favour of the disk than was anticipated. Indeed, it may be that, with the short exposures given, the scattered light, which comes upon the plate when the sun's image falls directly on the sensitive surface, may be favourable to the setting up of the photographic action by the comparatively feeble coronal light.

In consequence of the number of diaphragms which it was found desirable to introduce into the apparatus for the purpose of preventing any light but that from the sun and the sky immediately around it from reaching the plate, the extent of field in which the full aperture was in use was small. For this reason it was found of advantage to place the sun's image near the margin of the diaphragm limiting the field, and afterwards to combine the photographs, taken in four different positions.

The moving shutter being placed very near the sensitive surface, and practically in the focal plane, could not give rise to effects of diffraction upon the plate. Besides, the opening in the shutter was never less than half an inch in width, and often as much as an inch or even more, according to the sensitiveness of the plates used.

The most serious difficulty with which I have had to contend has been the absence of clear skies. On many days of bright sunshine the wind has been in a northerly direction bringing here the smoke of London, which produces a whity condition of sky, through which it was obviously hopeless to expect the coronal light to show itself upon the plates.

The few occasions of a better condition of sky were for the most part of short duration and did not allow time for a large number of photographs to be taken.

During the summer about fifty photographs have been obtained, which show photographic action about the sun of a more or less coronal character.

I placed these plates in the hands of Mr. Wesley, who has had very great experience in making drawings from the photographs taken during several solar eclipses, with the request that he would make a drawing for each day on which sufficient photographs had been taken, combining the results of the different photographs in one drawing. This was desiderable, as whenever a sufficient duration of sunshine permitted, photographs were taken on silver chloride films, as well as on silver bromide plates; some photographs were taken with the sun screened by the brass disk, others without it; also photographs were taken with the sun in different positions of the field. As a rule, Mr. Wesley has introduced into his drawings those coronal features only which are common to all the plates taken on that day.

The apparatus is attached to the refractor of the equatorial in such a way that the direction of the length of the plate is in that of a parallel of declination; a line, therefore, across the plate is in a direction north and south, and from the date of the photograph the angle of position of the sun's axis can be found. On Mr. Wesley's drawings the orientation is marked, as well as the position of the sun's axis. Four drawings accompany this paper Tav. CLXVIII. In most of the negatives more structure than is shown in the drawings is suspected when the plates are carefully examined.

I regretted greatly that on May 6, the day of the solar eclipse, the sky here was very unfavourable. Up to the time of writing this paper I have not seen the photographs taken during the eclipse. Mr. Wesley wishes me to state that he has not seen the photographs or any drawings of the eclipse, and that therefore he has been wholly without bias in making his drawings from my plates. If these drawings are compared with the

photographs taken during the eclipse, it should be borne in mind that the absence of sky illumination during the eclipse would allow a larger part of the fainter and more distant regions of corona to be photographed, and that any peculiar conformations or detailed structure of these outer portions could not be expected to be seen on my plates. The comparison should be restricted to the regions of the corona at corresponding distances from the sun's limb. It is probable that the short exposure eclipse negatives will be found to admit of comparison with my plates better than those exposed for a longer time.

Photographs of the sun have been taken on the days which follow :—

April	2	1 plate	June	6	3 plates
»	3	1 »	»	20	1 plate
»	6	2 plates	July	10	3 plates
»	26	5 »	»	15	2 »
May	23	1 plate	Aug.	8	2 »
»	24	6 plates	»	13	7 »
»	31	5 »	»	20	7 »
			Sept.	4	4 »

All these plates show a more or less distinct coronal appearance about the sun. On some of the days an unfavourable wind brought here the London smoke, which greatly increased the sky illumination relatively to the coronal light which could reach the plate. On these days the photographic action on the plates around the sun, though distinctly coronal in character, possesses less definiteness of form. I entertain the hope that it may be possible, by a careful comparison of all the plates, to gain some information in a general way of the amount, and possibly also of the character, of any large changes of form or of relative brightness which may have taken place in the corona or been due to its motion during the period covered by the observations.

I stated in my paper read before the Royal Society that all I could hope to do in this climate and at the low elevation of my observatory, was to show a method by which, « under better conditions of climate, and especially at considerable elevations, the corona may be successfully photographed from day to day with a definiteness which would allow of the study of the changes which are doubtlessly always going on in it. ' ' Problems of the highest interest in the physics of our sun are connected, doubtless, with the warying forms which the coronal light is known to assume, but these would seem to admit of solution only on the condition of its being possible to study the corona continuously, and so to be able to confront its changes with the other variable phenomena which the sun presents. « Unless some means be found, » says Professor C. A. Young, « for bringing out the structures round the sun which are hidden by the glare of our atmosphere, the progress of our knowledge must be very slow, for the corona is visible only about eight days in a century, in the aggregate, and then only over narrow stripes on the earth's surface, and but from one to five minutes at a time by any one observer. » ' [1]

P.S.—Messrs. Laurance and Woods, the observers sent out at the expense of the Government to photograph the eclipse of May last at Caroline Island, have compared Mr. Wesley's drawings, and the original negatives from which they were made, with the

[1] ' The Sun,' p. 289.

photographs taken during the eclipse. Mr. Laurance, in a letter to Professor Stokes, dated September 14, 1883, says: -

'Dr. Huggins called upon Mr. Woods this morning and showed us the drawings Mr. Wesley has made of his coronas. He told us that he particularly did not wish to see our negatives, but that he would like us to compare his results with ours. We did so, and found that some of the strongly marked details could be made out on his drawings, a rift near the north pole being especially noticeable; this was in a photograph taken on April 3, in which the detail of the northern hemisphere is best shown, while the detail of our southern hemisphere most resembles the photograph taken on June 6; in fact, our negatives seem to hold an intermediate position. Afterwards I went with Dr. Huggins and Mr. Woods to Burlington House to see the negatives. The outline and distribution of light in the inner corona of April 3 is very similar to that on our plate which had the shortest exposure; the outer corona is, however, I think, hidden by atmospheric glare. As a result of the comparison I should say that Dr. Huggins's coronas are certainly genuine as far as 8′ from the limb.'