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THE TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

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Fair weather and splendid success seem to have been the lot of most of the astronomers who were scattered all along the path of totality across the United States. Probably no eclipse has ever been so extensively and successfully observed and much is to be expected from the photographic and spectrographic results which have been obtained.

It is too early to have obtained copies of the photographs taken at the various stations, so that we can present in this number of Popular Astronomy only some of those obtained by our own party, but we shall expect to present others in due time.

The frontispiece is a reproduction of one of the photographs of the corona taken near the end of totality with the 8-inch photographic refractor belonging to Goodsell Observatory. The exposure was 5 seconds, on a Seed nonhalation plate, backed with a paste of lampblack in 6 parts of essence of cloves to 1 part of turpentine. The plate was developed with weak pyro developer. It shows the two great streamers of the corona extending toward the west and one toward the east to the edge of the field of the telescope, besides many small streamers, some within and some alongside of the large ones. The polar streamers and rifts are well defined and their curvature is quite marked. At the lower right hand edge of the Moon's disk a row of brilliant prominences may be seen, one extending one-sixteenth of the Sun's diameter, or 54,000 miles from its edge. The photographic print shows these prominences much less plainly than the negative, and in the engraving they may be expected to be almost wholly lost.

The expedition from Carleton College to observe the eclipse was made possible by the generous enthusiasm of the junior class in the college, a large part of which has been studying Young's General Astronomy during the fall and winter terms, and Campbell's Practical Astronomy during the spring term. The class voted to defray the expenses of the expedition to the extent of one hundred and fifty dollars. We are greatly indebted

also to the officials of the Chicago Great Western railway, through whose courtesy the party and instruments were conveyed to Chicago and back free of charge. Mention should also be made of the kind interest shown by the officials of the Chicago and Eastern Illinois and other roads, over which we passed, in their successful efforts to have our instruments handled carefully in transit.

The Faculty and trustees of Guilford College, near Greensboro, N. C., were much interested in the expedition and contributed largely to its success, in securing a favorable location, furnishing entertainment and rendering valuable assistance in the observations, a large party of the teachers and students being present at the observing station and taking assigned parts in the work.

The expedition was located near Southern Pines, N. C., on an eminence upon the large fruit farm of Mr. John Van Lindley, who very generously offered us the use of his commodious house and grounds, and bore the expense of our maintenance there. The Carleton party consisted of the writer as the astronomer in charge, with Professor and Mrs. A. H. Pearson, of Carleton College, as assistants. Mrs. Clements, of Faribault, also accompanied the party to North Carolina and assisted in sketching the corona. Our apparatus consisted of the 8-inch Clark photographic telescope of 9 ft. focus, the 6-inch Brashear stellar camera of 3 ft. focus and the 2½-inch Darlot lens of about 8 inches focus, all upon the same mounting and driven by clock work. With this apparatus, which was operated by the writer without assistance 8 photographs were taken: 4 of the corona during totality with the 8-inch telescope, the exposures being 1, 5, 30, and 5 seconds, the first two on Cramer crown plates and the last two on Seed nonhalation plates; 2 instantaneous exposures just a few seconds after totality upon nonhalation plates, both showing portions of the corona and chromosphere together with a reversed image of the sunlight crescent. With each of the cameras a single exposure was made, lasting 93 seconds, for the purpose of showing the outer extensions of the corona and any possible bright intra-mercurial planets. The last mentioned two photographs were both successful in showing the three long streamers of the corona extending out to at least two diameters from the edge of the Moon, but present only negative evidence of any bright planet other than Mercury near the Sun. Mercury is a conspicuous object upon both plates, but very few stars are noticeable.

The skylight was quite intense and comes out very black in the

negatives. It may be that when I get time to go over the plates systematically with a microscope I shall find many more star images than I think now are there.

The plate exposed in the 6-inch camera was an 8x10 Seed non-halation backed with essence of cloves and lamp black. The field covered was 16° in diameter. The plate exposed in the 2½-inch camera was a 4x5 Cramer slow isochromatic, covering a field of 30° diameter, 20° of which is quite sharp in definition. Both plates were developed with quite strong hydrochinon developer in order to bring out strong contrasts. Both plates give practically the same extent of coronal streamers. With the 6-inch camera the chromosphere comes out very brilliant and partially reversed, while the prominences are entirely reversed.

