

ART. XLV.—*On the Results of the Spectroscopic Observation of the Solar Eclipse of July 29th, 1878;** by GEORGE F. BARKER.

To Professor Henry Draper, M.D., Director of the Draper Eclipse Expedition:—

Dear Sir: I beg leave to submit to you herewith my Report on the spectroscopic observations made, and on the results obtained at Rawlins, Wyoming Territory, during the solar eclipse of July 29th, 1878, that portion of the work having been allotted to me by yourself in the organization of the expedition.

The instruments and apparatus used in the observations were loaned for the purpose from the physical cabinet of the University of Pennsylvania. They consisted (1) of an equatorially mounted achromatic telescope of four inches aperture made by Jones of London, (2) a direct-vision astronomical spectroscope by Merz of Munich, (3) a second direct-vision spectroscope by Hoffmann of Paris, (4) and a pocket spectroscope by George Wale & Co. Beside this spectroscopic outfit, a second four-inch achromatic telescope by Dollond was taken for use with the tasimeter by Dr. Edison, and a Savart, a Senarmont, and an Arago polariscope, for determining the polarization of the corona. The Merz spectroscope above mentioned is described in the *Philosophical Magazine*, IV, xli, Feb. 1871. It is provided with two compound direct-vision prisms, of which one or both can be used at pleasure, each consisting of five single prisms, two of flint glass with a refracting angle of 84° , and three of crown; one of these having a refracting angle of 84° , the others of 87° . The dispersive power of each of these compound prisms is about equal to that of two equilateral prisms of flint glass. The instrument has a collimating and an observing telescope, each furnished with an object glass two-thirds of an inch in aperture and four inches in focal length. The prism-tube is attached to the collimator by two centers, giving it a lateral motion about a line passing through these centers, which constitutes an axis parallel to the slit. The observing telescope is similarly attached to the tube carrying the prism. These motions serve to alter the incidence of the rays upon the surface of the prism, and also to bring any special part of the spectrum into the middle of the field. The observing telescope is provided with a positive eye-piece of an equivalent focal length of one inch, and also with a needle micrometer, having an eye-piece of one-half inch focus. The graduations upon this micrometer are strongly cut, enabling the positions and the distances of the lines measured with it, to be

* Read by permission of Dr. Draper at the St. Louis meeting of the American Association for the Advancement of Science.

easily read even in a faint light. The spectroscope was firmly attached to the draw tube of the equatorial telescope by means of an open frame made by Zentmayer, so that the position of the image with reference to the slit could be readily observed.

The time from the 19th of July, the date of our arrival at Rawlins, until the 29th, was occupied in setting up the instruments, in getting them into adjustment, and in practice with them. It was found that with only one of the compound prisms of the Merz spectroscope, the slit being placed radially, it was easy to observe the lines C and F reversed in the chromosphere, and also the bright line D₃. On the morning of the day of the eclipse, the solar edge was examined for protuberances, in order to locate them in advance of totality. But a single one was noticed, this being on the southwestern edge of the sun. As the time of first contact approached, the spectroscope was removed and a paper screen was attached to the draw tube, an image of the sun being formed on this screen by means of the eye-piece; thus enabling the time of this contact to be approximately determined and the subsequent progress of the eclipse to be conveniently observed. No spots were seen under these circumstances, though this could hardly have been expected since the solar image was so small, scarcely three inches in diameter, unless the spots were of large size. As the time of second contact drew near, the spectroscope was replaced upon the equatorial. Since you deemed it of importance to pay special attention to the oxygen lines in the vicinity of G, the micrometer of this instrument was, at your suggestion, so adjusted that one of its needle points rested on the hydrogen line near G, and the other on the line known as *h*. After the last ray of sunlight had disappeared, I took a few seconds of the precious time to observe the eclipse with the naked eye. The moon appeared intensely black, surrounded by a pinkish halo, extending to about two-fifths of a lunar diameter from the limb, and occupying the entire circumference. At two points this halo was expanded into radial streamers, one of which had parallel sides with a deeply indented or swallow-tailed end, extending westward of the sun and apparently lying in the ecliptic; the other appeared single, was on the eastern edge, and was inclined twenty degrees or more to the north of the ecliptic. The former of these streamers was traced to a distance of about a lunar diameter from the edge, the latter to a somewhat less distance. No structure could be seen in the halo, but in the streamers traces of parallel rays appeared to be present. The amount of light emitted by the corona was a surprise to me. Preparations had been made for using artificial light for reading the circles, but this was found not

to be at all necessary. The amount of light seemed to be nearly or quite equal to that given by the moon when ten days old. No protuberances were seen with the naked eye nor were any streamers observed, other than those already described. A glance at the eclipsed sun was then taken through the finder of the equatorial. The magnifying power being low, the corona presented much the same appearance as to the naked eye. But the streamers showed much more distinct evidences of a radiated structure and a pale rosy protuberance was observed on the southwestern edge of the dark disc. This was undoubtedly the same prominence which was observed previous to totality.

