an hour, in a direction from southwest to northeast. As totality approached, the interval between the bands diminished, till they were only an inch or two apart, and the speed of their apparent motion increased enormously—to the velocity of an express train. After totality they were more irregular, close together, with no decided progressive motion, but simply quivering or oscillating. They lasted about a minute and a half before fading out. Mr. Reilly attempted to photograph them upon the inclined tent-fly, but got nothing.

It is noteworthy that the motion (real or apparent) observed at our station before totality was exactly opposite in direction to that noted by the Smithsonian observers less than a quarter of a mile away.

C. A. Young.

Princeton, N. J.,
June 30, 1900.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.

BULLETIN NO. 14.

OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900, AT WADESBORO, N. C. ¹

The Yerkes Observatory eclipse party occupied an excellent site adjoining that of the Smithsonian Institution at Wadesboro, N. C., for the use of which we are indebted to Mr. John Leak.* The latitude of the site was determined by Professor A. S. Flint, of the Washburn Observatory, who was a member of our party, but as his observations are not yet reduced, the results here given are based upon the following determinations of position made at the Smithsonian site by Mr. G. R. Putnam of the U. S. Coast and Geodetic Survey:

\[ \phi = 34^\circ 57' 52'' \text{ N.} \]
\[ \lambda = 5^h 20^m 17'.88 \text{ W} \]

¹As it was not definitely known until after the middle of April that it would be possible to send out an eclipse expedition from the Yerkes Observatory, the work of preparation was very hurriedly done. For this reason the instrumental equipment was less complete than it would otherwise have been, and many appliances for facilitating the observational work could not be provided. Special credit is due to Mr. G. W. Ritchey, Superintendent of Instrument Construction, not only for designing most of the instruments and buildings required, but also for superintending their construction at a time when the optical work demanded his constant attention.
CONTACTS.

Contacts were observed by Professor Flint from a station near the coelostat with a 3-inch equatorial of 46 inches focal length, power 50. The chronometer, Bliss 2791 on sidereal time, was loaned by the Washburn Observatory. The observer's primary duty was to call out every 5 seconds of elapsed time for control of the spectroscope exposures made by Professor Frost and Dr. Isham. Beginning at the first stroke of the signal of five bells (sounded by Mr. Putnam), which was to mark an interval of 60s preceding the computed time of second contact, a count was made at the chronometer beat, starting at 0s. At 60s, or at computed second contact, the call was started, again from 0s. During totality two comparisons were made of the count with the chronometer readings, and two others were made after third contact. A part of the record, including the last two comparisons, is unintelligible, but the later comparisons agree with the second in showing that the difference between the chronometer and the count was a multiple of 5s. Hence, in the first comparison, although the seconds are recorded as 46s, they are assumed to be 45s. The chronometer corrections to reduce to sidereal time of station were computed from comparisons with the Washington noon signals.

OBSERVED TIMES OF CONTACTS, MAY 27.8, 1900, ASTRONOMICAL MEAN DATE.

<table>
<thead>
<tr>
<th>Contact</th>
<th>Chron. Time</th>
<th>Correction</th>
<th>Local Sidereal Time</th>
<th>Local Mean Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h m s</td>
<td>m s</td>
<td>h m s</td>
<td>h m s</td>
</tr>
<tr>
<td>1st</td>
<td>23 37 49.</td>
<td>+ 0 33.4</td>
<td>23 38 22.4</td>
<td>19 15 59.5</td>
</tr>
<tr>
<td>2nd</td>
<td>0 47 03.0</td>
<td>+ 0 33.6</td>
<td>0 47 36.6</td>
<td>20 25 2.3</td>
</tr>
<tr>
<td>3rd</td>
<td>0 48 30.</td>
<td>+ 0 33.6</td>
<td>0 49 3.6</td>
<td>20 26 20.1</td>
</tr>
<tr>
<td>4th</td>
<td>2 7 30.</td>
<td>+ 0 33.8</td>
<td>2 8 3.8</td>
<td>21 45 16.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact</th>
<th>Gr. M. T. Observed</th>
<th>Gr. M. T. Computed</th>
<th>O—C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h m s</td>
<td>m s</td>
<td>s</td>
</tr>
<tr>
<td>1st</td>
<td>0 36 17.4</td>
<td>36 10.</td>
<td>+ 7.</td>
</tr>
<tr>
<td>2nd</td>
<td>1 45 20.2</td>
<td>45 23.6</td>
<td>— 3.4</td>
</tr>
<tr>
<td>3rd</td>
<td>1 46 47.0</td>
<td>46 55.6</td>
<td>— 8.6</td>
</tr>
<tr>
<td>4th</td>
<td>3 5 34.2</td>
<td>5 43.</td>
<td>— 9.</td>
</tr>
</tbody>
</table>

