THE 1900 SOLAR ECLIPSE EXPEDITION

OF THE

ASTROPHYSICAL OBSERVATORY

OF THE

SMITHSONIAN INSTITUTION.

BY

S. P. LANGLEY, Director,

Aided by C. G. ABBOT.

(No. 1439.)

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CHAPTER I.

OBJECTS, AND PREPARATION FOR THE EXPEDITION.

The path of the total solar eclipse of May 28, 1900, was unusually accessible from Washington. Preliminary observations by the United States Weather Bureau indicated a fair prospect of good observing weather along the middle portion of the belt of totality within the United States. As the conditions on this occasion were so favorable to observation, it seemed desirable to send observers from the Smithsonian Astrophysical Observatory; and Congress was therefore asked to appropriate the sum of $4,000 to defray the expenses of the expedition, and this sum was so appropriated and made immediately available.[a]

1. OBJECTS OF THE EXPEDITION.

STRUCTURE OF THE INNER CORONA.

Although many excellent photographs of the corona had been taken in recent years, notably by Schaberle and by Campbell of the Lick Observatory, none of them had exhibited adequately the very curious and interesting structure which the writer and others had observed close to the sun's limb during the eclipse of 1878.[b] In the hope of obtaining material for a study of this peculiar structure of the inner corona, its photography upon a greater scale than any hitherto attempted was decided upon as a prominent object of the expedition.

[a] Observation of eclipse of May twenty-eighth, nineteen hundred: For cost of apparatus, transportation of observers and equipment, subsistence, reduction of observations, printing and publishing of results, not exceeding one thousand five hundred copies, and employment of such temporary aid as may be required, including all necessary field and other expenses, four thousand dollars.—*Deficiency act, February 9, 1900.*

[b] See Report of S. P. Langley, Washington Astronomical and Meteorological Observations, 1876, pt. 2, Vol. XXIII, p. 203.

Before procuring the apparatus for this purpose, several astronomers of great experience were consulted. It was found to be the consensus of opinion that a lens of both larger aperture and longer focus than that used by Campbell in 1898 would be required, and I was upon the point of ordering such an one of 8 inches aperture and 60 feet focus, when Prof. E. C. Pickering, the director of Harvard College Observatory, very generously offered me the loan of a lens of 12 inches aperture and 135 feet focus, together with other auxiliary apparatus. So welcome an offer could not but make the attainment of this object of the expedition paramount over all other considerations, and when in addition, through Prof. C. A. Young and the trustees of Princeton University, the use of a 5-inch lens of 38 feet focus was secured, similar to that used on several occasions by Lick Observatory eclipse expeditions, it was apparent that in optical equipment for photographing the inner corona the expedition would be well provided.

VISUAL OBSERVATIONS.

To supplement this special photographic study of the inner corona, the writer desired to have eye observations made in order to see if the filamentary appearance would be as well marked as in 1878. He therefore felt great gratification in accepting the loan through Prof. S. J. Brown, astronomical director of the United States Naval Observatory, of the identical 5-inch telescope which he had used in the observations on Pikes Peak in 1878. Two other visual telescopes of 3 and 7½ feet focus were also used.[a]

PHOTOGRAPHY OF THE OUTER CORONA.

To photograph the outer corona several cameras of moderate focal length were provided. Long exposures were intended for these, so as to reach the extremest limits of the corona which could be photographed at an eclipse of such short duration.

BOLOMETRIC WORK.

The long experience of this observatory in delicate bolometeric measures on the solar spectrum suggested the advisability of an attempt to detect the heating effect of the coronal radiations and, if possible, to determine the distribution of their energy in the spectrum; for if this latter point could be determined, light would be thrown on the still disputed question of the nature of the corona. It will be remembered that different sources of radiation emit very unequal proportions of energy at different wave lengths, so that, for example, if the corona owes its light to reflection of the photospheric radiations by particles of dust about the sun an energy spectrum generally similar to that of the sun itself would be formed; but if the light is, on the other hand, due to incandescence of such dust particles, owing to their proximity to the sun, a coronal spectrum relatively richer than the sun's in

[a] The expedition is indebted to Mr. Saegmuller, of Washington, for the loan of a mounting for one of these.

infra-red rays would be found, owing to the temperature of the particles being less than that of the sun itself. Bolometric study of the corona was therefore included among the objects of the expedition.

PHOTOGRAPHIC SEARCH FOR INTRA-MERCURIAL PLANETS.

It was learned after preparations for the eclipse were somewhat advanced that Prof. W. H. Pickering, of Harvard College Observatory, intended to make a photographic search for as yet undiscovered planets near the sun by the aid of a special apparatus of his own devising. It was further learned that Professor Pickering, and also the eclipse committee of the Astronomical and Astrophysical Society of America, desired, if possible, that a search with similar apparatus should be made by other eclipse parties. This observation was with some hesitancy added to the programme, for I had no strong expectation that anything but negative evidence would be secured.

PHOTOGRAPHY OF THE "FLASH SPECTRUM."

In loaning the great lens above referred to, the director of the Harvard College Observatory suggested the use of an objective prism with it at the beginning of totality for the purpose of photographing the "flash spectrum," and offered to supply the prism and an automatic apparatus for exposing the plate each second to the spectrum. This proposal was accepted, and led to the only attempt at photographic spectroscopy included in the programme.

TIMES OF CONTACT.

It was arranged that the observation of the times of contact should be made both by the usual method of eye observation and by a photographic apparatus.

GENERAL SUMMARY OF THE OBJECTS OF THE EXPEDITION.

Briefly, the eclipse expedition was sent out from the Smithsonian Astrophysical Observatory for the following purposes:

1. To photograph and to observe visually the minute structure of the inner corona and the prominences.

2. To photograph the outer extensions of the corona and possible intra-mercurial planets or other objects near the sun.

3. To measure the heating effect of the inner coronal radiations, and, if possible, to determine the distribution of their energy in the spectrum by the aid of the bolometer.

4. To photograph the flash spectrum.

5. To determine the times of contact.

2. PREPARATION FOR THE EXPEDITION.

(a) SELECTION OF SITE.

The most accessible point on the belt of totality was Norfolk, Virginia, and here also the duration of totality was a few seconds longer than at points farther west. But, on the other hand, the special observations of the Weather Bureau, extending over several years,[a] had showed that the chances of good observing weather at points near the coast were inferior to those in the inland districts, and rose to a maximum for portions of the States of Georgia and Alabama. Nevertheless the reports from a few stations in North Carolina came well up with the best Georgia records.

The advantages of accessibility, duration of totality, and height of sun during totality, all weighing in favor of eastern stations, with only slight and not very certain chances of better weather as an inducement to go farther to the south and west, I decided to send Mr. Abbot, aid acting in charge of the Astrophysical Observatory, to look over the ground and report recommending some station in North or South Carolina. He crossed the State of North Carolina, and being convinced that there would be no appreciable gain by going into South Carolina, he recommended as alternatives the towns of Winton and Wadesboro, North Carolina, situated respectively in the northeastern and south central portions of the State. According to the Weather Bureau bulletin the chances of fair weather at Wadesboro were almost 5 to 1, and were somewhat better than those recorded for Winton. Besides this difference for the towns themselves, the data for points in their near neighborhoods indicated a decided preference for Wadesboro, and with this in mind I finally selected it.

The ground occupied was a sod-covered level field of several acres extent, on the edge of the town, which was most cordially placed at the disposal of the Smithsonian Institution and its guests by its owner, John Leak, esq., of Wadesboro.

Mr. Abbot visited Wadesboro early in April to lay off the ground, and arranged with Mr. William Brasington, a local contractor, to erect a shed for the apparatus, and to provide material required for piers and support of apparatus. Accommodations were engaged for the party at the National Hotel, Wadesboro. The proprietor, Mr. Huntley, did his utmost to make arrangements for the unusual number of these and other eclipse guests, and at all times cared for their comfort.

(b) PERSONNEL OF THE EXPEDITION.

The staff of the Astrophysical Observatory available for the expedition consisted of three persons besides the writer, namely: Mr. C. G. Abbot, aid acting in charge, Mr. F. E. Fowle, jr., junior assistant, and Mr. A. Kramer, instrument maker. The observing force was increased by special detail, invitation, and volunteering as follows: Mr. T. W. Smillie, for many years photographer of the National Museum, was placed

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[a] Bulletin No. 27., W. B., No. 209., U. S. Department of Agriculture, Weather Bureau.

in charge of the photographic work, and Mr. De Lancey Gill, of the Bureau of American Ethnology, was detached to be photographic assistant to Mr. Smillie. Mr. C. W. Smith, a carpenter, was sent from the Smithsonian Institution. At my request the Superintendent of the United States Coast and Geodetic Survey detailed Assistant G. R. Putnam (since placed in charge of the survey of the Philippine Islands), to determine the latitude and longitude of the camp and assist in the orientation of apparatus, in which respect his services were most acceptable, as well as to observe visually on the day of the eclispe. The following five gentlemen joined the expedition by invitation: The Rev. Father Searle, C. S. P , with the Rev. Father Woodman, C. S. P., from the observatory of the Catholic University of America; C. E. Mendenhall, Ph. D., then instructor in physics at Williams College; Mr. R. C. Child, for several years connected with the Astrophysical Observatory, but more recently employed in the United States Patent Office; and Mr. P. A. Draper, of Washington. On the day of the eclipse two volunteers, Mr. Little, of Wadesboro, and Mr. W. J Hoxie, of Beaufort, South Carolina, assisted Mr. Putnam in giving signals and recording observations, while Mr. George Wells, of the Smithsonian Institution, recorded the observations of the writer.

Mr. C. D Walcott, Director of the United States Geological Survey; Mr. R. Rathbun, assistant secretary of the Smithsonian Institution; Mr. W. N. Bannard, of the Pennsylvania Railroad; and Mr. J. E. Watkins, of the National Museum, accompanied the writer to Wadesboro two days before the eclipse, and remained as interested spectators and observers of the general aspects of the phenomenon.

RELATIONS WITH THE YERKES OBSERVATORY EXPEDITION.

Several months prior to the eclipse an invitation was extended to Prof. G. E. Hale, director of the Yerkes Observatory, to take part as a member of the Smithsonian expedition. This invitation he at first was inclined to accept, and provision was made for his use of two beams of light from coelostat mirrors attached to a second axis added to the great Grubb siderostat. A little later, finding that the Yerkes Observatory itself would be able to observe the eclipse independently, Professor Hale withdrew as a member of the Smithsonian expedition, but as the two parties were located close together, he was still able to make use of the coelostat beams above mentioned. Much benefit was derived from the counsel and friendly interest of the director and members of the Yerkes Observatory expedition, thus so fortunately located near that of the Smithsonian Institution.

(*c*) TRANSPORTATION.

The plans of the observations had so far outgrown what was intended when the small appropriation was asked for that this proved hardly sufficient, with strictest economy, to defray all the expenses. In these circumstances I felt justified in asking the cooperation of the several railroads whose tracks should be traversed in the journey. They generously responded, offering each and all free transportation both for observers and freight. I take this opportunity, therefore, to acknowledge the indebtedness of the expedition to the Pennsylvania, the Richmond, Fredericksburg and Potomac, the Atlantic Coast Line, and the Seaboard Air Line Railroad companies for the free transportation of observers and equipment both going and returning over the portions of the route included by their several lines.

(*d*) PRELIMINARY PRACTICE AT WASHINGTON.

There can be no doubt that one of the first essentials to success in eclipse observations is adequate preliminary practice; for the time of totality is too short for thinking, and the mind is too much disturbed by the feeling of necessity for haste to do rightly anything which has not become a settled habit. In order that there should be the greatest possible opportunity for practice in the use of the most important pieces of apparatus, and a chance to make such modifications as actual trial might suggest while all the mechanical facilities were at hand, I gave especial attention to a field installation for rehearsal, which was made in April by setting up the apparatus in the Smithsonian Park.

A certain day and hour was selected at which an imaginary eclipse was to occur. The Brashear coelostat, the Grubb siderostat, the portable photographic house, the 12-inch lens of 135-foot focus, and the 5-inch lens of 38-foot focus, with the cloth tubes leading from the lenses to the photographic house, were all adjusted for the supposed eclipse. Signals were given in warning, and at the time of assumed totality actual shifting of the plate holders, as if for the photographic exposures, was gone through with. The assumed eclipse being more accommodating than a real one, it repeated itself a few minutes later to give a further opportunity for practice on the part of the observers. As a preliminary rehearsal the whole went off very well.

At the conclusion of the rehearsal, which, together with the preparations for it, lasted for several days, the apparatus and accessories were immediately taken down and packed for shipment to Wadesboro. A freight car filled to the roof with the equipment started from Washington on May 4 and reached Wadesboro on May 9.

CHAPTER II.

1. ESTABLISHMENT OF THE CAMP.

A few days after the shipment of the apparatus the advance guard of the party, consisting of Messrs. Abbot, Fowle, Kramer, Draper, and Smith, went on, carrying with them the galvanometer for the bolometric work, and the chronometer and other delicate pieces of apparatus. Immediately upon its arrival the carload of equipment was removed to the camp, shown in Pl. II, which had meantime been made ready for occupancy under the good auspices of Mr. Brasington. From then till after the eclipse day and night were filled with preparation.

Mr. Putnam, of the Coast and Geodetic Survey, reaching Wadesboro May 10, immediately established his meridian instrument, and the weather continuing fine he was able to get good observations for latitude and longitude on several nights. During the days he assisted to adjust the axes of the Grubb siderostat and the Brashear equatorial and coelostat, and ran north and south and east and west lines, and independently computed and ran lines parallel to the direction of the coelostat beam and the azimuth of the 40-foot direct telescope axis, so that his work during the few days that he remained at Wadesboro was most valuable.

Mr. Putnam returned shortly before the eclipse and made additional observations for position. The final values obtained for the latitude and longitude of the coast survey tent shown in the diagram of the camp (Pl. III) were:

Latitude	34° 57′ 52″	North.
Longitude	80° 04′ 27″ 5^h 20^m 17.8^s	West of Greenwich.

On May 16 Messrs. Smillie, Mendenhall, Child, and Gill came, and the rest of the observers arrived on Friday and Saturday, May 25 and 26.

Meanwhile members of the Yerkes Observatory expedition had arrived, and as Professor Hale was to make use of two mirrors mounted on a second axis connected with the Grubb siderostat, their camp was laid out immediately adjoining ours to the west.

From the first Mr. Brasington, the contractor, entered into the plans of both camps with hearty interest, and his aid was most valuable in supplying everything in his line, from bricks and lumber for the piers and building to barrels for reservoirs and washing tanks. He must have given up all his other work and devoted himself and his force of men wholly to the eclipse, for besides the Smithsonian and Yerkes expeditions, Professor Young and his party from Princeton, and the English expeditions of the Reverend Mr. Bacon, and Mr. Nevil Maskelyne, had all come to Wadesboro and found in Mr. Brasington their mainstay and ready helper for all demands.

RELATIONS WITH THE TOWNSPEOPLE.

