PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Drawings of the Corona from Photographs at Total Eclipses from 1896 to 1922

The Royal Society

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IX. *Drawings of the Corona from Photographs at Total Eclipses from 1896 to 1922.*

(*Communicated by the* Astronomer Royal.)

(Received November 11, 1926.)

[Plates 5–16.]

In the various Eclipse Expeditions from the Royal Observatory or sent out by the Joint Permanent Eclipse Committee, a number of excellent photographs of the Corona have been taken. Drawings of these photographs, embodying the more important features, have been made, but no reproductions have as yet been published. As the form of the Corona is intimately related to other Solar phenomena, it is desirable that permanent records should be kept of its appearance at every Eclipse.

Sir William Christie took a great interest in obtaining large-scale photographs of the Corona. By the use of a negative enlarging lens he avoided the necessity of telescopes of very great focal length. Even so, the total length of the instrument was 12 feet. The equatorial mounting of such a telescope in Eclipse Expeditions presents some difficulty, as it necessitates the transport and erection of heavy mountings for the instrument and provision for its housing accommodation. These were largely obviated by the use of the cœlostat introduced in 1896 by Prof. Turner and constructed for the Expeditions by Dr. Common.

Sir William Christie arranged that at each Eclipse photographs should be taken with varying exposures; the shortest near the commencement and end of totality to show prominences and inner Corona; the longest at mid-eclipse to show the greatest extension, and intermediate exposures to show as far as possible the detail and general structure of the Corona. It is impossible to reproduce such photographs satisfactorily, and as drawings of the greatest excellence from the photographs of previous eclipses had been made by Mr. Wesley, the Assistant Secretary of the Royal Astronomical Society (' Phil. Trans., vol. 180, 1889), Sir William Christie commissioned him to make drawings from the photographs of the eclipses of 1898, 1900, 1901 and 1905. These were made after prolonged study, and all details shown on the photographs are correctly reproduced in the drawings. The drawings of the 1914 and 1919 eclipses were made by Miss A. Crommelin, who was at that time working at the Observatory. They are very satisfactory reproductions of the details shown on the plates.

The following is a list of the various expeditions :—

(1) 1896, August 9. Japan. Christie, Turner. (Cloudy.)
(2) 1898, January 22. Sahdol, India. Christie, Turner.
(3) 1900, May 28. Ovar, Portugal. Christie, Davidson.

 [Published May 12, 1927.

(4)	1901, May 18.	Sumatra. DYSON, ATKINSON, Capt. OLDHAM. Mauritius. Mr. and Mrs. MAUNDER.*
(5)	1905, August 30.	Sfax, Tunisia. CHRISTIE, DAVIDSON, SAMPSON. Labrador. Mr. and Mrs. MAUNDER. (Cloudy.)
†(6)	1908, January 3.	Flint Island, Pacific Ocean. Mr. F. K. MCCLEAN.
(7)	1912, August 10.	Passaquatro, Brazil. EDDINGTON, DAVIDSON. (Cloudy.)
(8)	1914, August 21.	Minsk, Russia. JONES, DAVIDSON.
(9)	1919, May 29.	Principe, W. Africa. EDDINGTON, COTTINGHAM. Sobral, Brazil. CROMMELIN, DAVIDSON.
(10)	1922, September 21.	Christmas Island, Indian Ocean. JONES, MELOTTE. (Cloudy.)

The observers mentioned took a direct part in obtaining photographs of the Corona. Complete lists of those who assisted in various ways, or made other observations, will be found in the preliminary reports.

The instrument used in the large-scale photographs of the Corona in the eclipses of 1898, 1900, 1901 (Sumatra), 1905 and 1914 is a photographic telescope of 9 inches aperture and 8 feet 6 inches focal length in conjunction with a negative enlarging lens. The object glass was presented to the Royal Observatory by Sir HENRY THOMPSON and is used in the daily photography of the Sun's surface. At the eclipse of 1898 the enlarging lens was of 3 inches diameter and 12 inches focal length. To obtain a greater field, a lens of 4 inches aperture and 16 inches focal length was substituted in 1900. Each of these combinations was arranged to give an image of the sun 4 inches in diameter.

In 1901, when a second expedition was sent to Mauritius, the lens of a Dallmeyer 4-inch photoheliograph was used in conjunction with the 3-inch enlarging lens which had been used in 1898. The image of the sun was 2·4 inches in diameter. In addition Mrs. MAUNDER used a $4\frac{1}{2}$-inch Cooke photo-visual objective, of 71 inches focus, mounted equatorially.

In 1905 the object glass of the astrographic refractor was also employed in conjunction with a cœlostat. The diameter of the sun's image is $1\frac{1}{4}$ inches, and the definition is excellent over a field of 2 degrees square. The photographs were intended to give greater extension, but the short exposures show a remarkable amount of fine detail. This object glass was taken to Brazil in 1919; although the photographs were not satisfactory for the delicate deflection problem, they give good representations of the Corona.

In 1908 Mr. MCCLEAN used a telescope of $4\frac{5}{8}$ inches aperture and 8 feet focal length.

* Mrs. MAUNDER was not an official member of the Greenwich expedition. She obtained a series of excellent photographs, from which a drawing was made by Mr. WESLEY.

† No expedition was sent out by the Joint Permanent Eclipse Committee; this one was organised by Mr. (now Sir FRANCIS) MCCLEAN, and a drawing from his photographs was made by Mr. WESLEY.

In 1919 a 4-inch lens of 19 feet focus, lent by the Royal Irish Academy, and fed by a cœlostat, was employed. The diameter of the sun given by this instrument is 2·0 inches.

In 1922 the equatorial mounting was taken as well as the astrographic telescope, but unfortunately cloudy weather prevented observation.

For the small-scale photographs a Dallmeyer rapid rectilinear lens of 4-inches aperture and 34 inches focal length and a Ross "Unar" lens of 2·4 inches aperture and 12 inches focal length were employed. They were mounted equatorially and used at the eclipses of 1900, 1901 and 1905.

The eclipses at which successful photographs were obtained are distributed through the sun spot cycle. Those of 1900, 1901 and 1914 were within a year of sun spot minimum. Here the Corona has a long extension in the equatorial direction and large well-defined polar plumes. The eclipse of 1905 took place a year before maximum. Here long streamers are distributed round the whole of the sun's circumference and polar plumes cannot be distinguished. The eclipse of 1919 took place one and a half years after maximum. Long streamers are found in high latitudes, but polar plumes are also distinctly shown. The eclipse of 1898 was nearly midway between maximum and minimum of sun spots. Polar plumes are clearly shown and long streamers in middle latitudes.

The presence of arches in the Corona over prominences appears at four of the eclipses. In 1898 a striking streamer in the N.W. quadrant rises from an arch over three prominences. In 1901 a triple arch is shown over a prominence in the S.E. quadrant. This is shown on the Mauritius and Sumatra plates. A double arch is over a small prominence in the S.W. quadrant in the 1905 eclipse: also two large arches are shown over a chain of prominences in the N.E. quadrant. In 1919 conspicuous arches are shown over small prominences in the S.W. quadrant. The great prominence on the E. limb also appears to be covered by an arch in the Corona. The presence of arches in the Corona over prominences is a frequent feature: it indicates a close connection between prominences and Corona. It would appear that coronal matter is continually being driven off from the chromosphere. A striking example of the relationship between Corona and prominences is found in the eclipse of 1901, May 18. In the photographs taken by Mr. MAUNDER in Mauritius a large prominence is shown on the E. limb near the equator. The photographs obtained by Mrs. MAUNDER at the same time show the same remarkable tongue-shaped prominence. In the photographs taken in Sumatra 100 minutes later, it has entirely disappeared and is replaced by a dense patch of coronal matter. A small prominence immediately to the south is shown on the Mauritius plates and also on those taken in Sumatra, when it is slightly larger and is ejecting a thin stream of prominence matter.

Examination of these photographs shows that the general form of the Corona varies in accordance with the sun spot cycle, but that its exact appearance at any eclipse is considerably affected by the prominences which are near the limb at the time.

Fuller details are noted in the short description of each drawing. The original

photographs have in all cases been referred to by Mr. MELOTTE and the details shown in the drawings verified. The drawings are oriented so that the north pole of the sun is at the top and the east to the left. In the drawings of eclipses when totality amounted to several minutes, the want of circularity in the moon may attract attention. The image of the sun was perceptibly less than that of the moon. Consequently the photographs taken near the commencement and end of totality showed the Corona and prominences close to the sun's limbs on the east and west sides, whereas in a photograph taken at the centre of totality the Corona may be hidden to a distance of two minutes from the limb. To depict in a single drawing the details shown on all the photographs, the obscured part is not drawn circular.

1898 *January* 22. (PLATE 5.)

Taken at Sahdol, India. Sun spot maximum 1894·0. Sun spot minimum 1901·5. Seven photographs: exposures, $\frac{2}{3}$ second to 20 seconds. Duration of totality, 1 minute 45 seconds.

The Corona shows a considerable amount of detail, and roughly divides itself into large streamers in each of the four quadrants. That in the S.W. quadrant is the most conspicuous, and was observed visually at the time to extend to about $3\frac{1}{2}°$ from the limb. In the N.W. quadrant the coronal rays are arched over three conspicuous prominences, and unite to form one component of a striking double ray. The bounding edge of the Corona in the N.E. quadrant, adjacent to the polar plumes, is sharply defined and curves over a large prominence. The inner Corona is disturbed in the neighbourhood of the prominences, and traces of arches can be seen over certain of them.

The polar plumes are well shown. They extend to lower latitudes at the South Pole, and are somewhat longer. The northern plumes are, however, the brighter, whilst the southern are more clearly thrown into relief by interspersed dark rays.

A considerable number of prominences are visible fairly evenly distributed around the disc. In addition to those mentioned above in connection with the Corona, a large prominence is shown in the S.E. quadrant, around which there is a diminution in the density of the Corona.

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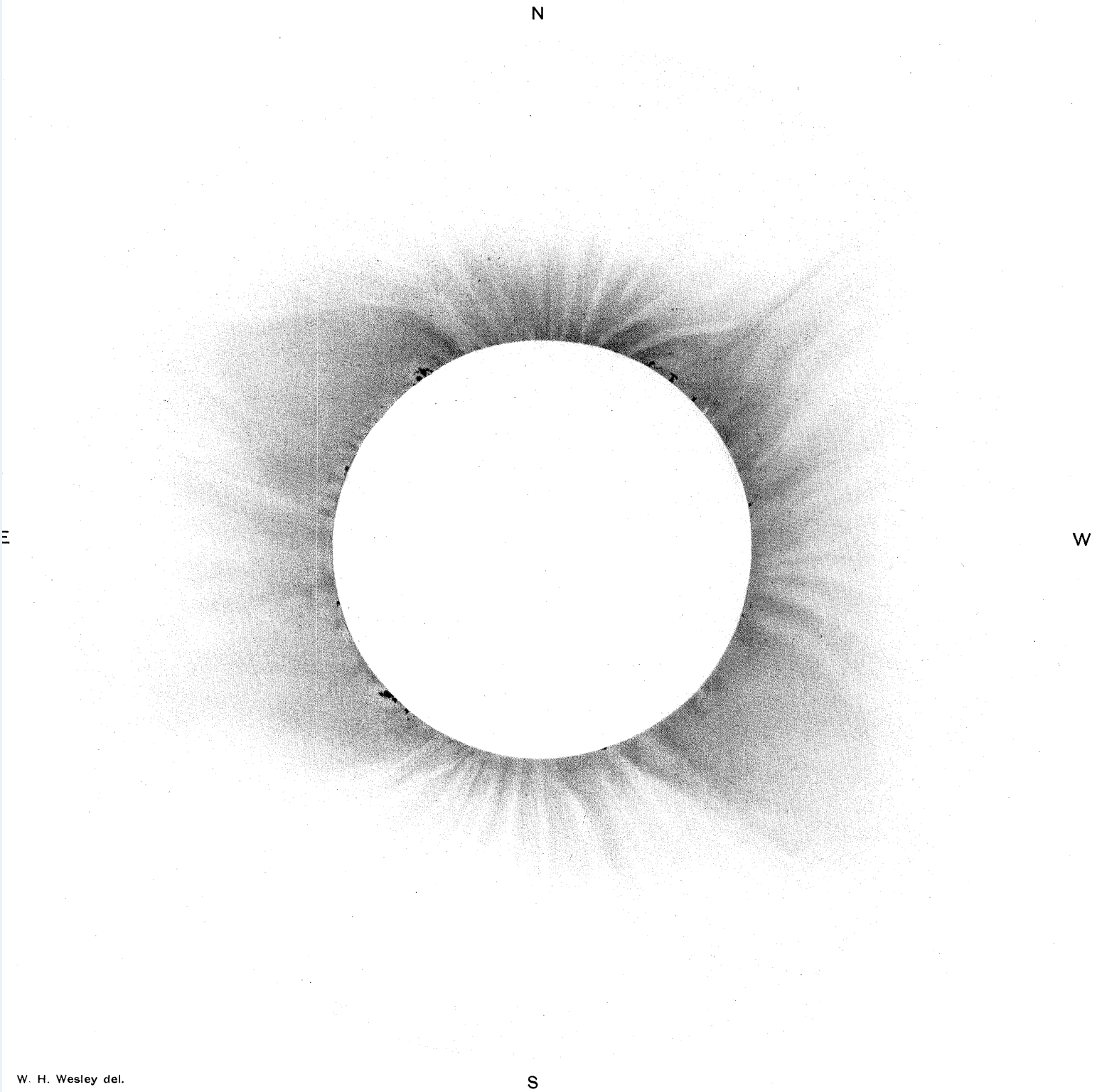

W. H. Wesley del.

1898 January 22

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1900 *May* 28. (PLATE 6.)

