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Total Eclipse of the Sun, May 28, 1900. Account of the Observations Made by the Solar Physics Observatory Eclipse Expedition and the Officers and Men of H.M.S. "Theseus," at Santa Pola, Spain

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VIII. *Total Eclipse of the Sun, May 28, 1900. Account of the Observations made by the Solar Physics Observatory Eclipse Expedition and the Officers and Men of H.M.S. "Theseus," at Santa Pola, Spain.*

By Sir Norman Lockyer, *K.C.B., F.R.S., and others.*

Received May 21,—Read June 20, 1901.

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By Sir Norman Lockyer *K.C.B., F.R.S.*

Objects of the Expedition.

The discussion of the series of photographs taken with the prismatic cameras employed in the last three eclipses indicated that continued work with this form of spectroscope should be undertaken, with the view (1) of obtaining data strictly comparable with the previous photographs, and (2) of extending the inquiry into the comparative lengths of the various arcs.

For the first purpose it seemed desirable to repeat the Indian work with the 6-inch camera having two prisms; while for the second an instrument of longer focus was necessary.

Representations as to the importance of the latter instrument were made to the Royal Society, and ultimately the purchase of a Taylor triple lens, of 6 inches aperture and 20 feet focal length, was authorised.

With these instruments it was hoped to obtain a very complete record of the spectra of the chromosphere and corona, and to obtain data relating to the distribution of different substances.

For comparison with the spectroscopic pictures of the corona given by the prismatic cameras, it was considered desirable to attempt to secure direct photographs of the corona with instruments having lenses of focal lengths nearly the same as those of the prismatic cameras, and arrangements were accordingly made to use coronagraphs of 16 feet and 8 feet focal length for this purpose. Other coronagraphs, of shorter focal length, were also provided, in case sufficient assistance should be available to enable them to be used, more particularly with the view of photographing the coronal extensions.

Some importance was also attached to visual telescopic observations of the inner corona, in order to determine whether the filamentary structure observed in the eclipse of 1871, at a time of maximum sun-spots, was also a feature of the inner corona at a time of sun-spot minimum.

A comprehensive programme of observations of the general phenomena of the eclipse was also arranged.

The Observing Station and Preparations.

The observing station selected for my party was determined upon from information supplied by the Hydrographer, Rear-Admiral Sir W. J. L. Wharton, R.N., K.C.B., F.R.S. Santa Pola appeared likely to meet the requirements of a man-of-war; and without such assistance as a man-of-war can render, the manipulation of long focus prismatic cameras in eclipse observations in a strange country is impracticable.

Santa Pola lies very near the central line of the eclipse, and good anchorage was available, protected from the North and West winds.

Before leaving England, I communicated with Professor Francisco Iñiguez é Iñiguez, Director of the Madrid Observatory, and Mr. Jasper W. Cumming, H.M. Vice-Consul at Alicante. These gentlemen, together with Don José Bonmati Mas, a large landed proprietor, and father of the Mayor of Santa Pola, very kindly made all the necessary preliminary arrangements with the local authorities, who had also been instructed by the Spanish Government, after representations had been made by the Foreign Office, at the request of the Royal Society.

As a result of the Royal Society's application to the Admiralty, H.M.S. "Theseus," commanded by Captain V. A. Tisdall, R.N., was told off to meet the expedition at Gibraltar, and convey the observers to Santa Pola.

The expedition consisted at first of Dr. W. J. S. Lockyer, from the Solar Physics Observatory; Mr. A. Fowler, the Demonstrator in Astronomical Physics, from the Royal College of Science; and Mr. Howard Payn, who joined as a volunteer. I subsequently received orders to accompany and take charge of it.

As the interval between the arrival of the expedition at Santa Pola and the day of the eclipse was somewhat short, owing to the dates of sailing of the Orient Line steamers to Gibraltar being once a fortnight, it was considered desirable that someone should go on in advance to select a site for the camp and arrange matters generally with the local authorities, and also find the necessary accommodation for the party.

Mr. Payn therefore proceeded to Alicante overland, and on his arrival placed himself in communication with Mr. Jasper W. Cumming, the British Vice-Consul, who had previously been apprised of his mission. Mr. Cumming afforded every assistance in his power.

From Santa Pola, a small seaside town of about 5000 inhabitants, the shore stretches away nearly due west for many miles in a flat sandy plain covered with low scrub, the open sea being to the south.

After a very cordial welcome by the Mayor, Mr. Payn went over the sites which had previously been offered for the use of the expedition through the Vice-Consul, and finally selected a spot on the open shore about half a mile west of the town.

The reasons for the selection of the site were that the south and west horizons were unobstructed; that the ground was slightly higher in elevation, and consequently drier; that it was at a sufficient distance from the town to be well clear of the houses and their surroundings; that it was close to a large bathing establishment built on piles in the sea, which could be used as a landing place for boats from the ship and so avoid the town pier (which was some distance away); and also because there was a coast-guard post on the spot, and the men stationed there could keep an eye on the camp until the arrival of the civil guards promised by the authorities.

With the assistance of the municipal authorities, Mr. Payn was enabled to make

arrangements for the supply of workmen and building materials for the foundations of the stands for the instruments, and also to arrange for the landing and transport of the packages, some eighty in all.

Facilities were also given for the landing of all articles for the camp, duty free, and without examination, on handing in a list to the Director of Customs. Authority was also obtained for keeping the telegraph station open day and night during the stay of the expedition; indeed, nothing could exceed the kindness of the authorities, who were obviously anxious to afford every assistance in their power.

As there were no bricks to be obtained in the town, they were ordered by telephone from Alicante, and were brought over the next day.

After Mr. Cumming had left for Alicante, the Mayor and the local authorities accompanied Mr. Payn to the camp, and assisted him to set out the limits and the positions of the various instruments, the Mayor good humouredly driving the first peg. A meridian line was set out roughly, and by dark all the measurements were completed. A good many inhabitants came out from the town to witness the rather unusual sight of the chief authorities engaged in manual labour.

The meridian line was checked the same night by an observation of the Pole Star. When this line was afterwards tested with the ship's instruments by Mr. Andrews, the Navigating Lieutenant of the "Theseus," it was found to be correct. The local deviation was 14° west.

The other observers, who had left England on the 11th of May by R.M.S. "Oruba," of the Orient Line, on arriving at Gibraltar, at once went on board H.M.S. "Theseus," and left for Santa Pola, which was reached just before noon the following day, May 17. I was glad to find that great interest had been shown in the expedition on board before our arrival, and that lectures on the work to be undertaken had already been given by the Chaplain, the Rev. G. Brooke-Robinson, M.A.

Assistants were at once forthcoming to take part in working the prismatic cameras, and also for manipulating several cameras which I had brought out to be used by the ship's company in obtaining photographs of the corona. Observing parties in charge of officers of the ship, to make observations along several lines, were at the same time organised.

On our arrival at Santa Pola, the following local officials came on board with Mr. Payn:—Srs. Francisco Bonmati Mas, Mayor of Santa Pola; Antoine Bonmati Mas, Vice-Mayor of Santa Pola; José Bonmati Mas, Municipal Councillor; José Salinas Perez, Municipal Councillor; Eladio Ponce de Leon, Secretary to the Mayor; Michel Sempere, Justice of the Peace; José Hernandez, Captain of the Port; Geronimo Agnati, Administrator of Customs; Eduard Fernandez, 1st Lieutenant of Coast Guards; Tomas Bueno, Medical Officer.

Work on the piers for the instruments was commenced on the day of arrival. The erection of the instruments, huts, and tents was commenced on the following morning,

May 18, and by the evening of May 21 the principal instruments were reported in approximate adjustment. Drills were begun on May 22, and were carried on several times a day up to the day of the eclipse.

By permission of the Captain, three of the officers of the "Theseus," Lieutenants Andrews, R.N., Doughty, R.N., and Pattrick, R.N., occupied quarters on shore to superintend the work of the parties in the camp. On board the Chaplain gave instructions in sketching coronas and recording stars, using for this purpose a lantern which had been placed at the disposal of the expedition by the Orient Steam Navigation Company.

The weather was very favourable for the work of the expedition, but at times the landing and embarking of parties from the ship was rendered difficult by strong sea breezes and the consequent surf.

Both day and night the instruments were carefully guarded by a detachment of "Guardias Civiles," told off for the purpose by the Spanish authorities.

The distribution of the various instruments is shown in the accompanying plan (fig. 1).

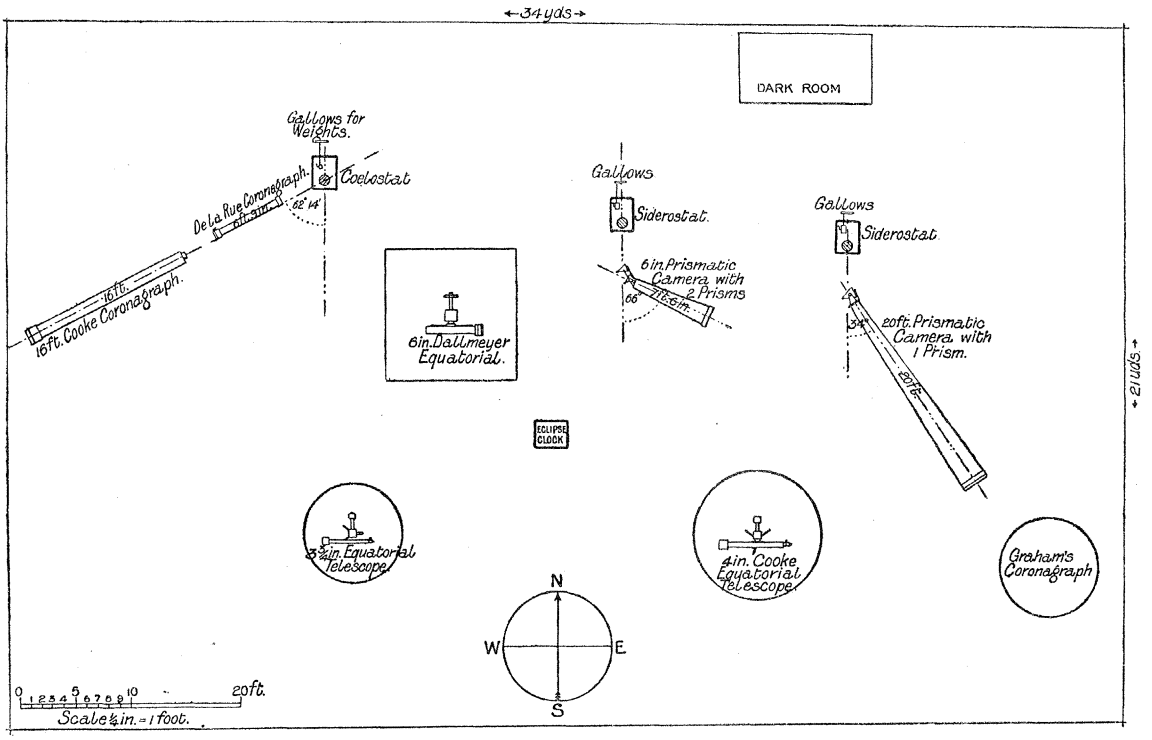

Fig. 1. Plan of Eclipse Camp at Santa Pola, May, 1900.

Local Conditions of Eclipse.

According to the Admiralty chart, the latitude and longitude of the place of observation are 38° 11′ 20″ N. and 0° 33′·66 W. respectively. For this point, the

times and position angles of contact derived from the formulæ given in the 'Nautical Almanac Circular,' No. 17, were as follows :—

Beginning of totality, May 28 4h. 12m. 51·7s. G.M.T.
End of totality, May 28 4h. 14m. 10·5s.
Duration of totality, 1m. 18·8s.
Position angle of first contact, 87° 3′·5 from N. towards W.
,, ,, last ,, 93° 47′·3 ,, N. ,, E.

The experience of the Indian Eclipse of 1898 suggested that the duration of totality given was too long, and for the practical working during the eclipse the adopted time was 75 seconds, so that there would be no chance of spoiling the coronagraph plates by exposing them after totality. The face of the eclipse clock was graduated accordingly.

The sun's altitude at mid-totality was calculated to be 33° 23′, and the amplitude 2° 25′ north of west. The apparent semi-diameter of the sun and moon were respectively 15′ 48″·1 and 16′ 5″·9, and the relative motion per second 0″·447. At mid-totality the north point of the sun's disc, direct view, was 57° 44′ to the right of the vertex, and as the sun's axis was 17° west of the north point, the sun's north pole was 74° 44′ to the right of the vertex. The heliographic latitude of the centre of the sun's disc being −0° 56′, the direct view was as represented in the accompanying diagram; the points of contact with reference to the sun's axis are also shown, and for 2nd and 3rd contacts they also represent very nearly the disposition with regard to the vertex.

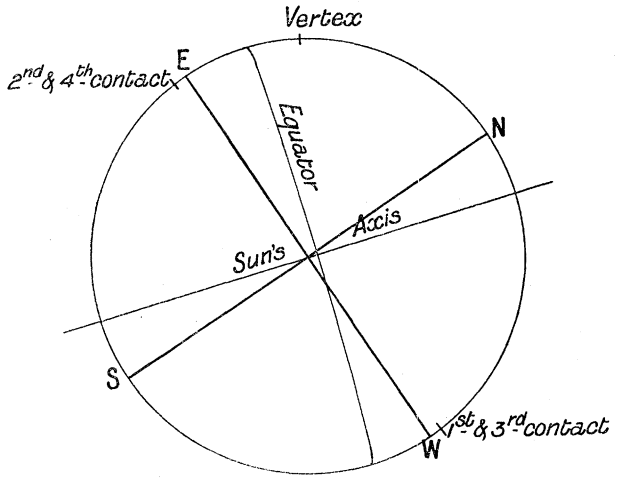

Fig. 2. Illustrating direction of sun's axis at time of totality, and position angles of contacts.

Time Arrangements.

The arrangements for the time service were similar to those made for the Indian eclipse of 1898. Greenwich time was ascertained by reference to the ship's chrono-

meters, and for the count of time during totality the eclipse clock, which has been described in my previous reports on eclipse expeditions, was utilised.

The arrangements for securing signals at definite intervals before totality were identical with that employed in Lapland and India. An image of the sun projected by the finder of the 6-inch two-prism prismatic camera was viewed on an adjustable screen, marked in such a way that it was easy to see when the cusps subtended angles of 90° and 55°, which occurred respectively at 16 seconds and 5 seconds before totality. The signals "Go" at the commencement of totality, and "Over" at the end, were given by myself from observations made with the 4-inch Cooke telescope.

The complete system of signals was as follows :—

1. "Rise up," 10 minutes before totality—

   Observers turn backs to sun.
   Clocks to be wound.
   Stops and caps of telescopes, siderostats, and cœlostats to be removed.
   Eclipse clock to be set.

2. "Alert," 5 minutes before totality—

   Disc observers to be blindfolded.
   Observers report all in readiness.

3. "G G," 16 seconds before totality.
4. "G," 5 seconds before totality.
5. "Go," beginning of totality.
6. "Over," end of totality.

At the eclipse clock two men were stationed, one calling the number of seconds remaining up to 30, and the other during the remainder of totality.

In consequence of the perfect drill during the rehearsals, the operations during the eclipse were carried out with great precision.

Acknowledgments of Assistance.

The thanks of the expedition are due especially to those named in the foregoing account, not only for assistance rendered, but also for their great kindness to us. I have already, in a letter, expressed to the Royal Society my deep sense of obligation they have laid us under.

As in the case of the "Volage" and "Melpomene," the officers and men of the "Theseus" not only assisted us with certain instruments, but organised crews for others, and many lines of work which it was impossible for the observers sent out from England to attempt. Their skill, resourcefulness, and steadiness were alike truly admirable.

Thanks are also due to the Managers of the Orient Steam Navigation Company, who conveyed the instruments to and from Gibraltar freight free.

To the Mayor of Santa Pola the whole expedition owes a debt of gratitude for his unwearying kindness. He was accessible at all times, always ready to afford us assistance, and spared no trouble to make things easy and pleasant for all. He was kind enough to open an eclipse account, and all payments to be made locally were made through him, and so useful was this that the stores for the ship were afterwards obtained in the same way; it was found to be not only a check upon the prices, but on the qualities and quantity of the goods. This alone involved considerable labour to him, but it was of the greatest assistance to us. One of our pleasantest recollections of Santa Pola will be the kindness and hospitality of Don Francisco Bonmati. I may add, the Civil Governor of the Province of Alicante, Señor Don Hipoldo Caras y Gomez de Andino, visited the camp to assure himself that all the assistance the Spanish authorities could give had been rendered.

Part II.—Observations made by the Officers and Men of H.M.S. "Theseus."

(*Forwarded by* Captain V. A. Tisdall, R.N.)

Preliminary Work.

The Chaplain of the "Theseus," the Rev. G. Brooke-Robinson, who undertook to give preparatory courses of instruction to the men, has prepared the following statement:—

"On learning that H.M.S. 'Theseus' was ordered to take a party of astronomers to Santa Pola for the purpose of observing the total eclipse of the sun, May 28, 1900, arrangements were made for the delivery of preliminary lectures on board, previous to the arrival of the eclipse party.

"Lectures were given on the 6th, 7th, and 13th May. The blackboard was used with great advantage on all three occasions. The duration of each lecture was about an hour and a half.

"When Sir Norman Lockyer arrived, he desired that the lectures should continue, giving instructions as to the sort of work to be done preparatory to the eclipse. Three parties of observers were to be trained, a magic lantern, slides, and star charts being provided by the astronomical party. The three sets to be trained were divided as follows:—

Set A. The disc party.
,, B. The corona sketching party.
,, C. The star chart party.

"Set A began their preliminary training on board after erecting the disc poles on shore. They joined the corona sketching party already at work in the submerged torpedo flat where the magic lantern slides were being shown.

"Commencing with 3 minutes in which to sketch a corona, the time was reduced to 2 minutes, then to one minute and a half, and finally to one minute and a quarter, the actual time of totality.

"After a few lectures on board, they returned ashore to complete their training under Lieutenant DOUGHTY and Mr. DANIELS, and to learn to what use the discs were to be put.

"Set B. The corona party continued under instruction on board from Friday, May 18, to Friday, May 25. On Saturday one-half went ashore to complete their drills under Lieutenant DOUGHTY. While on board they, too, had been trained to sketch against time. Three minutes was the time allowed for a sketch at the outset; it was gradually reduced to one and a quarter minutes.

"Set C were selected from amongst those who showed the most aptitude for star charting. Their attention was directed to the importance of accurately noting distance and direction.

"A diagram of constellations to be expected at the time of the eclipse was placed in the lantern, and then repeatedly sketched as it appeared on the sheet.

"From 8.30 P.M. to 9.30 P.M. star charting was tried on deck. The constellation Ursa Major, 'the pointers' and their distance from Polaris forming the preliminary lesson. When proficiency in setting down the seven brighter stars of this constellation was attained, the more intricate work of identifying the constellations, shown in the star maps of the overhead sky, supplied by Sir NORMAN LOCKYER, was proceeded with.

"I wish to lay special stress upon the difficulty I found in training a class to deal with a map upon which 'the line parallel to the horizon' was drawn across one of its angles. I would suggest that in future maps supplied for this class of work have 'the line parallel to the horizon' placed parallel to the lower edge of the map. I think it would be well to omit the cardinal points round the solar disc, since I found they tended to confuse observers who were in an elementary stage of training, and that the reason of their not being shown like a compass card required careful and repeated explanations.

"I recommend that only planets and stars of the first three or four magnitudes be shown on future maps.

"I find that Neptune shown with a large symbol has conveyed the idea that a large body was to be expected in that direction, whereas Neptune was not visible at all at the time of the eclipse.

"Mr. BENNETT, Clerk, was of very great assistance. He gave much valuable aid in the training of the star chart party ashore.

"A. PHILLIPS, Leading Shipwright, did good service in preparing extra tracings of star charts. All his work was noteworthy for its accuracy and extreme neatness. The first tracing he took was submitted to Sir NORMAN LOCKYER, who described it as excellent."

Diary of the Expedition.

A careful diary of the expedition was kept by Midshipman LAMBERT from the time of the arrival of the expedition on board the "Theseus" to their leaving the ship at Gibraltar on the return journey.

The substance of this is as follows :—

Wednesday, May 16.—H.M.S. "Theseus" left Gibraltar at 11 A.M. with the following observers on board : Sir NORMAN LOCKYER, K.C.B., F.R.S., &c., Dr. RALPH COPELAND, Dr. W. J. S. LOCKYER, Mr. A. FOWLER, Mr. T. HEATH, and Mr. FRANKLIN ADAMS. Mr. WYLLIE, A.R.A., also accompanied the expedition.

Thursday, May 17.—Arrived at Santa Pola at 11.15 A.M. Mr. HOWARD PAYN, who had gone in advance by the overland route, came on board with the local authorities, and reported the arrangements made; a party landed with Mr. FOWLER and Dr. LOCKYER in the afternoon, and the site which had been selected by Mr. PAYN was approved. The meridian line laid down by Mr. PAYN was confirmed by Lieutenant ANDREWS, R.N., with a large azimuth compass. The foundation for one of the siderostats was built.

Friday, May 18.—Landed gear. Set up brick piers and some of the instruments.

Saturday, May 19.—Setting up instruments and discs.

Sunday, May 20.—Setting up and adjusting instruments.

Monday, May 21.—Adjusting instruments. Parties were told off for each instrument. At 6 P.M. the chief instruments were reported in approximate adjustment.

Tuesday, May 22.—Commenced drills. In the forenoon drilled coronagraphs and prismatic cameras with eclipse clock. In the afternoon drilled coronagraphs, prismatic cameras, and disc parties. Screens were erected for the observation of shadow bands. In the evening photographs of stellar spectra were taken for focussing the prismatic cameras.

Wednesday, May 23.—In the forenoon the instruments were drilled individually. Mr. FOWLER gave a short lesson to the disc party. In the afternoon the coronagraphs were drilled, and in the case of each instrument one trial plate was exposed to test focus. At eclipse time there was a full rehearsal of all parties.

The meteorological house was erected, and three thermometers and a Watkin aneroid were set up.

No stars visible in the evening.

Thursday, May 24.—Meteorological observations were commenced. At 2.30, drilled disc party. Rehearsals at 3.15, and at eclipse time. At 4.30, drilled disc party. From 8.30 to 11, star trails were photographed with the four coronagraphs, and in each case the focus was found satisfactory. Tried spectrum photograph with Dr. LOCKYER's instrument, but exposure was interrupted by clouds.

Friday, May 25.—At 2.20, drilled disc party. At 3.0 and eclipse time general drills. A photograph of the spectrum of Arcturus was taken with Mr. Fowler's instrument.

Saturday, May 26.—At 11.45 general drill. Señor Don Hipoldo Caras y Gomez de Andino, Civil Governor of the Province, visited the camp. At 3.30, general drill, and full rehearsal at eclipse time. French astronomers from Elche visited the camp. At 5.5 the French astronomers, Spanish Commission, and Governor visited the camp and witnessed a full rehearsal. Two photographs of the spectrum of Arcturus were taken with Mr. Fowler's instrument.

Sunday, May 27.—General drill at 4.45 p.m. Three photographs of spectrum of Arcturus taken with Mr. Fowler's instrument.

All plate holders loaded in readiness for eclipse.

Monday, May 28.—Full rehearsal, without plate-holders, at 10.30. The eclipse was observed under perfect conditions, and all operations successfully performed.

A crowd of over 2000 of the inhabitants collected round the camp to watch the eclipse. At 5 p.m. a photograph of the corona, taken with the De la Rue coronagraph, was successfully developed. At 8 p.m. photographs numbers 5 and 10, taken with the two prismatic cameras, were successfully developed.

Tuesday, May 29.—Commenced dismounting and packing instruments. Mr. Wyllie and Dr. Lockyer left Santa Pola. Mr. Fowler made paper prints and glass positives of spectra developed yesterday. In the evening Mr. Fowler developed photographs numbers 1 and 2 taken by Mr. Payn with the long focus coronagraph; also spectra, numbers 1 and 2, taken by Dr. Lockyer, and number 1 taken by Mr. Fowler.

Wednesday, May 30.—Made glass positives of photograph taken with De la Rue coronagraph, and those taken by Mr. Payn. Finished packing instruments, negatives, and undeveloped plates. Everything on board except dark room.

Thursday, May 31.—Posted box containing copies of photographs. Settled accounts with local people. Observers returned to the "Theseus," which left for Gibraltar at 8.30 p.m.

Friday, June 1.—At sea.

Saturday, June 2.—Arrived at Gibraltar 5 a.m.

The ship was anchored outside the Mole, and in consequence of the roughness of the sea it was impossible to transfer the instruments to the lighter which was sent for them. The observers also remained on board.

Sunday, June 3.—By permission of the Commander-in-Chief, the "Theseus" proceeded inside the Mole, and the instruments were put into the lighter. At 9.30 a.m. the party left the ship and took up their quarters at the Royal Hotel. Left Gibraltar per R.M.S. "Cuzco," at 6 p.m. Wednesday, June 6.

The groups of observers were as follows :—

Timekeepers.

Lieutenant F. A. Andrews, R.N.
Mr. Boughey, Midshipman.
Mr. Lambert, Midshipman.

J. Wale, 2nd Yeoman Signals.
W. Webb, Petty Officer, 1st class.
Bugler Sneller, Ordinary Seaman.

6-inch Prismatic Camera.

Dr. Lockyer.
S. Birley, E.R.A.
J. Green, A.B.
C. Fishenden, Ordinary Seaman.

C. Willmott, Ordinary Seaman.
A. Humphries, Ordinary Seaman.
G. Hyatt, Ordinary Seaman.

20-foot Prismatic Camera.

Mr. Fowler.
W. F. Cox, Armourer.
A. Whitbourne, A.B.
F. Burt, A.B.

A. Maskell, A.B.
E. Davies, Ordinary Seaman.
H. Cristopher, Ordinary Seaman.
W. Harrison, Stoker Mechanic.

4-inch Equatorial.

Sir Norman Lockyer, K.C.B.

C. C. Lambert, Midshipman.

$3\frac{3}{4}$-inch Equatorial.

Lieutenant H. M. Doughty, R.N.

A. G. N. Lane, Midshipman.

Long-focus Coronagraph.

Mr. Payn.
T. McGowan, A.B.
E. Woodland, A.B.

H. Eary, A.B.
W. Mann, Ordinary Seaman.
H. Brooks, Ordinary Seaman.

Graham Coronagraph.

Mr. W. J. S. Perkins, Assistant Engineer, R.N.
W. Walker, Leading Stoker.

J. Knowles, Chief Stoker.

De la Rue Coronagraph.

Mr. H. W. Portch, Assistant Engineer, R.N.
W. Waterfield, E.R.A.

H. Frost, Chief Stoker.

Dallmeyer Coronagraph.

Surgeon J. Martin, R.N.
E. Buckingham, E.R.A.

R. Quint, Chief Stoker.

Discs.

Mr. J. B. Bateman, Midshipman, R.N.
W. Fraser, Arm. Crew.
R. S. Bradbrooke, A.B.

Mr. J. A. Daniels, Torpedo Gunner, R.N.
G. Fair, Armourer.
E. Gordon, Ship's Carpenter.

H. W. Richardson, Petty Officer, 2nd class.
E. Voyle, Leading Shipwright.
T. Orange, Boy, 1st class.

W. Tucker, A.B.
W. Brewer, A.B.
B. Salmon, Boy, 1st class.

A. Mason, A.B.
A. Steven, A.B.
C. Paul, Boy, 1st class.

A. May, A.B.
H. Bailey, A.B.
J. Entwistle, Ship Steward's Boy.

Sketches of Corona without Discs (*on shore*).

W. Butt, M.A.A.
G. Guilliame, A.B.
H. Meacher, Private, R.M.L.I.
H. Schmidtoel, Ordinary Seaman.

Sketches of Corona without Discs (*on board*).

W. Baxter, A.B.
W. Butts, Private, R.M.L.I.
C. Jacob, Private, R.M.L.I.
J. Wheeler, Private, R.M.L.I.
E. Willis, Sick Berth Attendant.

Observations on Stars (*on shore*).

Mr. Bennett, Clerk.
W. Riches, Leading Seaman.
A. Pontifex, A.B.
W. Bosworth, A.B.
H. Angus, Ordinary Seaman.
W. Kinvett, Private, R.M.L.I.
W. Oliver, Private, R.M.L.I.

Observations on Stars (*on board*).

Rev. G. B. Robinson, M.A.
H. Croxon, Ship's Corporal.
A. Phillips, Leading Shipwright.
R. Vigus, Corporal, R.M.L.I.
E. Price, Private, R.M.L.I.
E. Hammond, Stoker.
G. Andrews, Stoker.
G. Nightingale, Stoker.
S. Wilson, Stoker.
E. Savage, Private, R.M.L.I.

Observations of Shadow Bands (*on shore*).

Commander Hon. R. F. Boyle, R.N.
Mr. T. Slator, Naval Instructor, R.N.
Mr. J. G. Walsh, Midshipman, R.N.
Mr. F. C. Skinner, Midshipman, R.N.

Meteorological Observations (*on shore*).

Lieutenant Pattrick, R.N.
Mr. G. S. Hallowes, Midshipman, R.N.

Meteorological Observations (*on board*).

G. Donnelly, Yeoman Signaller.
E. Gant, Leading Signaller.
A. Enstidge, Signaller.
W. Hearne, Signaller.
J. Beach, Signaller.

Meteorological Observations (*Wind, &c.*).

G. Perrin, Leading Stoker.
H. Clackett, Stoker.
T. W. Empson, Stoker.
G. Guy, Stoker.
J. Wignell, Stoker.

Landscape Colours (*on shore*).

Captain F. V. Whitmarsh, R.M.L.I.
Ship's Steward D. Green
Lance-Corporal Wade, R.M.L.I.
W. Birkett, Writer.

Landscape Colours (*on board*).

Fleet Paymaster A. W. Askham, R.N.
Lieutenant W. J. Frazer, R.N.

Shadow Phenomena (*on shore*).

Mr. C. Prynn, Carpenter, R.N.

Shadow Phenomena (*on board*).

Lieutenant H. R. Shipster, R.N.

Photographers.

J. KNIGHT, Sick Berth Steward. B. BULBROOK, A.B.

Aide-de-Camp to Sir NORMAN LOCKYER, *K.C.B., F.R.S.*

Mr. C. C. LAMBERT, Midshipman, R.N.

As the expedition was on board the "Theseus" for one day only before the eclipse, and as the ship's parties returned to the ship every evening, it was not possible to give instruction in the observation of spectra, and parties for this branch of eclipse work could not therefore be organised.

Assistance in Time-keeping.

Lieutenant ANDREWS, R.N., who assisted in the important duty of time-keeping, has drawn up the following statement of the procedure adopted :—

"A time signal was made daily, at noon, from the ship by the Commander; the error of the chronometer having been ascertained by telegraph on the 16th May, the day we left Gibraltar.

"The deck watch (which was daily compared with the chronometers) was also landed, so that I could give any comparison or time required.

"On the day of the eclipse I gave the time from the deck watch, 10 minutes before totality, on which the 'Rise up' was sounded on the bugle, and 5 minutes before totality, on which the 'Alert' was sounded."

The observations of the cusps to signal intervals of 16 and 5 seconds before totality were also made by Lieutenant ANDREWS, who remarks that the apparatus provided worked most satisfactorily. During the drills, when the cusps were of course not observable, the corresponding signals were given by reference to the deck watch.

The Coronagraphs.

Three coronagraphs were employed by officers and men of H.M.S. "Theseus," particulars of which are appended :—

(1.) The De la Rue coronagraph. Aperture $4\frac{5}{8}$ inches, focal length 8 feet. Assistant Engineer H. W. PORTCH in charge.

The instrument, which had previously been used in Nova Zemlya and India, was fed by a spare part of the cœlostat mirror used for the long-focus coronagraph. Three exposures were made of approximate durations, 40 seconds, 15 seconds, and 0·5 second respectively, the plates employed being "Sandell" triple coated, 6 inches square.

(2.) The Dallmeyer coronagraph. Aperture 6 inches, focal length 54 inches. Surgeon J. MARTIN in charge.

The instrument was mounted equatorially, and provided with an excellent driving clock.

One photograph was taken with an instantaneous exposure at call of 70 from the timekeeper at the eclipse clock, and another from, as soon as the plate could be changed, to the call of 5, the exposure thus being about 60 seconds. Sandell triple-coated plates, 6 inches square, were employed in each case.

(3.) The Graham coronagraph. Aperture 3 inches, focal length 20 inches. Assistant Engineer W. J. S. Perkins in charge.

This instrument, together with the small cœlostat with which it was used, was loaned to the expedition by the Marquis of Graham. Only one exposure was made during totality—from the call of 70 to that of 5 from the eclipse clock—the exposure being about 60 seconds. Seven additional plates were exposed at half-minute intervals after totality, with the view of ascertaining how long the corona could be photographed after the sun had reappeared. Sandell plates, 3 inches square, were employed throughout.

The exposures were successfully made in each case.

Discs.

Six discs for cutting out the bright light of the inner corona were erected, with the view of enabling the observers to detect the long extensions if there should be any.

The following are particulars relating to the observations :—

Sun's altitude at mid-totality	= $33\frac{1}{2}°$.
,, azimuth ,, ,, ...	= N. $87\frac{1}{2}°$ W.
,, semi-diameter 15′ 48″·12.	= 948″·12 Radius
Disc to cover 3′ round sun	= 1128″·12 ,,
,, ,, 6′ ,, ,, ...	= 1308″·12 ,,

Example.

Disc No. 1, 6-inch diameter—

Distance from eye to cover 6′ round sun ..	= $39\frac{1}{2}$ feet.
Height above eye	= 22 feet 1 inch.
Height above ground	= 26 feet.

With reference to this branch of work, the following statement has been drawn up by Mr. J. A. Daniels, Gunner, R.N., who superintended the erection of the discs and eye-pieces, adjustments for azimuth and altitude being made by Lieutenant Andrews :—

"The eclipse camp being on perfectly level ground, the six discs were fixed up on poles, rough spars from the ship being found suitable for this purpose.

"Owing to the loose sandy nature of the soil, it was found necessary to secure the

heels of the poles in casks sunk in the ground, stones and turf being rammed down tight round them, the heads being further secured by four rope stays, taken to pegs about 4 feet long driven into the ground.

"On the poles being set up, steps were fixed for convenience of mounting the poles to place and adjust discs.

"The discs, which were made of wood, varied from 6 to 2 inches in diameter; they were painted a dead black, and were fixed at the ends of brass rods which projected at right angles to the poles. These brass rods were placed at correct height, allowance being made for height of eye. The rods were further secured and stayed to the pole by twine. They were then turned to an angle of $33\frac{1}{2}°$ with the vertical, so as to place them at right angles to the line of observation. The correct angle of each disc was obtained by fixing a plumb line to the edge of a triangle which was ruled with pencil at the angle of $33\frac{1}{2}°$.

"*Eye-pieces.*—These in each case consisted of a small piece of sheet brass, with a hole pierced in it of about $\frac{3}{16}$ inch in diameter, which was fitted on the front face of a framework made sufficiently large for a seat for the observer to be placed inside it. The front face was carefully adjusted so as to be parallel to its corresponding disc, and the eye-piece arranged so as to have a movement on its frame, both in altitude and azimuth, for purposes of final adjustment. The correct position of these frames and eye-pieces required a good deal of very careful observation to arrive at. Compass, spirit level, and a large wooden triangle having an angle of $33\frac{1}{2}°$ were used for this purpose."

Arrangement of Observers.—The six discs were each worked by three persons, who were told off as Nos. 1, 2, and 3. Their duties were as follows:—

No. 1 to observe the corona and describe to No. 2.

No. 2 to write down the description given by No. 1.

No. 3 to blindfold No. 1, and to lead him to the eye-piece at the correct time, and to repeat time calls from the eclipse clock.

The routine carried out was as follows:—

10 *minutes before totality* (bugle "Alert")—

Blindfold No. 1; then Nos. 1 and 2 turn their backs to the sun, No. 3 takes the place to be occupied by No. 1, and keeps eye-piece adjusted.

16 *seconds before totality* (bugle 2 G's)—

No. 1 is led to position at eye-piece by No. 3.

5 *seconds before totality* (bugle 1 G).

Order "Go" at totality, and 75 seconds is called from eclipse clock and repeated by No. 3. At 65 being called from clock the bandage was removed from the eyes of No. 1, who looks through eye-piece and describes to No. 2 what he can see of the corona. No. 3 continues to repeat the time called from the eclipse clock, and makes a rough sketch of the corona to assist No. 1, who makes his sketch from his description given to No. 2 when totality is over.

Training of Observers.—To bring the observers to the necessary stage of efficiency a considerable amount of training was required; those of the disc observers who could be spared after the discs were set up were instructed in sketching coronas of former eclipses, illustrated by magic lantern slides, the time allowed for sketching these being gradually decreased from a period of 3 minutes to a period of $1\frac{1}{4}$ minutes, the expected duration of totality.

On and after Tuesday, May 22, the disc parties were landed and general rehearsals were commenced; the disc observers were drilled in sketching and describing a typical corona outlined on a large piece of cardboard with chalk, the same time being allowed for exposure of the typical corona as the time totality would last. After the sketches were made by the Nos. 1 from the descriptions given to Nos. 2 they were handed in for inspection and very carefully checked in regard to position and length of streamers, the result being that each day showed an improvement.

A variety of methods were tried before it was finally decided as to the best way of sketching coronas. It was found necessary to use abbreviations as much as possible whilst taking down the descriptions. This at first was found to be very confusing, but it was eventually got over by using ruled forms.

The best means found for sketching coronas was to cut a service pistol target in four parts, and use the back on which to sketch. A small disc was painted in the centre, and the card was marked in concentric circles, each increasing by one diameter of the disc already painted. The position of streamers were described in terms of the clock, the direction of streamers by compass bearing, and length of streamers in diameters of the painted disc.

The forms used for taking down descriptions left very little writing for No. 2 to get through, and no difficulty whatever was experienced by the observers in utilizing these notes for the sketches made immediately afterwards. Of the six discs used, four covered a radius of 6 minutes outside the moon's diameter, and the remaining two covered a radius of 3 minutes. Although the 6-minute discs covered much more of the inner corona according to the sketches and descriptions handed in, practically the same results were obtained from both 6-minute and 3-minute discs, allowance being made for the difference in diameter of discs.

The disc observers were personally instructed by Lieutenant H. M. Doughty, R.N., the rehearsals being held four or five times daily. A different sketch was used on each occasion.

The discs were set up and the eye-pieces fixed under the direction of Lieutenants Andrews and Doughty, assisted by Mr. Hallowes, Midshipman.

It has been thought desirable, instead of forwarding all the original sketches, to select the best of each sort, and to make a separate sketch representing the mean of the results in each case. These are—

(1.) With discs covering 6 minutes of arc outside the moon's perimeter.

(2.) With discs covering 3 minutes.

(3.) Free-hand drawings without discs.

The sketches made with discs agreed fairly well in each case. The mean sketches appended have been made with much care from the originals, and in the opinion of others besides myself very fairly represent the general results.

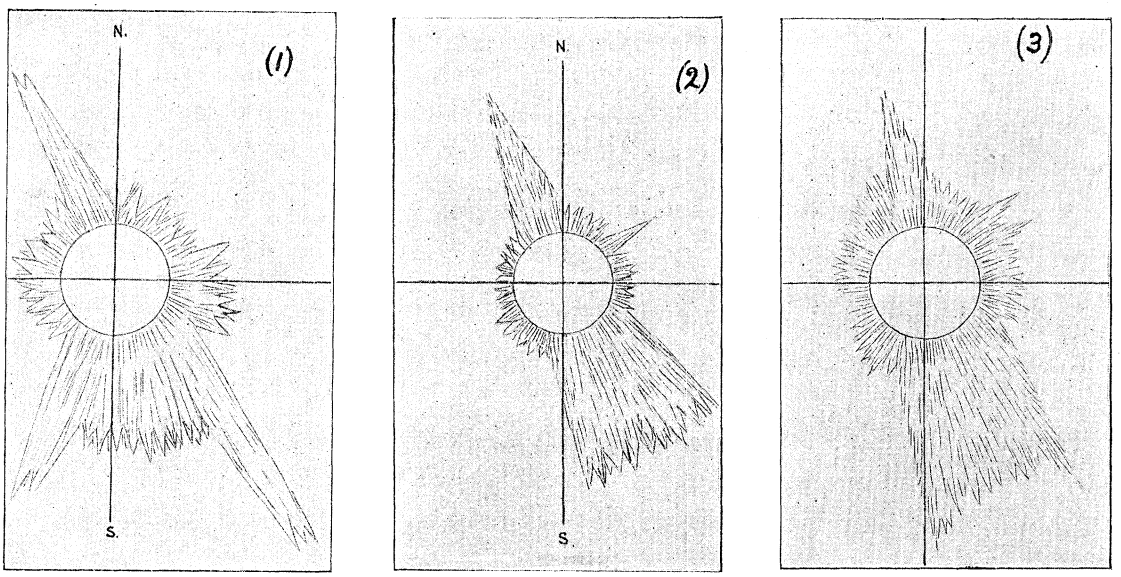

Fig. 3. Sketches of Corona. (1) With discs covering 3 minutes round Sun's limb; (2) with discs covering 6 minutes; (3) without discs.

Sketches of Corona without Discs.

Particulars as to the selection and training of the observers who made drawings of the corona as seen by the unaided eye have already been given.

Observations of Inner Corona with the $3\frac{3}{4}$-inch Telescope.

A telescope of $3\frac{3}{4}$ inches aperature, with a magnifying power of thirty-six, mounted on a portable equatorial stand, was employed by Lieutenant Doughty, R.N., in a search for minute coronal structure, such as that observed by Sir Norman Lockyer in the eclipse of 1871. His account of the observations was as follows :—

"For the purposes of description, I propose to make the moon's disc a clock face, 12 o'clock being in the zenith. The corona appeared perfectly white except that the lower portion of the bright ring just after the commencement of totality was of a rosy colour, as also was the upper portion just before the finish of totality. I noticed the following red prominences. Two, straight and radial, very close together, at 12.30 o'clock. Two rather further apart and not so long at about 1.15. One at 4.30. This prominence I lost sight of just before the end of totality. No detailed structure was visible from 1.30 to 4.

"Straight radial lines of bright light were visible outside the bright ring. They appeared to grow out of the ring of bright light and gradually get brighter as they grew, and then as gradually fade. The spaces between these lines started as pale light, and gradually assumed a soft mouse-coloured brown.

"The radial lines visible from 7 to 10.30 were slightly brighter and longer. They were curved in appearance, curling outwards from about 9 o'clock. Round the remaining portions of the moon's disc, outside the bright ring, the light appeared to gradually fade; I could see no dark spaces, and, except those previously mentioned, very few radial lines, these being most noticeable at 10.30 to 11, 7 o'clock and 4.30."

Observations of Stars Visible During Eclipse.

The following account of the preparatory work, and of the observations of stars made during totality, has been prepared by the chaplain, the Rev. G. Brooke-Robinson.

"The party landed for the purpose of star observations consisted of one officer and six men; the men were divided into two sections, each section taking half the heavens; all were provided with maps to assist them in recognising such stars and planets that might appear.

"The arrangements for the party on board were similar to those for the shore party.

"The actual observations of stars during the eclipse were taken during a period extending from 20 minutes before totality to 15 minutes after totality.

"*Venus* showed distinctly throughout the whole period of these observations. A particularly bright body was seen close to the sun at the lower right-hand quadrant; this was taken to be Mercury. The stars α Orionis and α Tauri were both visible during totality. All observations were carried on with the naked eye. No luminous body unmarked in the maps was noted."

Landscape Colours.

Two parties of observers were told off to record the general colour phenomena, one party being stationed on board the "Theseus," and the other on a hill on shore. Fleet Paymaster A. W. Askham has prepared a report on the first set of observations, and Captain F. V. J. S. Whitmarsh, R.M.L.I., has presented a separate report on the shore observations. The following general statement has been combined from these. (See table accompanying.)

Captain Whitmarsh further remarks:—"I did not notice any appreciable difference in the cultivated land in front as regards colour at any time. What I noticed particularly was that the clouds travelled in a northerly direction, and as we neared totality they travelled southwards, and I certainly imagined that a cold breeze came up from a northerly direction as soon as the sun was totally eclipsed. The hills

Direction.		Sky.			Clouds.			
		Before totality.	During totality.	After totality.	Before totality.	During totality.	After totality.	Be tot
	On ship.	Light blue, softened off to the horizon.	Indigo with a drab colour near horizon.	Light blue, softened off to the horizon.	Nil.	Nil.	Nil.	Distar grey colou patcl
N.E.	On shore.	Blue	...	...	Nil.	...	...	As u cept dark as to proa
		3.41 P.M., blue; 4 P.M., pinkish on horizon; 4.12P.M., slate colour.	As at daybreak.	Slate colour.	Nil.	Nil.	...	Same ordi day.
	On ship.	Light blue, softened away to the horizon, slight tinge of warm colour near horizon.	Indigo, with a drab colour on the lower portion.	Light blue, softened away to a warm tinge.	Nil.	Nil.	Nil.	]
S.E.	On shore.	Yellowish pink hue on horizon, and blue overhead.	...	...	Nil.	...	...	]
		3.41 P.M., light blue; 3.45, yellow streaks appeared on horizon; 3.55, changed into pink.	Horizon from pink to violet hue.	Slate colour.	4.3 P.M., slight horizontal streaks of clouds appeared on horizon.	Nil.	Nil.	Same ordi day
	On ship.	Light blue, softened away to the horizon, slight tinge of warm colour near horizon.	Indigo, slight drab colour on lower portion.	Light blue, softened away to a warm tinge.	Nil.	Nil.	Nil.	]
S.W.	On shore.	Yellow shadow extending across from W. to S.	...	..	Horizontal grey streaks over the hills S. of W.	...	...	Norma grey creep
		Horizon light grey, shading off to blue overhead.	As at daybreak.	Blue.	Nil.	Nil.	Nil.	Hill i tanc almo scure Brown
	On ship.	Light greenish	Indigo, with	Very light	Slight streaks	Nil	Nil	Distan

Land.			Sea.			Observer.
Before totality.	During totality.	After totality.	Before totality.	During totality.	After totality.	
ant hills ey, showing our in ches.	Very dark grey.	Distant mountains grey with purple, land very distinct.	Light slate colour.	Dark blue, with a green tinge.	Light indigo.	Fleet Paymaster, A. W. A Staff Engineer, F. T. Geo Lieutenant, W. J. Frazer
usual, except getting ker brown totality approached.	...	...	Nil.	...	...	Captain Whitmarsh, R.M
e as on an linary clear y.	Dark brown, and hill blue.	Normal.	Nil.	Nil.	Nil.	G. Birkett, Writer.
Nil.	...	...	Slate colour.	Very dark slate colour, greenish tinge in foreground.	Indigo green tinge in distance.	Fleet Paymaster A. W. A Staff Engineer F. T. Geo Lieutenant W. J. Frazer
Nil.	...	...	Dark blue, and getting still darker blue near totality.	...	...	Captain Whitmarsh, R.M
e as on an linary clear y	Dark brown.	Light brown.	3.41, blue. Yellow shadow coming across from S.; 3.57, sea very blue; 4.10, horizon like early dawn.	Dark blue to light blue.	Light blue.	Lance-Corporal Wade, R.
Nil.	Mountains dark purple, looking grey middle distance, and foreground very dark grey.	Mountains purple grey. Foreground similar colours, but darker.	Slate colour.	Dark blue (indigo), with a green tinge.	Blue, with touches of indigo and cobalt green.	Lieutenant W. J. Frazer, Fleet Paymaster A. W. A Staff Engineer F. T. Geor
nal, with y haze eping over.	...	...	Yellow shadow extending from S. to W.	...	...	Captain Whitmarsh, R.M
in the distance W.S.W. most obured. vnish hue.	Dark fawn, hills blue.	Normal, as would usually appear after a shower.	Horizon S., yellow shade; 4.10 P.M., dark blue.	Dark blue.	Blue.	Daniel Green, Ship's Ste
Distant moun-	Distant hills	Distant hills	Blue, with a	Indigo with	Light slate	

server.

A. W. Askham, R.N.
. T. George, R.N.
. Frazer, R.N.

RSH, R.M.L.I.

r.

A. W. Askham, R.N.
T. George, R.N.
Frazer, R.N.

RSH, R.M.L.I.

VADE, R.M.L.I.

Frazer, R.N.
A. W. Askham, R.N.
T. George, R.N.

RSH, R.M.L.I.

Ship's Steward.

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								Brown
N.W.	On ship.	Light greenish blue.	Indigo, with a fawn colour tinge on lower portion.	Very light blue.	Slight streaks of cloud near horizon.	Nil.	Nil.	Distan tains
	On shore.	Blue overhead, distance grey, similar to early dawn.	Very dark blue overhead, and like day breaking over the hills.	Not so blue as during totality; over the hills, light grey.	Horizontal grey grey streaks over the hills.	Nil.	Nil.	Greyis haze over

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vnish hue.		shower.				
ant moun-ns grey.	Distant hills grey, fore-ground dar-ker grey.	Distant hills purple, fore-ground nor-mal colour.	Blue, with a slight green tinge.	Indigo, with a green tinge.	Light slate blue tinged with green.	Lieutenant W. J. FRAZER, Fleet Paymaster A. W. A Staff Engineer F. T. GEOR
rish blue ze creeping er the hills.	Hills slate colour, fore-ground dark brown.	Hills brown, foreground usual col-our.	Nil.	Nil.	Nil.	Captain WHITMARSH, R.M

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

FRAZER, R.N.
A. W. ASKHAM, R.N.
T. GEORGE, R.N.

RSH, R.M.L.I.

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

changed their hue from pinkish-brown to dark slate colour. I also noticed that a bird which had been chirupping long before the first contact carried on doing so right through totality; he remained in the same place the whole time. I also noticed a yellow shadow about 6 miles to sea which extended from S.W. to S.E. by S."

Shadow Phenomena.

The moon's shadow was not seen at all, although observers were stationed at the mast-head of the ship at a height of about 80 feet from the water, with careful instructions as to the measurement of its speed, &c., had it been seen. The relative positions of the shore line, the ship, and the island to seaward gave reason to hope for good results; but in this we were disappointed.

Shadow Bands.

Mr. T. Slator, B.A., Naval Instructor, who took charge of this section of the observations, presents the following report of the preparatory work and the observations made:—

"Two canvas screens, 18 × 6 feet, were placed vertically, one in the meridian and the other in the prime vertical, on a road crossing the camp, which was as nearly as possible horizontal. The sides of the screens facing the sun, and the 18-foot square included by them on the horizontal plane, were whitewashed.

"Rods 3 feet long were provided to mark the direction in which the bands were travelling on the horizontal plane, and two wooden "T's" were made, with a 3-foot head and a 6-foot handle to secure permanent impressions on the screens.

"The heads were smeared with a mixture of blacklead and tallow, and the long handles enabled the observers to stand at some distance from the screens.

"It was decided to place the rods and mark the screens perpendicular to the directions of the bands, and in the directions in which they were travelling. To make a more accurate estimate of the distance between successive bands the rods and the heads of the 'T's' were painted white at the ends, and the centre foot was painted black.

"Commander Hon. R. F. Boyle volunteered to mark the screen in the meridian, Mr. J. G. Walsh, Midshipman, was watching the other screen; Mr. F. C. Skinner, Midshipman, placed the rods on the horizontal plane, and I had a stop watch to note times, and to be used if possible to form an estimate of the speed at which the bands were travelling.

"Unfortunately the bands were very faint and elusive, and on the screen in the prime vertical no shadows were seen at all. Only one mark was made on the other vertical screen before totality began, and this was found to be inclined to the horizontal at an angle of 20°, the bands moving upwards from N. to S. One mark was made

after totality, and this was inclined at an angle of $40\frac{1}{2}°$ to the horizontal, and the bands were seen to be travelling downwards from S. to N.

"Two rods were placed by Mr. SKINNER on the horizontal plane, one before and one after totality. Before totality the bands were travelling S. 28 E. and after totality N. 36 W. The bands were first seen at 4h. 12m. 16s. G.M.T., that is, 22 seconds before the beginning of totality, but no reliable estimate was formed as to their width or their speed.

"They were described as being like a mirage, or like the faint rippling on a smooth surface of water when light airs disturb it, and at first it was hard to believe that the slight trembling seen on the screen was not due simply to the shaking of the canvas in the wind."

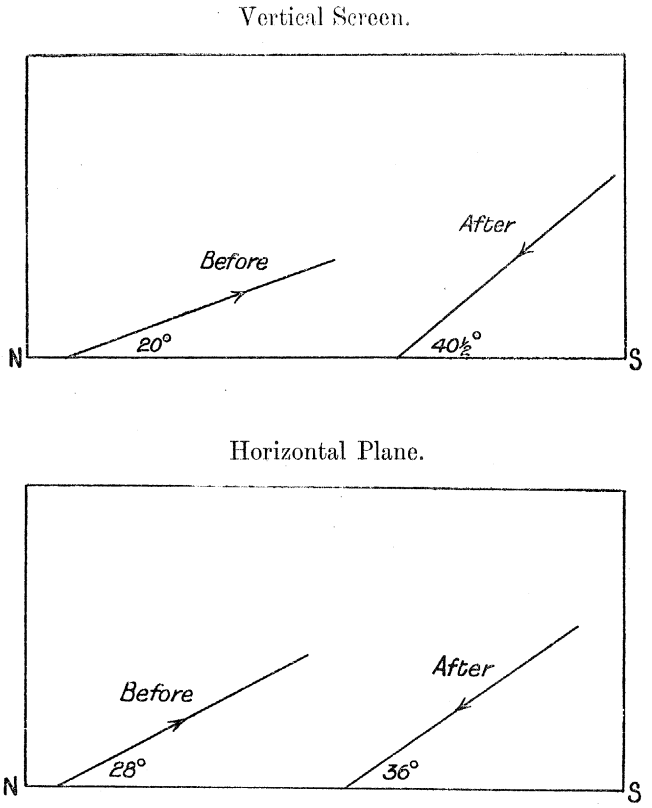

FIG. 4. Direction of Shadow Bands.

Contact Observations.

Although observations of the times of the contacts did not form a definite part of the programme of the expedition, it may be useful to state the times recorded. Observations of the first contact were made by Lieutenant ANDREWS and Mr. FOWLER, while the times of beginning and end of totality were noted from signals given by Sir NORMAN LOCKYER.

The times recorded were as follows :—

	G.M.T. h.	m.	s.	Observer.
1st contact . . .	2	58	30	Fowler (telescopic view).
	2	59	0	Andrews (projected image).
2nd ,, . . .	4	12	38	Lockyer.
3rd ,, . . .	4	13	53	Lockyer.
4th ,, . . .	Not observed.			

Meteorological Observations.

The following report on the meteorological observations made at the Eclipse Camp and on board the "Theseus" from the 25th to the 29th May, has been prepared by Lieutenant Pattrick, R.N.

The results of the observations are given in four separate tables, instead of in their original form, so that comparisons of the data for different days can readily be made. A graphical representation of the temperature observations on the day of eclipse and the preceding and following day is also given.

On Thursday, May 24, a shelter was erected, in the Eclipse Camp, at Santa Pola, for the meteorological instruments. The shelter was about 7 feet square, the sides being made of three thicknesses of bunting, with a foot space between the bottom and the ground, to allow a free current of air. The height was about 7 feet, the roof being of canvas, whitewashed on the outside.

Inside two posts were planted, with a cross-bar between, to which the instruments were hung, viz. :—A "Watkins" aneroid, and three Centigrade thermometers. They were about 3 feet 6 inches from the ground, and suspended from the cross-bar with twine.

The observations were commenced at noon on May 25, and were all taken by Mr. Hallowes, Midshipman, and myself. A copy of the observations is appended.

It will be noticed that for 3 days before the eclipse the barometer was more or less steady, there being a slight rise till midnight of May 27, after which it fell steadily till the time of totality, when it rose again slightly for 10 minutes, then continued falling till 6 P.M., after which it was unsteady for some hours. The temperature usually rose till noon, and remained the same till about 3 P.M., when it would fall gradually.

On the 28th, from the time of first contact, the thermometers dropped much faster than usual till 10 minutes after totality, falling from 24°·5 C. to 19°·8 C.—a total drop of 4°·7 C. After this it again rose steadily till 5.45 P.M., when it reached its normal height for the time of day.

The wind, which was always from the sea during the afternoon, and usually steady

as regards direction and force, became very fitful and uncertain in strength, though constant in direction, for about half-an-hour at totality. This may indicate a current of air from the opposite direction, which was not strong enough to overcome the regular sea breeze prevailing at the time.

Meteorological observations were also kept on board the ship, by the signal staff. These, which are also appended, are nearly identical, as regards the variation of barometer and thermometers, with those taken at the camp.

The more important observations are also illustrated graphically in figs. 5 and 6.

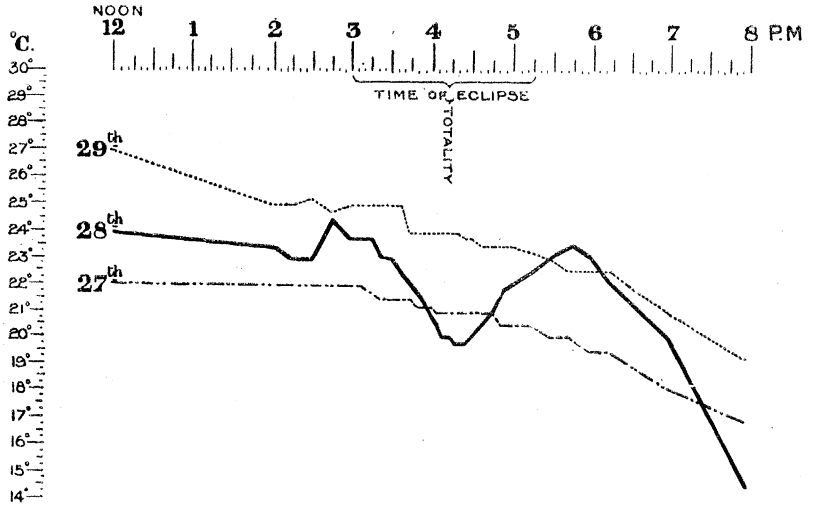

FIG. 5. Curve of temperature observations, May 27, 28, 29.

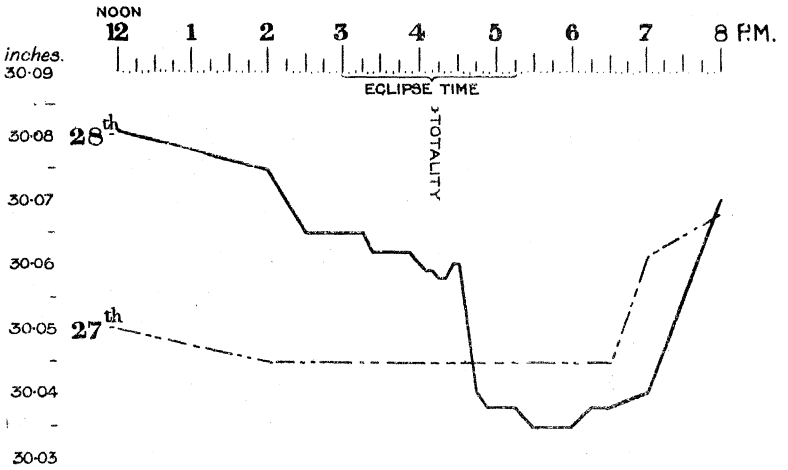

FIG. 6. Curve of barometer observations, May 27, 28.

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Table I.—Temperature Variations.

	A.M.			P.M.	Time of Eclipse.														
										Time of Totality.									
Date (1900).	4	8	12	2	3	3.15	3.30	3.45	4.0	4.10	4.15	4.20	4.30	4.45	5	5.15	6	7	8	12
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
May 25 . .	—	—	22·2	21·0	21·0	21·1	20·4	20·4	20·8	21·1	20·8	20·5	20·3	20·4	20·3	20·1	19·4	17·8	16·8	14·6
,, 26 . .	10·5	20·0	21·5	21·4	21·1	20·6	20·6	20·6	20·1	20·1	20·1	20·3	19·9	19·9	20·0	19·6	19·0	17·7	16·3	13·0
,, 27 . .	10·9	22·0	22·0	22·0	22·0	21·8	21·5	21·5	21·2	21·0	21·0	21·0	21·0	21·0	20·5	20·5	19·5	18·2	17·0	11·0
Eclipse day, ,, 28 . .	10·2	20·2	24·0	23·5	24·0	24·0	23·0	22·0	20·8	20·0	20·0	19·8	20·0	21·0	22·0	22·5	23·0	20·0	14·5	12·0
,, 29 . .	16·2	20·3	27·0	25·0	25·0	25·0	25·0	24·0	24·0	24·0	24·0	24·0	23·8	23·5	23·5	23·2	22·5	21·0	19·2	14·2

Table II.—Barometric Readings.

	A.M.			P.M.	Time of Eclipse.														
										Time of Totality.									
Date (1900)	4	8	12	2	3	3.15	3.30	3.45	4.0	4.10	4.15	4.20	4·30	4.45	5	5.15	6	7	8	12
May 25 .	—	—	20·965	29·96	29·95	29·945	29·943	29·943	29·942	29·942	29·940	29·94	29·935	29·93	29·935	29·935	29·935	29·945	29·965	30·00
,, 26 .	29·995	29·99	29·995	29·995	29·975	29·975	29·975	29·975	29·975	29·975	29·975	29·975	29 975	29·975	29·975	29·975	29·975	29·80	29·99	30·00
,, 27 .	30·05	30·025	30·05	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·045	30·061	30·068	30·090
,, 28 .	30·089	30·089	30·081	30·075	30·065	30·065	30·062	30·062	30·06	30·059	30·058	30·06	30·06	30·04	30·038	30·038	30·035	30·04	30·07	30·06
,, 29 .	30·053	30·04	30·022	30·005	29·90	29·90	29·72	29·70	29·70	29·70	29·70	29·70	29·70	29·97	29·967	29·965	29·965	29·97	29·98	29·975

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

Table III.—Wind (Direction and Force).

Date.		A.M.			P.M.	Time of Eclipse.														
											Time of Totality.									
		4	8	12	2	3	3.15	3.30.	3.45	4	4.10	4.15	4.20	4.30	4.45	5	5.15	6	7	8	12
1900. May 25	Direction	—	—	E.S.E.	S.E.b.E.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	E.S.E.	E.S.E.	E.S.E.	E.S.E.	E.S.E.	S.E.b.S.	S.E.b.S.	S.E.	Calm	Calm
	Force ..	—	—	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	1	0	0
26	Direction	N.W. b.W.	S.	E.S.E.	E.S.E.	E.S.E.	S.E.b.E.	S.E.b.E.	E.S.E.	E.S.E.	S.E.b.E.	S.E.b.E.	S.E.b.E.	S.E.b.E.	S.E.b.E.	E. b. S.	E.S.E.	S.E.b.E.	S.E.	S.E.	Calm	Calm
	Force ..	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	0	0
27	Direction	Calm	S.E.	E.S.E.	S.E.	S.E.	S.E.b.S.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.	S.E.b.E.	Calm	Calm
	Force ..	0	2	2	3	2	2	2–3	3	3	3	3	3	3	3	3	3	2	1	0	0
28	Direction	Calm	W.S.W.	S.E.b.S.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S.S.E.	S. b. E.	S.E.	Calm	Calm
	Force ..	0	1–2	3	3	3	3	3	3	3	2–3	2–3	2–3	3	2	2	2	1	1	0	0
29	Direction	Calm	W.S.W.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.b.S.	S.E.	S.E.b.S.	Calm	Calm
	Force ..	0	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	0	0

Table IV.—Clouds (proportion) and Direction of Movement (Upper Wind).

Date.		A.M.			P.M.	Time of Eclipse.															
											Time of Totality.										
		4	8	12	2	3	3.15	3.30	3.45	4	4.10	4.15	4.20	4.30	4.35	5	5.15	6	7	8	12
1900. May 25.	Proportion of cloud .	—	—	3	2	1	1	1	2	3	0	3	2	1	1	1	0	0	0	2	1
	Upper wind . . .	—	—	W.	W.	N.W.	N.W.	N.W.	N.W.	N.W.	N.W.	0	N.N.W.	N.N.W.	N.W.	N.W.	N.W.	N.W.	0	0	0
26.	Proportion of cloud .	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Upper wind . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.	Proportion of cloud .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upper wind . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.	Proportion of cloud .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upper wind . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.	Proportion of cloud .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
	Upper wind . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Part III.—Photographs of the Corona taken with a 4-inch Cooke Lens of 16 feet focal length. *By* Howard Payn.

The Camera.

The instrument I used during the eclipse was a telescope fitted with a camera for taking pictures of the corona. The lens was a Cooke photovisual objective (Taylor's Patent) of 4 inches aperture and 16 feet focal length, the sun's image being therefore $1\frac{3}{4}$ inches in diameter. The fittings of the telescope were specially drawn for me by Mr. George Scorer, Architect, of Newman Street, and gave every satisfaction.

The object glass was fitted in a mahogany box, the wood being 1 inch thick; this in its turn slid in and out of a holder of the same thickness; the camera at the other end was similarly fitted.

Between the two ends were two sets of battens, each 8 feet long, supported in the centre by a square wooden frame into which the battens screwed. The screws worked in 2-inch slots, so that by loosening the thumb screws at either end room was afforded for any shrinkage or expansion of any part of the instrument.

The telescope when put together was supported on three solid piers, the two on which the ends rested being of brick. The whole was perfectly steady, even with a strong breeze blowing.

The battens were covered in with brown paper pasted round them, and outside this was a covering of tarred paper. The covering on the whole was fairly light-tight, but the paper was very easily torn, especially when the telescope was covered up at night with sails from the ship. During this operation the wind would flap parts of the sail against the tube, in spite of every care, and the paper was often broken. This could be repaired by pasting on fresh paper, but it was always a source of anxiety, and had any tearing of the paper happened during the exposures, the plates would probably have been spoilt.

I think that it would be better on another occasion to cover the battens with black cloth, with a mackintosh cover to fasten securely over that. The only covering then required at night would be for the object-glass and camera. This would save a good deal of trouble, and would much facilitate working the instruments at night, as, after the bluejackets have returned to the ship, it is often very difficult to open out coverings single-handed, especially in the dark.

The focus was obtained by sliding the object-glass box in and out of the holder. The focus was tested by exposing plates on the sun and by photographing star trails.

Mawson's Castle plates were used, size 10 × 10, F No. 56, relative speed 1·5 (Wynne's exposure-meter scale.)

The Cœlostat.

The telescope was fed by a cœlostat, with a 16-inch mirror, mounted on a brick and cement pier. This instrument is the property of the Royal Astronomical Society, and was lent for the purpose of the expedition. It had previously been used in India at the last eclipse.

This instrument gave a great deal of trouble at first. Fortunately Mr. Herbert Portch, Assistant Engineer, R.N., of H.M.S. "Theseus," who was working the smaller coronagraph with the spare light from my mirror, was a skilled mechanic, and after taking the clock and the driving gear to pieces several times, was at length able to get it fairly in order. During the 75 seconds of totality it fortunately was at its best.

Before this instrument can be used at another eclipse it will be necessary to repair or alter the present clamping arrangements in R.A.

The Exposures.

The time of totality at Santa Pola, as given by the "local particulars," was 79·4 seconds; but as the American eclipse measurement of the moon was followed, the estimated duration of totality was reduced to 75 seconds.

The times arranged by Sir Norman Lockyer for my instrument were as follows:—

1. At call of 70 expose till 60 = 10 seconds.
2. Snap = 1 second.
3. Expose as soon as possible after this snap until the call of five = 40 to 45 seconds.

I had five bluejackets to assist at the instrument, four being employed to hand and receive from me the plates and carriers and return them to their covers, the other man making the exposures from the object-glass end, by cutting off the light from the mirror by a piece of millboard.

Although we were able to carry out the programme without mistakes during the drills, at the eclipse the 10-seconds exposure of the first plate was accidentally reduced to 5. At the moment of totality the shouts and hand-clappings of 2000 spectators outside the ropes drowned for the moment the time signals, and the first count I heard was 65. I exposed at once, and at 60 the light was cut off by the bluejacket, as previously arranged. It was impossible at that moment to make him hear me, and I was afraid of confusing him in the other exposures, so it stood at that.

The snap and the long exposure were carried out as arranged. Two of the plates were developed at the eclipse camp by Mr. Fowler. The long exposure was also developed by him after our return to South Kensington.

Description of the Photographs.

No. 1 (Plate 2), an exposure of about 5 seconds, commencing 10 seconds after the beginning of totality.

The structure of the corona to a height of 5′ of arc shows much fine detail, and, speaking generally, it is lower at the poles. Several prominences are shown on the east limb, but the most conspicuous are two bright ones in the south-west quadrant, which were of sufficient height to extend above the moon's edge at this phase of the eclipse; the smaller prominences on the west were covered when the photograph was taken.

From the south to the east point the moon's limb is very jagged and rough, apparently caused by the chromospheric light being seen in the valleys of the Rook Mountains in the south, and the Cordilleras and D'Alemberts towards the east point, which have an elevation of from 4 to 5 miles. There is also a rough surface at about the position of the Hercynian range, north of the east point, but it is not so well marked as in the case of the southern ranges.

The chromosphere extending from a little north of east to slightly beyond the south pole has a well-defined serrated outer edge. This is much brighter than the adjacent corona.

No. 2. An instantaneous exposure at about 18 seconds after the commencement of totality.

The same remarks apply to this photograph. The corona is faintly visible, chiefly on the east and west limbs, where it extends only about 1·3 seconds of arc. The prominences differ from those in No. 1 in their great distinctness and in the slight variation produced by the change in the moon's position. The corona fades off very gradually from the limb and shows some detail.

No. 3 (Plate 3), an exposure of about 40 seconds, lasting until 5 seconds before the end of totality. This photograph is remarkable for the sharp outline of the moon, which must have moved nearly 18 seconds of arc (about $\frac{1}{70}$th of an inch on the negative) during the taking of the plate. This effect is probably due to the rapidly increasing brightness of the lower part of the inner corona, so that the parts of the corona last uncovered on the retreating side of the moon, and those first covered by the advancing side, are strongly impressed, notwithstanding their relatively short exposures.

The inner part of the corona is rather dense owing to the length of the exposure, but there is a good deal of detail in the higher parts, which can be well seen in the negative, but which can hardly be brought out in a reproduction. The prominences are clearly seen by making a small hole in a piece of black paper and placing it on the photograph, as suggested by Mr. Wesley when he examined these plates.

The corona extends about 16 minutes of arc on the eastern side, and to a rather less degree, about 12 minutes, on the western side of the sun's equator.

The Prominences.

The photographs show that at the time of the eclipse there were several prominences visible, the shorter exposure showing about twenty in all, most of them being small, and the whole of them being in the southern hemisphere.

The two most conspicuous in the south-west quadrant are shown in Professor Langley's photograph taken at Wadesboro, and a copy of both is given here for comparison (Plate 4). The interval between the taking of the two photographs would be about 2 hours, the time occupied by the moon's shadow in crossing the Atlantic. In this interval the prominences have altered somewhat; the dark central rift of the more northerly one has disappeared, and so has the spiky appearance of the rays. In this photograph it has become a broad flame like a prairie fire, the tips of the flame for the most part pointing towards the north.

This prominence appears from the report on the prismatic cameras to be composed chiefly of calcium, but it also shows on the hydrogen, helium, titanium, strontium, 4687 (unknown), asterium and magnesium (*b*) rings.

The other large prominence, somewhat to the south of the last, is shaped like a fleur-de-lys. In Professor Langley's photograph the three flames are nearly straight; but on this plate the two outside ones have bent over inwards towards the central flame, forming two loops.

This prominence is well defined in the calcium, less well in the hydrogen, and feebly in the helium rings.

The Corona.

The plates show none of the coronal rays, the longest being only about half the sun's diameter in extent. The polar rifts are somewhat sharply separated from the equatorial extensions, and are about 5 minutes of arc in height. The prominences are not situated in any relation to the rays, and appear indiscriminately under rays and rifts.

A comparison which has been made with Professor Langley's photograph shows that no change in the corona took place in the interval between the taking of the plates.

This is illustrated by the two photographs reproduced in Plate 5, showing the north polar rays in both cases.

Part IV.—The Prismatic Cameras.

By W. J. S. Lockyer, *M.A., Ph.D., and* A. Fowler.

Description of the Instruments.

The instrument employed by Dr. Lockyer was that employed in India by Mr. Fowler, the aperture being 6 inches, and focal length 7 feet 6 inches, and two prisms of 45° being fixed in front of the objective. A different series of exposures, however, was arranged, and unlike those made in India, each was made on a separate plate, so that proper treatment in developing could be given. The spare part of the mirror was utilised for a finder, as in India, with which observations of the cusps for giving signals before totality were also made.

The instrument employed by Mr. Fowler consisted of a 6-inch Taylor triple objective, of focal length 20 feet 3 inches, with the 9-inch prism of 45° belonging to the Solar Physics Observatory. The camera tube was a skeleton one, similar to that described in Mr. Payn's report. The lens and prism were provided with a substantial mounting of steel and brass, which rested on a brick pier, and the camera, of solid construction, was placed at the proper distance on another brick pier. Two plate holders were provided, each holding five plates of size 15 inches by 3 inches. The back of the camera was an extended one, so arranged as to protect all the plates except the one which was being exposed through an opening of the same size as the plate. The moon's disc as represented on the photographs is $2\frac{1}{4}$ inches in diameter, so that a small margin of the plate was available in case there should be a slight error in centering the spectrum. A finder was arranged to view the sun or stars by reflection from the first surface of the prism. It may be mentioned that in all the plate holders employed, the use of springs was discarded, the plates being held in position by india-rubber pads arranged to give even pressure on the edges. This change was considered desirable in consequence of certain slight departures from perfect focus in some parts of the spectra photographed in India, which were attributed to the bending of the plates by the central springs of the usual form.

The 20-foot lens was received so shortly before the expedition left England, that it was only possible to make a rough trial of the instrument before it was set up at Santa Pola.

Both prismatic cameras were worked in conjunction with siderostats, calculations having shown that the position angles of contact were favourably situated after reflection.

In the case of each instrument the necessary assistance was rendered by men from the "Theseus." One man made the exposures at the prism end at pre-arranged signals from Dr. Lockyer or Mr. Fowler at the camera end; another recorded the times at which the exposures were made, the beginnings being marked by the signals

to expose, and the ends by certain calls from the time-keeper at the eclipse clock. In each case also a bluejacket handed the dark slides as they were required, and another placed them in their bags when the exposures had been made.

In the case of each siderostat a spare portion of the mirror was used to reflect light into a camera with a transmission grating in front of the lens, these instruments being worked by bluejackets.

The instruments were roughly focussed in the first instance by observing the sharpness of the edges of the spectrum when the light of the sun was reflected into them, and afterwards by taking photographs of the spectrum of Arcturus. In the case of the 20-foot, considerable difficulty was experienced with the focussing, for the reason that the focus determined by a star did not hold good for the sun next day; this was especially noticed on the day of the eclipse, when it was further found that between early morning and eclipse time, the focal length, as judged by the sun's edge, was shortened by nearly 2 inches. The stellar focus was accordingly disregarded, and an attempt was made to obtain the focus by observing on the ground glass the Fraunhofer lines given by the disappearing crescent just before totality. It was then found that the range of adjustment was insufficient to allow perfect focussing, and there was no time to make the necessary alteration in the length of the tube. The photographs consequently lack the perfection of definition which had been hoped for, but they nevertheless give a good deal of information, as will appear later. The cause of the variation of focus has not yet been investigated, but it is recalled that in a general way the focus appears to have depended to some extent on the hour angle at which the siderostat mirror was used.

Table of Exposures.

It was intended that the exposures in both instruments should be as nearly as possible alike. The actual times in the case of the 20-foot prismatic camera were as follows:—

Number of plate.	Time of exposure.	Duration.	Remarks.
	hr. min. sec.		
1	4 12 36	Inst.	
2	4 12 38	,,	Totality commenced, 4h. 12m. 38s.
3	4 12 40	,,	
4	4 12 42	,,	
5	4 12 44 to 4 12 50	6 secs.	
6	4 12 58 to 4 13 30	32 ,,	
7	4 13 34 to 4 13 45	11 ,,	
8	4 13 47	Inst.	
9	4 13 49	,,	
10	4 13 51	,,	Totality ended, 4h. 13m. 53s.

EDWARDS' snap-shot Isochromatic plates were used throughout, and the expedition is greatly indebted to Messrs. EDWARDS for supplying special batches of plates on patent plate glass.

A few of the plates were developed at Santa Pola, and the remainder were developed at the Solar Physics Observatory, pyro-soda developer being used.

Description of Photographs. (*Plate* 6.)

The photographs indicate the same succession of phenomena recorded in the three previous eclipses, but the recent eclipse was specially advantageous, for the reason that the chromospheric arcs at the instant of contact were of greater length.

Taking the 20-foot series as typical of both, we find the following general appearances in the ten photographs :—

(1.) "Instantaneous" exposure 2 seconds before beginning of totality. Chromospheric arcs in great numbers, those corresponding with hydrogen, calcium (H and K), and helium being of great length; the whole crossed longitudinally by streaks of continuous spectrum from the uneclipsed photosphere. A number of small prominences are shown on the H and K arcs, and less strongly on the arcs due to hydrogen and helium. The arcs, like the continuous spectrum, are broken up by the irregularities of the moon's limb.

(2.) "Instantaneous" exposure, at (or just before) beginning of totality (Plate 6, A). Plate almost identical with No. 1, but with fewer streaks of continuous spectrum.

(3.) "Instantaneous" exposure 2 seconds after beginning of totality. Somewhat similar to No. 2, but without marked continuous spectrum from the photosphere. There is a general shortening of chromospheric arcs, more especially noticeable in those which are shortest in Nos. 1 and 2.

(4.) "Instantaneous" exposure 4 seconds after beginning of totality. Nothing now visible but a comparatively small number of arcs due to the upper chromosphere. Chief among these are H and K, Hβ, Hγ, &c., of the hydrogen series, D_3 and other arcs due to helium, and others due to strontium, iron, &c. Plate under-exposed.

(5.) Exposed from 6 to 12 seconds after beginning of totality. The increased exposure at this stage has had the effect of increasing the intensity of the chromospheric spectrum as compared with No. 4, the arcs now being nearly as numerous as in No. 3, but relatively less intense. A notable feature is the relative increase in the intensity of the lines of helium and the line 4687, to which reference was made in the report on the Indian eclipse.

Fragmentary rings due to the corona appear on this plate, their position-angles of maximum intensity being quite different from those of the chromosphere and prominences. The brightest ring is that in the green, λ 5303·7, but others are also distinctly seen.

(6.) From 20 to 52 seconds after beginning of totality. In this photograph the decided chromospheric arcs seen in No. 5 are replaced by fragmentary rings representing prominences and crests of the serrated parts of the chromosphere. H and K appear almost as complete rings, a little stronger on the eastern side. Several coronal rings, to which reference will be separately made later, are seen. The general continuous spectrum overlapping the chromospheric and coronal rings, on account of the long exposure, is rather strong in this photograph.

(7.) From 58 to 69 seconds after beginning of totality. The brighter chromospheric arcs now appear on the western side of the sun, together with the images of certain prominences, and parts of coronal rings, the whole being involved in continuous spectrum of moderate intensity.

(8.) "Instantaneous" exposure 6 seconds before end of totality. Only a few of the brighter chromospheric arcs, on the western side of the sun, and a few prominences are seen in this photograph. Plate under-exposed.

(9.) "Instantaneous" exposure, 4 seconds before end of totality. Very similar to No. 8, but more chromospheric arcs are visible.

(10.) "Instantaneous" exposure probably about 2 seconds before end of totality. The photograph is very similar to No. 2, but the arcs are on the opposite (western) side.

The spectra taken with the 20-foot prismatic camera are $10\frac{3}{4}$ inches long from Hα (which appears on some of the photographs) to the strong titanium line at 3685·34, and nearly $7\frac{1}{2}$ inches from D_3 to K. Those taken with the 6-inch 2-prism instrument have corresponding dimensions of about $8\frac{1}{2}$ inches and $5\frac{3}{4}$ inches respectively.

Photographs No. 2 (A), taken with the 20-foot prismatic camera, and Nos. 5, 6, and 7 (B, C and D), taken with the 2 prism instrument, are reproduced in Plate 6.

The photographs taken with the small objective gratings are very good, but show no features which are not seen in the larger photographs. They are chiefly of interest as showing what can be done with small and inexpensive instruments.

Part V.—Discussion of Results.

By Sir Norman Lockyer, *K.C.B., F.R.S.*

The Spectrum of the Chromosphere.

The spectrum of the chromosphere, as shown on the series of photographs taken with the prismatic cameras, greatly resembles that photographed in India in 1898.* It is, therefore, not considered necessary to discuss at present the wave-lengths, intensities, and origins of the chromospheric arcs.

* 'Phil. Trans.,' A, vol. 197, p. 151

In connection with the intensities it is important to note that the relative intensities are not the same at different stages of the eclipse. Thus in photographs Nos. 1 to 4, the helium line 4026·34 is very much less intense than the adjacent strontium line, 4077·89, while in photograph No. 5, which shows the spectrum of the chromosphere only, the two are of practically equal intensity. As both arcs are of the same length, this change indicates that while the strontium vapour extends down to the sun's limb, the helium exists only in an elevated shell concentric with the photosphere. A similar behaviour is noted in the lines of asterium; in numbers 1 to 4, for instance, the asterium line 4922·10 is only very slightly stronger than the adjacent barium line 4934·24, whereas in No. 5 the latter is scarcely visible, while 4922·10 is a well-marked arc.

The same feature is observed in other arcs due to asterium and helium, and also in the unknown line at wave-length 4687. Arcs due to other substances, however, gradually become shorter and less bright as the moon eclipses more and more of the chromosphere.

The Spectra of the Prominences.

The prominences photographed during the eclipse are few in number, and with two exceptions were of no considerable magnitude. For convenience of reference the accompanying diagram (fig. 7) has been prepared from photographs 5 and 7 of the 20-foot series, by painting out all parts except the images in K light, and the various prominences have been numbered as shown.

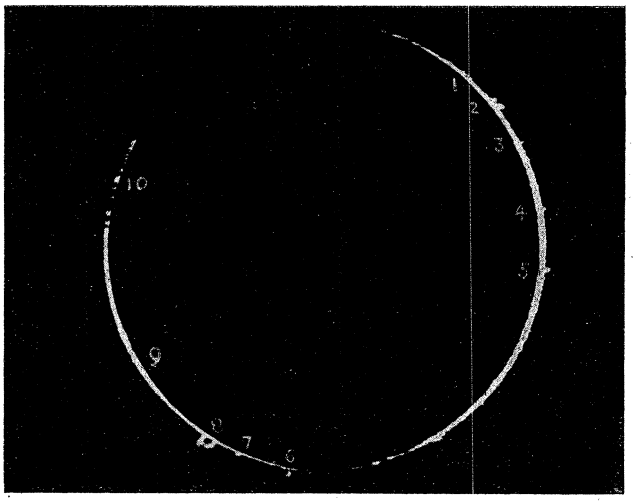


FIG. 7. The chromosphere and prominences in K light.

The prominences numbered 1, 2, 4, 6, 7, and 9 have spectra in which H and K are very bright, the chief lines of hydrogen less bright, and those of helium com-

paratively faint. The small prominence No. 10 and the long thin one No. 3 appear in H and K and the lower part of the latter is shown feebly in Hβ and Hγ. Those richest in bright lines are numbers 5 and 8, the spectra of which are indicated by the following table. The wave-lengths and probable origins are taken from the table of chromospheric lines which forms part of my report on the eclipse of 1898. In the column of origins the prefix *p* is an abbreviation for *proto*, indicating that an enhanced line in the spectrum of the substance in question agrees in position with the prominence line, enhanced lines being those which are intensified in passing from the arc to the spark spectrum.

SPECTRUM of Prominences Nos. 5 and 8.

Wave-length.	Photographic Intensity.	Probable Origin.	Remarks.
3685·34	1	*p* Ti	
3711·9	< 1	H	Hν
3721·8	1	H	Hμ
3734·15	1	H	Hλ
3750·2	2	H	Hκ
3759·45	3	*p* Ti	
3761·46	3	*p* Ti	
3770·7	2	H	Hι
3798·0	3	H	Hθ
3820·59	1	Fe	
3835·6	5	H	Hη
3860·06	1	Fe	
3889·15	8	H	Hζ
3900·68	1	*p* Ti	
3913·61	1	*p* Ti	
3933·83	10	*p* Ca	K
3968·63	10	*p* Ca	H
4026·34	4–5	He	
4045·98	< 1	Fe	
4077·89	4	Sr	
4102·00	8	H	Hδ (*h*)
4120·97	< 1	He	
4215·70	3	Sr	
4226·90	< 1	Ca	
4247·00	< 1	Sc	
4340·63	8	H	Hγ (G)
4395·20	< 1	*p* Ti	
4471·65	5	He	
4687·0	< 1	—	
4713·25	1	He	
4861·53	8	H	Hβ (F)
4922·10	< 1	Ast	
5015·73	< 1	Ast	
5183·79	1	Mg	b_1
5875·87	6	He	D_3
6563·05	2	H	Hα (C)

A comparison with the chromospheric arcs indicates that the spectrum of the

prominences consists of the radiations which are brightest in the spectrum of the chromosphere.

Heights of Chromospheric Vapours.

Measurements of the lengths of the arcs photographed at the commencement of totality have been made in order to determine the heights above the photosphere to which the corresponding vapours are visible. The results obtained from measurements of photograph No. 2 of the 20-foot series are shown in the following table, in which the corresponding results obtained in 1898* are introduced for purposes of comparison.

HEIGHTS of Chromospheric Vapours.

Lines.	Heights in Seconds of Arc.		Heights in Miles.	
	1900.	1898.	1900.	1898.
	″	″		
Proto-calcium (K)	13·0	13·3	5900	6000
Hydrogen	8·9	10·0	4000	4500
Helium (4471·65)	8·7	8·9	3900	4000
Strontium (4077·89)	6·7	6·0	3000	2700
Strontium (4215·70), Helium (4026·34)	5·8	6·0	2600	2700
Calcium (4226·90)	4·1	4·4	1850	2000
Titanium (3761·46)	3·6	—	1600	—
Scandium (4247·00), Mg ultra-violet triplet (3832·45)	3·4	4·4	1500	2000
Ti enhanced lines (4572·16, &c.)	3·3	—	1500	—
Fe triplet (4045·98, &c.), Al (3944·16, 3961·67), $b_{1,3}$ (Mg) (5183·79, &c.)	2·6	3·2	1180	1450
Mn quartet (4030·92, &c.), Fe enhanced (4233·25, 4584·02)	2·4	2·4	1090	1100
Majority of other arc lines	1·6	—	700	—
Carbon fluting 3883·55 and many other lines	0·6	1·05	270	475

As I pointed out in connection with the eclipse of 1898, these results do not necessarily give the actual heights reached by the various vapours, as only the brightest lower portions of the chromospheric arcs may be registered on the photographs. That the heights given in the table do not represent the upper limits of the respective vapours is indicated by measures which have been made of photograph No. 5, which had an exposure of 6 seconds; some of the arcs in this photograph are as long or longer than the corresponding ones in Nos. 1–4. