

construction, to see it at all, and the experience of Professor Lord at Barnesville, who observed it with a more powerful instrument, a prismatic camera, but found it surprisingly faint.

Of visual observations, besides the observations of contacts, naked-eye and telescopic drawings of the corona were secured, three of which are of much merit. These, as well as all the photographs, show the striking similarity between the coronas of 1878 and 1900.

Observations of the shadow bands were secured at many places from Georgia to the coast. While some of the observations are apparently conflicting, there seems to be no doubt from a study of their irregular structure and motion at the many stations that they are of purely atmospheric origin, and will probably find their explanation in the same causes that produce the twinkling or scintillation of the stars.

S. J. BROWN.

A PRELIMINARY STATEMENT OF THE RESULTS OF THE SMITHSONIAN OBSERVATORY ECLIPSE EXPEDITION.[†]

IN accordance with a special act of Congress, the Astrophysical Observatory of the Smithsonian Institution was enabled to send an expedition to observe the total eclipse of May 28, 1900. This expedition was directed and the preliminary arrangements for it were made by Mr. S. P. Langley, Secretary of the Smithsonian Institution, the field work and immediate supervision being in charge of the writer. The party consisted of fourteen persons, and the site chosen for the observations, which was selected not only after consideration of the Weather Bureau's reports for the eclipse belt, but also after a careful examination of various localities, was Wadesboro, N. C. The instruments and equipment were placed upon ground most generously offered for the purpose by John Leak, Esq., of Wadesboro, to whom and to many other citizens of the town are due hearty thanks for the hospitality enjoyed there by the large number of visiting astronomers. The Yerkes Observatory party was on the same ground, and there were also in Wadesboro expeditions from the Princeton Observatory and from the British Astronomical Association, making in all a most pleasant international gathering.

As the most thorough preparation and drill was recognized by Mr. Langley to be one of the prime conditions to success in eclipse observations, several months were almost wholly devoted to preparing for

[†] Published by permission of the Acting Secretary of the Smithsonian Institution.

the expedition. The whole outfit was set up upon the green south of the Smithsonian building, in Washington, early in April, and preliminary experiments and even two practice eclipses, in which actual photographs were taken, were carried through there. The apparatus was removed to Wadesboro very early in May and reached the grounds May 7, and here also all things were tested and drilled, that nothing might be lacking to a satisfactory result. On the morning preceding the eclipse a "full-dress rehearsal" took place, at which every detail was attended to as if the phenomenon was actually occurring, Mr. Langley remarking that if a pin was going to fall and be picked up during the eclipse it should be dropped and picked up for practice in that rehearsal.

The main object of investigation of our party was the corona, and of this it was desired, first, to obtain large-scale photographs of the inner details, with other photographs showing the extent of the corona, and second, to examine the inner corona with the aid of the bolometer to obtain thermal evidences of coronal radiations and, if possible, of the form of its prismatic spectrum energy curve.

In addition to these investigations, five cameras of large field were used to photograph the region around the Sun, visual telescopic observations and sketches were made, and the times of contacts were observed visually and with a camera exposed each second by a chronometer. An objective prism used in connection with the 135-foot focus camera was used also with an automatic exposure to obtain the flash spectrum at second contact.