1 26.8 1 32.0 — 5.2
No significance is attached to the tenths of a second except in the case of the second contact.

PHOTOGRAPHS OF THE CORONA.

The corona was photographed with eight lenses as described below.

The principal instrument was a horizontal telescope of 61 ½ feet focus, fed by a coelostat. The 6-inch photographic objective of this telescope was made by Brashear, and gave photographs of the corona on a scale of 13 inches to the degree. The coelostat was constructed in the instrument shop of the Yerkes Observatory under the supervision of Mr. Ritchey, who himself made the very perfect silvered plane mirror of 12 inches aperture. The same mounting carried a 15-inch plane mirror by Petitdidier for Professor Frost's spectroscopic work. The 6-inch objective was connected with the photographic house by a long light-tight tube, shielded from the Sun's rays by a white cotton screen, and fitted throughout with diaphragms to prevent internal reflections. The light-tight photographic house, 6 feet wide and 30 feet long, stood with its long axis perpendicular to the tube. In order to facilitate handling the large photographic plates employed, they were mounted on a wooden carrier 15 feet long, free to move on ball bearings on a steel track extending the entire length of the photographic house. In this carrier the plates were all placed at an angle equal to the latitude, so that the long axis of the plates was parallel to the celestial equator. A catch operated by hand served to stop the carrier at the proper place for each exposure.

With this apparatus seven plates were exposed during totality. Details of these exposures are given in the following table:

<table>
<thead>
<tr>
<th>No. of plate</th>
<th>Exposure</th>
<th>Size</th>
<th>Make</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>½ second</td>
<td>14×17 in.</td>
<td>Cramer D. C.</td>
<td>Not backed</td>
</tr>
<tr>
<td>2</td>
<td>2 seconds</td>
<td>14×17</td>
<td>Cramer Crown</td>
<td>Backed</td>
</tr>
<tr>
<td>3</td>
<td>8 &quot;</td>
<td>25×30</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>30 &quot;</td>
<td>25×30</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>5</td>
<td>14 &quot;</td>
<td>25×30</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>6</td>
<td>4 &quot;</td>
<td>25×30</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>7</td>
<td>1 second</td>
<td>14×17</td>
<td>Cramer D. C.</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

The very sensitive plates employed were made expressly for this purpose by the Cramer Company. They were carefully backed, with a

*Double-coated. The first plate was purposely left unbacked.*
GROUP OF PROMINENCES IN SOUTHWEST QUADRANT

PHOTOGRAPHED WITH A TELESCOPE OF 6 INCHES APERTURE AND 6½ FEET FOCAL LENGTH BY E. E. BARNARD AND G. W. RITCHEY
solution of caramel and burnt sienna in a little alcohol, by Professor Barnard the night before the eclipse and mounted in the carrier. The backing used, which Professor Barnard had adopted after a series of careful experiments, would not dry rapidly in the moist climate of Wadesboro, and had to be protected with pieces of soft paper covering the backs of the plates, which served the purpose perfectly.

The exposures were made with a wooden shutter, which could be moved across in front of the lens by cords leading into the photographic house. Mr. Ritchey stood at the carrier and moved the successive plates into position for exposure. At the signal from him the exposure was made by Professor Barnard, the proper interval being counted from a telegraph sounder beating seconds in the room.

The previously arranged program was successfully carried out. From the adjoining camp of the Smithsonian party the signals at the beginning of totality and 10 seconds before the close were struck on a bell which could be plainly heard in the photographic house. At the first of these signals the exposures were immediately begun. At the last signal preparations were being made for the last exposure, and when the image was seen on the plate the Sun had just made its appearance, though the interval from the signal could hardly have exceeded four seconds.

The plates were developed at the Yerkes Observatory by Professor Barnard with pyro developer, which he had found to give softer and more transparent negatives than any other developer tried. The resulting negatives offer abundant evidence of the advantage of long focus objectives for photographing the details of the corona. The greatest extension of the equatorial corona is about 40' from the center of the Moon. The whole of the inner corona is well shown, but to bring out extensions of a degree or more would have required an exposure of not less than a minute. The polar fans are shown with remarkable beauty on these plates, and the inner corona is full of detail. In the area covered (1°9 × 2°2, the longer direction parallel to the equator and the Sun central), four fixed stars are clearly shown, both on the 14-second and 30-second exposures, while at least two appear on the 8-second exposure. These stars are:

\[
\begin{align*}
\text{DM.} & \quad +21^\circ 642 & \quad 4.3 \text{ magnitude} \\
& \quad +21 \ 643 & \quad 6.0 \\
& \quad +21 \ 647 & \quad 6.5 \\
& \quad +20 \ 751 & \quad 6.2 \\
\end{align*}
\]
It would thus appear probable that no intra-mercurial planet, photographically as bright as the 6.5 magnitude, was in the region covered by the plates at the time of the eclipse.

A discussion of certain important facts brought out in these large photographs of the corona will be published hereafter. Briefly, however, it may be said that there seems to be no very striking connection between the prominences and the coronal details, such as was suggested by the photographs of the Indian eclipse of 1898.

The other instruments used included a 6-inch and a 3½-inch portrait lens, carried on an equatorial mounting kindly loaned by Professor Comstock of the Washburn Observatory. Three exposures each, of 15 seconds, 30 seconds, and 12 seconds, were made by two gentlemen who kindly volunteered their services, but as the driving-clock did not perform well the image of the corona drifted during the exposures.

Two cameras fixed rigidly to a post, a 4½-inch portrait lens by Brashear and a Voigtländer lens of 4 inches aperture and 8 inches focus, were exposed for 1 second, 2 seconds, and 4 seconds by Mr. Wolff, janitor of the Yerkes Observatory. The Brashear lens gave excellent results, the corona being carried three fourths of the distance to Mercury with a single second exposure. The negatives made with the Voigtländer lens are less successful, but the rapidity of the lens is attested by the fact that Mercury gave a reversed image with 1 or 2 seconds exposure.

Several photographs of the corona were also secured with smaller lenses, but in no case do the streamers extend more than about three fourths of the distance to Mercury. As the images are too small for successful reproduction, Mr. P. R. Calvert has very kindly made an excellent drawing (Plate I) combining the different pictures made with the small instruments with some details supplied from the larger photographs. In this drawing the coronal streamers have not been carried as far out as they can be traced on the small pictures.

Professor Barnard states that a glance at the corona projected on the plates in the coelostat house showed at once that it was almost a duplicate of the corona of January 1, 1889, and the images on the small plates fully confirm this impression. It is evident that this form is characteristic of the period of Sun-spot minimum. The prong-like projection to the east, the wide flaring streamers to the west, and the beautiful polar fans form almost a duplicate of the corona of 1889.
SPECTROSCOPIC RESULTS.

The following slitless spectrographs, supplied with light from the coelostat, after a second reflection, were used by Professor Frost, who was assisted in making the exposures by Dr. George S. Isham:

1. A train of three prisms of very white flint glass (from the new stellar spectrograph), 2 3/4 inches high, curate face for 2 inches aperture, set at minimum deviation for \( \lambda 4227 \), with total deviation of 182° 30'. The resolving power of the train for this region is about 100,000. Photographic camera objective of 3 1/4 inches aperture and 42 inches focus. Cramer Crown plates.

The plate-holder was one belonging to the solar spectroscope, and could be moved in a direction perpendicular to the length of the spectrum, so that several exposures could be made on one plate, avoiding loss of time in changing plates. Thus the spectra of the cusp, of the first flash, and of the corona were taken on one plate, and those of the second flash and of the cusp after totality on the second. The plates were cut during development, so that development of the coronal exposure could be pushed further than for the other exposures.

Exposures: Cusp, 15 seconds before totality (1/2 second), first flash (2 seconds), corona (30 seconds), second flash (about 2 seconds); cusp, 10 seconds after totality (1/2 second).

2. Concave grating of 60 inches radius; ruled surface 1/8 inches, 14,438 lines per inch. \( \lambda 4600 \) (first order) at middle of plate. Cramer Crown plates. Used direct, without slit or image lens.

Exposures: First flash and second flash, each intended to be of about 2 seconds.

3. Plane grating of 2 1/2 inches surface, 14,438 lines per inch, second order, set for the yellow region. Objective of 2 inches aperture and 20 inches focus. Used by Professor Frost for visual observations of the flash, to give the signal for other spectroscopic exposures.

At 45 seconds before totality the dark lines were very sharply defined in the quite limited field of view of the eyepiece. The bright helium line \( D_3 \), showing prominences, was seen perhaps 10 seconds before totality, and other lines, appeared in succession as totality approached. There was, however, no such multitude of lines reversed as had been expected by the observer, some fifteen or twenty lines being visible when the observer gave the signal for exposing the objective-prisms and concave grating, and himself made the exposure for the red portion of the spectrum.
4. Plane grating of 5 inches ruled surface, 20,000 lines per inch, used in first order, in front of a visually corrected lens of 3½ inches aperture and 42 inches focus, for photographing cusp and flash spectra in the red portions of the spectrum with Erythro plates. A rather too thick color screen of red glass was inserted for cutting off the overlapping violet of the next order.

Exposures: First flash (about 5 seconds), corona (55 seconds), second flash (7 seconds), cusp after totality (½ second).

First flash.—On the photograph taken with the prism train 70 bright lines have been measured between λ4070 and λ4340. No dark lines are shown on the plate. The concave grating negative shows about 70 measurable bright lines between Hβ and Hδ, and no dark lines.

Second flash.—On the photograph taken with the prism train 266 bright lines have been measured between λ4026 and λ4381 (Fig. 1, Plate IX). Some dark lines are visible, especially at the violet end of the plate. The bright lines are there found to be at the violet edges of the dark lines.

In attempting to determine the identification of the lines from Rowland’s list of wave-lengths the following points are noted:

There is a marked dissimilarity from the solar spectrum, particularly in regard to the intensities.

A large number of the identifications which appear most probable are found to be with lines designated in Rowland’s list as N, or N d ?; that is, with lines which are nebulous or are difficult doubles. Professor Frost suggests that the nebulous character of these dark lines may be due to the superposition of the chromospheric light, and that the duplicity may possibly be on account of a reversal at the center of the dark line.

Aside from the lines of hydrogen and helium, the identification seems to be certain for numerous lines of iron, titanium, chromium, and several of calcium, strontium, vanadium, and zirconium. High level and low level lines can be to some extent differentiated by the length of the bright arcs.

The concave grating negative of the second flash shows about 150 lines, 110 between Hγ and Hδ in sharp focus. The bright lines generally seem to be on the violet side of the dark lines, with some exceptions.

Cusp at first contact.—The negative taken with the prism train shows a small number of bright lines superposed upon the strong solar
PLATE IX

Fig. 1.—The Flash at Third Contact

Fig. 2.—The Cusp Ten Seconds after Totality

Spectra photographed with objective-prism train by E. B. Frost
spectrum. Several strong lines near the middle of the plate indicate that the bright lines are on the violet side of dark lines. At the ends of the plate, however, the displacement would appear to be in the other direction, at least in the case of several lines.

Cusp at second contact.—About 250 bright lines between $\lambda$ 4058 and $\lambda$ 4375 have been measured in this cusp spectrum taken with the prism train (Fig. 2, Plate IX). Many of the bright lines appear to fall on the violet edge of the dark lines. Direct comparison of bright and dark lines shows marked dissimilarity between them.

Corona.—The plate exposed for the coronal spectrum with the prism train shows an intense continuous spectrum, and parts or the whole of seven rings, the wave-lengths corresponding to which are: $\lambda$ 4078 (chromospheric), $H\beta$, $\lambda$ 4216 (chromospheric), $\lambda$ 4230 (coronal), $\lambda$ 4311 (probably chromospheric), $H\gamma$, and $\lambda$ 4358 (perhaps coronal).

The exposures on the red portion of the spectrum, with plane grating, were insufficient, partly on account of the absorption of the color screen and partly on account of the less degree of sensitiveness of plates for these wave-lengths. The cusp spectrum shows a few dark and bright lines.

HEAT RADIATION OF THE CORONA.

Through the kindness of Secretary Langley the bolometric apparatus, with which the writer, assisted by Mr. Ellerman, intended to measure the heat radiation from the bright and dark parts of the corona, was used in conjunction with an 18-inch coelostat mirror mounted on the large siderostat of the Smithsonian party. The image of the corona was formed by a 20-inch silvered concave mirror, of 27 feet focus, made in the optical shop of the Yerkes Observatory by Mr. Ritchey. In the cardboard disk on which the image fell was a radial slit, 10 mm long and 1 mm wide, which could be rotated in position angle so as to receive radiations from any part of the inner corona. By means of a suitable combination of mirrors an image of the slit, formed on the fixed bolometer strip by a quartz lens placed beyond the principal focus of the concave mirror, was automatically kept from rotating when the disk revolved. The bolometer, which had to be made in Wadesboro a few days before the eclipse (on account of a serious change in resistance of the old bolometers while in transit from Williams Bay), was 10 mm long and 1 mm wide. The very sensitive galvanometer (figure of merit about $3 \times 10^{-16}$) was one made by Professor C. E. Mendenhall, who kindly loaned it for this occasion.
With a period of 5 seconds, and a battery current of 0.3 amperes through the bolometer, this apparatus gave a deflection of about 20 mm for a candle at a distance of 3 m from the bolometer strip with no lens or mirror interposed.

The apparatus was in perfect adjustment just before totality, but at the critical moment an accident disturbed the balance of the bolometer circuit, and sent the spot of light off the scale. The work of rebalancing the circuit was completed during the total phase, but just as the signal was given to expose the Sun reappeared. During the succeeding partial phase a large number of measures were made of the heat radiation of the sky near the Sun. Like many similar measures made at Williams Bay in previous years, they show no certain difference between the radiation of corona plus sky and sky alone. Fortunately Mr. Abbot's measures of the heat radiation of the corona explain this, and as they also answer the question which had led to our own eclipse work, its failure is of less consequence. The deflection which he obtained from the corona (as compared with the dark Moon) was very small—much smaller than had been anticipated. The bolometric apparatus used in our work at Wadesboro, as well as that of previous experiments, was rather more sensitive than that employed by Mr. Abbot, but the angular aperture of our concave mirror, and consequently the intensity of the (larger) solar image, has always been much less than his. Thus in our observations the difference between corona plus sky and sky alone has never been great enough to be detected. Further experiments, made in the hope of measuring in full sunlight the position angle of the edges of the great coronal streamers with an extremely sensitive radiometer, are now in progress at the Yerkes Observatory.

Arrangements had been made to photograph the chromosphere and prominences at the Yerkes Observatory at the time of the eclipse with the spectroheliograph attached to the 40-inch telescope, but clouds prevented.

ACKNOWLEDGMENTS.

It is a pleasure to be permitted to express our sincere thanks to all who contributed to the success of the expedition. We are indebted to the mayor and citizens of Wadesboro, who made every possible provision for our comfort and welfare during our stay in North Carolina;