The townspeople of Wadesboro manifested a lively interest in the eclipse preparations; and not only were they interested, but helpful, and they treated the observers with marked cordiality. At one of the first preliminary visits of Mr. Abbot Judge Bennett, a prominent citizen and ex-Representative to Congress, called upon him and tendered any assistance in his power to give—an example followed by others. After the arrival of the parties a meeting was held by the townspeople and a committee appointed to assist the astronomers in any possible way. As a further act of hospitality several carriages were placed at the disposal of such of the guests as chose to ride; and finding that in the press of preparation this kindly offer could not be improved so much as the people could have liked, the carriages were made to call regularly to convey the observers to and from the hotels to the camps, morning, noon, and night. Along with this public cordiality, private hospitalities were not wanting, and one and all of those who observed at Wadesboro must join in acknowledgment of the courtesies received.

As some slight return one or more of the Smithsonian party was usually in attendance at the 5-inch visual telescope on fair nights to show celestial objects to such as wished to look, and quite a number of the people gathered there every night and seemed to enjoy the opportunity.

Provision was made by the town authorities for effectually guarding the grounds from intrusion on the day of the eclipse. The whole space was roped off, the nearest street closed, and special constables prevented all approach until after the eclipse had passed.

2. APPARATUS AND ACCESSORIES.

The location of the apparatus at the camp is shown in Pl. III. On the left of the "wagon track" is the main portion of the Yerkes camp. All at the right of the "wagon track" appertains to the Smithsonian expedition, with the exception of the places marked "spectroscope," "concave mirror," and "bolometer house," and those marked "shadow band screen" and "meteorological station." The first three of these were under Professor Hale's immediate charge, and were supplied with beams of light from the Grubb siderostat, while the two last named were occupied by Mr. Clayton of the Blue Hill Meteorological Observatory.

Passing now to the Smithsonian camp proper, there is shown at the northwest corner the Brashear equatorial and coelostat, and immediately in front the 12-inch

Harvard lens and objective prism through which the beam from the coelostat passed into the two-branched camera tube. The direct beam through the lens came to focus in the small dark room, within which the operator changed plates and made the exposures by a cord operating a shutter at the lens. Immediately before and after totality the prism was to be interposed just in front of the lens to catch the "flash spectrum" to be thrown down the northerly branch tube to a photographic plate moved each second by the automatic plate carrier.

On the right of the dark room is seen projecting easterly the inclined tube of the 5-inch Princeton lens. This lens and its tube were fixed permanently at an inclination suitable to the position of the sun on the moment of totality; and the image was received on a moving plate holder driven by a water clock within the dark room. An observer within the dark room changed plates and operated the exposing shutter by a cord.

Under a little shelter on the north of the dark room was a chronograph and chronometer, from which electric circuits ran to the shutters of the 12-inch and 5-inch lenses, to the plate carrier of the prismatic camera, to the automatic contact camera (shown north and east of the dark room), to the Coast Survey tent (shown at the south of the camp), where contacts were observed by Mr. Putnam, to the 3½-inch telescope where contacts were observed by Rev. Fr. Woodman, and finally to the Yerkes camp.

Nearly west of the photographic dark room was the main building containing the bolometric and "intramercurial planet" photographic apparatus. The bolometric apparatus was scarcely less thoroughly installed than when permanently in use in Washington. It was contained within a double-walled inner chamber. The galvanometer rested on a mercury float, itself supported on a system of stone and rubber blocks, which in turn rested upon a heavy and deeply bedded pier. At a later page the bolometric arrangements will be more fully described.

Within the bolometer chamber is shown the clock used to drive the intramercurial planet apparatus. This clock[a] is the one customarily used to drive the spectro-bolometric train at Washington, and was placed within the bolometric chamber, as shown, in order to utilize its outside gearing with hand driving for producing a bolograph of the coronal spectrum, if this proved practicable, at the same time that the clock itself was driving the large camera.

The intramercurial planet apparatus in the eastern wing of the building consisted of four cameras mounted upon one polar axis. Of these, two were of 3 inches aperture and 11 feet focus, and designed to cover fields of about 1 hour in right ascension by 10° in declination east and west of the sun, respectively. The two other cameras had Ross lenses of 4½ inches aperture and 39 inches focus.

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[a] See Pl. XIII, Annals of Astrophysical Observatory, Smithsonian Institution, Vol. I.

Between the main building and the Coast Survey tent is located the 5-inch equatorial, and in a line running northeast from it were stationed a $3\frac{1}{2}$-inch telescope with rough altazimuth mounting, and still farther in the same line, but beyond the dark room, a 6-inch equatorial of $7\frac{1}{2}$ feet focus. Near the Coast Survey tent was located the signal bell upon which warnings were struck at the time of the eclipse, as directed by the observer within the tent.

Several of the separate pieces of apparatus are shown in Pls. IV, V, VI, VII, VIII, IX, X, and XI, and these may be consulted in connection with the following description of some of the instruments.

THE COMBINED EQUATORIAL AND COELOSTAT.

(Plate IV.)

As long ago as 1880 I employed a 12-inch plane mirror on the south end of the polar axis of the equatorial at Allegheny Observatory to give a fixed solar beam, and was accustomed to use it either as a polar siderostat sending the beam down the axis, or as what is now termed the coelostat. In this latter use the mirror lay in the plane of the polar axis, which was then caused to rotate once in forty-eight hours instead of once in twenty-four hours, as usual. Suppose the mirror to be set so that an observer stationed at the east sees the sun's face as it rises, he will obviously continue to see it, because the mirror turns half as fast as the earth. I did not then know that this simple arrangement for a fixed beam was in fact described in 1863 by von Littrow[a] who refers its discovery to August, nearly thirty years earlier.

This instrument is so simple mechanically and so desirable in practice from the fact that it gives a fixed field of view instead of one rotating about a fixed central point as in other siderostats, that I determined to employ the coelostat in connection with the long-focus lens.[b] It was desired also to have an accurately driven equatorial mounting for a 6-inch photographic lens of $7\frac{1}{2}$ feet focus, and the two requirements were combined in the instrument shown in Pl. IV, which was constructed for the occasion by Brashear. Two polar axes, one for the equatorial camera, the other for the 18-inch coelostat mirror, are driven by a common clock. The observer is shown ready to manipulate both the exposure of the camera and the setting of the objective prism for the "flash spectrum," both of which duties were included in his charge.

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[a] O. von Littrow, Wien. Berichte, XLVIII, II, pp. 337–348, 1863.

[b] As generally employed the coelostat reflects the beam in a horizontal direction to the east or west according as the celestial object is east or west of the meridian; so that as thus used the instrument is least efficient when the object is farthest from rising or setting, respectively. A second mirror has recently been introduced here in connection with the coelostat in such a way as to produce an efficient universal instrument, which is now (1903) proving useful in the work of the Astrophysical Observatory, and it is hoped may meet with favor elsewhere. The second mirror is mounted above and south of the coelostat proper, upon a support provided with slides in both an east and west and north and south direction, like the slide rest of a lathe. The beam is sent north in a horizontal direction from the second mirror. This mirror occupies different positions on its north and south track, according to the declination of the celestial object, and is sometimes shifted east or west to avoid interrupting the entering beam. For the sun, and at this latitude, two 27-inch mirrors will at the most unfavorable time give a 20-inch circular beam.

THE LONG-FOCUS TELESCOPES.

(Plates II, V, and VI.)

The tubes for the 135-foot focus lens were 42 inches square, of black canton flannel stretched by ropes running longitudinally at the four corners, and supported on trestlework. They were provided with diaphragms at 10-foot intervals and were covered over with a canvas in the form of a prolonged A tent. For the direct photography 30-inch square plates were used in plate holders with roll shutters. All the photographic plates, specially prepared by the Cramer Company, of St. Louis, were double coated, extremely rapid, and of the so-called "isochromatic" preparation.

The 38-foot focus tube was composed of a conical spruce frame of square cross section covered with canvas blackened within and was supported at the proper angle on the tops of posts. . The lens with its adjustments was separately supported upon a post 8 inches square and braced well from the sides. As has been said the exposures of both the long-focus cameras were made by the aid of cords running from the dark room to shutters at the lenses. A water clock with horizontal cylinder was constructed to control the movement of the 11 by 14 inch plates along inclined guides at the focus of the 38-foot lens.

INTRAMERCURIAL PLANET CAMERAS.

(Plate VII.)

As already stated, it had been recommended by Prof. W. H. Pickering that several stations should be equipped with 3-inch lenses of 11 feet focus, to be used to photograph large fields of view about the sun, in the hope of discovering possible intramercurial planets. In Pl. VI the projecting box marked "1, 2" is the end of a pair of cameras of this type with axes inclined so that together the cameras covered a field of view extending from about one hour east to one hour west and from 5° north to 5° south of the sun. It was intended to use a nest of 8 by 10 inch plates in each of these cameras, arranged on a curved surface so as to be in the best focus in all parts of the field, but single plates 24 by 30 inches were substituted finally, although as the result proved the focus was not the best all over their extent. Two other large cameras, shown in Pl. VII, had Ross portrait lenses of 4½ inches aperture and 40 inches focus, and these were used with 30-inch square plates. All these four rather heavy cameras were mounted on a single "home-made" polar axis, but this was so well counterbalanced that the clock drove it with great ease and accuracy.

THE AUTOMATIC RECORDING CONTACT CAMERA.

In this instrument a 22-inch focus lens, with pin-hole diaphragm, formed the solar image on a 15-inch circular celluloid photographic plate of little sensitiveness, which was rotated by a ratchet wheel of 168 teeth, driven with an electric escapement. This escapement and a shutter in front of the lens were operated once a second by the break circuit chronometer, but the impulses were so timed by aid of relays that the shutter was always opened and closed before the plate was moved along one tooth. An observer was charged with the duty of cutting off exposures with a card at certain seconds after the minute break. In consequence of the fifty-ninth impulse being dropped by the chronometer, only 59 images were made by the instrument in a minute, and as there were 168 teeth on the ratchet wheel it is apparent that more than two and one-half minutes were consumed in one rotation of the plate. During that time the image of the sun would be carried so far by the earth's diurnal motion that the successive rows of images would not overlap, but would be in a spiral.

THE BOLOMETRIC APPARATUS.

(Plates VIII and IX.)

The bolometric observations lay in a wholly untried field, and practically no forecast could be made of the heating effect of the coronal radiations to be measured, and hence provision was made for a considerable modification of the programme, according to the results reached in the first seconds of totality. A 17-inch mirror, on the Grubb siderostat, reflected the beam horizontally south through a cat's-eye diaphragm, whose aperture could be controlled by cords running to a slider on a scale at the left of the observer at the galvanometer. He could thus vary the intensity of the beam several thousand fold. The beam was concentrated upon a slit 1 centimeter high and 1 millimeter wide by a concave mirror of 50 centimeters aperture and 1 meter focus, controlled by the second observer, who, watching the image on the jaws of this slit, adjusted the concave mirror so as to throw the desired part upon it. Two small flat mirrors beyond the slit reflected the beam to a collimating mirror of 75 centimeters focus, whence it passed to the prism.

This was a compound objective prism, loaned by the Harvard College Observatory, having two circular half prisms rotating about a common axis, so that their combined angle could be varied from 0° to 15°. This feature was not used during the eclipse, but previously the prisms were set at an angle judged proper for dispersing the coronal spectrum, should this prove desirable. One of these prisms was silvered on the back, the intention being that the combination could be used simply as a plane mirror in the early part of totality to get an idea of the intensity of the coronal radiation, but could later be turned round so that the collimated beam would pass through the prism from front to back and return as a spectrum. In either case the rays next fell upon an image-forming mirror of 75 centimeters focus and were brought to focus upon the bolometer strip, which was 1 centimeter high and 1 millimeter wide. The warming of this strip was to be determined by the deflection of the sensitive galvanometer, and it was arranged that this deflection should be read visually and photographically recorded, in the manner described in Volume I of the Annals of the Astrophysical Observatory.

Two observers were employed. One was to read the galvanometer deflections, record all observations, and operate the cat's-eye diaphragm, while the other was to adjust the position of the image upon the slit, set the prism to previously adjusted stops and clamp it, and to turn the prism and recording plate by clockwork through previously determined intervals for observing the energy spectrum of the corona. He also had in hand a pasteboard shutter and a plate of glass, which he was to interpose before the bolometer at certain times to give readings, corresponding to zero of outside radiations upon the bolometer, and to give an idea of the amount of radiations transmissible by glass, respectively.

3. ASSIGNMENT OF OBSERVERS AND PRELIMINARY REHEARSALS.

The disposal of the observing force was as follows:

Mr. S. P. Langley, Director, telescopic observations with the 5-inch equatorial.

Mr. C. G. Abbot, aid acting in charge, manipulation of the spectrobolometer.

Mr. T. W. Smillie, in general charge of photographic work, manipulation of the 135-foot focus camera.

Mr. F. E. Fowle, jr., manipulation of the 38-foot focus camera.

The Rev. Father Searle, C. S. P., in general charge of intra-mercurial planet apparatus, manipulation of the 11-foot focus cameras.

Mr. G. R. Putnam, determination of times of contact and direction of warning signals.

Mr. C. E. Mendenhall, observing at the galvanometer.

Mr. R. C. Child, telescopic observations with 6-inch equatorial and in charge of electric circuits, including especially the prismatic camera and the automatic contact camera.

The Rev. Father Woodman, C. S. P., times of contact and general observations with 3½-inch telescope.

Mr. Delancey Gill, manipulation of 7½-foot focus camera and the objective prism.

Mr. P. A. Draper and Mr. C. W. B. Smith, exposures of the two 40-inch cameras

Mr. A. Kramer, instrument maker, looking to movements of the siderostat and the 5-inch equatorial.

Two volunteers, Mr. Little, of Wadesboro, and Mr. Hoxie, of Beaufort, South Carolina, were assigned, respectively, to strike signals and to record times of contact under direction of Mr. Putnam.

On the two days next preceding the eclipse, several full rehearsals were carried through to familiarize all the observers with their duties, which were specified in written directions furnished each observer, that nothing might be overlooked.

CHAPTER III.

OBSERVATIONS AND RESULTS.

The day of the eclipse proved cloudless; the sky, while not of the deepest blue, was yet more than ordinarily clear, and the observing programme was carried through with general success. In what follows, the observations will be described under these four heads: (1) General and telescopic observations; (2) Photography of the inner corona and prominences; (3) Photography of the outer corona and outlying regions of sky; (4) Bolometric observation of the corona.

1. GENERAL AND TELESCOPIC OBSERVATIONS.

(*a*) GENERAL OBSERVATIONS.

The degree of darkness during totality was considered by several to be about the same as on a clear night at full moon, but of planets and stars only a few of the brightest were noted. Shadow bands were seen by several observers, but not very distinctly. Mr. Child reported a pronounced pulse of light and shade eight minutes before totality. The cessation of the noises of birds and animals as the time of totality drew near was remarked. The equatorial extensions of the corona on either side of the sun were variously estimated at from 2 to 5 lunar diameters by naked-eye observers.

(*b*) COLOR OF THE CORONA.