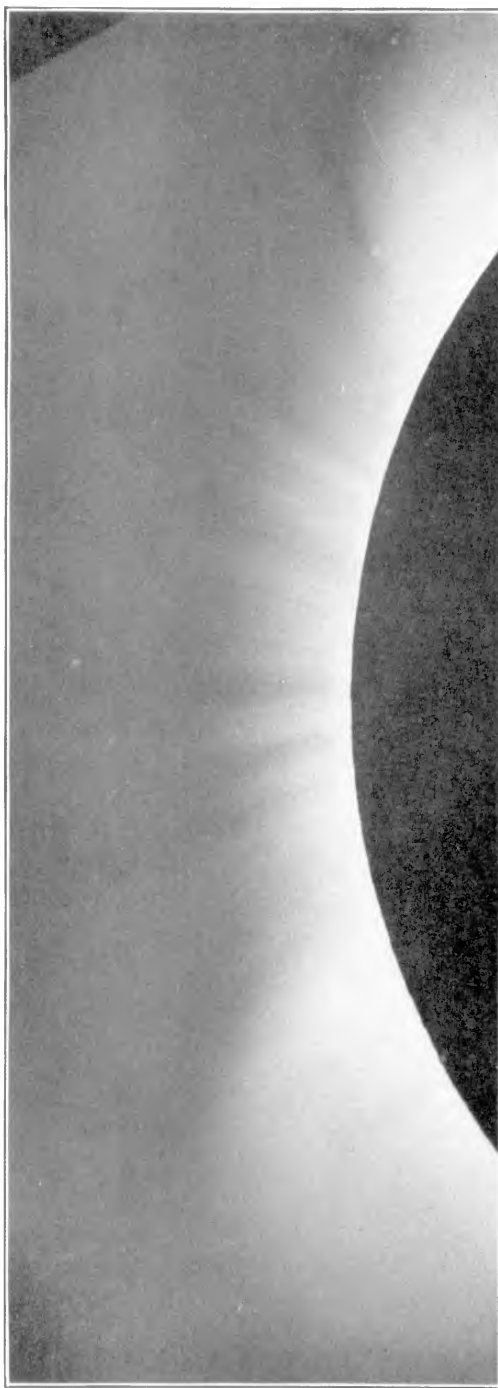
Before proceeding further it may be said that all these investigations yielded interesting results excepting the last, which from some unknown cause was unsuccessful.

I will now briefly describe these several kinds of observations, the instruments employed in them, and their results.

I. DETAIL PHOTOGRAPHS OF THE INNER CORONA.

Mr. Langley had long been specially interested in the details of structure of the inner corona in consequence of the surprising definiteness in this respect noted by him in visual telescopic observations made at Pikes Peak in 1878. While knowing and admiring the fine photographs of Campbell, and earlier of Schaeberle, with a 5-inch 40-foot focus lens, it was his belief that still more of structure might be obtained with an instrument of greater aperture and focal length. He

PLATE VI



THE NORTH POLAR STREAMERS OF THE CORONA
PHOTOGRAPHED WITH A 12-INCH TELESCOPE OF 135 FEET FOCAL LENGTH BY T. W. SMILLIE

was on the point of ordering a lens of 8 inches aperture and 60 feet focus for this purpose, when he received the extremely welcome offer of Professor E. C. Pickering of the loan of the new 12-inch achromatic lens of 135 feet focus belonging to the Harvard College Observatory. At the same time, Professor Pickering offered several other pieces of optical apparatus, including that for the automatic flash spectrum with the objective prism. It is needless to say that this most generous offer was accepted.

In addition to the great 12-inch lens, one of the set of "Transit of Venus" lenses, of 5-inch aperture and 38-foot focus, was used through the kind offices of Professor Young, of Princeton.

The former was employed as a horizontal telescope in connection with the 48-hour polar axis type of coelostat carrying an 18-inch plane mirror, while the latter was pointed in a stationary position toward the sky and the photographic plate moved in the focus by a water clock. The first instrument had 30-inch square plates, and was manipulated by Mr. T. W. Smillie, of the United States National Museum (who also had general charge of photography, including the development of all plates), and the second, employing 11×14 plates, was in charge of Mr. F. E. Fowle, Jr. The plates used, not only in this but in all the photographic work, were Cramer double coated isochromatic plates, not backed. They were extremely rapid, being for general purposes nearly twice as fast as Seed's 26x ordinary.

Six exposures were made by Mr. Smillie during totality, ranging from $\frac{1}{2}$ second to 16 seconds. All these were entirely successful. Three others made after totality showed little of interest. The illustration (Plate VI) is from a print of the 16 seconds exposure. All the original plates (on a scale of $15\frac{1}{2}$ inches for the Moon) are full of detail, the prominences being very striking. There seems to be no question that the details are more numerous than those shown upon the smaller scale of the 38-foot lens.