Taken at Ovar, Portugal. About one year before sun spot minimum. Five photographs: exposures, $1\frac{1}{2}$ seconds to 20 seconds. Duration of totality, 1 minute 24·5 seconds.

The Corona is singularly free from disturbance. The equatorial streamers on the western side are well balanced, forming two wings, one north and one south of the sun's equator. On the eastern side the equatorial rays unite to form a single streamer.

The polar plumes are well defined, and there is little difference in their appearance at the two poles.

A group of three large prominences is shown in the south-west quadrant. Two much smaller prominences are shown on the east limb and there are a large number of very small ones, particularly in the neighbourhood of the poles.

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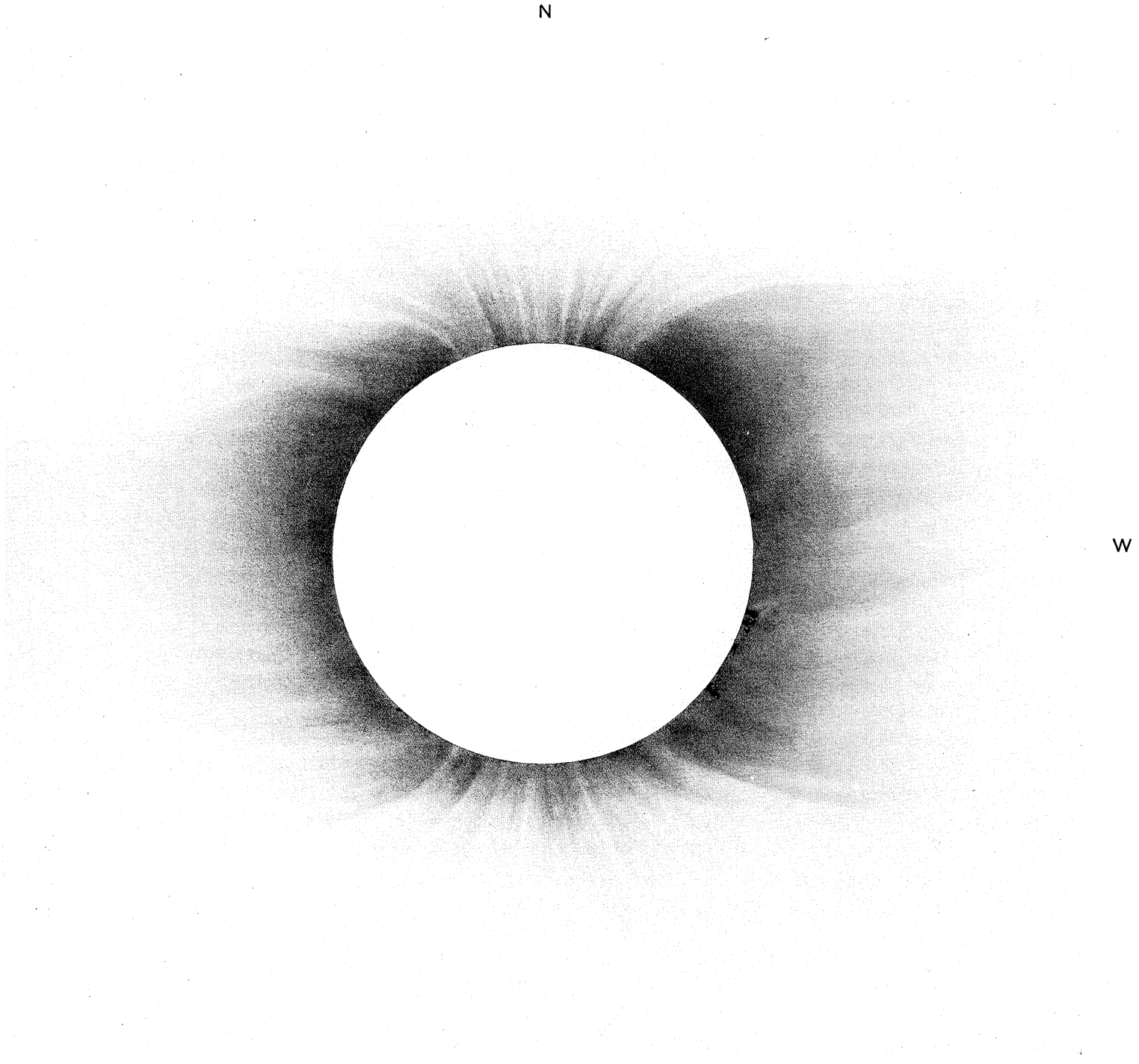

W. H. Wesley del.

1900 May 28

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1901 *May* 18. (PLATE 7.)

Taken at Pamplemousses, Mauritius. Sun spot minimum. Seven photographs: exposures, 4 seconds to 40 seconds. Duration of totality, 3 minutes 32·5 seconds.

The Corona is fairly symmetrical in form, though the equatorial streamers on the eastern side are better defined and of greater extension. Two dark rays, which originate close to a very remarkable large prominence on the east limb near the equator, are conspicuous. The inner Corona on the eastern side is very disturbed and an arch over a large prominence in the S.E. quadrant is faintly shown. The bounding ray of the equatorial streamers in the N.E. quadrant is very sharply defined.

The polar plumes are well shown, those at the north pole being somewhat the brighter.

In the S.E. quadrant, between the two large prominences mentioned in connection with the Corona, are two smaller ones. A bright prominence is shown in the S.W. quadrant, and in the N.W. quadrant a string of small prominences extends from the equator to the bounding edge of the equatorial streamers.

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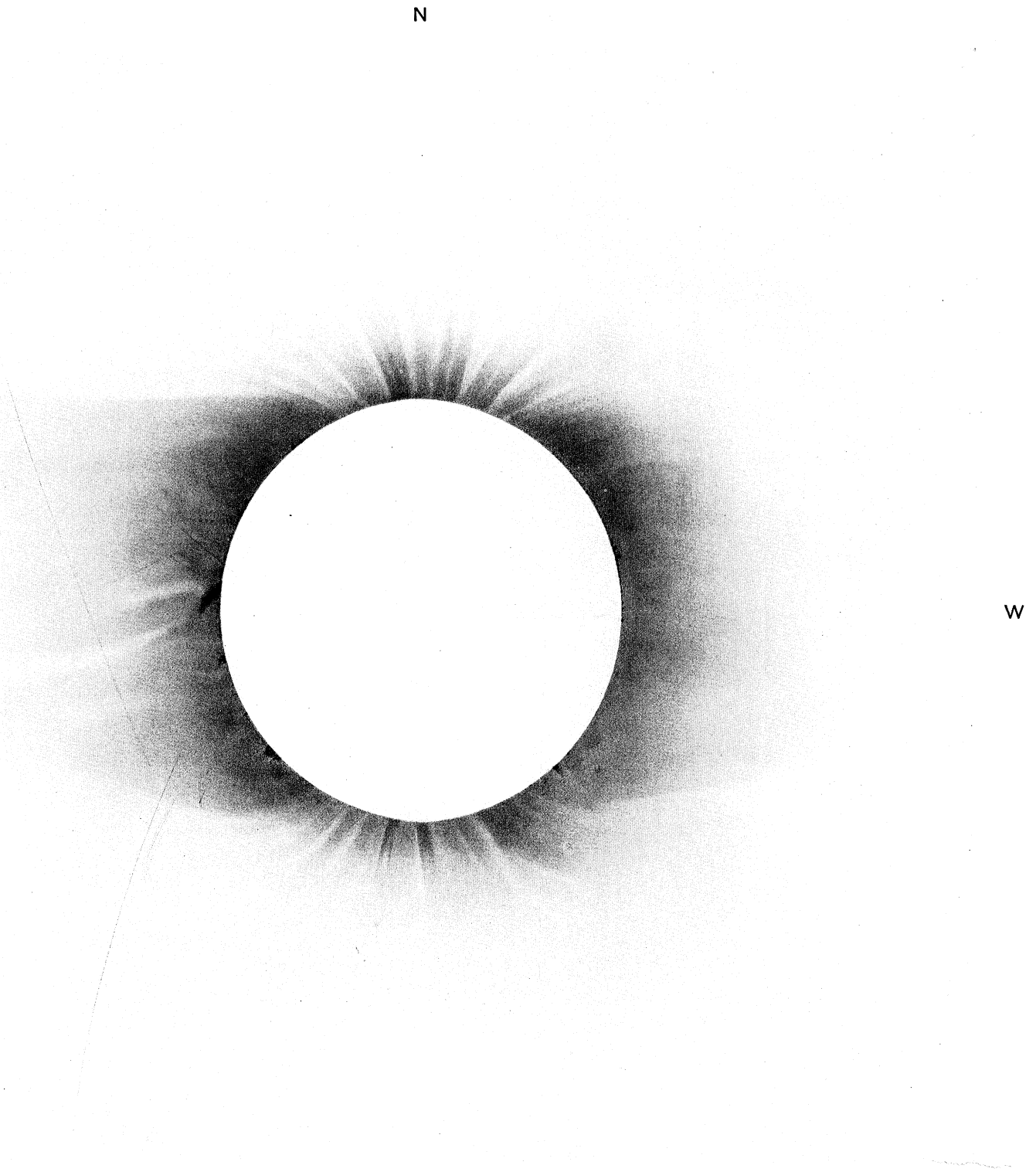

W. H. Wesley del.

1901 May 18

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1901 *May* 18. (PLATE 8.)

Taken at Pamplemousses, Mauritius, by Mrs. MAUNDER. Sun spot minimum. Fourteen photographs: exposures, "instantaneous" to 10 seconds. Duration of totality, 3 minutes 32·5 seconds.

The detail shown in the Corona supplements that obtained with the Dallmeyer Coronograph (Plate 7). In particular, the appearance of the large prominence on the east limb and of the surrounding Corona is confirmed. The triple arch over the prominence in the S.E. quadrant is well shown. Two interesting features appear in the polar plumes. At the north pole they are crossed by a sharply defined straight ray, whilst at the south pole the outermost rays of the equatorial streamers are shown crossing the polar rays.

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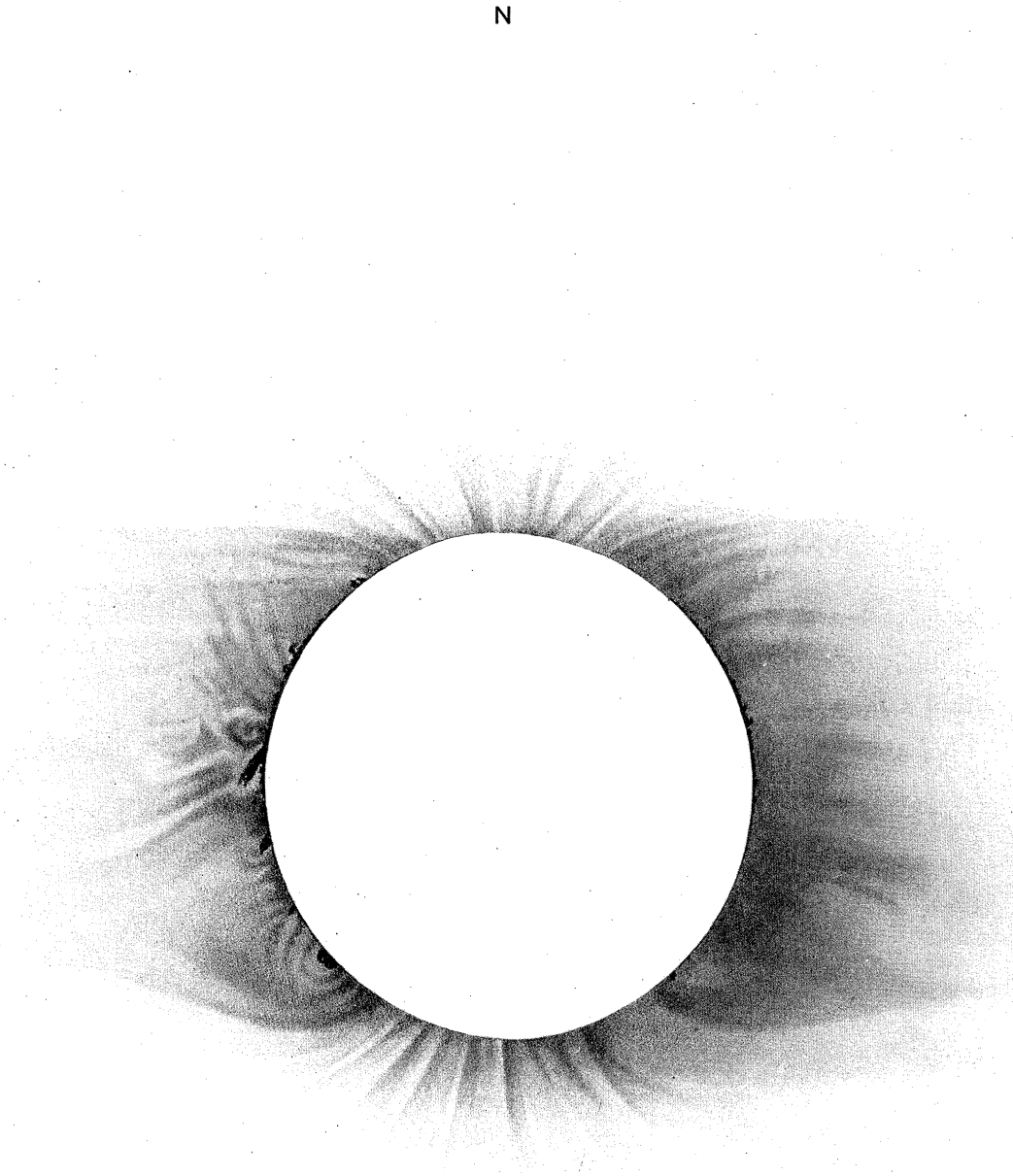

W H. Wesley del.