Another piece of apparatus used was a prismatic camera consisting of two small 60° prisms, and a 3-inch visual lens of 30 inches focus, which were mounted in a box constructed at our station, after the photographic telescope had been got into adjustment. We had not fully decided to use these but took them along in case we should find time to mount them, yet doubtful whether the prisms, 1½ inches face, would give light enough for successful photographs of the "flash" spectrum. We were urged by Professors Hale and Frost, whom it was our great pleasure to accompany from Chicago to Wadesboro, to by all means make the attempt. The result shows that the combination of these small prisms and lens was quite sufficient to give at least the chromospheric spectrum. We had no collimator along and had to depend for the focus upon the sharpness, visually, of the edge of the continuous spectrum of the Sun. We adjusted it in this way as nearly as possible for the visual spectrum from D to K and used Cramer's instantaneous isochromatic plates 5x8.

With this camera, stationary during totality, Professor Pearson, assisted by Mr. Kelly of Haverhill, Mass., made four exposures, one beginning at the instant time was called by myself for the beginning of totality, as seen through the 5-inch guiding telescope, and ending at the count of 3 seconds; another from 15 to 75 seconds for the purpose of photographing the coronal ring; a third beginning at 87^s and ending at the call of time for the close of totality; and a fourth as short as possible, at 100^s, 6 seconds after the sunlight reappeared.

The photographs show a spectrum 5 inches long extending from D_3 to a little beyond K. Unfortunately, in planning for the long exposure without driving apparatus, I placed the edge of the prisms parallel to the direction of diurnal motion, not rea-

lizing that the curved cusp-lines of the Sun and chromosphere would be very nearly perpendicular to this direction. As a result the lines cross each other, all being nearly tangent at their brightest parts to a line lengthwise of the spectrum. They are therefore not suitable for reproduction and will be difficult of measurement. The first shows 12 very prominent chromospheric lines besides about 85 lesser ones. The plate is too much fogged to show the coronium line. The second is much blurred of course by the drift during the 60 seconds exposure, but is very interesting. It shows 15 prominences around the elliptic rings corresponding to the *H* and *K* lines, each prominence being drawn out into a line by the drift. The brighter of these prominences are shown in several other lines of the spectum, notably D_3, *F*, *G'* and *h*. The coronal spectrum is continuous from below D_3, running off the plate above *K*. The spectrum of the polar regions is faint forming a dark center to the band of the continuous spectrum. In the place of "coronium" line a ring is faintly shown. I was not able to see it until today, but when once pointed out it is easily seen. There is a faint suggestion of another similar ring near *H* and *K*, a little less refrangible than *H*, at about wavelength 3988. It is very vague but seems to me to be of the same form as its neighbor *H*, except as to the prominences.

The third plate, exposed just before the close of totality was jarred so badly during exposure that it is useless, but the coronium ring is plainly shown. An exceedingly faint suggestion of a ring is shown near *H*, but not sufficiently definite to be used as a verification of that in the second plate.

The fourth plate exposed 6 seconds after totality came out a surprise to me. It was intended to give the dark lines in the solar cusp spectrum, but it does not show a single dark line that I can find. The west edge of the spectrum is continuous, (this may be partly due to the overlapping of the lines) while beside it is a beautiful bright line spectrum of one of the cusps, the lines most of them running into the continuous spectrum, and some of them exceeding it in brightness. I have counted 170 lines between D_3 and *K* and there are fragments of perhaps as many more. They are distributed as follows:

Below D_3	2	From *h* to *H*	15
From D_3 to *F*	37	From *H* to *K*	3
From *F* to *G'*	58	Beyond *K*	2
From *G'* to *h*	56		

I have been puzzled to account for the total absence of dark lines in this photograph, for several minutes before totality and

again after totality they were visible to the eye upon the ground glass of the camera. It would seem possible that we may have caught that moment when the radiations of the reversing layer and those of the reappearing photosphere were of equal intensity so that no reversal would be produced.

The party from Guilford College, associated with us, consisted of Professor George W. White and Mrs. White, Professor Robert W. Wilson, Professor Hodgins, Miss Field and students Walter Hobbs, Thomas Hinton, Homer Ragan, Lacy L. Barbee and Emmit Shepard. Professor White photographed the corona with a 3-inch visual telescope, exposing four plates for 1 and 2 seconds each during totality. He obtained four very good photographs of the middle parts of the corona. Professor Wilson counted off the seconds of time during totality, so that those making the photographic exposures might follow their assigned programs without looking at timepieces. Messrs. Barbee and Shepard noted on a sidereal chronometer and an ordinary watch independently the times of the contacts as observed by the writer with the 5-inch telescope. Professor Hodgins, Mrs. White, Miss Field and Mrs. Couts, under the direction of Mrs. Pearson, sketched portions of the corona, using white crayon on blue paper. Their results agree well with the photographs in the main features of the corona. Four of the students watched for the shadow bands and noted their direction.

Description of the Eclipse.

For a popular description of the eclipse the following abstract from an article in the Haverhill (Mass.) Evening Gazette, by Mr. Austin P. Nichols, who was present with our party during the eclipse, is as good as any I have seen:

"As the Moon crept further and further over the face of the Sun the interest and excitement increased. Several times each member of the party took their assigned places and while the astronomer in charge of the chronometer counted off the 94 seconds of expected totality, rehearsed the part they were expected to perform an hour later. The light gradually diminished and the air became somewhat cooler, but the change was not especially marked. The writer took his place on the roof of a barn, with instructions to note the approach of the shadow from the westward. Another member of our party had been impressed into the service of Professor Pearson to assist him in photographing the spectrum. The martyr to science who was to count the seconds, and was therefore debarred from seeing the eclipse, took charge

of the chronometer. A bewildered rooster gave a feeble, inquisitive crow, and all was in readiness for the great event.

"Five minutes, called the timekeeper, and everyone busied themselves to be sure that everything was all in order at the last moment—four minutes, three, two, one, and a great hush fell over the party like that which occurs between a lightning flash and the thunder clap. The sky rapidly darkened, except that around the horizon were tints of orange, and to the southwestward the country was wrapped in the gloom of the approaching shadow. Time! called the man at the telescope, and the eclipse was upon us.

"In an instant everything was transformed. The darkness was not intense, it was about that of late twilight, and the hands of a watch could easily be made out. Everyone was busy at their appointed task, not a sound was heard but the calling of the seconds by the timekeeper. Only 94 of them, and so much must be done in that brief time. One fairly begrudged every second as it was called off.

"Up in the heavens where an instant before had been the brilliant crescent of the Sun, hung the black disk of the Moon; around its edge was a narrow but brilliant ring of an indescribably beautiful pearly, silvery shimmering light—the inner corona. Extending out into space on either side of the Sun, like the wings of a gigantic bird, were the streamers of the outer corona less brilliant than the inner ring, but bright and equally beautiful. The light of this outer corona was not uniform but varied in intensity, giving the appearance of structure to it; the writer particularly noticed a leaf-like form in one of the wings, similar to those observed in previous eclipses. The outer corona wings were strikingly similar to the tail of a brilliant comet, in appearance, although nothing has yet been observed to indicate that they have the same composition. The length of these wings seemed to be from three to four times the diameter of the Sun, although to other observers they appeared much shorter. A few red prominences, due to masses of red hot hydrogen gas thousands of miles high, were also observed around the edge of the sun, but to the unaided eye they were not very conspicuous, and could only be seen to good advantage in a telescope. Close to the Sun the planet Mercury shone with an unaccustomed brilliancy, while lower down in the east Venus, the evening star, glowed even more brightly. No other stars were noticed.

"A more beautiful or more impressive scene is rarely witnessed, but the time was all too short. Probably no one who observed

the eclipse but felt that he had left something undone that he ought to have done, but one cannot do everything in a minute and a half.

"The monotonous counting of seconds continued—ninety-one, two, three, four. A flash of sunlight like the sudden lifting of a thunder cloud, the corona vanished like a burnt-out firework, familiar features of the landscape shone out again, and, except for a certain pale, ghastly light, which lasted for nearly half an hour, everything took on its usual appearance. Everyone heaved a sigh of relief, and the great eclipse of 1900 was a thing of the past."

THE CORONA.

The general form of the corona, as it appeared to me in the 20 seconds I had in which to look, while the 30 second exposure was going on, struck me as being very similar to that which I had seen in 1889; the difference being that it was reversed east and west, the two equal parallel streamers extending toward the west instead of east and the long single streamer with smaller attendants extending toward the east. Thus the view is confirmed which has been tentatively held for some years that certain types of corona are associated with the phases of the sunspot period, and that the type which corresponds to the sunspot minimum is characterized by great streamers parallel to the Sun's equator and by very marked polar filaments and rifts.

The four photographs taken by the writer with the 8-inch telescope do not show any noticeable changes in the structure of the corona in the one minute and a half. They differ from each other because of differences of exposure and of development. Comparing any one of them with Barnard's print of the corona of Jan. 2, 1889, one would almost say it is the same corona rotated half way round on the polar axis.

THE SHADOW BANDS.

These were seen three minutes before totality and for an equal length of time after totality. A white sheet was stretched upon the ground for these observations, but it was unnecessary for the bands could be seen all around us upon the light colored sand. They came approximately from the direction from which the great shadow approached, but the direction of movement was not constant and at one time it seemed to be from the northwest. The lines of the shadows were not smooth curves, but were sinuous and continually wavering. I had asked the young men,

if possible, to count the number of bands seen upon the sheet at once and how many passed in 10 seconds, but the movement was too swift for this and they could only catch the direction of the wave fronts by laying sticks down parallel to the bands. This they did four times, 3 minutes before totality; just as the great shadow came; just after it receded; and when they last saw the bands distinctly. The following angles with the meridian were measured by myself a few minutes after totality was over:

I S 42.°0 E. II S 37.7 E. III S 52.°4 E. IV S 37.7 E.

According to the map of the path of totality the direction of movement of the shadow was about N 60° E at Southern Pines.

Various estimates of the distance between the successive shadow bands placed it at from 6 to 8 inches.

OBSERVATIONS OF CONTACTS.

The four contacts were observed by the writer, the first three with the 5-inch guiding telescope of 9 feet focal length, the last with the 3-inch telescope belonging to Guilford College. The sidereal chronometer Bond 374 was compared by telephone with the signals transmitted from Washington to Pinehurst, N. C., on May 26 and 27 and with the mean time chronometer Negus 1749 at the U. S. Naval Observatory Station at Pinehurst on the afternoon of May 28, giving consistent rates between times. The watch used had a variable rate and the times noted on it are only rough checks of the chronometer times. The position of our station was determined by a rough triangulation from the station at Pinehurst and cannot be determined very exactly until certain data are obtained from that station, but the position was very nearly in longitude 79° 24′ and latitude 35° 12′. The predicted times calculated with these data before the eclipse are here given for the sake of comparison, for the observed duration of totality agreed exactly with computed duration, which does not appear to have been the case at all the stations.

	Bond 374.	Corrections.	Reduced Greenwich Time.	Watch (corrected) Central Standard Time.	Computed Greenwich Time.
	h m s	m s	h m s	h m s	h m s
First contact....	22 57 19.5	+ 43 48.6	0 36 45.1	6 36 41	0 36 48.2
Second contact.	0 07 02.0	+ 43 48 8	1 46 16.4	7 46 14	1 46 26 5
Third contact...	0 08 36.0	+ 43 48.8	1 47 50.1	7 47 48	1 48 00 6
Fourth contact.	1 28 01.7	+ 43 48.9	3 07 02.9		3 07 08.3

AT OTHER STATIONS.

Pinehurst, N. C.—As the United States Naval Observatory station at Pinehurst was only 3 miles to the west of our loca-

PLATE XII.

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At their Station near Southern Pines, N. C., May 28, 1900.

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tion, we had the opportunity of visiting with the astronomers and physicists there, seeing the apparatus, and becoming pretty well acquainted with the work which was to be done. The station was under the charge of Professor A. N. Skinner, who determined the latitude and longitude and had general oversight of all the work.

The most noticeable object as one approached the station was a large scaffold supporting the objective of the 40 foot telescope with which Mr. A. L. Colton was to secure large photographs of the corona, by the method which was so successfully used by Professor Campbell of the Lick Observatory in the Indian eclipse of 1898. The objective was of only 5 inches aperture but of 40 feet focal length. The tube was made of white canvas, supported by a skeleton framework of steel tubing. The plate-holder was placed in a pit covered by a dark hut, and was moved by a clepsydra during the short interval of totality. Mr. Colton was to expose five 14 x 17 Seed nonhalation plates, the exposures being 2^s, 10^s, 45^s, 10^s and 2^s. He was assisted by Mr. M. G. Skinner.

A long shed with one-half of the roof covered with canvas, which could be rolled up out of the way, sheltered a row of equatorial telescopes, polariscopes and cameras which looked formidable to the spectator. The most important work, however, as it seemed to me was to be done with some instruments under a rougher looking shed partly covered only by loose boards. Here were three great slitless spectroscopes: one, operated by Dr. J. S. Ames of the Johns Hopkins University, having a 6-inch concave grating with 15,000 lines to the inch and giving a spectrum 2 feet long; another, also under Dr. Ames' charge, having a flat grating of the same dimensions as the concave grating; and a prismatic camera, with a 60° prism whose faces were 6 inches square and a lens of about 6 feet focal length. The last was under the charge of Dr. Chase of Yale University. Dr. Ames was assisted by Messrs. Hough, Rees and Gilbert of Johns Hopkins University. I understand that Dr. Ames made 15 exposures with the concave grating spectrograph and it is to be hoped that these have all turned out well.

The battery of cameras upon a long polar axis was managed by Professor W. S. Eichelberger and Assistant Astronomer T. I. King of the Naval Observatory assisted by Messrs. Beal, Kent and Gore. One of the cameras was provided with a color screen which would allow only the green rays to pass through it, the hope being to obtain an image of the corona largely from the light due to coronium.

Professor Edgar Frisby of the Naval Observatory and Mr. Everett I. Yowell of the Cincinnati Observatory observed the contacts and made visual observations of the corona with two 5-inch equatorials. Mr. N. E. Parsons and Dr. Dorsey of the Johns Hopkins University operated two polariscopes, the former a photographic and the latter a visual instrument.

Mr. R. W. Wood of the University of Wisconsin made interesting observations of the shadow bands with a peculiar instrument called the strobo-scope. His conclusion was that the shadow bands were not periodic. He also observed with a polariscope and made an excellent drawing of the corona.

From Professor Skinner we learned that the U. S. Naval Observatory had sent out three other parties, one at Barnesville, Ga., under Professor Brown, one at Winnsboro, S. C., under Professor Ormond Stone, Director of the Leander McCormick Observatory and one at Griffin, Ga., under Professor L. E. Jewell, of the Johns Hopkins University.

Barnesville, Ga.—The instruments used here were a 40 ft. telescope and polar axis with several cameras, similar to those at Pinehurst. Professors Updegraff and See of the Naval Observatory were assisted by a number of volunteer observers.

Winnsboro, S. C.—Professor Stone assisted by volunteers operated a third 40-foot telescope for the purpose of securing large photographs of the corona upon 14 x 17 plates.

Griffin, Ga.—This station was chosen near the edge of the path of totality for the purpose of obtaining long duration of the "flash" and chromospheric spectra, the whole expedition being spectroscopic. Professor Henry Crew, of the Northwestern University, worked with a flat grating. We are sorry to learn from a recent newspaper note, that his photographs all proved failures from insufficient exposure. Professor Humphrey, of the University of Virginia, operated with a concave grating of 21 feet focal length. Professor Mitchell, of the Columbia University, was also to be located at this station.

Wadesboro.—On our return journey Professors Hale and Frost gave us an interesting account of the work at this city, which seems to have been the favorite location for observing the eclipse, chosen no doubt on account of the low percentage of cloudy weather given in the special report of the Weather Bureau. Three important expeditions were located here, from the Smithsonian Institution, Princeton University, and the Yerkes Observatory. We can only speak definitely of the work done by the Yerkes party.

Professor E. E. Barnard assisted by Mr. Ritchey made 7 exposures with a 6-inch lens of 62 feet focus mounted horizontally. The light was thrown into the telescope by a coelostat with a 12-inch mirror made by Mr. Ritchey. The exposures made varied from one-half second to thirty seconds in duration, three upon 14 x 17 plates and four upon 25 x 30 plates, the largest that have ever been used for photographing the corona, with exception of those used at the same station by the Smithsonian Institution. A newspaper report, June 14, states that one of these plates, the last exposed, duration 1 second, had been developed and brought out many interesting details close to the edge of the moon. Mr. Barnard's hope is to bring out upon the longer exposed negatives the details of the outer corona as well as the inner upon that magnificent scale, which makes the diameter of moon's disk 7 inches; and we may be sure that Mr. Barnard will do it if any man can.

Several smaller cameras, from a 6-inch Voightlander down, were operated by volunteers. Some were mounted equatorially and driven by clockwork, others were simply fixed upon posts.

Professor E. B. Frost assisted by Dr. Isham of Chicago photographed the spectrum, using three slitless spectroscopes, one with a train of three prisms, one with a single prism and one with a concave grating. The signal for photographing the "flash" spectrum was given by Professor Frost observing with a flat grating. He said that he saw only dozens of lines reverse where he expected to see hundreds. Elsewhere also the "flash" appears to have been disappointing. At Pinehurst the whole party depended upon the observation of this phenomenon for the signal for the beginning of their program during totality. The one deputed to make this observation and give the signal failed to see the "flash" and as a result several seconds of totality had elapsed before the signal was given.

The coronium line too appears to have been weaker than usual, and Professor Young who made the determination of the position of this one line his special work failed to see it.

Professor Hale assisted by Mr. Ferdinand Ellerman undertook the very delicate operation of measuring the heat of the corona with bolometric apparatus, in connection with a large siderostat kindly loaned by the Smithsonian Institution. He had a very unfortunate experience. On arriving at Wadesboro ten days before the eclipse he found that a very delicate part of the apparatus had been broken. He had been warned by previous experience and had shipped a lathe and all necessary tools as a part of the

equipment of the expedition. With characteristic energy he set about constructing a new bolometer and succeeding in making a better one than he had before and performed satisfactory preliminary experiments. All was in perfect adjustment and ready for use during totality, when just as the important moment arrived a small stick, which was used for some purpose in the dark bolometer room and had been leaned against the wall, fell and threw the galvanometer needle out of balance. The operation of balancing requires usually from two to three minutes. Professor Hale said that he never worked harder in his life than during the next minute and a half, and he succeeded in getting the instrument into balance, but only to see the sunlight reappear before any measures could be taken.

Mr. C. G. Abbott of the Smithsonian Institution by similar methods succeeded in detecting a slight amount of radiation from the corona as compared with that from the black disk of the moon. Professor Hale is confident from the results of his preliminary experiments that by these methods he can detect the change of heat at the edges of the great coronal streamers in full sunlight.

Professor A. S. Flint of the Washburn Observatory made the observations for time and position at Wadesboro, and noted the times of contact and counted the seconds of totality for Professor Frost.

The longest focus telescope ever used in observing an eclipse is probably that used by the Smithsonian Institution at Wadesboro, which had a focal length of 135 feet. This would give an image of the moon nearly 15 inches in diameter.

The telescope was mounted horizontally, the light being furnished by a coelostat. In the Chicago Journal of June 15, we find this statement concerning the photographs taken with this instrument:

"Mr. Smillie exposed six 30 x 30 plates during totality, with times ranging from one-half second to sixteen seconds. All these negatives have not yet been developed. Those of one-half second, two seconds and four seconds exposure have been hurriedly examined, however, and they give clear indications of the crossing and recrossing of filaments like the appearance of a field of grain bending in the wind. The prominences and polar streamers appear in imposing magnitude and detail."