Turning my attention now to the spectroscope, upon the slit of which the coronal image had already been brought by means of the finder, the slit being placed radially, the first glance through the instrument showed me a bright but an absolutely continuous spectrum. The region under examination was of course that portion of the spectrum which had been placed before totality between the needle-points of the micrometer. Totally unprepared for so unexpected a result, I moved the observing telescope so as to bring the green portion of the spectrum into the field, expecting certainly to see 1474 K and by the appearance of this line to determine whether my instrument was out of adjustment; and if it was to adjust it again. But no bright line was there; the green region appeared as continuous as the blue. I then gradually closed the slit—which had been previously adjusted on the solar spectrum so that the line D appeared nebulous on its edges—thinking that I might in this way improve the definition; but with no better result; no bright lines could be seen. To my great surprise however, when the slit was thus narrowed, the region which was then under examination, that extending from *b* to G, appeared filled with dark lines on the brighter background, these dark lines being readily recognized from their general appearance as the solar lines of Fraunhofer. Still intent on getting bright lines, I opened the slit again gradually, moved the observing telescope over the entire length of the spectrum from red to violet, repeating the operation three times and varying the width of the slit from time to time in each region; but not a single bright line could be detected. I then requested you to come and take a glance through my spectroscope, as had been previously agreed; saying that although I could see dark lines and a continuous spectrum, I was unable to detect a single bright line and knew not what to make of it. You were then looking at the eclipse through your ingenious little telespectroscope of two inches aperture. You came to my instrument, looked at the spectrum, moved the observing telescope over its

whole length and remarked that the results in my spectroscope agreed entirely with those in yours, and that the spectrum appeared in both absolutely continuous. My mind being thus relieved, I took my place again at the spectroscope, and this time, placing the slit tangential to the moon's limb, I moved the observing telescope from end to end of the spectrum, opening and closing the slit at intervals; but the spectrum appeared as continuous as before. Again the image was adjusted so that the slit was once more radial; and this time on still a different portion of the corona. On examining again the spectrum, no bright lines appeared, except once for an instant, when the slit passed over the small chromospheric prominence already noticed. Warned by Mrs. Draper's clear and distinct counting that the precious 165 seconds had two-thirds gone, I decided to devote the time still remaining to a more careful observation of the dark Fraunhofer lines. Now, for the first time, as I adjusted the width of the slit and its position on the corona with more care, I observed that these lines did not pass clear across the field, but were of a length corresponding to the width of the coronal image on the slit. At the base of the spectrum, which corresponded to the base of the corona, they appeared bright and sharp; certainly quite as much so as in the light of the moon similarly condensed; though the continuous spectrum which formed their background was relatively brighter than in moonlight. There was no difficulty in identifying them as Fraunhofer lines from their general appearance and position; but some of them could be identified beyond question. Such were *b* and *F*, which were especially distinct, and *D*, *E* and *G* which were considerably less so. They faded gradually out from the base of the spectrum upward, appearing to end where the continuous spectrum of the corona was limited above. While thus employed, a flash of sunlight told us that totality had ended and that the solar eclipse of 1878 was over.

In discussing the results of the spectroscopic observations which have now been detailed, I am, in the first place, quite at a loss to account for the fact that no bright lines were seen by me, notwithstanding the persistent efforts made to get them. The failure to observe them can be accounted for, as it would seem, only on the ground that with the dispersive power employed, the bright lines were too faint to be seen on the much brighter background of the continuous spectrum.

The lessons to be drawn from these spectroscopic observations appear to be few and simple. The absence of bright lines, or at least of any which were at all brilliant, proves clearly the absence in the solar coronal region of any considerable mass of incandescent gas or vapor, which shining by its own light would of course give a bright-line spectrum. The presence of

Fraunhofer lines in the coronal spectrum shows conclusively the presence of reflected sunlight in the light of the corona and goes to establish the theory, long ago suggested, that masses of meteoric matter raining down upon the solar surface from all directions reflected to us the light of the sun, and were, therefore, the essential cause of the coronal phenomena. And, finally, the fact of the increased brightness of the continuous spectrum, as compared with the intensity of the dark lines of Fraunhofer, goes to strengthen the probability that there is still other light in the corona which comes to us from the incandescent liquid or solid matter of these intensely heated meteoric masses. These conclusions, deduced very simply from my own spectroscopic results, agree completely, I am happy to find, with those drawn from your most excellent photographs, as well as from the ingenious heat-measurements of Dr. Edison and the polariscopic determinations of Dr. Morton.

In concluding this Report, you will permit me I am sure, to express the great gratification which the Draper Eclipse Expedition has continually afforded me. The delight at being able to witness a total eclipse of the sun, has been intensified by the complete success of all the attempts made to observe it, and by the most agreeable companionship during the trip. My obligation to you for the opportunity is as profound as my thanks to you for it are sincere and cordial.

Truly yours,

GEORGE F. BARKER.

Philadelphia, August 10th, 1878.