1901 May 18

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1901 *May* 18. (PLATE 9.)

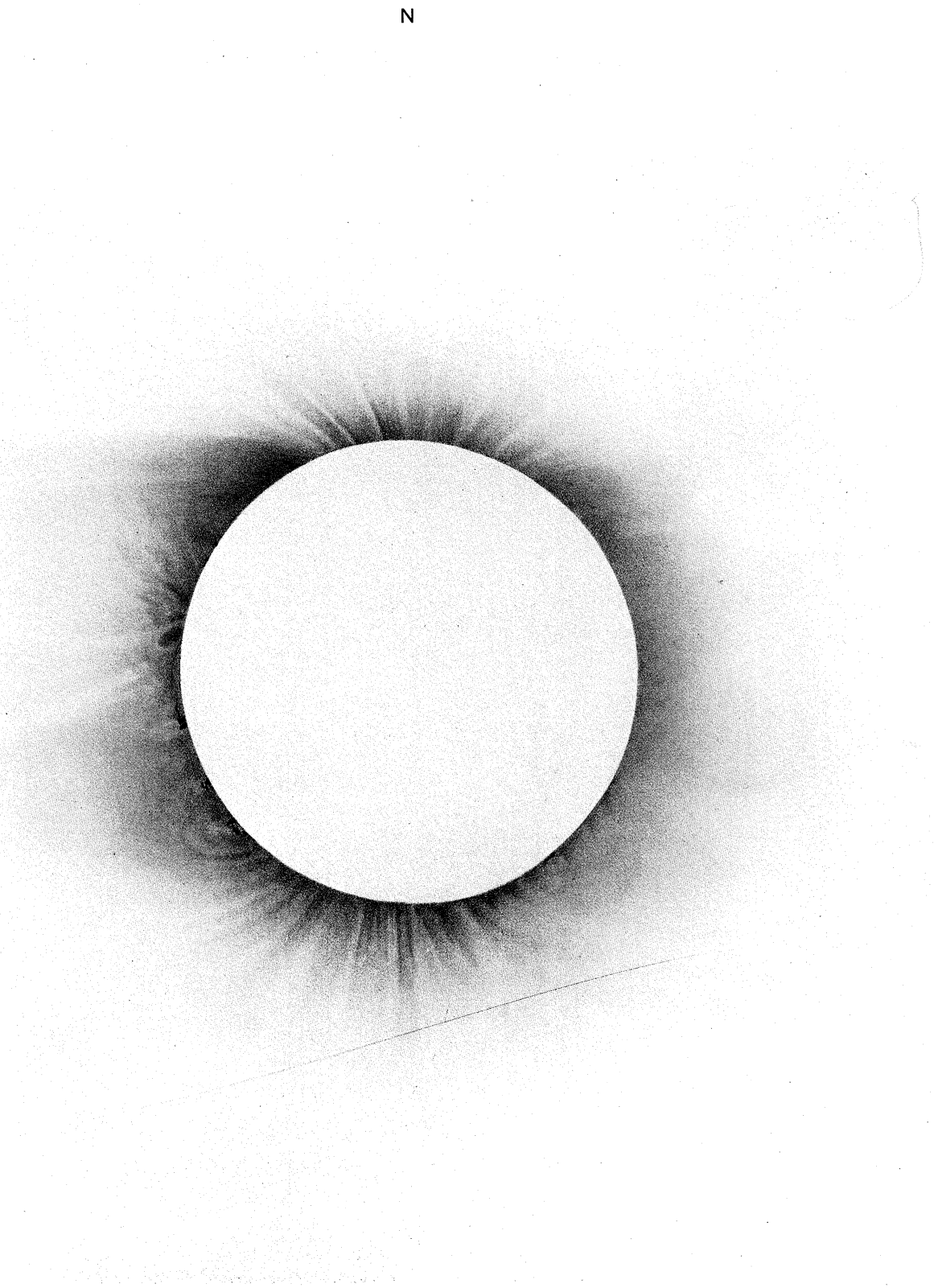
Taken at Aoer Gadang, Sumatra. Sun spot minimum. Seven photographs: exposures, 5 seconds to 40 seconds. Duration of totality, 6 minutes 21 seconds.

The form of the Corona agrees, in general, with that observed in Mauritius, showing the disturbance on the eastern limb. In particular it is to be noted that the large prominence near the equator on the east limb (shown on the Mauritius photographs) is here represented by a bright coronal mass in a very disturbed region, and is surrounded by a narrow belt of coronal matter of noticeably low density forming a dark arch around the coronal mass. The dark rays connected with it are also visible, and are now accompanied by two others. Three arches in the Corona, one inside the other at radii of $1'{\cdot}2$, $2'{\cdot}4$ and $3'{\cdot}7$ respectively, are shown over the large prominence in the S.E. quadrant. The N.E. bounding ray of the equatorial streamers is sharply defined. The coronal streamers on the western side show little of interest.

The polar plumes are well shown, the southern being the more extensive and brighter.

Considerable changes have taken place in the appearance of the small prominences in the S.E. quadrant, and they have increased in size. A new eruptive prominence is shown immediately to the south of the bright coronal mass referred to above, which appeared as a prominence on the Mauritius photographs. No prominences are shown on the western limb.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



W. H. Wesley del.

1901 May 18

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1905 *August* 30. (PLATE 10.)

Taken at Sfax, Tunisia. Sun spot maximum 1906·0. Seven photographs: exposures, 5 seconds to 30 seconds. Duration of totality, 3 minutes 27 seconds.

The drawing, made from the photographs taken with the Thompson Coronagraph, represents the detail shown in the inner Corona. This is very disturbed around the whole limb of the sun, and particularly so in the N.E. quadrant. A marked feature is the "plume" of rays on the eastern side, a little north of the equator, in which originates the dark ray mentioned in the description of Plate 11. In the N.E. quadrant two arches are shown in the Corona, falling near the extremities of the chain of large prominences. In the S.W. quadrant is a very small well-defined double arch over a prominence at about position angle 200°. Two other arches in the Corona can be seen over prominences in the S.E. and N.W. quadrants respectively. There is no indication of any polar plumes.

In the N.E. quadrant a chain of large prominences extends over an arc of more than 30°. In the S.W. quadrant is a continuous chain of small prominences extending over 40°. Above the southern part of this, a number of spots of bright prominence matter are shown in the Corona, thrown up to a height of 10′ from the limb.

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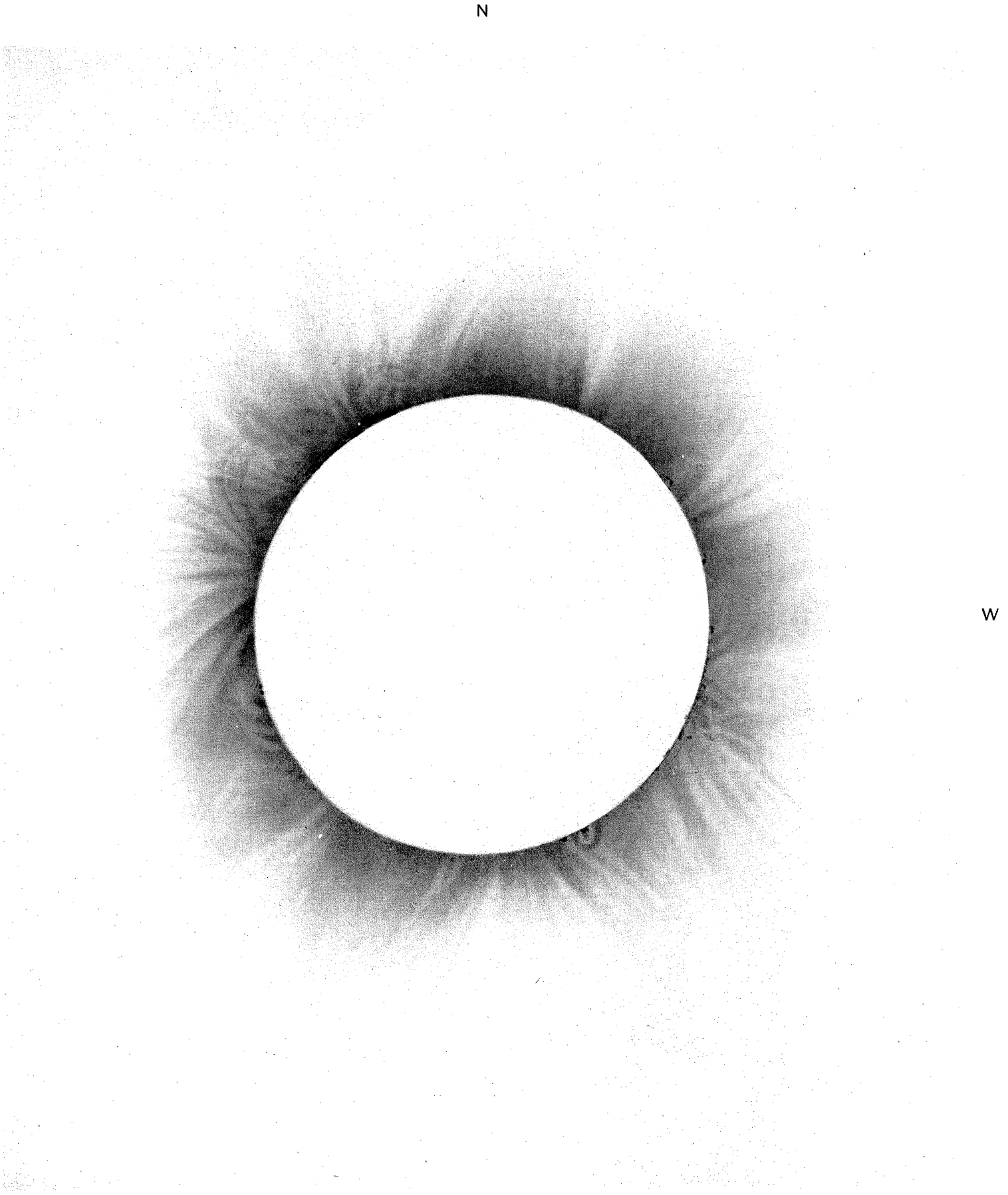

W. H. Wesley del.

1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1905 *August* 30. (PLATE 11.)

Taken at Sfax, Tunisia. Sun spot maximum 1906·0. Eight photographs: exposures, 2 seconds to 20 seconds. Duration of totality, 3 minutes 27 seconds.

The drawing is from photographs taken with the 13-inch astrographic refractor and is designed to show the form of the outer Corona. This consists of long streamers, particularly in high latitudes; near the sun's equator, both east and west, the Corona consists of shorter, straight rays. The streamers in the south-east quadrant have the greatest extension, and there is also a long double streamer in the N.W. quadrant, a little north of the sun's equator. A dark ray on the east limb of the sun is very prominent and can be traced to a distance of 26′ from the limb, but it is impossible to say that this is not an effect of contrast.

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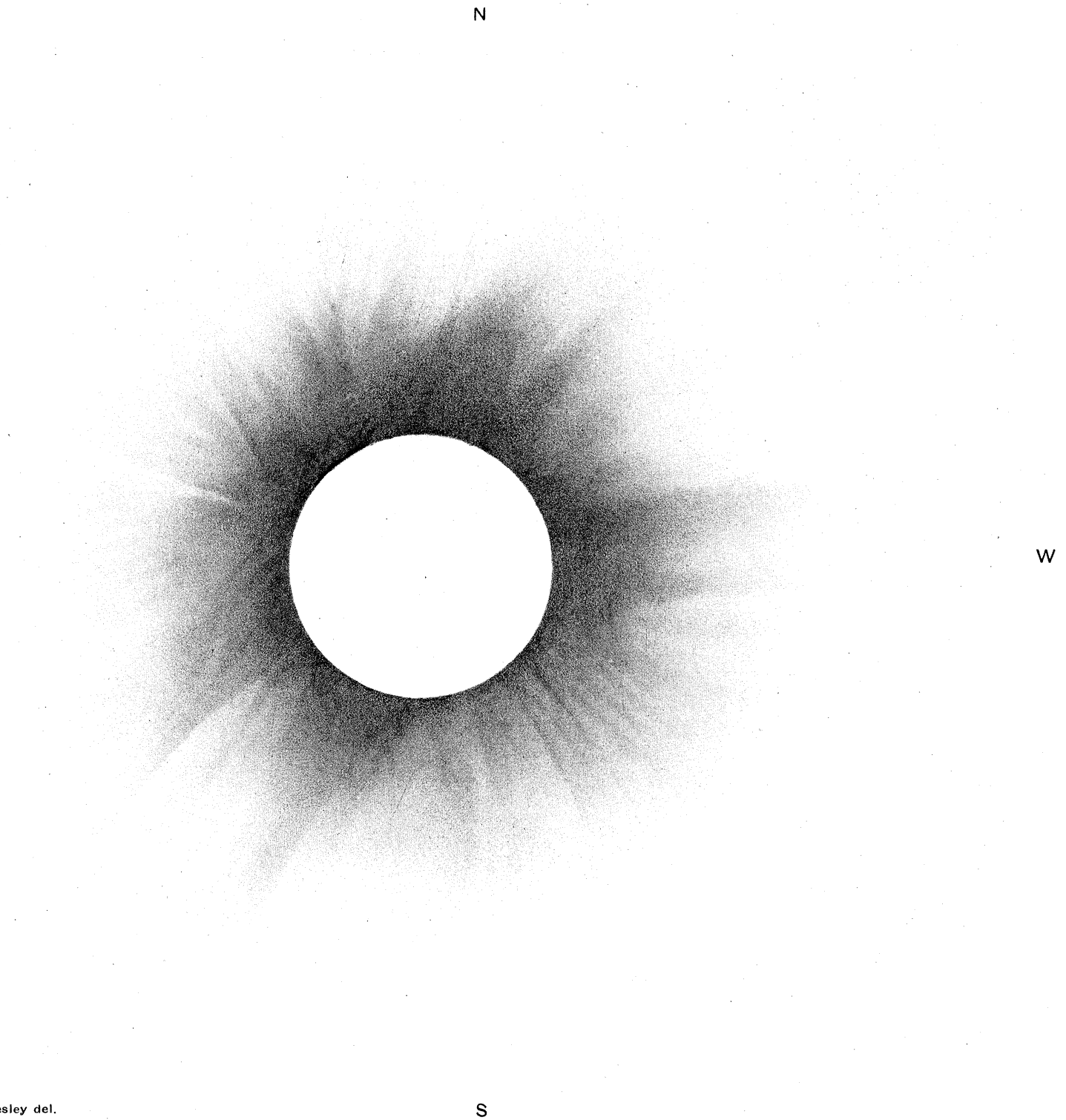

W. H. Wesley del.

1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Small-Scale Drawings and Prominences. (PLATE 12.)