Mr. Fowle obtained seven negatives with this latter instrument during totality, all of which are excellent. The times of exposure varied from $\frac{1}{2}$ to 8 seconds. The 8 seconds exposure shows the corona somewhat further than the 16 seconds exposure with the great lens.

II. BOLOMETRY OF THE INNER CORONA.

This was in the hands of Mr. C. E. Mendenhall and myself, he reading at the galvanometer, I manipulating the optical apparatus. As

the results obtained seem to be of importance in their bearing on the composition of the corona, a diagram of the apparatus is inserted (Plate VII) that a clear understanding of the experiment may be obtained.

The light from the Sun, falling upon the plane siderostat mirror of 17 inches aperture, passed first through a cats-eye diaphragm of gray cardboard controlled by Mr. Mendenhall. Thence it fell upon a 50 cm mirror of 1 m focus, and came to a focus upon the slit, 1 cm high, 1 mm wide, in the optical axis of the mirror. Behind this slit was a little plane mirror which reflected the beam out of the path of the entering light to a second plane mirror, thence to a concave, of 26 cm aperture and 75 cm focus, acting as a collimator.

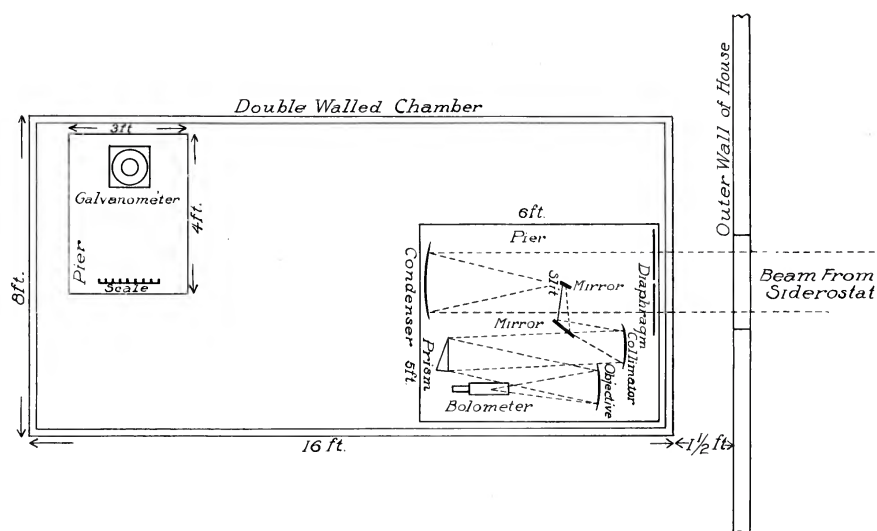
Thence the beam passed to the prism silvered on one face which was intended to serve either of two purposes as desired: to refract or merely to reflect the beam to the mirror of 26 cm aperture and 75 cm focus which formed the image on the 1 cm high, 1 mm wide bolometer strip. There was no plate of glass or other material in front of the bolometer during the experiments, as the galvanometer was found steady enough without, nor was any water in the bolometer water-jacket, as no "drift" was encountered. The case of the bolometer had a conical blackened opening just taking in the cone subtended by the image-forming mirror. A dark gray card was sometimes inserted before the bolometer to give a zero reading. The resistance of the bolometer strip was 0.5 ohm and the current flowing through it 0.2 ampere. The strip was well smoked with camphor smoke.

I have been thus particular to specify details, as I regard them necessary to an intelligent criticism of the results to be described.

About five minutes before totality the image of the diminishing crescent was brought almost tangent to the bolometer strip, and the silvered face of the prism turned to the beam. With the diaphragm aperture at 0.4 sq. cm, galvanometer deflections diminishing from +60 to +6 mm were obtained in the next few minutes, the last being about 40 seconds before second contact. The zero of the series was obtained by inserting the gray card above mentioned.

Immediately after totality, the diaphragm having been enlarged to 280 sq. cm aperture, a deflection of —13 mm was obtained in the same place, *i. e.*, the inner coronal region, and upon turning the Moon's

PLATE VII



BOLOMETER HOUSE OF THE SMITHSONIAN PARTY

dark image upon the slit by means of the adjusting screw of the condensing mirror, a deflection of — 18 mm was observed.¹

Resetting upon the inner corona, the glass face of the prism being now turned to the beam, and H and K of the spectrum being on the bolometer, no deflection was observed.

These observations seem to me to yield the following results:

1. The coronal radiation was recognized by the bolometer, and gave at least 5 mm deflection over that of the dark Moon.
2. The radiation reflected by the Earth's atmosphere during the partial phase is vastly more intense than that of the corona.
3. *The corona is effectively cooler than the bolometer, and appears, therefore, neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature, or at least with the preponderance of infra-red rays usual in the spectra of hot bodies.*

As the last statement involves a rejection of both the eruptive and meteoric coronal theories, it ought to receive searching criticism, and the experimental observations on which it rests ought to be verified at future eclipses. The statement depends on the following experimental evidence:

The corona gave a negative deflection with respect to a card and to the walls of the room as reflected by the glass prism surface, both being supposed to be at the same or a lower temperature than the bolometer strip. From this it follows that the bolometer strip was losing energy by radiating toward the corona, not the corona toward the strip. That the card, the walls of the room reflected by the glass prism surface, and the bolometer were all of the same temperature, is open to question. But they were all in a fairly constant temperature double-walled room, close together, and all at the same height from the ground. The bolometer strip, however, may probably have been a little *warmer* than the others, for it had constantly passing through it the current of 0.2 ampere. Hence it would appear most probable that the card reading was not the true zero which would be given by a body at the temperature of the bolometer, but a negative value, and

¹ Owing to a slight maladjustment of the condensing mirror not noticed till it was too late to change, the image of the Moon fell a little too low at the slit, so that a little of the polar corona fell on the bolometer strip during the Moon exposure, and hence the negative deflection of 18 mm should be numerically increased slightly.

that in consequence the negative deflection recorded from the corona should have been numerically still larger.

I am unaware of quantitative experimental investigations on the heating effects of radiations emitted from the spark and glow electrical discharges in high vacua, from phosphorescent substances, from so-called luminescent substances, from the aurora and other such supposedly cold sources, excepting the investigation¹ of S. P. Langley and F. W. Very on the "Cheapest Form of Light," in which they show a nearly complete absence of radiations other than visible ones from the tropical insect *Pyrophorus Noctilucus* Linn. But it is generally supposed that the quality of radiations emitted by the sources of light I have mentioned is not similar in nature to that of heated bodies in having associated with the light emitted a preponderance of long wave-length rays.

It is hoped to investigate here the glow and spark electrical discharges with a view to their possible bearing on the coronal observation I have just recorded.

It may not appear conclusive to some that these results are inconsistent with the supposition that the corona gives light by reflection, or by the radiation of heated particles, nor do I wish to make a dogmatic statement to this effect. Evidently it is not inconsistent with the experiment that a small portion of the coronal light may be due to these sources, but that most of it is thus caused I am unable to reconcile with the observations. For we know that the full Moon is intrinsically less bright than the inner corona and the daylight sky not much more bright. Both these bodies give light by reflection from the Sun, and both give large positive deflections with the bolometer, chiefly caused by the preponderating amount of infra-red rays they reflect. How then can the corona be composed of particles sufficiently numerous to give a practically continuous surface brighter than the Moon if it shines by light reflected from the Sun, and not give a large positive indication at the bolometer? Again, as regards incandescent particles, we know that white light due primarily to high temperature is invariably associated with a far larger proportion of infra-red rays. How is it possible that incandescent particles sufficiently numerous to give the coronal light should not give bolometric evidence of their high temperature, but rather give the appearance of being cold?

The bolometric study of the Moon may suffice to illustrate either the reflection or incandescence theories. For the Moon is but a mirror

¹*Am. Jour. Sci.*, 40, 97, 1890.

reflecting light from an incandescent body, the Sun. The bolometric studies of Langley (*Mem. Nat. Acad. of Sci.*, Vol. III, p. 24, 1884) have shown that with fairly similar arrangements to those used at Wadesboro the full Moon's reflected visible rays plus her reflected invisible rays gave enormous positive deflections. How then can a beam from the corona containing at least an equal amount of visible rays give so much less a deflection, except the infra-red rays be absent? If this be the explanation, the radiations of the corona are not of the quality ordinarily emitted by a heated body.

Additional evidence against the theory of reflecting particles is found in the Indian eclipse spectroscopic results of Campbell, who found a continuous spectrum from the inner corona with total absence of dark lines.¹

If, then, an investigation of glow electrical discharges in high vacua should be found to yield effects approximating those of the corona, it would seem plausible to adopt this explanation of coronal light.

III. PHOTOGRAPHS OF THE OUTER CORONA AND SKY NEAR THE SUN.

Four photographs of the outer corona were obtained. The instruments used were: first, an equatorial of 6 inches aperture and $7\frac{1}{2}$ feet focus, in charge of Mr. De Lancey Gill, used with color screen cutting off the violet; second, two Ross lenses of $4\frac{1}{2}$ inches aperture and $3\frac{1}{2}$ feet focus, one of which had a color screen; and, third, one of a pair of 3-inch lenses of 11 feet focus. The two Ross lenses and the two 11-foot lenses were mounted on a polar axis with excellent clockwork and were designed to search for possible objects of interest near the Sun. They were in charge of Rev. G. M. Searle, C.S.P., assisted by P. A. Draper and C. Smith. Incidentally they give a test of the advantages of the long and short focus for star photographs on a fairly light sky. All the instruments just mentioned were given an exposure of 82 seconds.

The four coronal photographs showed an extension of about three diameters, that with the $7\frac{1}{2}$ -foot focus lens being slightly longest while that with the 11-foot focus lens showed best detail.

The two 11-foot focus lenses (covering together a field of $25^\circ \times 10^\circ$ or thereabouts in the equatorial region of the sky) showed most stars, reaching, I think, the seventh magnitude and possibly fainter. The Ross lenses got no farther than the sixth magnitude, but their plates were not as favorably developed. No search has yet been made for new objects.

¹ This JOURNAL, April 1900.

IV. VISUAL OBSERVATIONS.

Visual observations of the corona were made by Secretary Langley, observing, through the courtesy of Professor S. J. Brown, astronomical director of the Naval Observatory, with the 5-inch equatorial formerly used by him on Pikes Peak and reemployed with the especial intention of enabling him to compare his observations on this occasion with those made in 1878, and by Mr. R. C. Child, with a 6-inch equatorial. Their observations showed little detail in the coronal structure compared with that formerly noted. Mr. Child, before having seen photographs, prepared from his sketches an excellent picture in pastel of the corona, and this is strikingly like the photographs subsequently developed.

Mr. G. R. Putnam, of the Coast Survey, detailed for latitude and longitude observations, determined times of contact and gave signals to the other observers. It appears from his observations and those of Rev. Fr. Woodman that the duration of totality was not appreciably different from that which had been computed from the American ephemeris. Mr. Putnam's latitude and longitude, the result of five nights observations with a reversible meridian transit instrument, was as follows:

Latitude, $34^{\circ} 57' 52''$ North.

Longitude, $80^{\circ} 04' 27''$ West of Greenwich.

The photographic time of contact results are not as yet reduced.

On the whole the results of the expedition are satisfactory. Those of chief importance now appear to be:

1. The bolometric examination indicates that the coronal light is not chiefly due to reflecting or incandescent particles, and that its radiations, though measurable, are extremely slight.
2. The 12-inch 135-foot telescope with coelostat proved well adapted to securing detailed photographs of the inner corona, and six excellent photographs have been obtained with this instrument.
3. The plan outlined in a recent Harvard College Observatory *Circular* for photographing faint objects in the sky near the Sun at the time of the eclipse gave good results in practice, seventh and possibly eighth magnitude stars having been photographed over a region $25^{\circ} \times 10^{\circ}$ in the direction of the Sun's equator.

C. G. ABBOT.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY,
Washington, D. C., June 30, 1900.