Mr. Child, an artist, noted a distinct apple-green tinge to the outer coronal light, which held to within a half diameter of the limb, where the color began to grow more yellow, the extreme inner coruna appearing to him of a pale golden hue. Others likened the coloring to that of mother-of-pearl, but nearly all noted a distinct yellowish tinge. One observer reported a ruddier color toward the outer end of the streamers on the lower side of the sun, but several noted, on the contrary, a tendency toward green at increasing distances from the limb.

(*c*) TELESCOPIC VIEW.

To the writer's view with the 5-inch telescope the inner corona was filled with detail, but far less sharp and definite than he saw it on Pikes Peak in 1878. He could not identify any connection between the coronal structure and the presence of prominences, while his impression was that the details contained more ogival curves than straight streamers. Having in mind the wonderful structure seen with the same instrument in the clear mountain air twenty-two years before,[a] the impression was a disappointing one.

Mr. Child and the Rev. Father Woodman noted the appearance of Bailey's beads very distinctly, and the former made sketches from which he later prepared a representation of the corona in pastel colors.

(*d*) TIMES OF CONTACT.

Times of contact were observed by Mr. Putnam and by the Rev. Father Woodman by eye and ear methods, and were also signaled to the chronograph. Plate X shows the Coast and Geodetic Survey tent as adapted for the former's observations on the day of the eclipse. Owing to the imperfect working of Mr. Putnam's circuit, his chronograph record was lost, but Mr. Hoxie, recording for Mr. Putnam, noted the instant of his key taps as well as the results of his eye and ear observations. The following table gives the mean of these two records. Third contact, as given below, was not observed in the telescope by Mr. Putnam, as he was hindered by giving signals, but Mr. Hoxie recorded the flash of light on the chronometer face. Rev. Father Woodman's observations were recorded by him with a pocket chronometer, and his signals also appear on the chronograph sheet; and since there is a slight discrepancy both records are given. The times given below depend on three chronometers compared for several days with telegraphic noon signals supplied from Washington. A further check was given by transit observations on the night after the eclipse.

Number of contact.	Mean time for seventy-fifth meridian.						
	Mr. Putnam.			Rev. Father Woodman.			
						By pocket chronometer.	*By chronograph sheet.*
First	19^h	36^m	$19^s.7$	19^h	36^m	21^s	$22^s.0$
Second	20	45	15.5	20	45	16	16.4
Third	20	46	44.1	20	46	47	43.5
Fourth	22	05	37.3	22	05	26	27.8

The record of the automatic contact camera proved of little value; for at first and fourth contacts there is an uncertainty of ten seconds just when the indentation of the image ceases; second contact was lost by failure of the electrical circuit, and five seconds elapsed after third contact before the images became strong enough to be distinguishable. The record is, however, so striking that a reproduction of the negative which includes totality is here given. (Pl. XI.)

[a] Washington Astronomical and Meteorological Observations, Vol. XXIII, pt. 2, p. 203, 1876.

A record of third contact is practically furnished by the chronograph sheet which recorded the exposures of the 38-foot camera, for the negative corresponding to an exposure terminating at $20^h\ 46^m\ 43^s.7$ shows a thin, bright crescent streak inside the very black overexposed prominence layer. Therefore at the time noted a portion of the sun had emerged which was sufficiently bright to produce a positive effect on the plate.

2. PHOTOGRAPHY OF THE INNER CORONA AND PROMINENCES.

(*a*) THE 135-FOOT CAMERA.

Mr. Smillie secured five negatives during totality, which were given exposures of ½, 1, 4, 16, and 8 seconds, respectively, the last exposure ending a little after third contact. Owing to a failure of the electric circuit, the exact times of exposure were not recorded on the chronograph, as had been intended, but all the negatives are excellent and show both the inner corona and the prominences with much detail. The originals must be seen to be appreciated, for there is no way of reproducing on the printed page what can be seen on looking through a glass negative against a ground-glass surface. Nevertheless, where there is so much of interest in the original a good deal remains in a good reproduction, so that the series of Pls. XII to XX are given in the hope of conveying to the reader something of the structure of the inner corona and prominences at the time of the eclipse.

Pls. XII to XIX, inclusive, show the whole corona as photographed near midtotality with sixteen seconds exposure and Pl. XX from an exposure of eight seconds ending at third contact gives the best view obtained of the great prominences on the southwest quadrant. The positions indicated are determined as follows: From the center of the sun's disk radii were drawn, of which that which passed through the north pole of the sun was numbered 0°, and starting from north the numbering increases in the direction NESW.

(*b*) THE 38-FOOT CAMERA.

Mr. Fowle secured eight good negatives during and immediately after totality. The times of exposure as recorded on the chronograph were as follows:

No.	Beginning of exposure.	End of exposure.	Interval.
1	$20^h\ 45^m\ 17^s.7$	$20^h\ 45^m\ 18^s.7$	1 sec.
2	20 45 27.7	....	1 sec. (?)
3	20 45 38.3	20 45 40.3	2.0 sec.
4	....	20 45 53.9	4 sec. (?)
5	20 46 3.7	20 46 12.0	8.3 sec.
6	20 46 23.4	20 46 31.8	8.4 sec.
7	20 46 40.1	20 46 43.7[a]	3.6 sec.
8	20 46 51.0	20 46 52.0	1.0 sec.

[a] End of totality.

These negatives are excellent, though in detail they do not equal those secured with the 135-foot camera, as was to be expected. Pl. XXI is reproduced from the exposure beginning at $20^h\ 46^m\ 23^s.4$ and shows the coronal streamers somewhat farther out than Pls. XII to XX because of its relatively greater exposure.

The original negatives of the inner corona, especially those secured with the 135-foot focus camera, are so full of detail that only confusion would result from an elaborate inventory, but as years go by and future eclipses yield new points of view in regard to the nature of the corona, it is believed that these plates will be of increasing value for reference. In a general view one gets the impression that the coronal streamers belong in two sets, respectively polar and equatorial in position. The polar streamers, like the lines of force of a bar magnet, curve as if to run together from the north pole to the south. The equatorial streamers start in a general way radially and curve in such a manner as soon to stretch out farther and farther from the sun in a direction roughly parallel to the plane of the ecliptic, and exhibit no tendency ever to run together from east to west. Thus the polar streamers in numerous instances appear to cross the equatorial streamers before becoming too faint to be readily followed.

On closer inspection it is seen that the radial appearance of the equatorial streamers as they emerge from the limb is by no means general. Near the large prominences on the southwest limb some of the streamers are much curved, while one group very remarkably exhibits what seems to be its origin. Beginning at the corner of the large fan-shaped spreading prominence at position angle 265°, two sickle-shaped coronal rays, broad at the base, start out tangent to the limb and at first run toward the equator, but soon curve outward to join the general direction of the equatorial rays, crossing over several radially directed rays in their path, while two other noticable rays above the prominence seem to be directed toward the same origin, but from the other side. Thus the four rays present the appearance of a doubled-framed lyre with the center of its bow just outside the photosphere and in a region of great prominences. Indeed, it may be said in general that disturbed regions of the corona seem to be associated with large prominences.

3. PHOTOGRAPHY OF THE OUTER CORONA AND OUTLYING REGIONS

(*a*) The 7½-foot focus camera. Mr. Gill obtained an excellent negative of eighty-two seconds exposure, on which the coronal streamers are seen to extend about to the image of the planet Mercury. Better results would have been reached by reducing the aperture, as the sky was overexposed. No stars fainter than the sixth magnitude are shown.

(*b*) The 40-inch cameras. A good coronal negative of about eighty-two seconds exposure was obtained with each of these instruments, in one of which a color screen was employed, but without marked effect. The coronal streamers are seen to extend about three diameters, but no stars are shown fainter than the sixth magnitude.

(*c*) The 11-foot cameras. The two negatives obtained with these instruments were of unequal merit. That covering the region west of the sun is very good; the other unfortunately had numerous defects in the film, and is of little value. Pl. I (frontispiece) is taken from a careful enlargement by Mr. Smillie of the corona as shown on the first mentioned of these two plates, though much of the fainter outlying region is lost in reproduction. A glass positive from the enlarged negative shows the whole region bounded by the northwest and southwest streamers to be filled with faint coronal light quite out to the image of the planet Mercury, a sharp boundary line separating this faint luminosity from the outlying sky to north and south.

In searching over this plate for possible planetary objects, 114 stars were found. The faintest is of the 8.4 magnitude as given in Argelander's Durchmusterung, though not all parts of the plate show stars as faint as this, owing to imperfect focus. The other negative, covering the region east of the sun, showed only 13 stars, of which the faintest was of the 6.3 magnitude.

In all, on both plates, eight uncharted objects of starlike appearance were found. Four of these are more or less uncertain in their appearance, and deserve little notice. The other four can not be differentiated in appearance from the nearest stars, but nothing is certain in regard to their character, because, so far as the writer is aware, no other plates taken by any of the eclipse expeditions show stars as faint as these, so that their reality can not be verified.

The positions of these objects as interpolated on the Durchmusterung charts of 1855 is as follows:

EPOCH 1855.

Right ascension.	Declination.	Magnitude.	Appearance.
3^h 40^m 22^s	20° 08′	7.2	Doubtful.
3 47 55	20 21	5.0 to 5.2	Good.
3 52 28	17 50	6.5	Good.
3 58 48	18 31	6.1	Good.
4 08 08	19 39	6.2	Good.
4 15 30	21 49	7.0	Doubtful.
4 31 00	19 50	4.5	Doubtful.
4 52 00	20 36	5.5 to 6.0	Doubtful.

Pl. XXII, drawn from measurements of the original negative, shows the position of all stars and starlike objects found in the region west of the sun.

The results obtained with the 11-foot cameras make it certain that no new planets brighter than the fifth magnitude exist, unless these were hidden by the sun or the brightest coronal regions, though it is possible that there may be such planets fainter than the fifth magnitude. If there be any brighter than the ninth magnitude, they can be photographed in future eclipses with cameras of this type.

4. BOLOMETRIC OBSERVATIONS OF THE CORONA.

Referring to Pl. IX, and to the accompanying description of the bolometric apparatus, the reader will recall that the beam entered the spectrobolometer room through an aperture of variable size, that the image was adjusted upon the slit jaws by moving the large concave mirror; that the prism was used sometimes with glass face forward, sometimes with silvered face forward as a mirror; that a cardboard screen was at times interposed in front of the bolometer to give the zero reading; that a glass screen was sometimes thus interposed; and that by a common clockwork the prism could be rotated and a photographic plate at the galvanometer could be moved vertically so as to record automatically the proposed spectrum observations.

Recalling all these arrangements the following data of the observations may now be considered:

BOLOMETRIC OBSERVATIONS.

[Current in each bolometer strip, 0.2 ampere. Time of single swing of galvanometer, 2.0 seconds. Observer at galvanometer, C. E. Mendenhall. Observer at prism, C. G. Abbot.]

Aperture of cat's-eye diaphragm.	Position of slit with reference to image.	Prism acting as mirror or as prism.	Screen.	Time of observation (75th meridian mean time).	Galvanometer reading.	Deflection of galvanometer.	No. of observation.
$0^{cm}.8 \times 0^{cm}.5 = 0^{cm^2}.4$	Nearly tangent to diminishing crescent of sun's limb.	As mirror...........	Cardboard inserted in front of bolometer after each deflection.	20^h 42^m (?)[a]	....	40^{mm}	1
				20 43 00	....	25	2
				Immediately after above.	....	25	3
				20 44 15	....	6	4
				Immediately after above.	....	6	5
				20 44 35	....	6	6
			Cardboard screen.	20 45 15(?)	60	60	7
$17^{cm} \times 17^{cm} = 289^{cm^2}$	At center of moon....	.....do..............	No screen.........	20 45 30(?)	42	−18	8
	On inner corona 0.2 mm. beyond moon's preceding limb.	.....do..............	.....do............	20 45 45(?)	47	−13	9
	At center of moon....	.....do..............	.....do............	20 45 55(?)	42	−18	10
	On inner corona	.....do..............	Glass plate	20 46 05(?)	51	− 9	11
$35^{cm} \times 35^{cm} = 1,225^{cm^2}$	Tangent to moon's advancing limb.	As prism for wave length $0\mu.40$.	No screen.........	20 46 15(?)	60	00	12
	....do...............	.....do..............	.....do............	20 46 30(?)	60	00	13
	....do...............	.....do..............	.....do............	20 46 40(?)	60	00	14
	....do...............	.....do..............	.....do............	20 46 45(?)	60	00	15

This part of the observations was, it will be remembered, in the immediate charge of Mr. Abbot, whose notes written five minutes after totality are as follows:

The spectrum was intended to be turned from H through to Ω, but the clamp screw was not turned by me so that all spectrum readings were on H in the violet. The photographic plate may or may not have been exposed by C. E. M. He has a vague idea that he raised the shutter. It may pay to develop, but all deflections are superposed. C. G. A. interposed piece of cardboard in preliminary readings, but not during totality. The slit was a very little (about 0.2 millimeter) west[a] of limb of sun, i. e., beyond the advancing moon. The beam was a little too low on the slit during the exposure, so that in the moon deflections about one-fifth of the strip

[a] "West" here refers to position in bolometric house.

was affected by the radiations from the polar coronal region. The moon's path was nearly at right angles with the slit. C. G. A. could observe image on white asbestos paper. The corona visible to him extended out about one-half sun's diameter in all directions. He could observe no special structure or shape other than circular in the time he could spare to see.

Later during the same day an attempt was made by a bolographic process to calibrate the apparatus on the solar spectrum, but owing to accidental fogging of the plate this work was lost. The plate supposed to be taken during the eclipse appears not to have been exposed, as nothing showed on developing it.

The bolometric apparatus was employed in August, 1900, to measure the radiations of the moon. Two days before full moon, with the apparatus in every way as nearly as possible like that of experiment No. 9 of the preceding table, but with a very humid and hazy—indeed, almost cloudy—atmosphere, *positive* deflections of 55 millimeters were obtained with the slit at the center of the moon's image, as compared with a cardboard screen at the room temperature, and 86 millimeters as compared with the dark zenith sky.

DISCUSSION OF THE BOLOMETRIC OBSERVATIONS.

The observations 1 to 6, inclusive, were made just before totality on the region of sky where the corona was shortly to be observed and with an aperture of only 0.4 square centimeters. Reduced to the same aperture of diaphragm as that used during the coronal observations 7 to 10, inclusive, the positive deflections in experiments 1 to 5 would range from 28,800 down to 4,300 divisions. During totality all the deflections were negative. This was extremely disconcerting to the observer at the galvanometer, for in anticipation of considerable positive deflections from the corona the spot of light had been brought near the zero of the scale, and hence but little room remained for negative deflections. Hence it was that the cats-eye diaphragm was not opened wider in experiments 7 to 10, inclusive.

If we assume the temperature of the dark moon to be approximately the temperature of space,[a] we find on comparing the negative deflections observed in experiments 8, 9, and 10, that the radiation of the corona caused a deflection of five divisions [— 13 — (—18)]. The brightest coronal radiation is then very feeble indeed as compared with the radiation scattered by our atmosphere when illumined by the narrow crescent of the photosphere even at a single minute before totality.