FIGS. 1, 2 and 3.—The Corona as shown on small-scale photographs at the eclipses of 1900, May 28 (1); 1901, May 18 (2); and 1905, August 30 (3). These show the form of the Corona in its greater extension.

FIG. 4.—Prominences in the S.W. quadrant at the eclipse of 1900, May 28.

FIG. 5.—Large prominence on the east limb, near equator, as shown on Mauritius photographs of eclipse of 1901, May 18.

FIG. 6.—Prominences on east limb of sun as shown on Sumatra photographs of eclipse of 1901, May 18. The dark arch over the coronal mass, which appears as a prominence on the Mauritius photographs, is particularly striking, and the drawing represents well its appearance on a short exposure photograph. The scale of fig. 6 is slightly larger than that of fig. 5.

FIG. 7.—Group of large prominences in the N.E. quadrant at the eclipse of 1905, August 30.

FIG. 8.—Prominences on the west limb at the eclipse of 1905, August 30. The bright prominence matter thrown up in the inner Corona is well shown.

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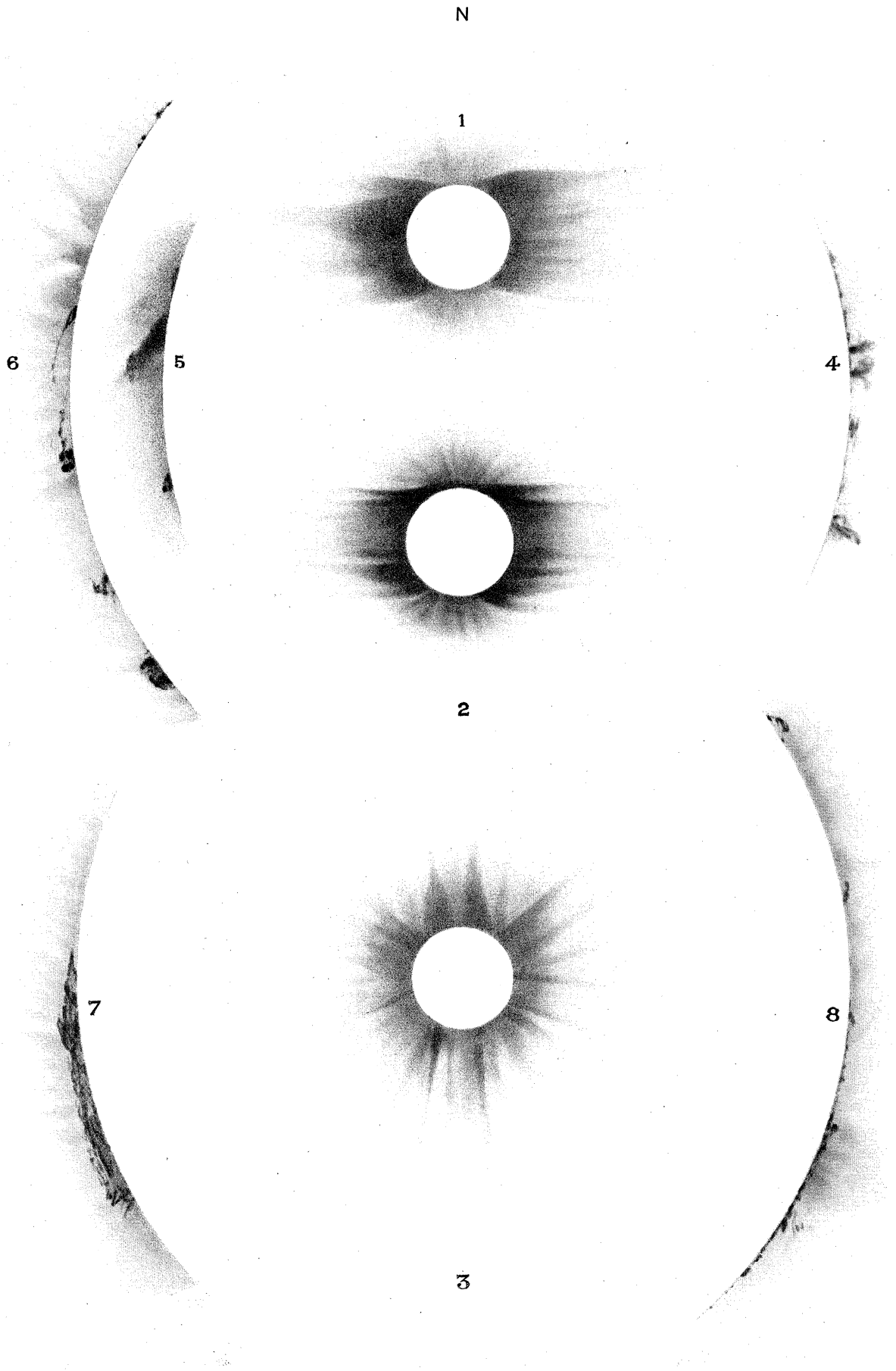


W. H. Wesley del.

1900 May 28
1901 May 18
1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

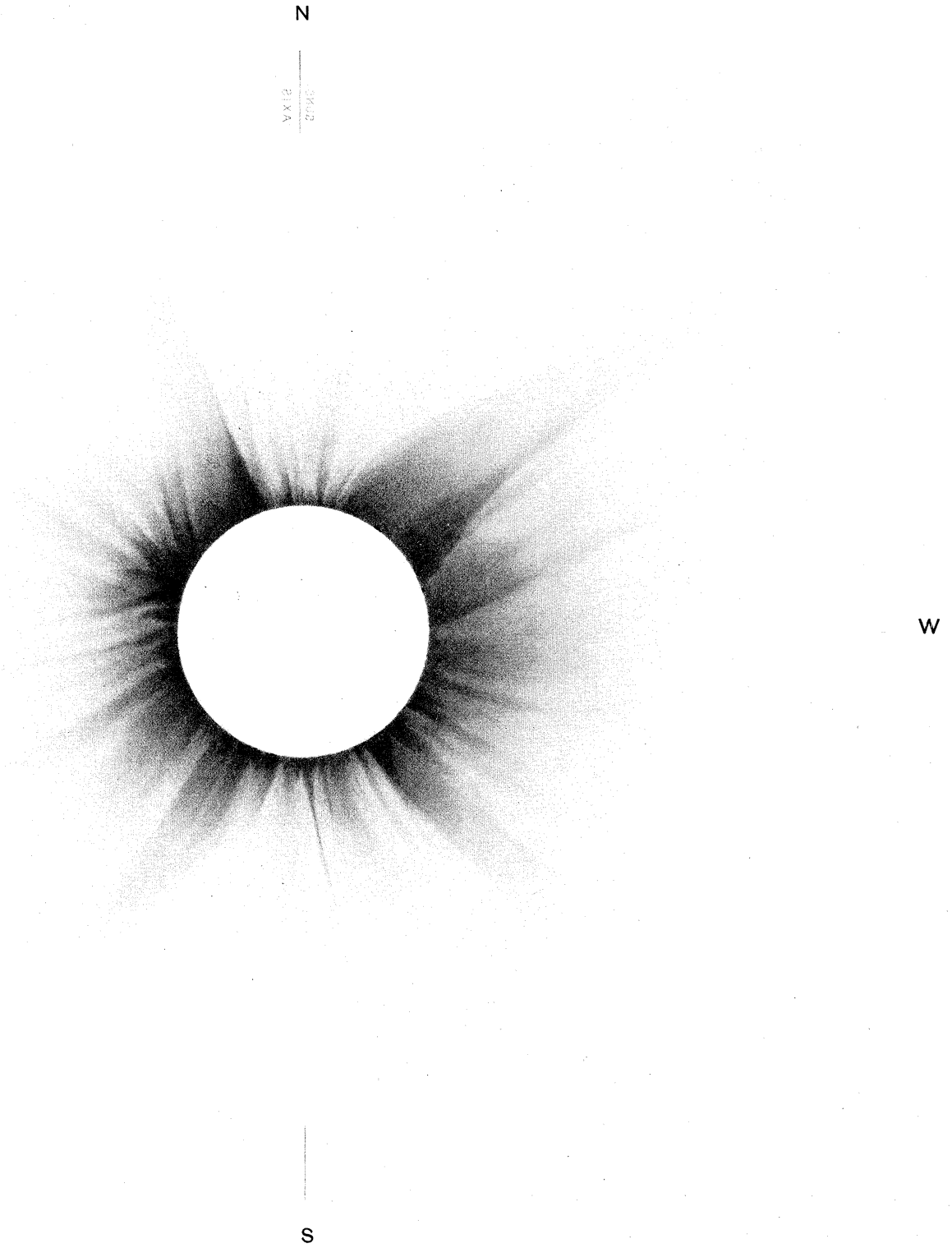
1908 *January* 3. (Plate 13.)

Taken at Flint Island, Pacific Ocean, by Mr. F. K. McClean. Two years after sun spot maximum. Four photographs: exposures, 3 seconds to 45 seconds. Duration of totality, 3 minutes 49 seconds (approx.).

The Corona is remarkable for the number of long streamers fairly evenly distributed around the sun. On the east limb the inner Corona is much disturbed in equatorial regions; several well-marked rays are shown radiating outward from a very bright tongue-shaped portion of the inner Corona about 10° north of the equator. The outline of the bright coronal matter mentioned in the foregoing is brought into relief by a thin edging of less density. In the N.E. quadrant a long streamer, with well-defined gradually converging bounding edges, extends to a distance of about 40′ from the limb. In the S.E. quadrant is a smaller streamer, between latitudes 50° and 80°. In the N.W. quadrant a large streamer with curved outline is shown between N. latitudes 18° and 75°, which extends to 50′ from the limb. In the S.W. quadrant are a number of smaller streamers, the most marked being in the neighbourhood of the large prominence. Immediately to the south of the prominence are three well-marked "dark" rays, one immediately above a small prominence at latitude 63°, the other, a double one, at latitude 68°. Two remarkably well-defined rays are shown very close to the south pole. At a distance of 10′ from the limb the rays appear to cross and proceed outward radially.

The polar plumes can be recognised at the north pole, extending about 15° to either side, where they are bounded by the large streamers in the N.E. and N.W. quadrants. At the south pole the polar rift is not so well marked, being confused by two broad streamers and the remarkable straight rays mentioned in the above.

A large curved prominence appears in the S.W. quadrant at latitude 56°, with a much smaller one about latitude 62°. Two small prominences are shown in the N.W. quadrant at latitudes 18° and 53°. There are also two in the S.E. quadrant at latitudes 67° and 74°.



W. H. Wesley del.

1908 January 3

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1914 *August* 21. (PLATE 14.)

Taken at Minsk, Russia. Sun spot minimum 1913·5. Seven photographs: exposures, 2 seconds to 25 seconds. Duration of totality, 2 minutes 13 seconds.

The Corona shows little disturbance. On the west side it forms two streamers, one north and the other south of the equator. On the east side, in the neighbourhood of the equator, the Corona extends outward uniformly to a distance of about 20′. Between N. latitudes 50° and 67° a number of rays form a bright streamer among the polar plumes. No disturbance is shown in the Corona surrounding the large prominence in the S.E. quadrant. The bounding edge of the coronal streamers in the N.W. quadrant is sharply defined and overlaps the polar rays. The general extension is greater on the western side than on the eastern.

The polar plumes are well shown, and extend for about 20° on either side of the poles. Those at the N. pole have a slightly greater extension.

Two large prominences are shown in the S.E. quadrant. There are a number of small prominences in the S.W. quadrant and also in the equatorial region on the east limb.

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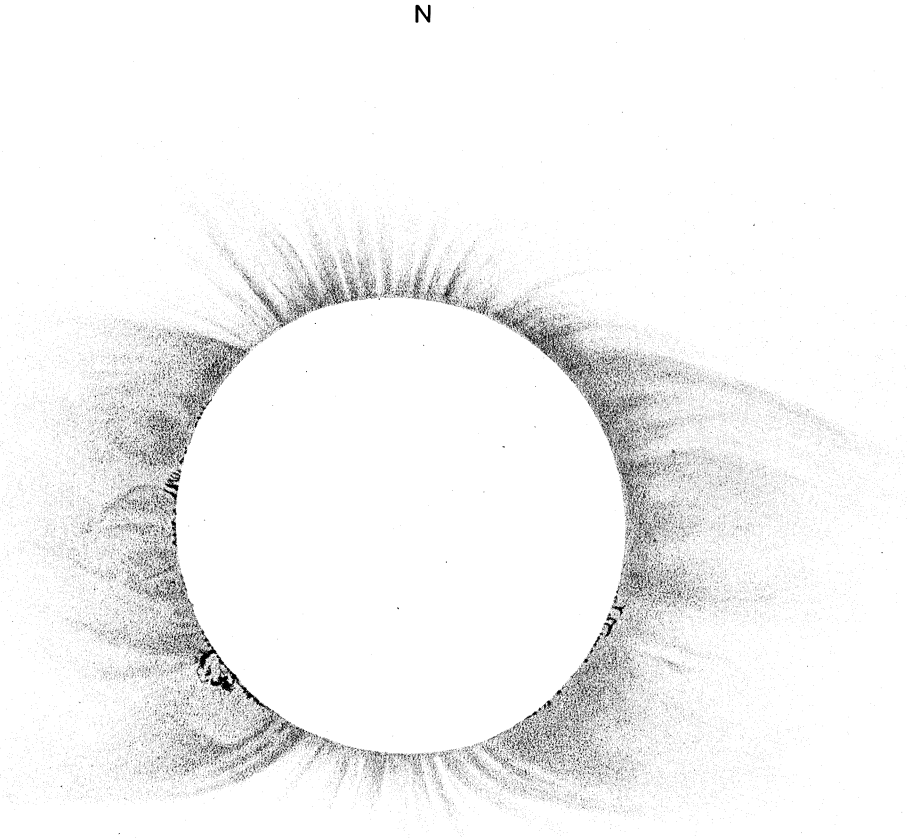

A.M.C. del.

1914 August 21

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1919 *May* 29. (Plate 15.)

Taken at Sobral, Brazil. Sun spot maximum 1917·5. Minimum 1923·5. Eight photographs: exposures, 28 seconds. Duration of totality, 5 minutes 10 seconds.

The structure of the Corona is very complicated. On the eastern side the equatorial streamers extend between latitudes 70° N. and 70° S. On the western side the main mass lies between latitudes 70° N. and 40° S., whilst a number of rays form a separate conspicuous streamer between S. latitudes 45° and 80°. On the east limb, in the neighbourhood of the great prominence, there is considerable disturbance. Two arches, one inside the other, extend over the whole prominence; these are crossed by coronal rays which complicate the appearance of this part of the Corona. Both east and west there are a number of straight rays extending over half a degree from the limb. In the S.W. quadrant a complete double arch is shown over a prominence; this forms the base of the delicately curved streamer forming the bounding edge of the S.W. wing of the Corona.

The polar plumes are well shown and extend a considerable distance from the limb.

The great prominence in the S.E. quadrant is the outstanding feature. A smaller group of prominences lies immediately to the north. Two other small prominences are shown on the east limb.

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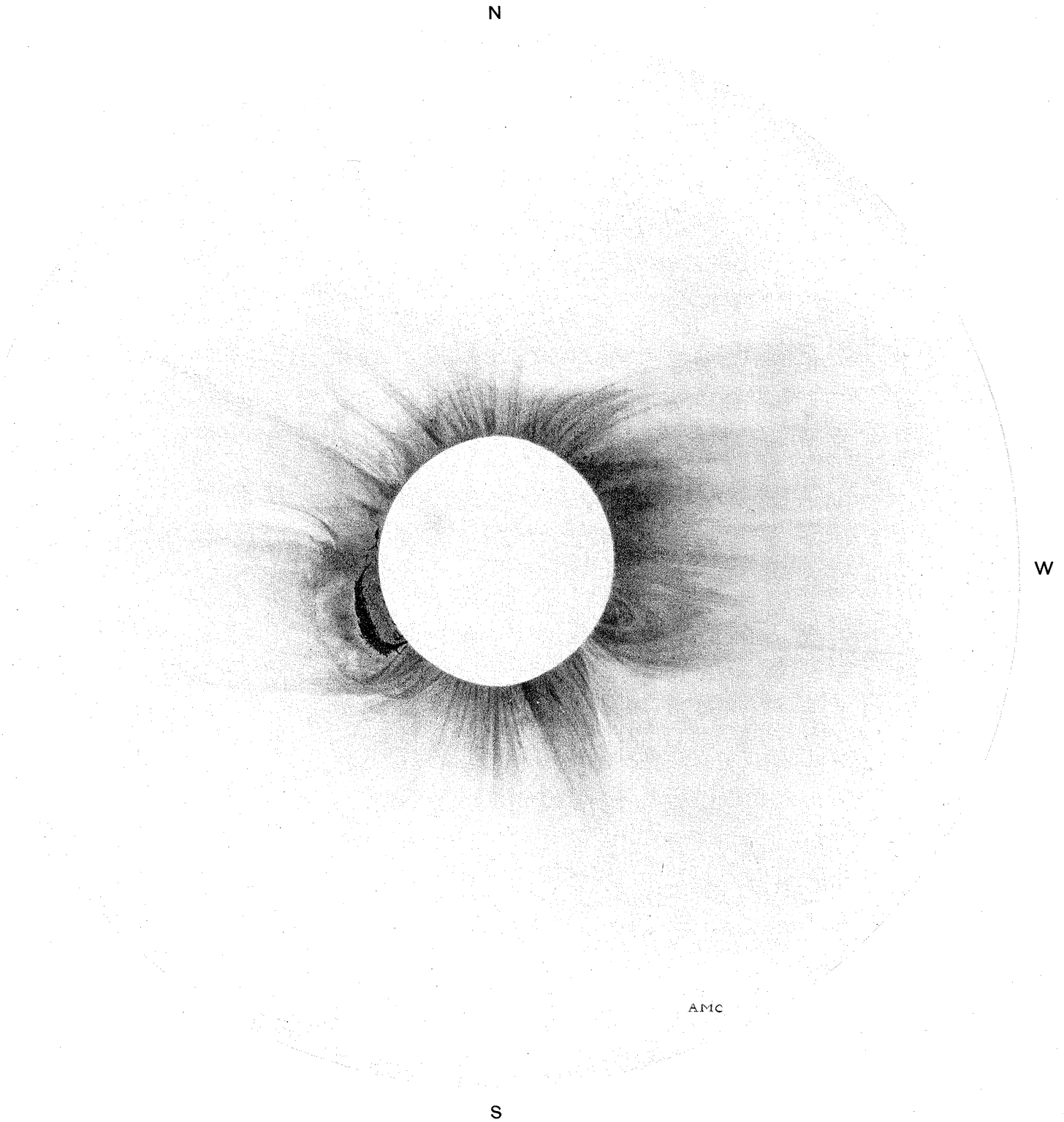


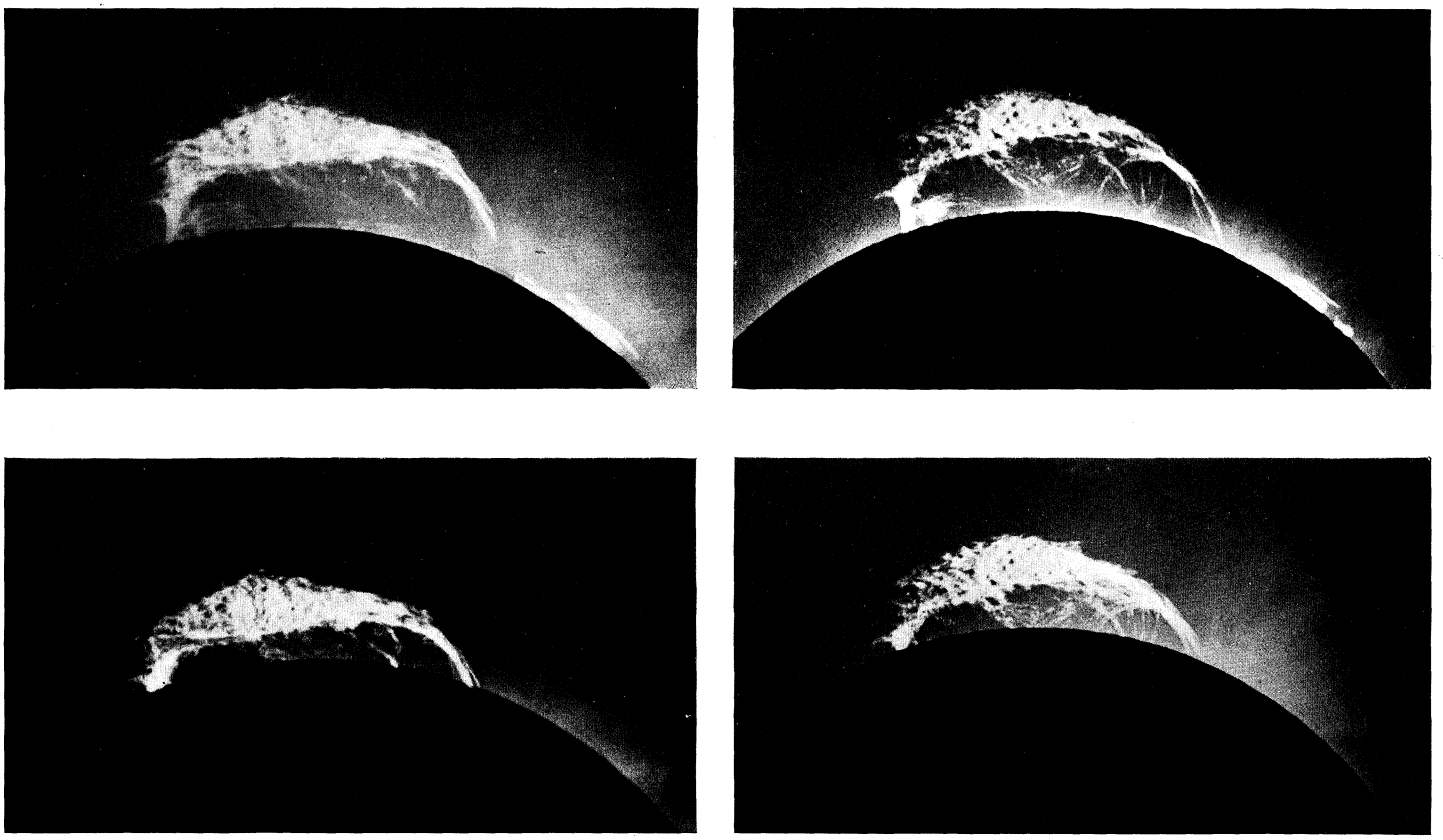
1919 May 29

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Great Prominence, 1919 *May* 29. (PLATE 16.)

		d.	h.	m.	s.		
Sobral	May	28	23	58	35	G.M.T.	Exposure, 28 seconds.
		29	0	2	27	G.M.T.	Exposure, 28 seconds.
Principe ..	May	29	2	13	9	G.M.T.	Exposure, 5 seconds.
		29	2	15	53	G.M.T.	Exposure, 3 seconds.

The appearance of the great prominence on the photographs taken at Sobral and at Principe is well shown in the reproduction. Whilst the general outline remains nearly the same, there is a considerable difference in the small prominences under the large arch, and the arch itself appears more "rounded" on the Principe plates, as though the centre had moved outward from the limb. The photographs should be compared with those taken with different spectroheliographs during the period in which the prominence was under observation.



1919 May 29

Sobral Principe

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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W. H. Wesley del.