The meaning of the negative deflections deserves explanation.[b] It is well known that in a room of uniform temperature bodies in general radiate the same amount of energy they absorb, while a warmer body radiates more than it absorbs in its exchanges with a cooler body. In the experiment number 7, just before totality, the interposition

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[a] See Memoirs National Academy of Sciences, Vol. III, p. 31, and also Vol. IV, Part 2, Third Memoir, pp. 158–160.

[b] See also Memoirs of the National Academy of Sciences, Vol. IV, Part 2, Ninth Memoir, pp. 113–116.

of the screen of cardboard may be regarded as completing a constant temperature chamber in which the bolometer was inclosed. If we disregard the slight warming of the bolometer by the electric current, it may be said to have absorbed radiations from the screen equal in amount to the radiations which itself emitted toward the screen. But when the screen was removed in passing from experiment 7 to experiment 8, the surface of the moon in effect replaced the screen and became a small portion of the wall of the chamber inclosing the bolometer. Owing to the low temperature of the dark moon, which, as the writer and others have elsewhere shown is indistinguishable from the temperature of space, less radiation now reached the bolometer from this direction. Hence the rate of output of energy of the bolometer for an instant exceeded the inflow, until with diminished temperature its radiation was sufficiently reduced to establish a new condition of equilibrium. The corresponding reading of the galvanometer was of course in a negative direction from the reading corresponding to the card at room temperature which was taken as zero.

The interpretation of the negative deflections then is that the dark moon and inner corona were effectively cooler than the room temperature, which was reasonably to be expected in the former case, but was surprising in the latter, when the visible intensity of the coronal radiations is considered. From a comparison of the results of several observers of the eclipses of 1870, 1878, and 1898, it has been concluded that the average brightness of the coronal region observed with the bolometer was about equal to that of the full moon. But the bolometric experiments of August, 1900, as given above, show that a deflection of eighty-six divisions was given by the nearly full moon as referred to the dark sky, and a positive deflection of fifty-five divisions as compared with the screen at room temperature.

To restate the matter in another form, it has been shown by the writer and others that the radiation of the dark moon is practically indistinguishable in amount from that of space; the reading on the dark moon may therefore be regarded as the zero of the series,[a] and the same which would have been obtained upon the sky in the direction of the inner corona had the latter been absent. Referred to this zero the radiation of the inner corona produced a deflection of five divisions; that of a card at room temperature produced eighteen divisions; that of the full moon produced eighty-six divisions, and the diffuse reflection of the rays of the crescent sun in the five minutes before totality from 4,300 to 29,000 divisions.

Why then should the coronal radiation of equal apparent brightness to that of the full moon be comparatively so feeble in heating effect? It might be urged that this is occasioned by the supposed rare gaseous structure of the corona, through

[a] The radiation of our own atmosphere depending upon its temperature, is superposed on that of the moon, and also on that of each of the other sources measured, but being small in amount, and as appears from the equality of the two readings on the dark moon, presumably constant in the single half minute of the eclipse observations, it disappears from the differences of the galvanometer readings, and is hence neglected. It should be noted that as the sun is hidden, the diffuse reflection of the sky is not here in question.

which the radiations of the bolometer may pass readily and reach the cold space beyond; and, furthermore, it might be said that the Milky Way, known to be composed of numerous hot stars, would undoubtedly be indistinguishable by the bolometer from the blackest sky. To these considerations it must be replied that the amount of radiation of the bolometer outward is a function of its own temperature only, and is independent of the nature of the objects it radiates upon; so that what is different in the observations of the full moon and the inner corona is not the outward radiation of the bolometer, but rather the amounts of radiation they send back to it. But if these are to the eye the same, why should they be different in heating effect? Obviously a natural explanation would be the comparative absence of some invisible radiations in the case of the inner corona, which are present in the case of the moon, such as would be due to an absence of infra-red rays. In the case of the Milky Way cited above no such conclusion is to be drawn, because the Milky Way is as faint to the eye in comparison with the full moon as it is feeble in heating effect upon the bolometer.

The conclusion just reached from experiments 7, 8, 9, and 10, namely, that the inner corona appears to be lacking in infra-red rays, depends mainly on two assumptions, first, that the experiments are substantially correct; second, that the average visible brightness of the coronal region observed is nearly equal to the average brightness of the full moon. Both require confirmation in future eclipses.

As regards experiment number 11, the result reached is irreconcilable with the others unless the glass, which was small, failed of being interposed so as wholly to cut off the beam, or unless an error of recording was made so that the reading should have been 61, not 51. The result to be expected by the interposition of the glass was that a small positive deflection would result, for glass is opaque to the radiations of the bolometer, and would have the essential properties of a screen at the room temperature, while at the same time it would transmit most of the feeble coronal radiations, which would cause a slight positive deflection.

Experiments 12 to 15, inclusive, are in effect equivalent to a repetition of experiment 7, for the coronal spectrum in the violet is evidently too feeble in heating effect to cause a deflection, and the prism would act only as a reflector of the radiations from the walls of the room to the bolometer. These experiments are then to be regarded as furnishing four additional zero readings, and indicate by their agreement the excellent behavior of the bolometric apparatus.

SUMMARY AND CONCLUSION.

The expedition was generally successful in its observations.

The eclipse was attended with only a moderate degree of darkness. Telescopic observations indicated considerable coronal detail, though less than had been observed in 1878. Large prominences were present, and these appear to have been associated with regions of coronal disturbance. The equatorial streamers were followed on photographs to nearly 4 solar diameters, and were there lost by reason of diminished intensity rather than as appearing to end. The polar streamers were conspicuous, and curved in much the same way as the lines of force of bar magnets. Excellent photographs filled with detail were secured with the long-focus cameras, and these, it is hoped, will have great and increasing value for reference in future years. The 135-foot focus lens proved of the highest value for the purpose of eclipse photography.

In the bolometric observations the heating effect of the inner coronal radiations was recognized and found unexpectedly feeble. The results seem to indicate a comparative weakness of the infra-red portion of the coronal spectrum, alike inconsistent with the hypothesis that it radiates chiefly by virtue of a high temperature, or acts chiefly as a reflector of ordinary sunlight. This, taken in connection with the appearance of the corona, seem to support the hypothesis that the principal source of its radiations is of the nature of an electrical discharge. The well-known polorization of its outer portions, and the presence of faint dark lines in the outer coronal spectrum, announced many years ago by Janssen and confirmed by the photographs of Perrine in the eclipse of 1901, prove that a small portion of the coronal radiation is due to reflected photospheric light. But the photographs of the coronal spectrum by Campbell in 1898, and Perrine in 1901, indicate that the principal part of the coronal light is not reflected sunlight. Many are disposed to believe the main source to be the incandescence of particles due to the proximity of the hot photosphere, but so far as the writer is aware the spectroscopic evidence is equally in accord with the hypothesis of a glow electrical discharge. An example of such a discharge is found in the aurora of the terrestrial atmosphere, but while we can hardly deny the possibility of its existence in the case of the sun the above observations do not seem to the writer to be conclusive on the point. In any case bolometric observations at future eclipses seem very desirable as furnishing a method of determining the real nature of the coronal radiations.

The results of the search for intra-mercurial planets render it improbable that any of these bodies exist brighter than the fifth stellar magnitude, but there may still be some fainter than this. Several suspicious objects were found on one plate, but could not be confirmed for lack of a duplicate photograph of equal merit. The 3-inch aperture 11-foot focus camera proved well adapted for the search, and in future eclipses intra-mercurial planets may be photographed with similar apparatus, if any such planets brighter than the ninth stellar magnitude exist.

In conclusion, I desire to express my gratitude for the aid furnished by so many in furthering the interests of the expedition, and to each and all of the observers whose untiring efforts in preparation and rehearsal, and whose skill and coolness during the eclipse, insured the successful issue.

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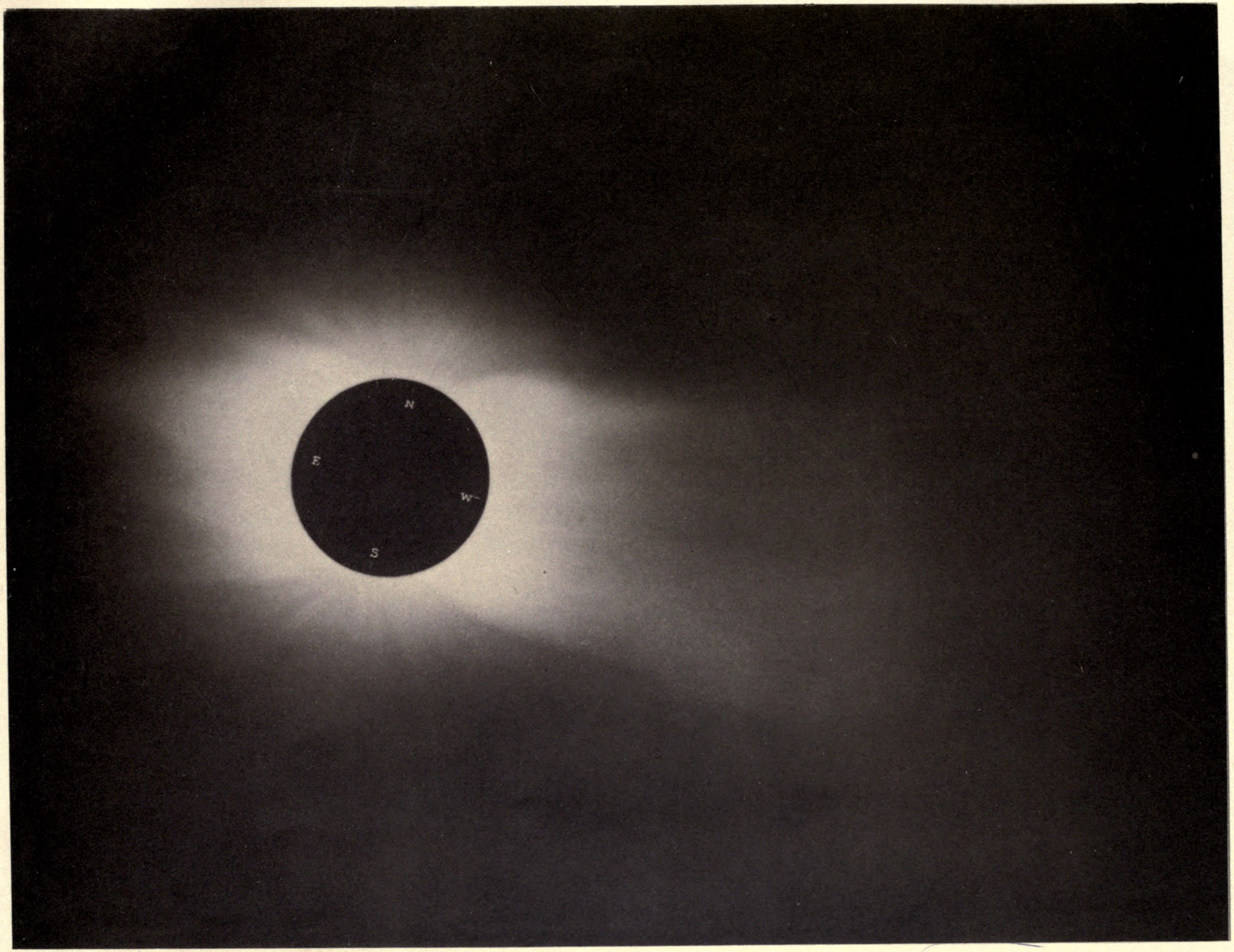
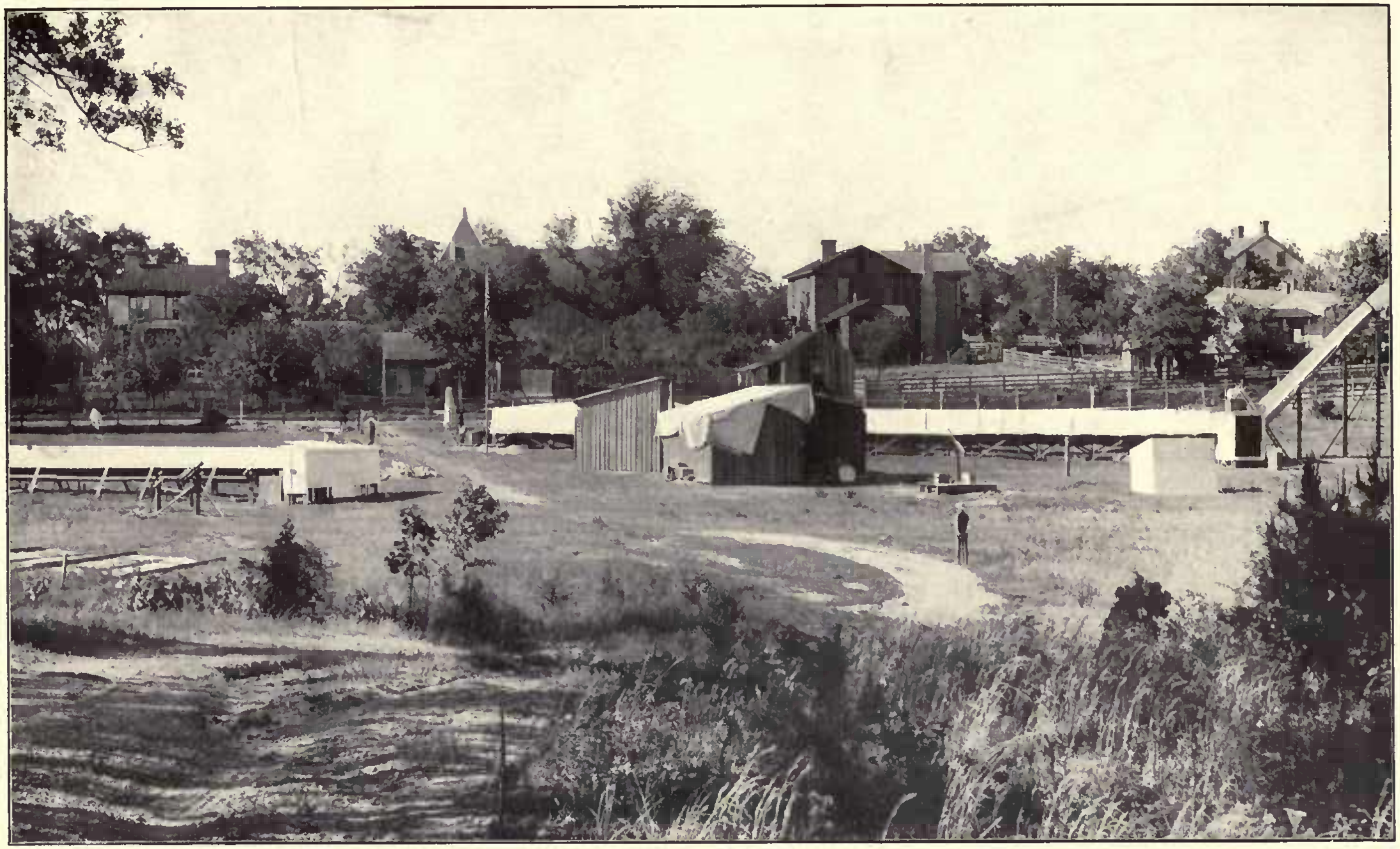


General View of the Corona. From 82-Second Exposure with 11-Foot Focus Camera.



THE ECLIPSE CAMP AT WADESBORO, N. C.

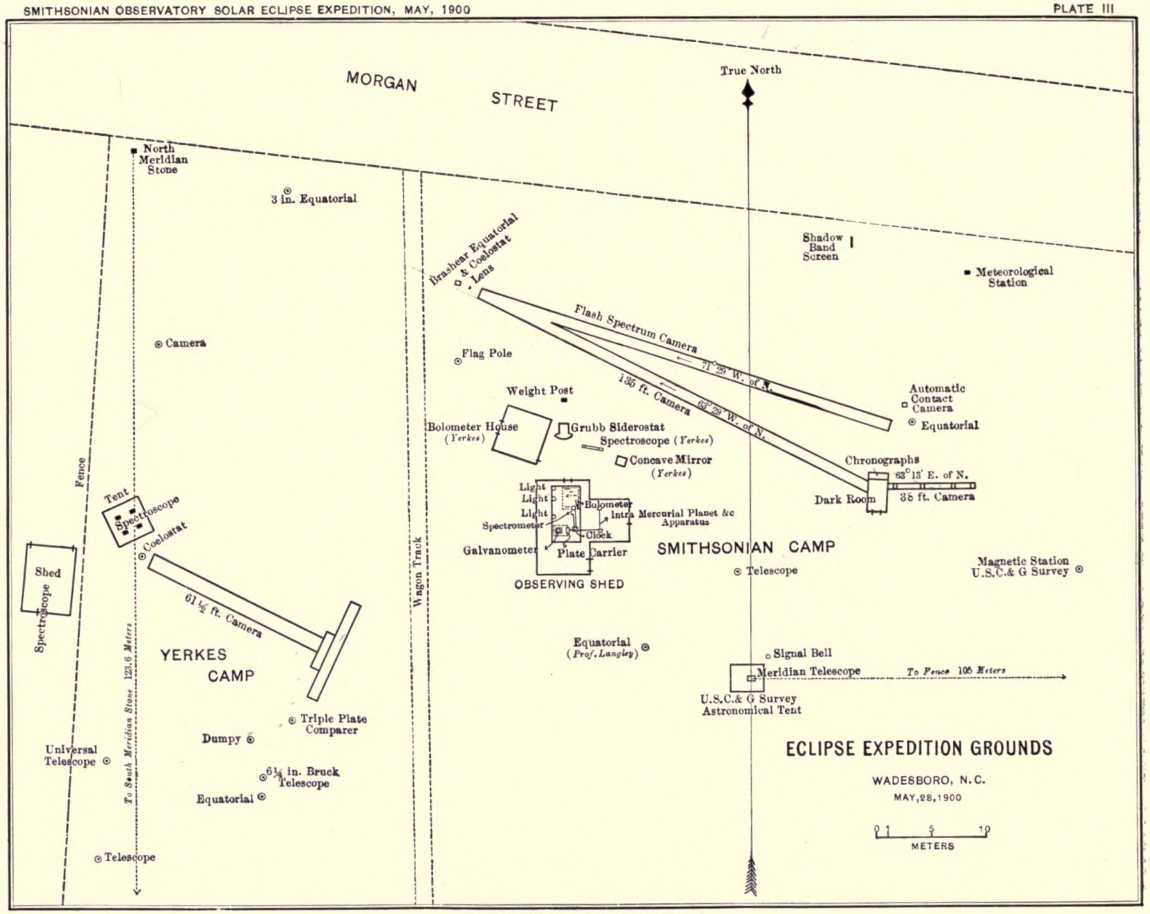
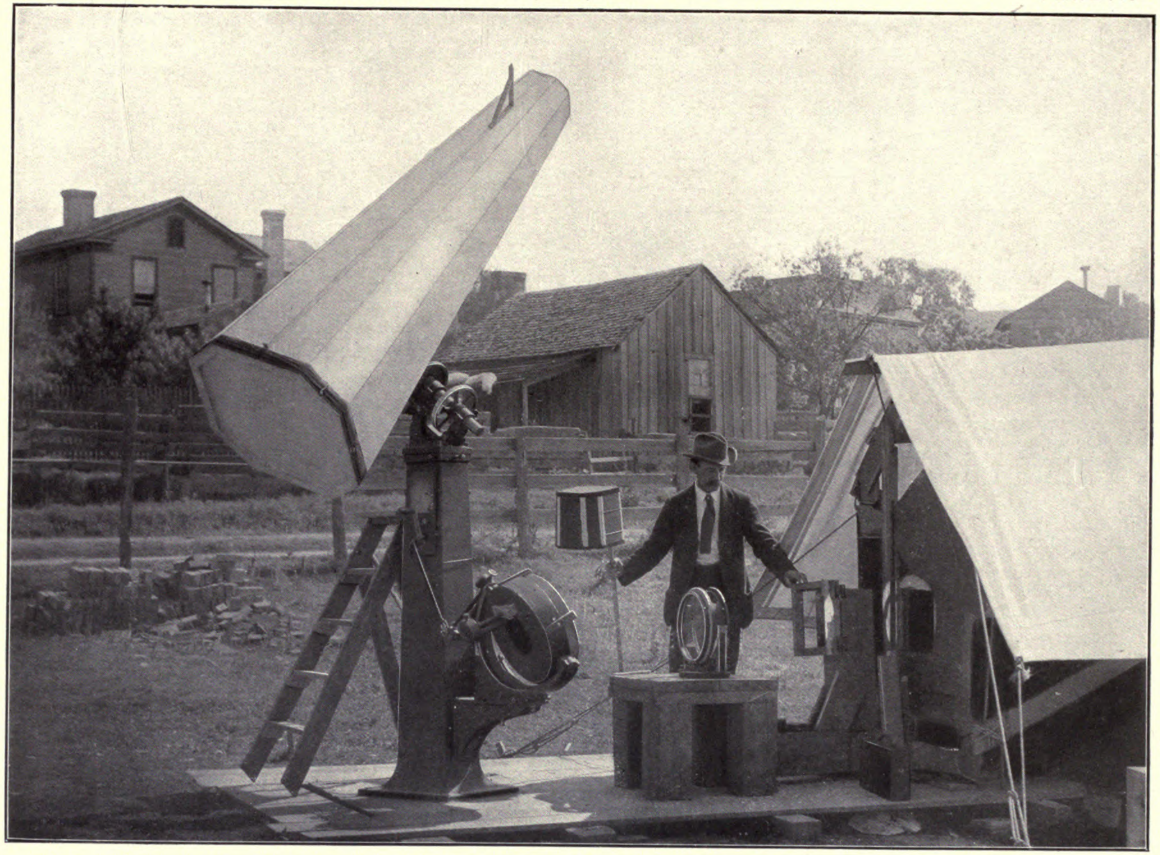
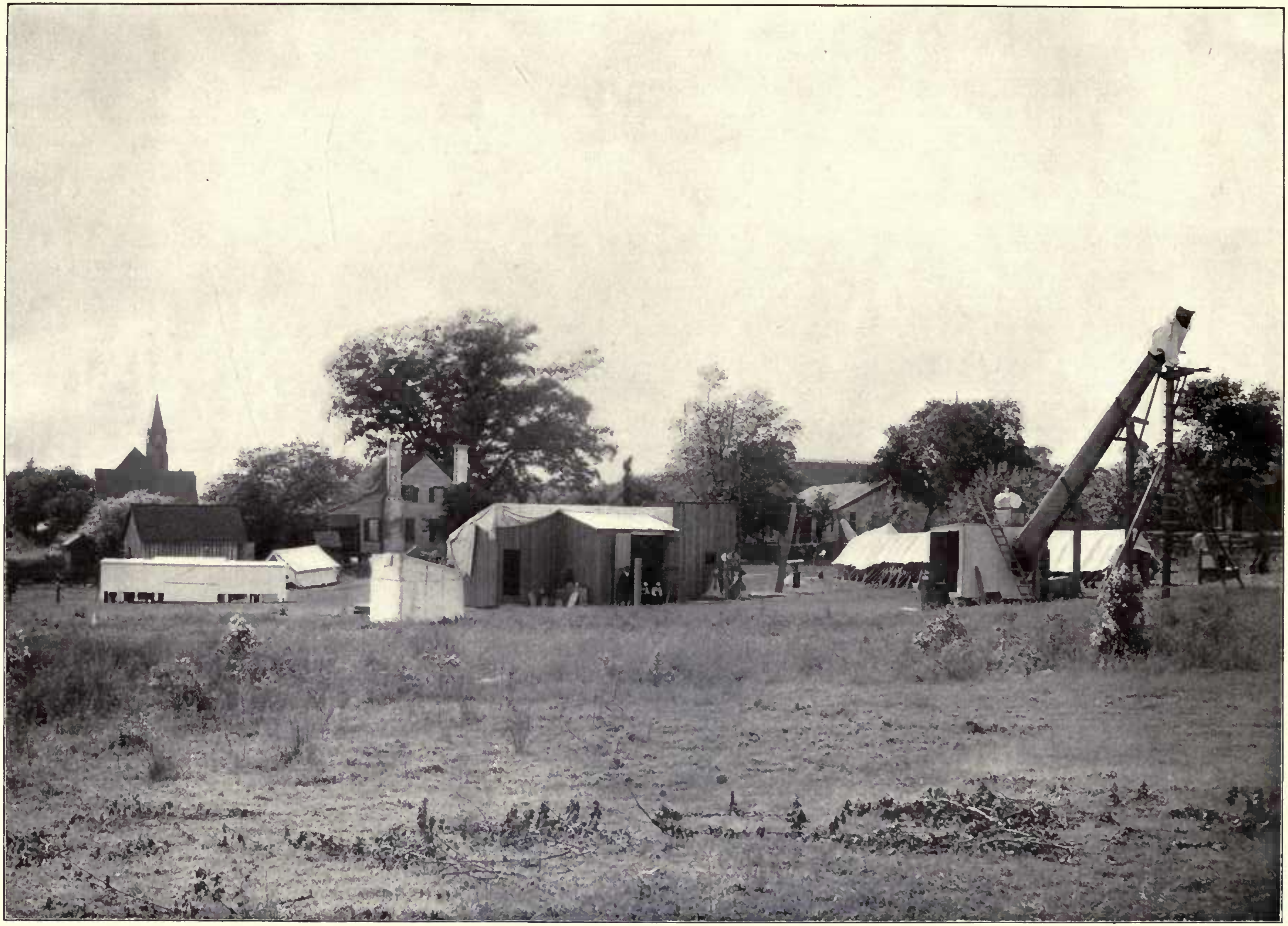


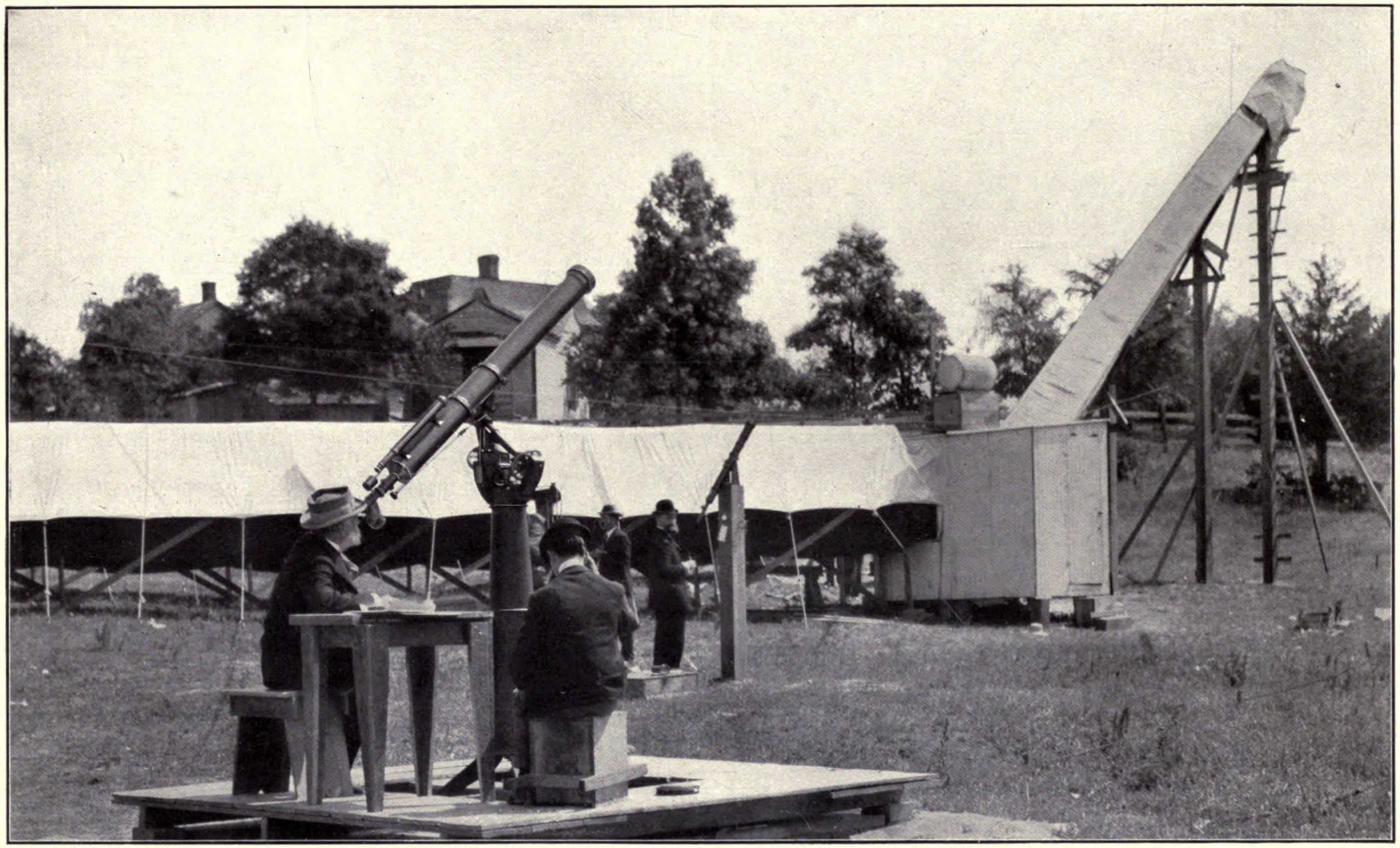
DIAGRAM OF ECLIPSE CAMP



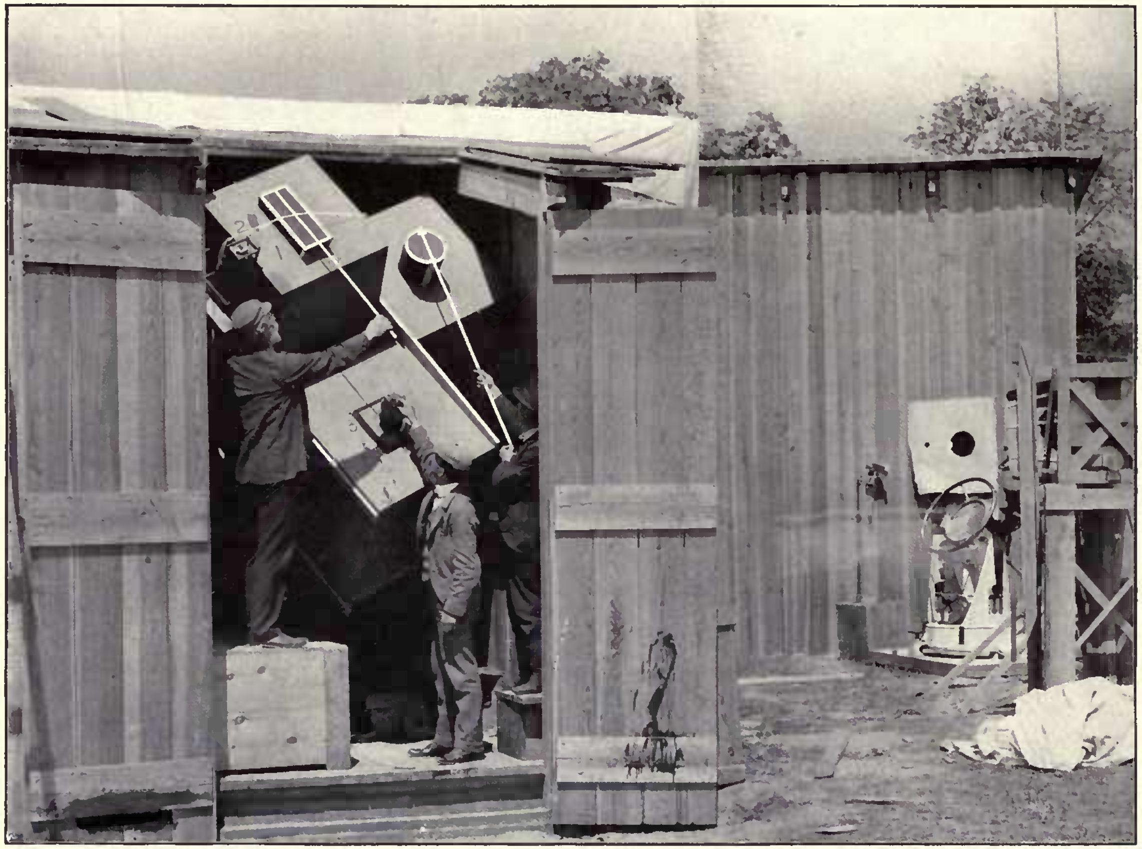
CŒLOSTAT WITH EQUATORIAL CAMERA AND SHOWING THE GREAT LENS AND PRISM.



VIEW OF THE CAMP, LOOKING WEST.



THE PHOTOGRAPHIC AND VISUAL TELESCOPES.



INTRAMERCURIAL PLANET CAMERAS.

THE BOLOMETRIC APPARATUS.

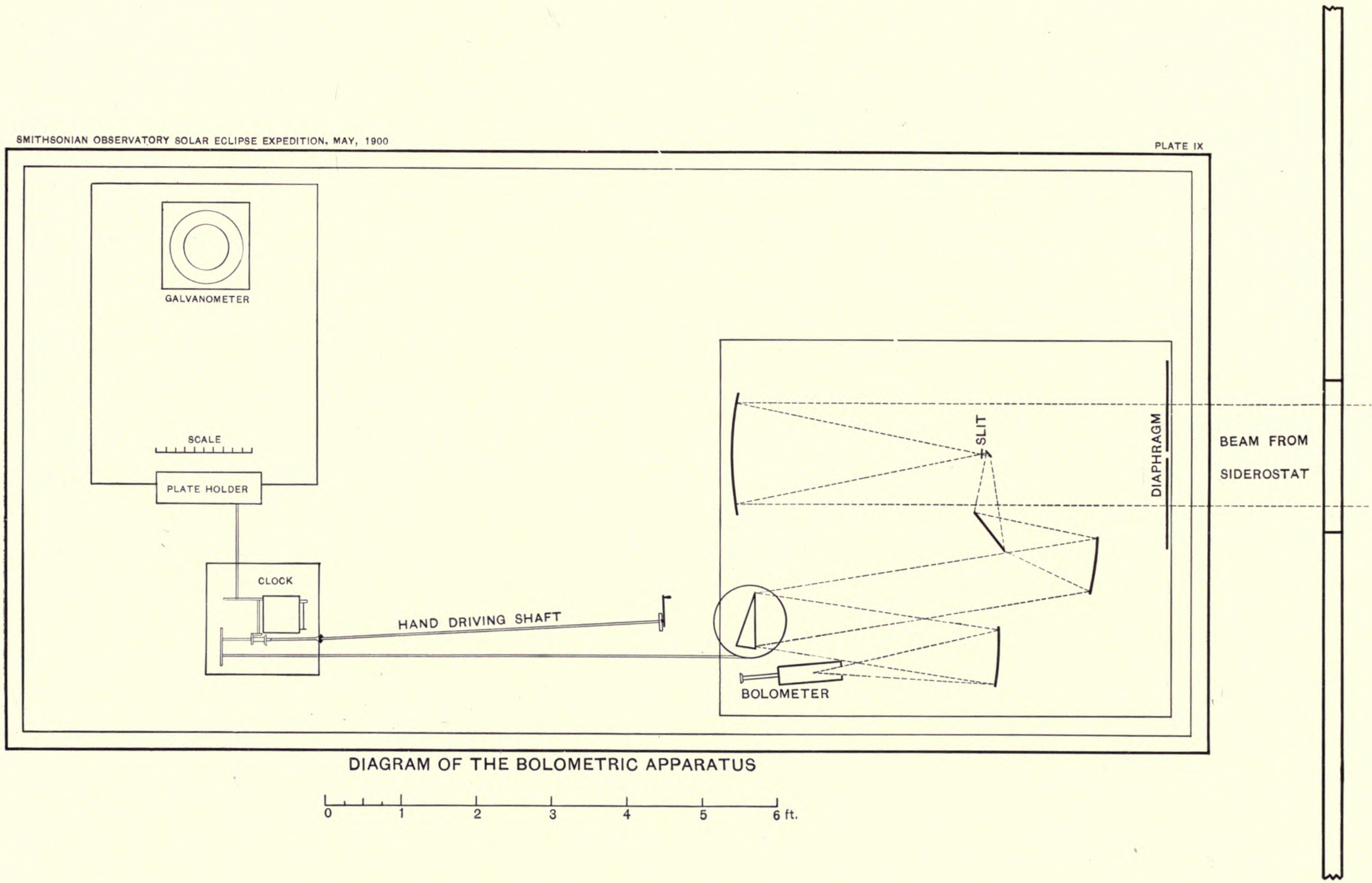
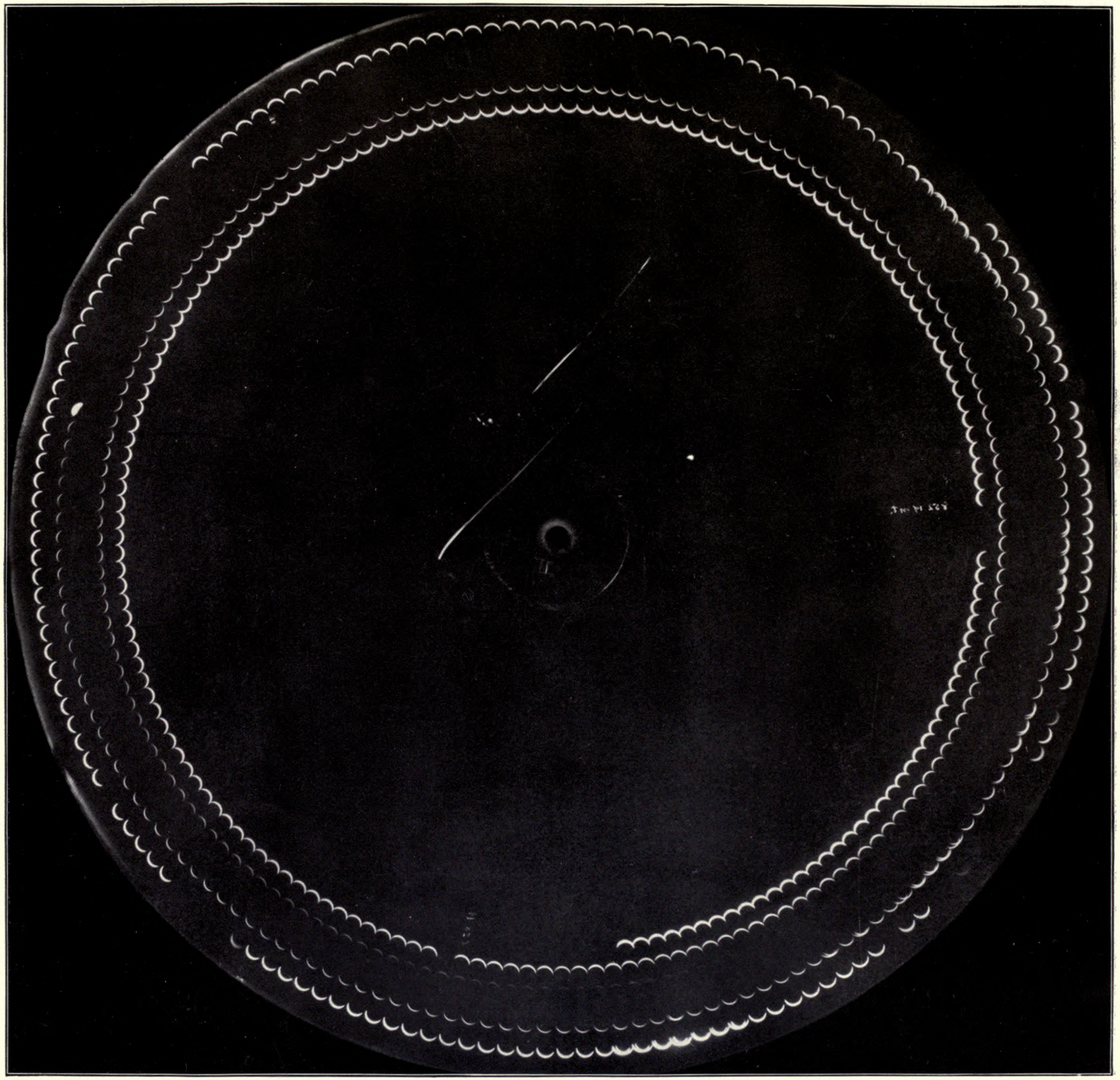


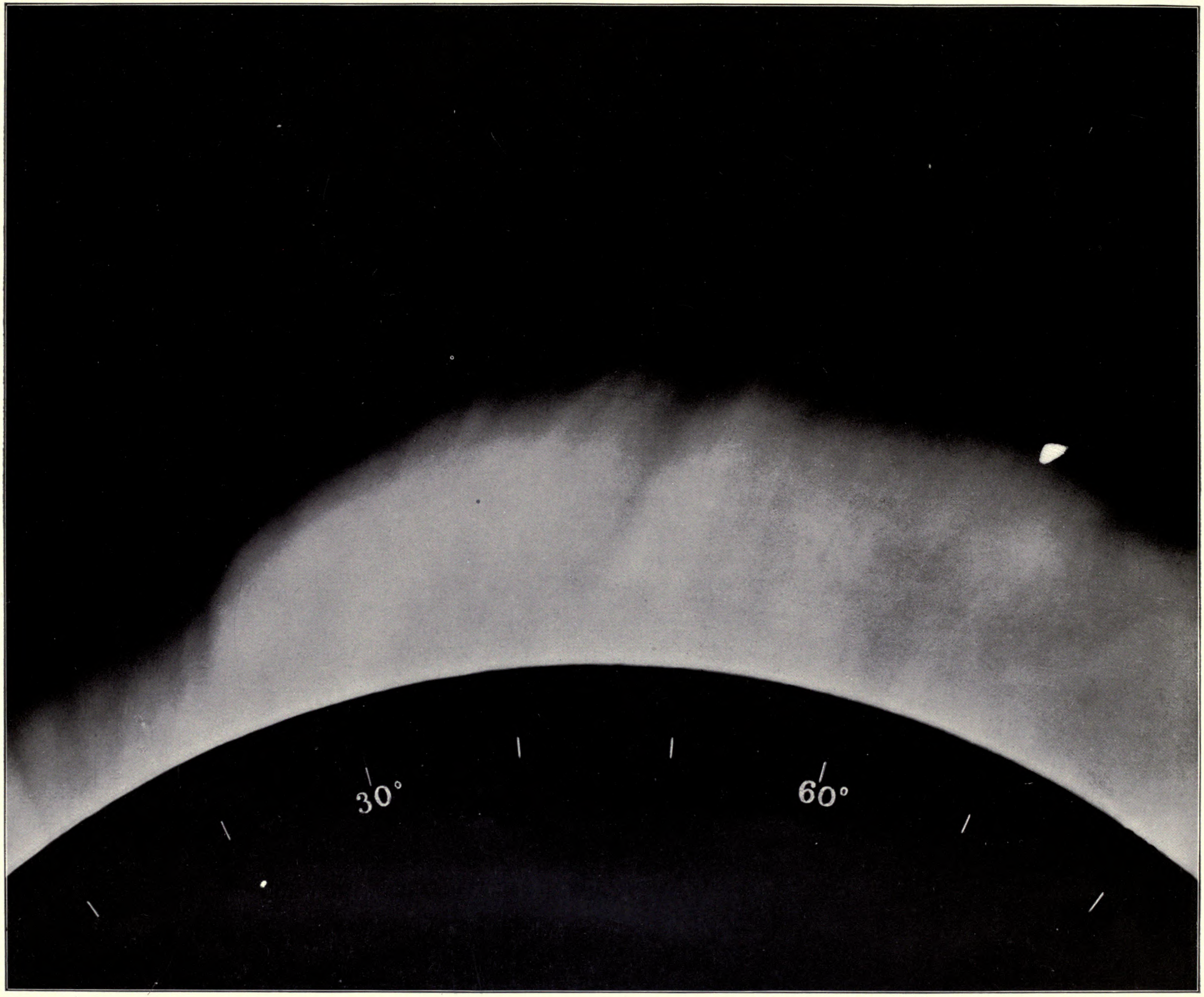
DIAGRAM OF THE BOLOMETRIC APPARATUS

UNITED STATES COAST AND GEODETIC SURVEY TENT.



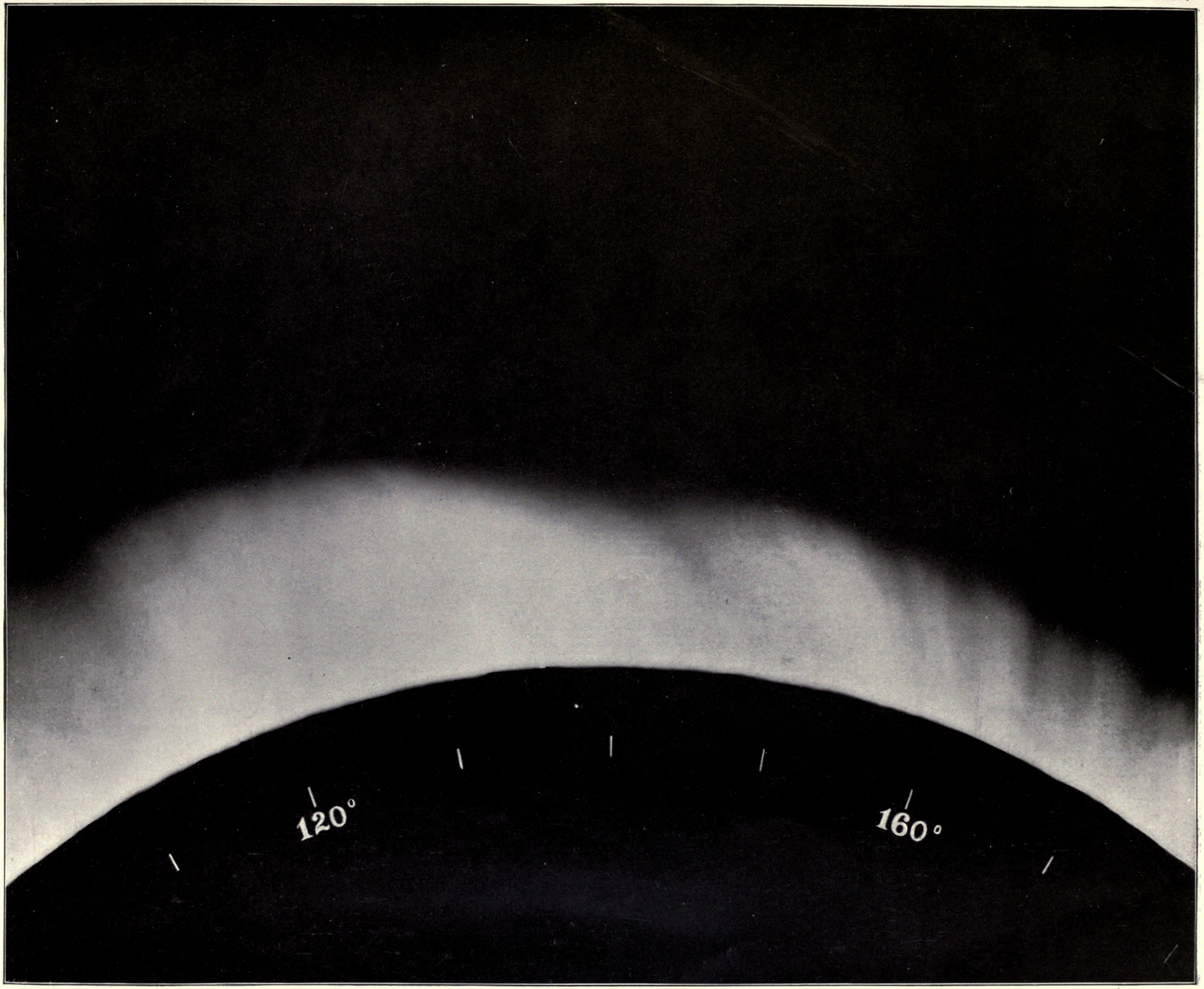
PHOTOGRAPHIC RECORD OF TIMES OF CONTACT.

THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.

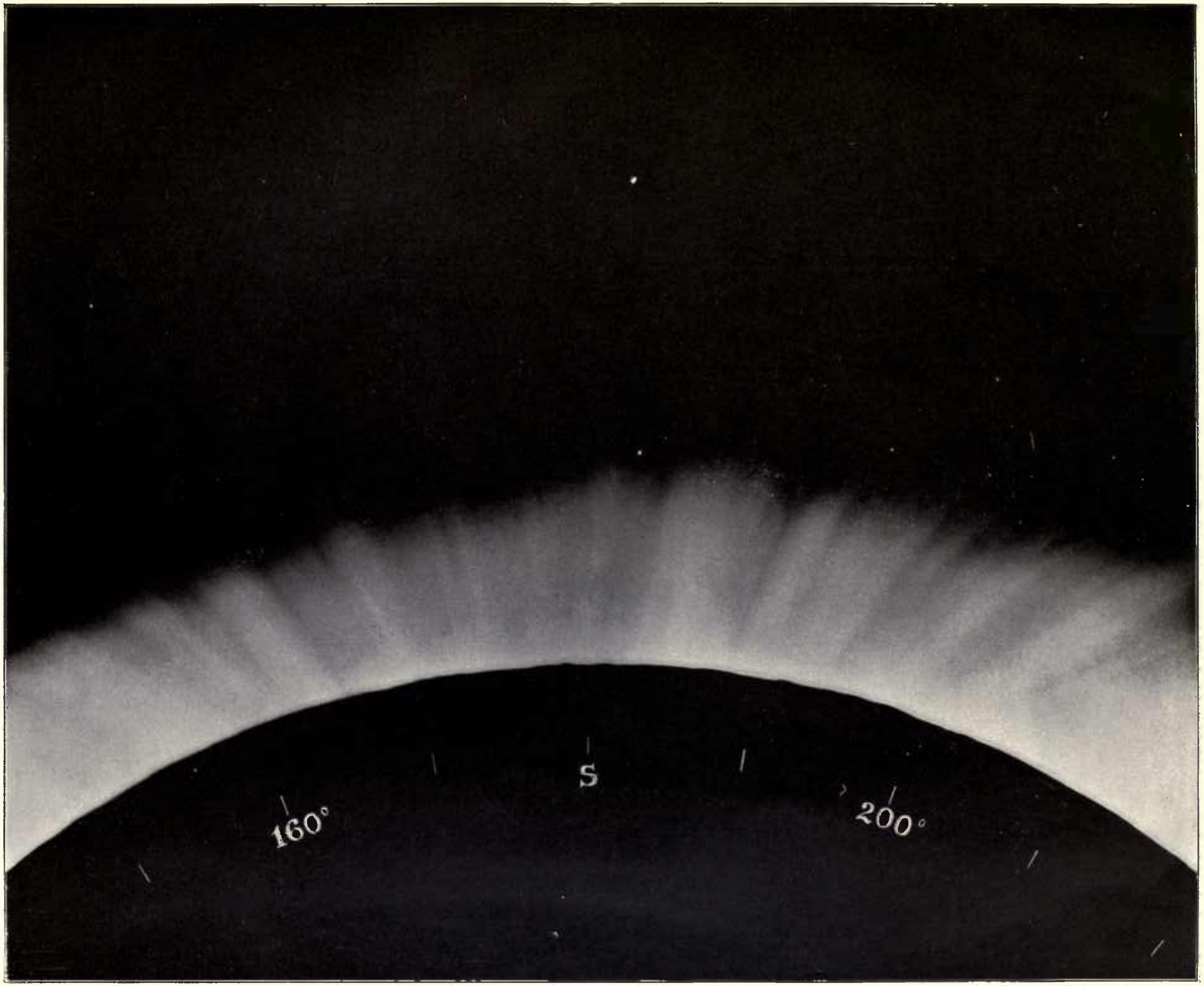


THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.

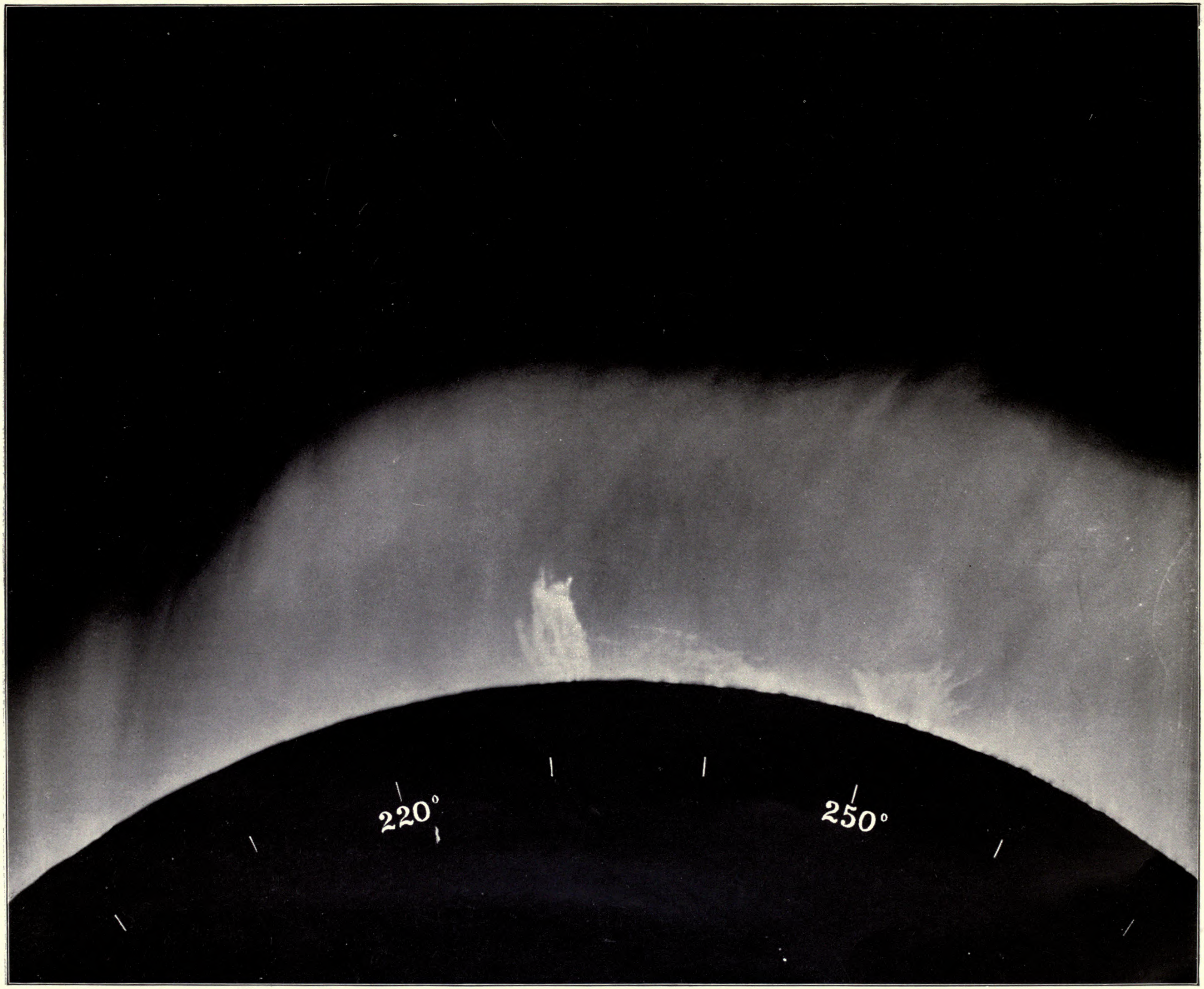
THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



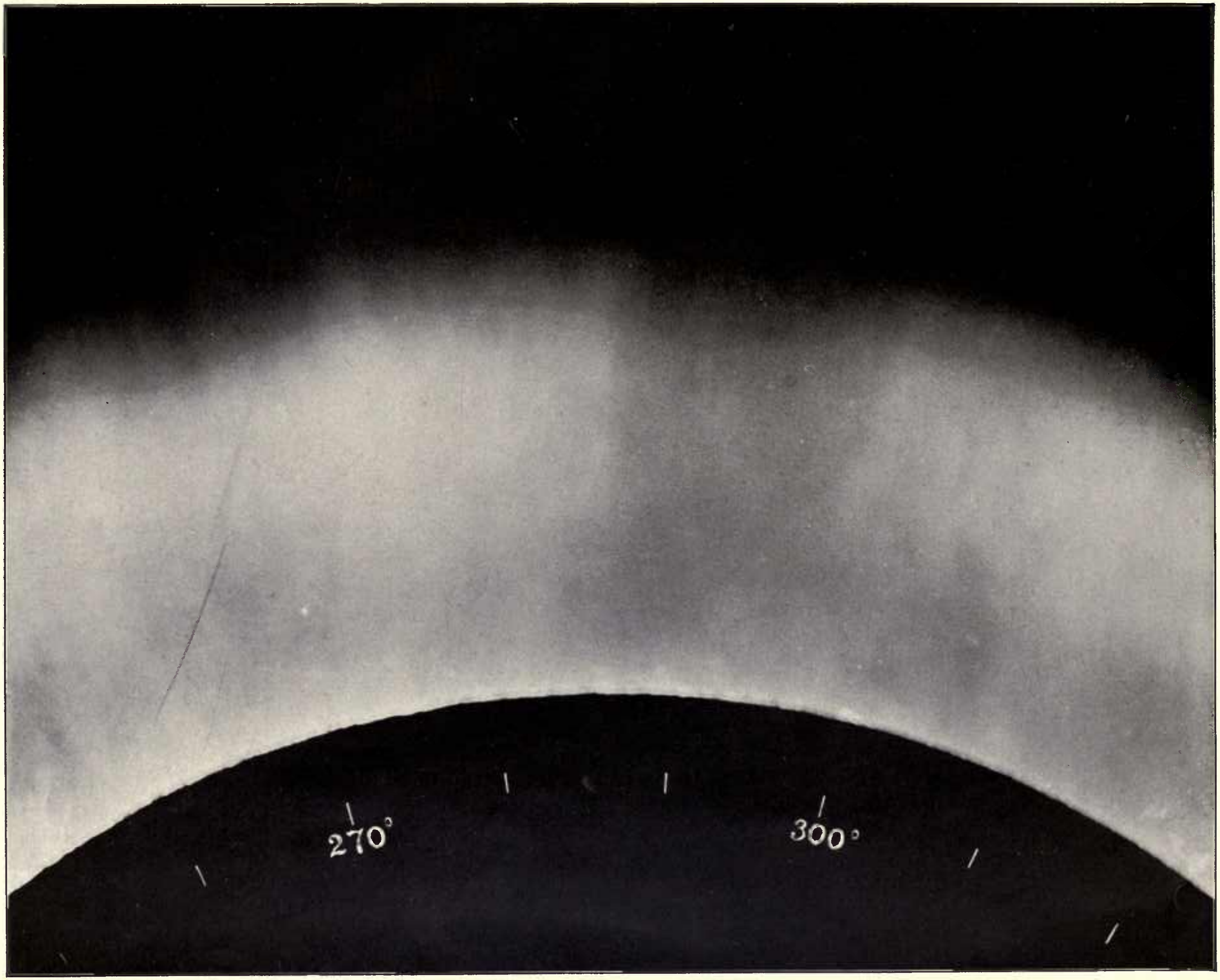
THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



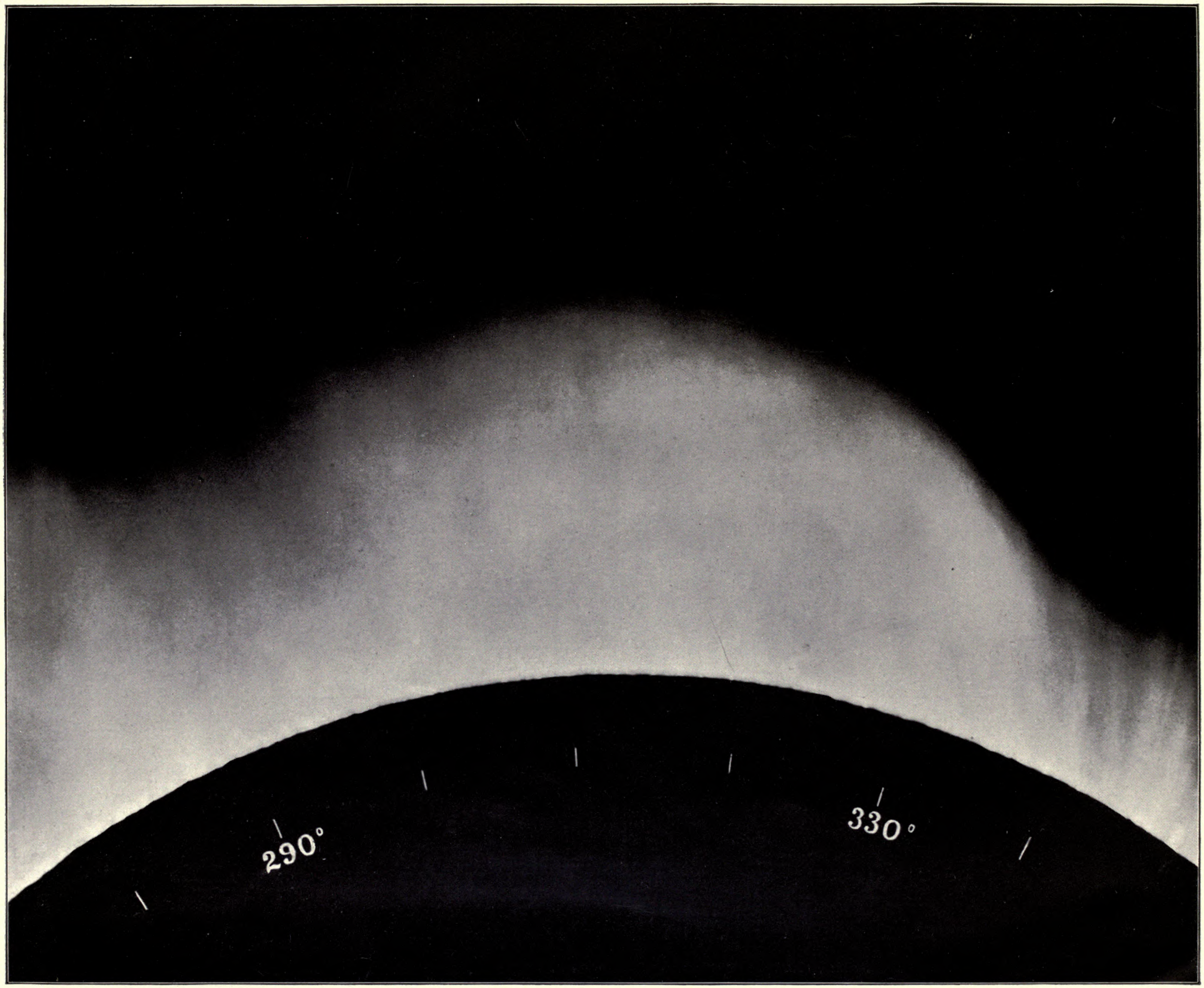
THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



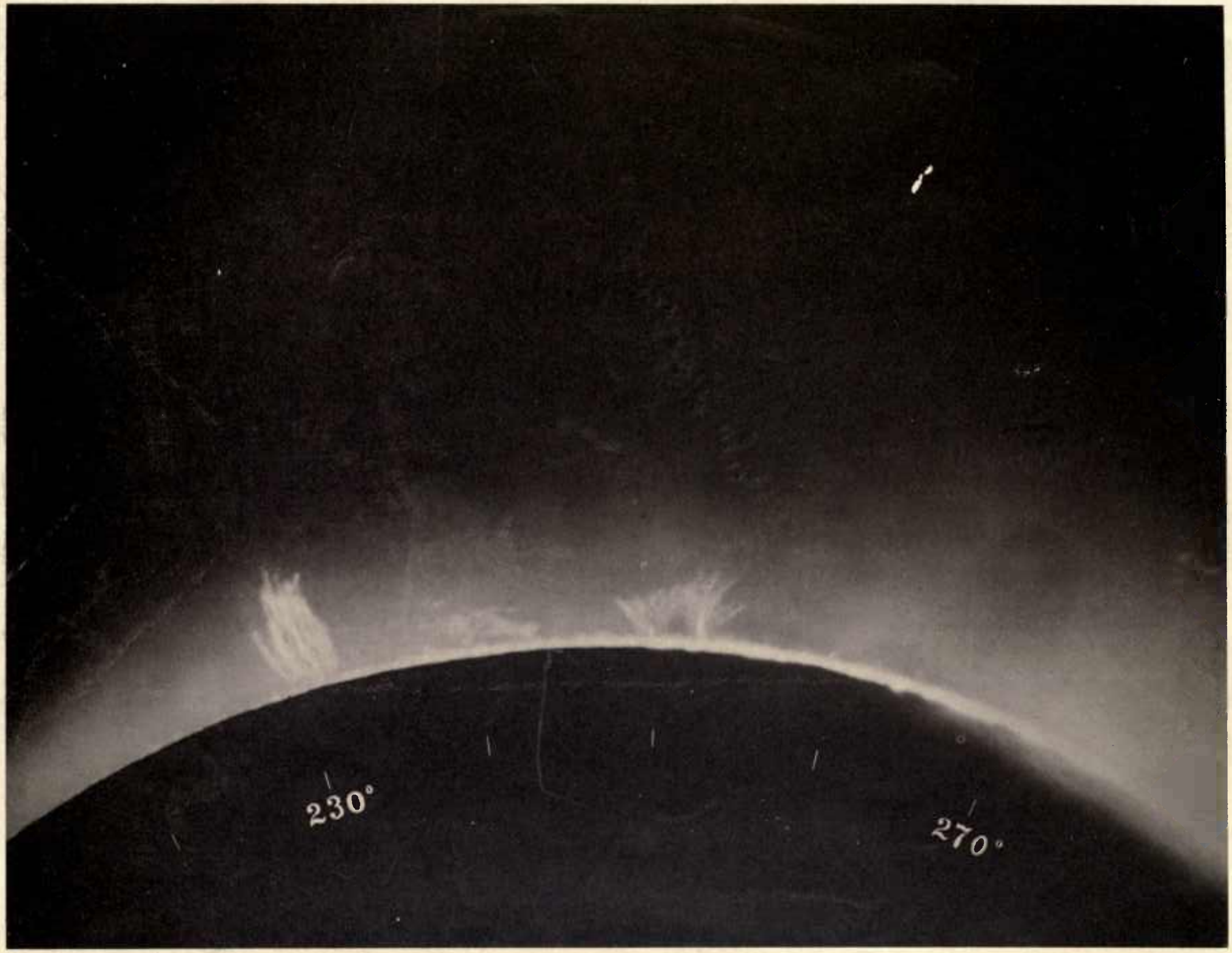
THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



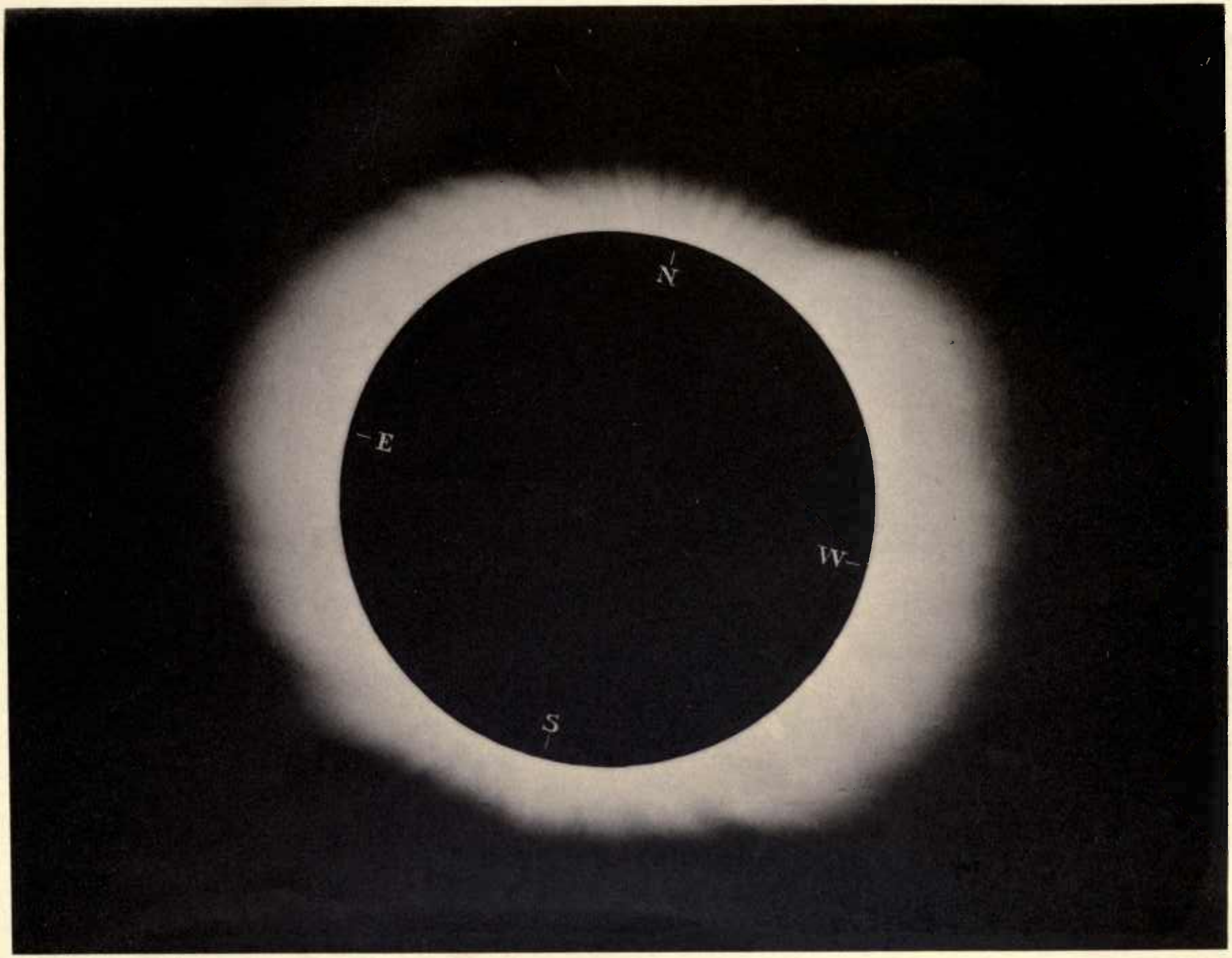
THE INNER CORONA. FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



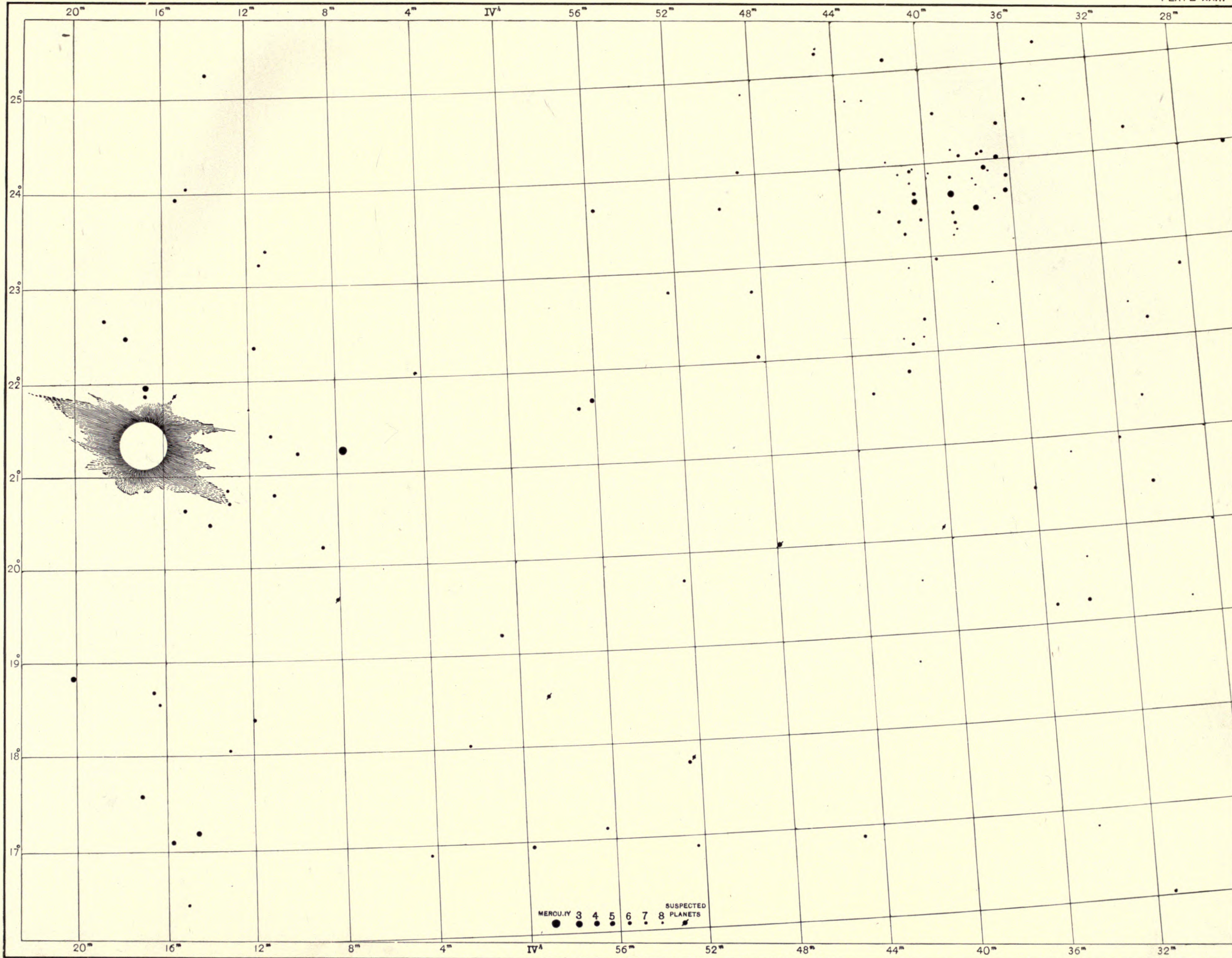
THE INNER CORONA FROM 16 SECONDS EXPOSURE WITH 135-FOOT FOCUS CAMERA.



THE SOUTHWEST PROMINENCES. FROM 8-SECOND EXPOSURE WITH 135-FOOT FOCUS CAMERA



GENERAL VIEW OF THE INNER CORONA FROM 8-SECOND EXPOSURE WITH 38-FOOT FOCUS CAMERA



THE SUSPECTED INTRAMERCURIAL PLANETS.