1898 January 22

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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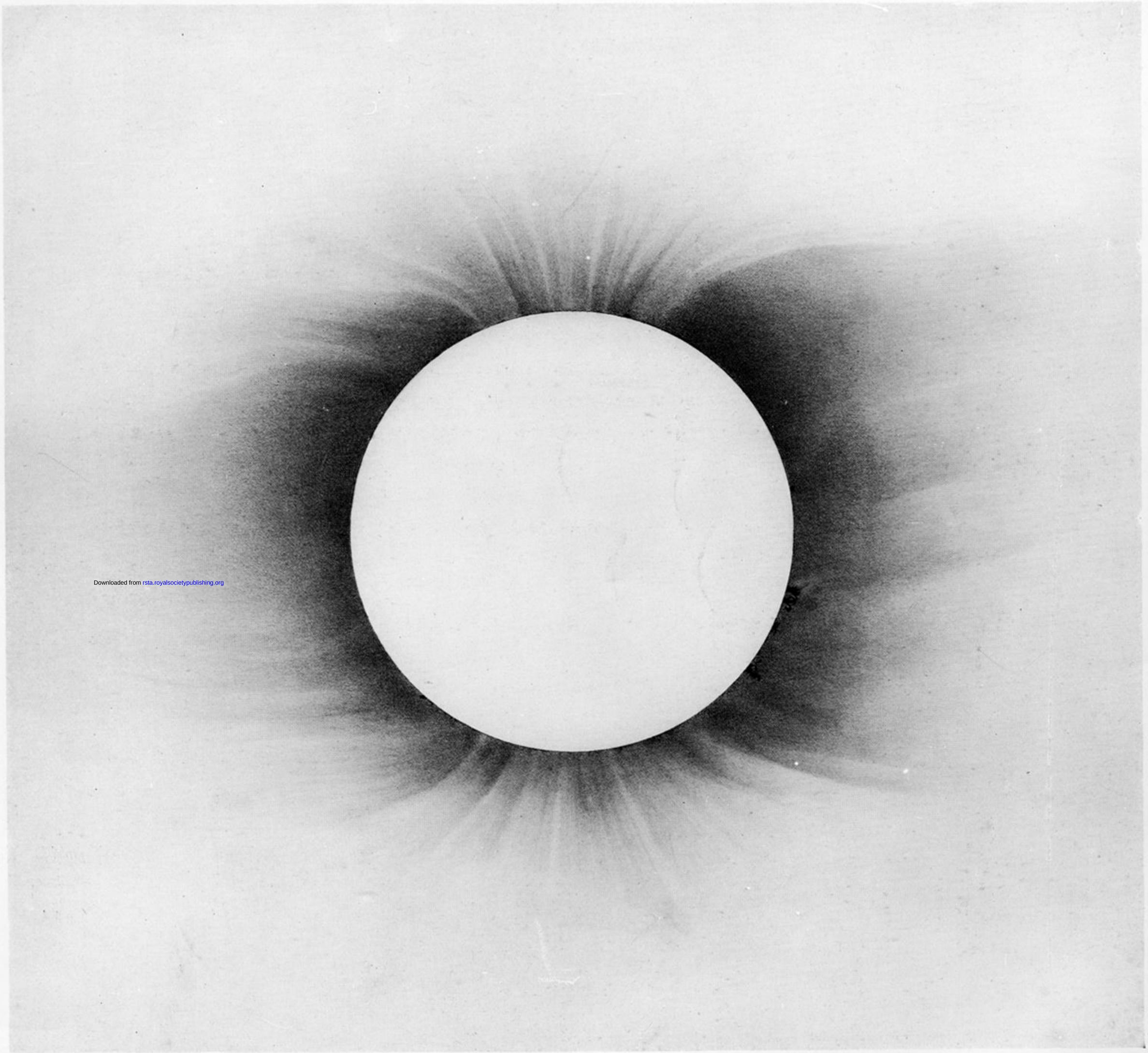

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1900 May 28

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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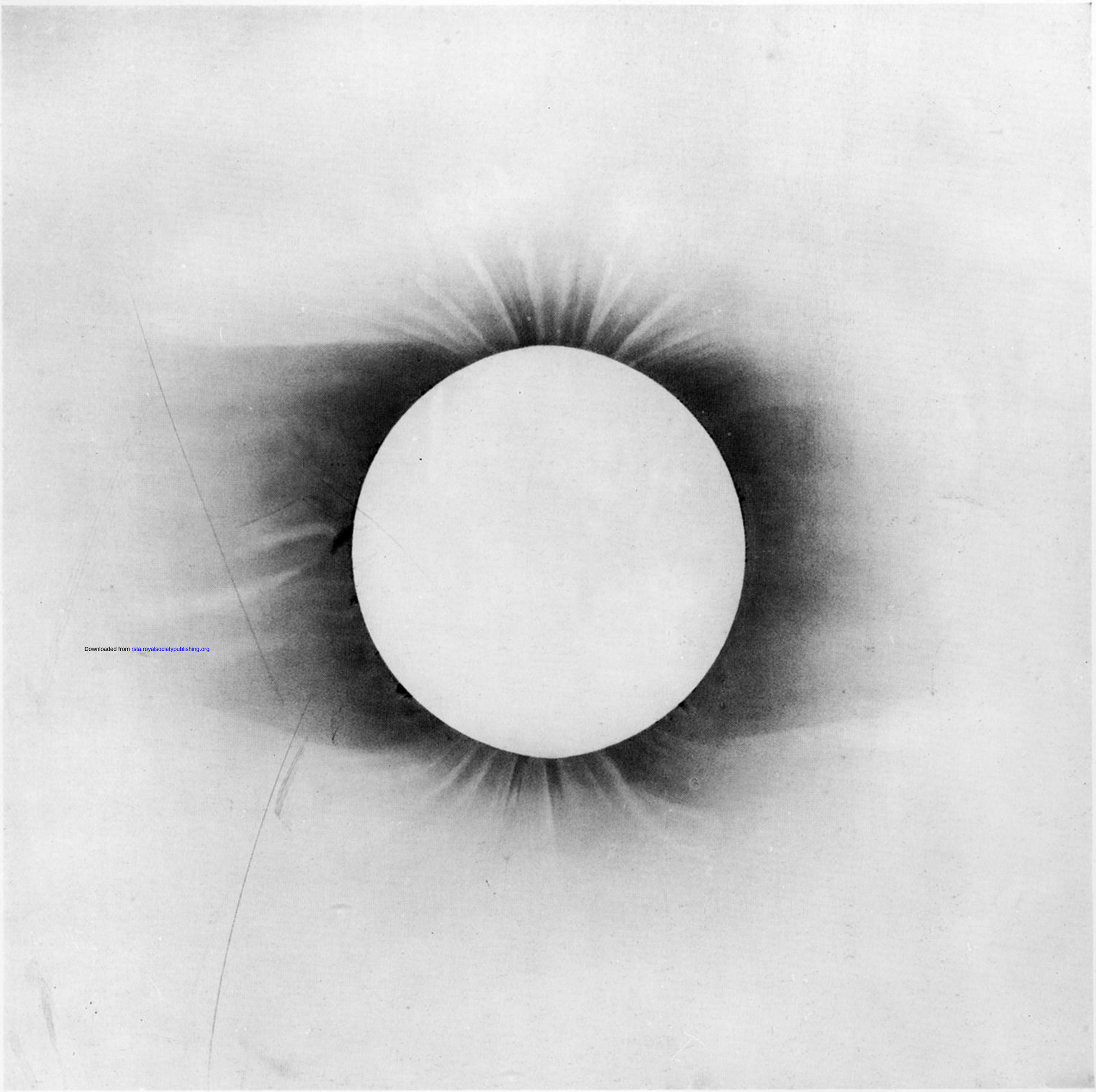

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1901 May 18

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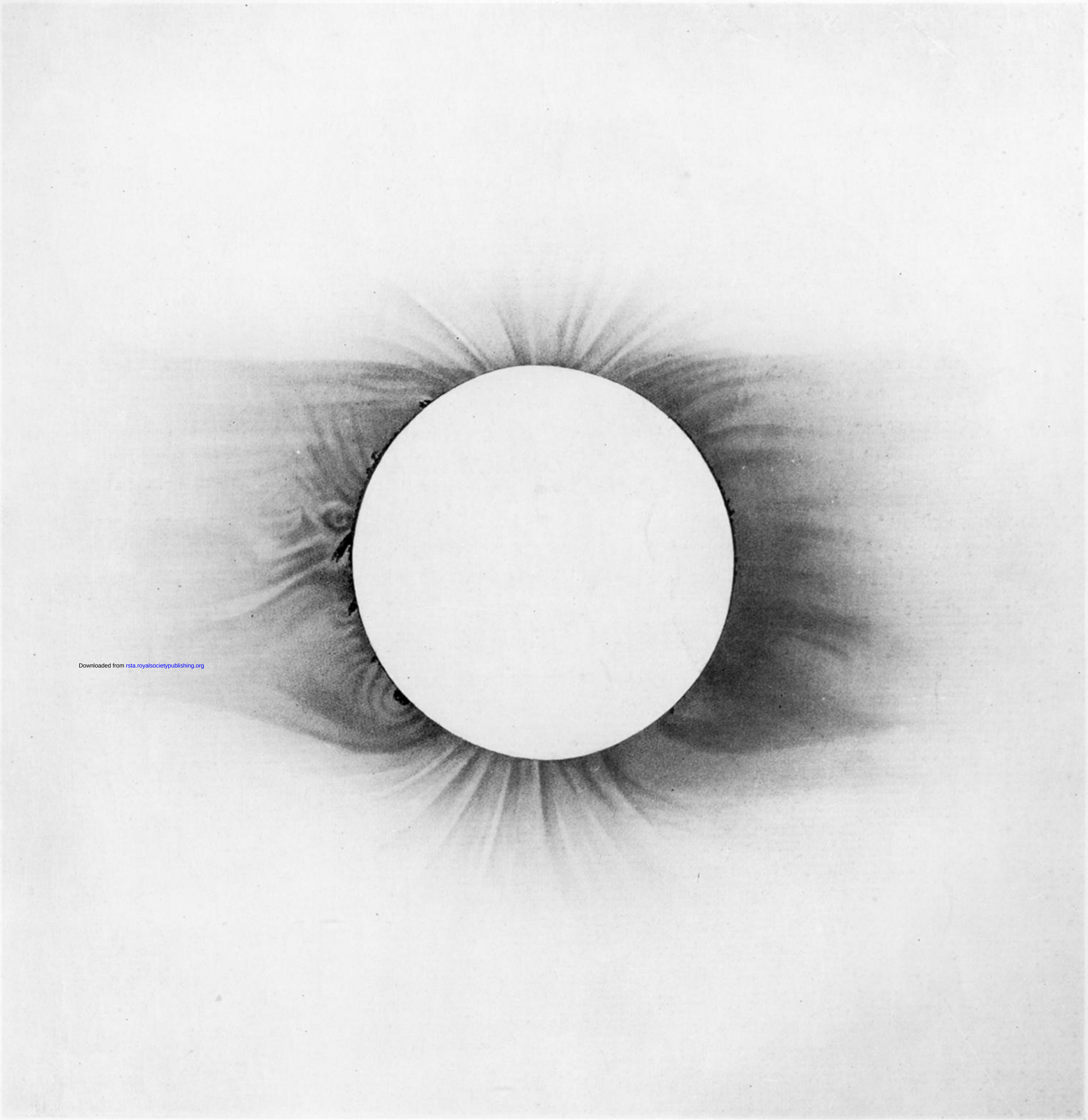

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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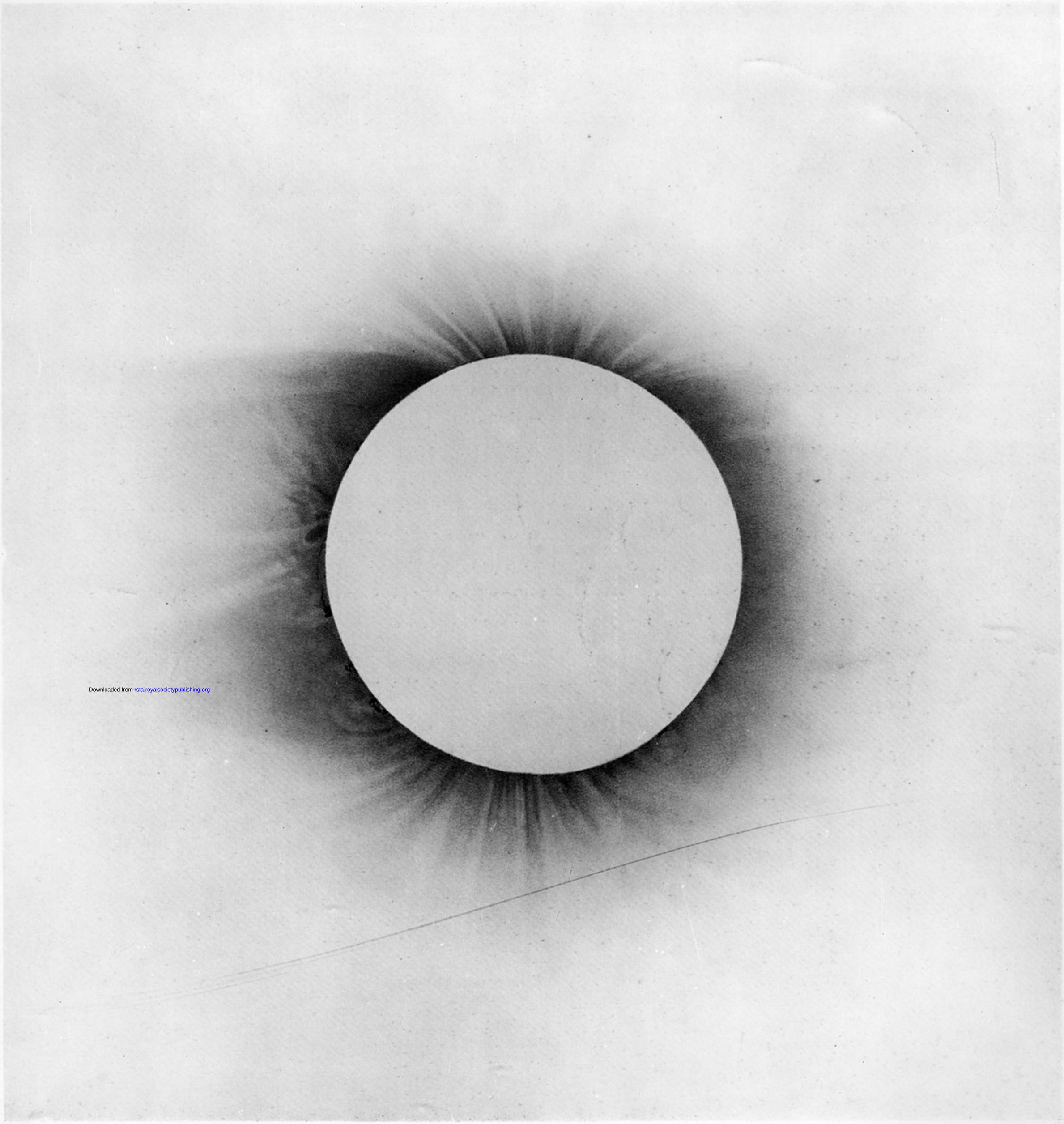

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1901 May 18

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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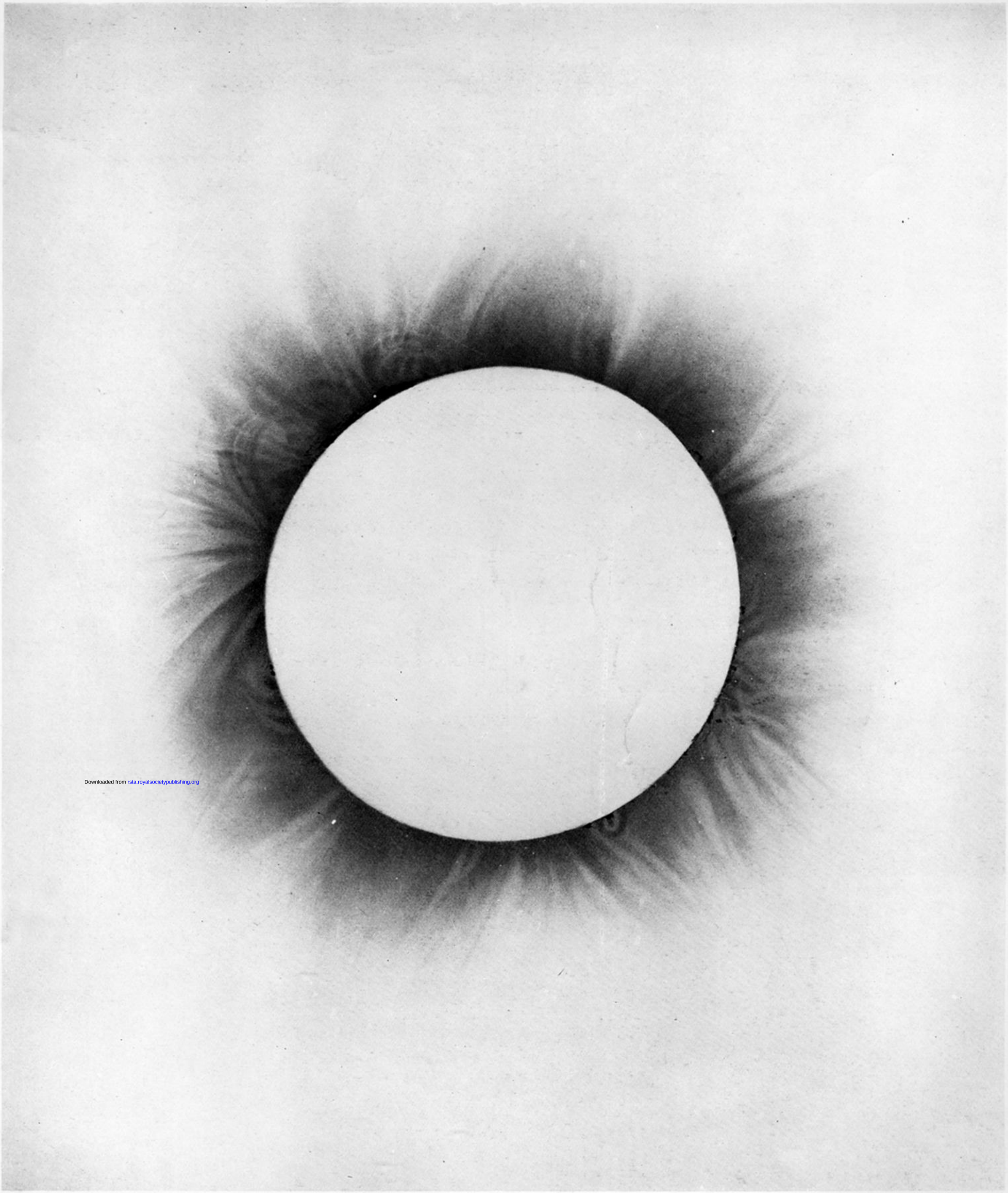

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1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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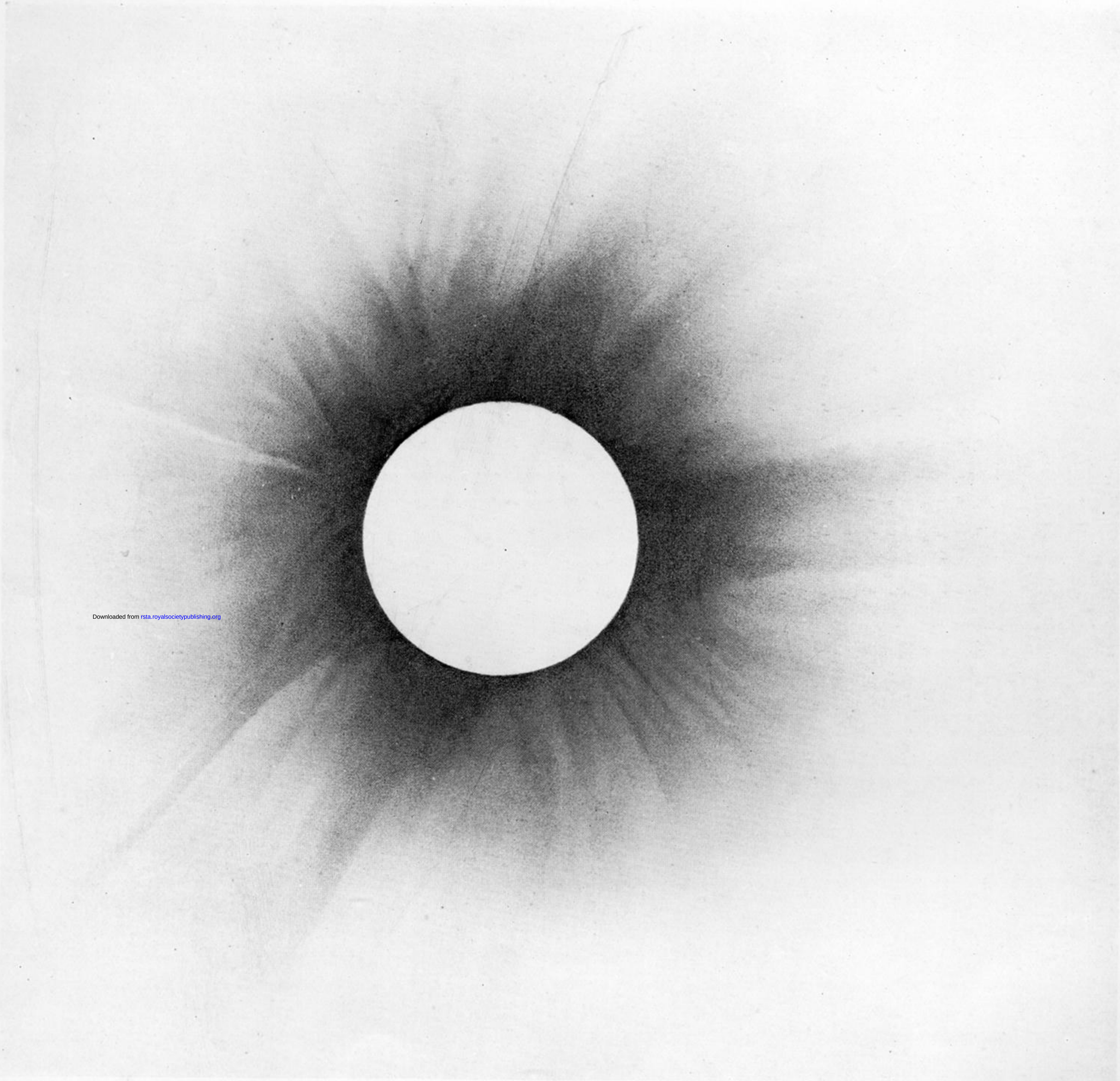

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1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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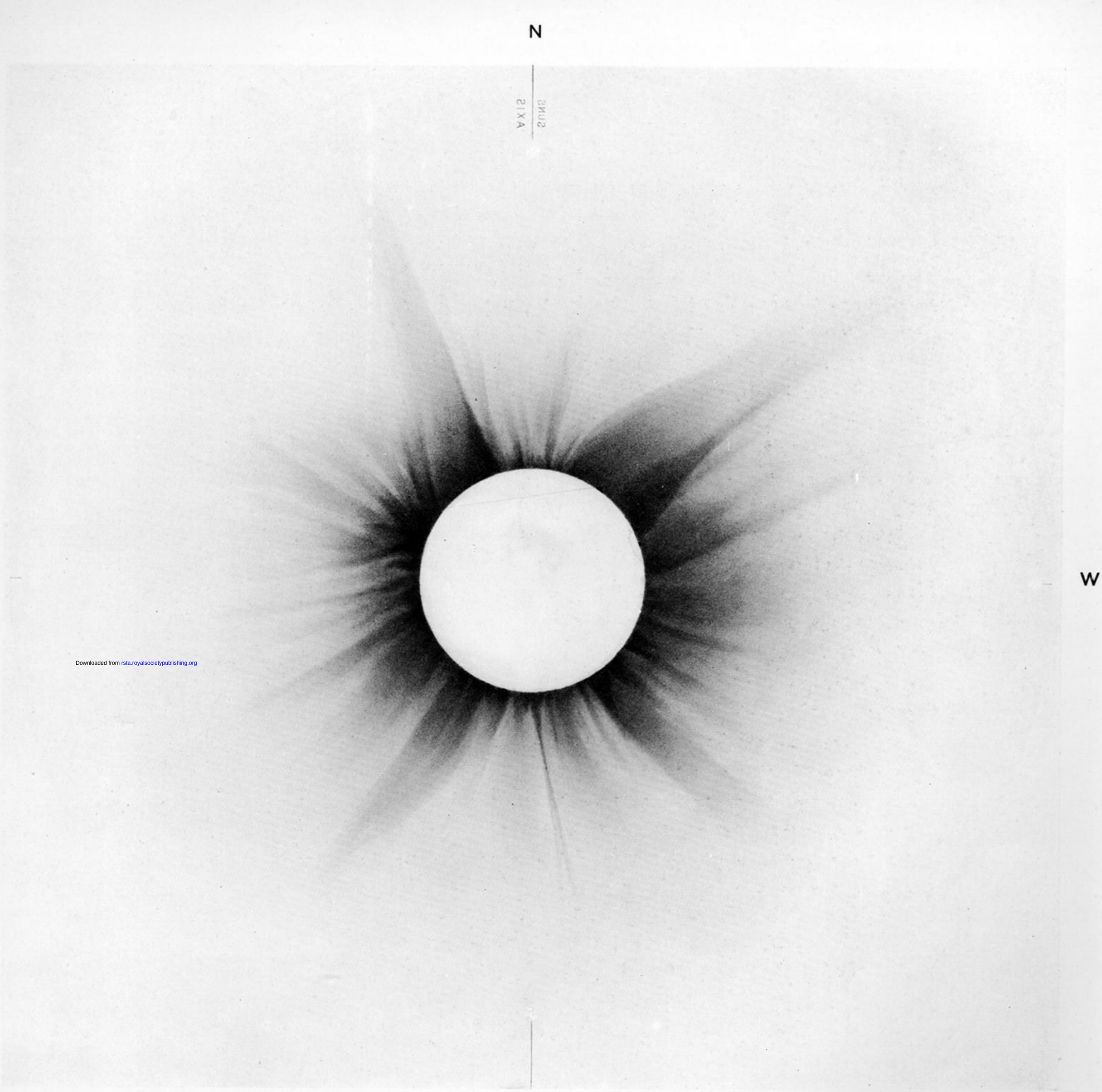
1900 May 28
1901 May 18
1905 August 30

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



W. H. Wesley del.

1908 January 3

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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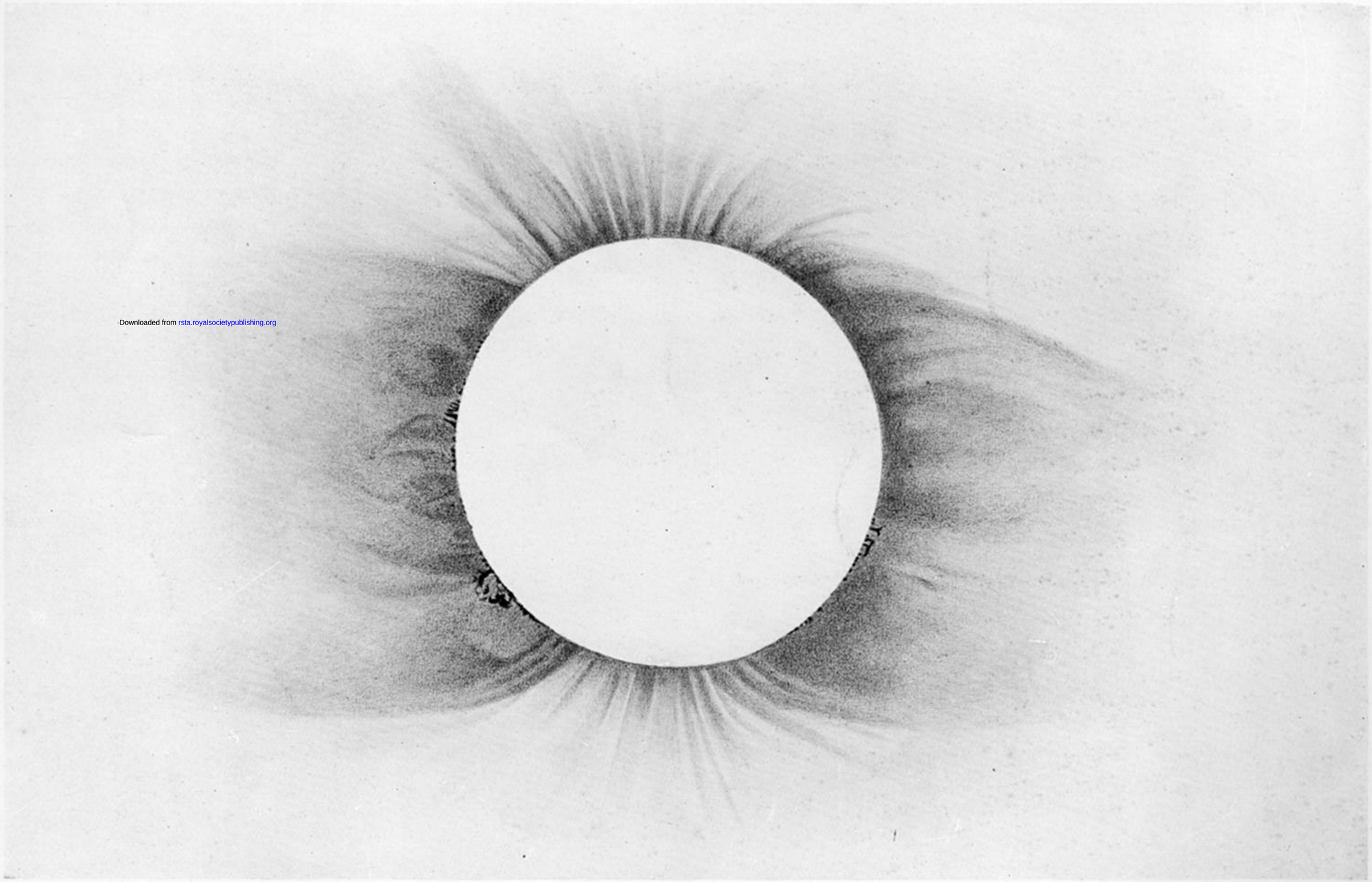

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1914 August 21

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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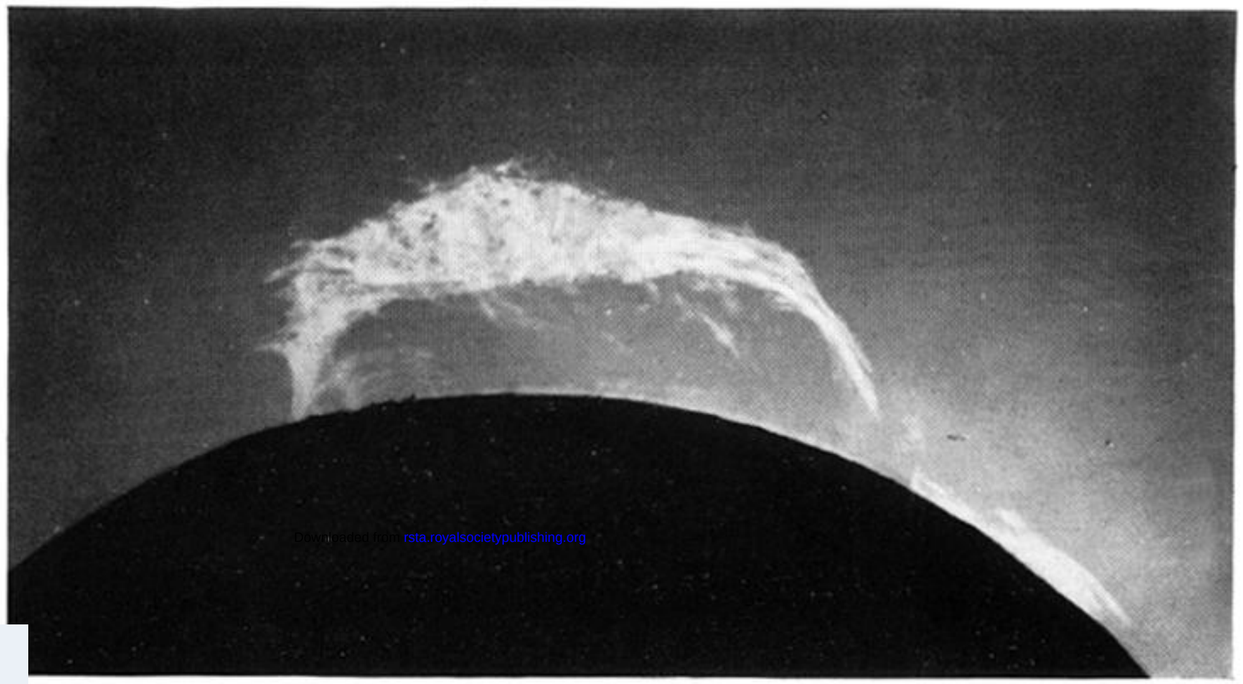
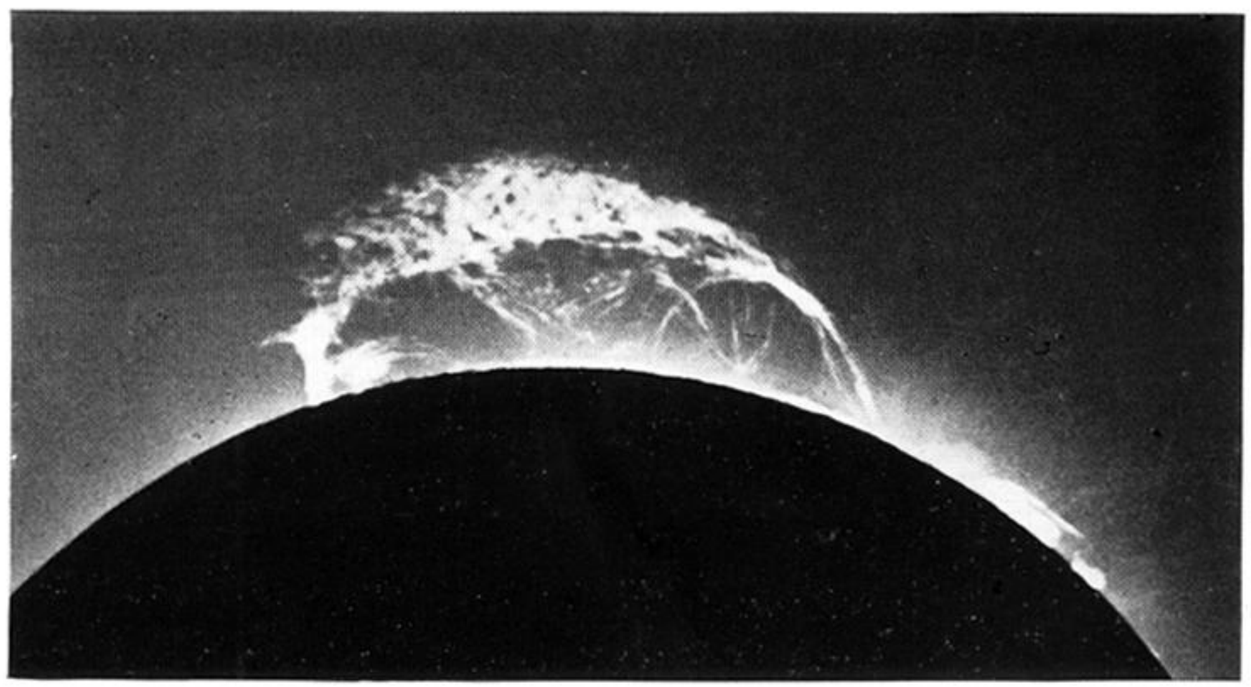
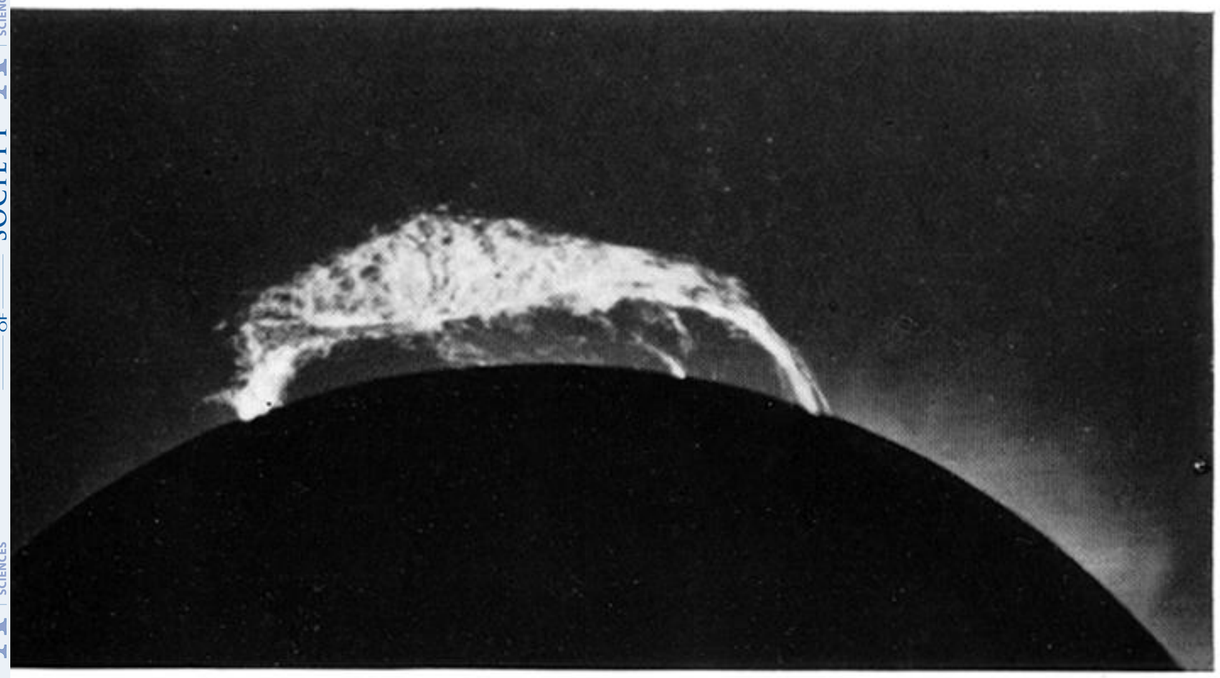
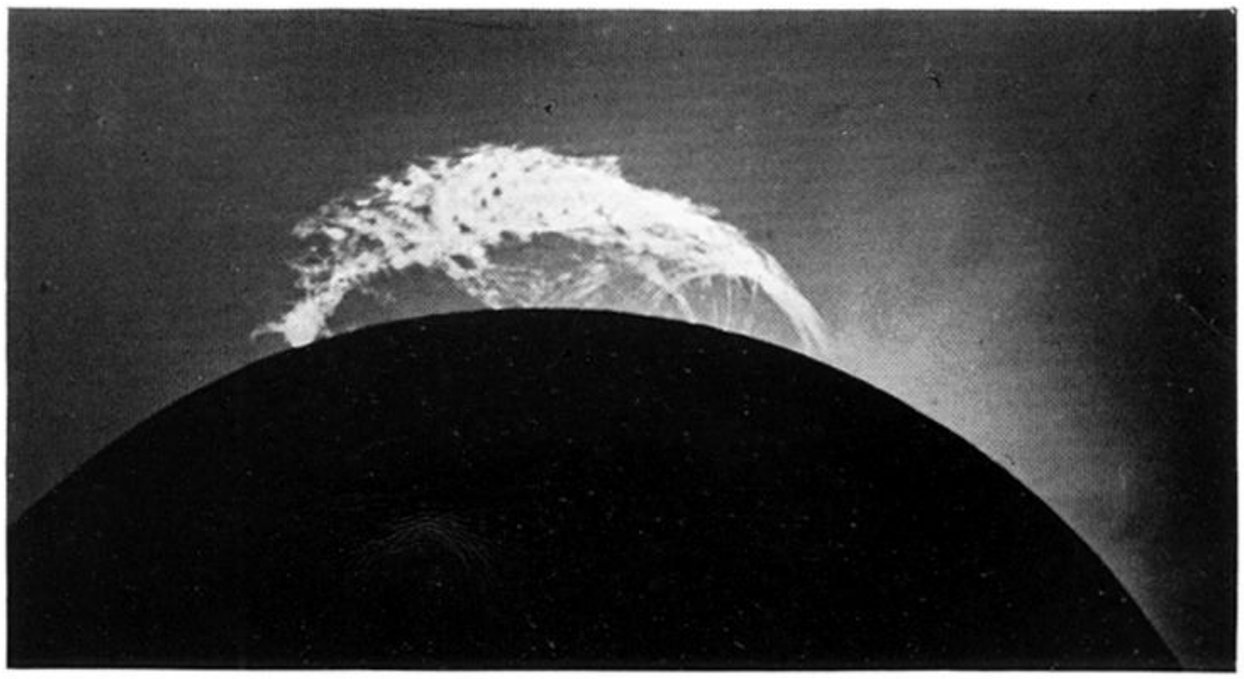
1919 May 29









1919 May 29

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES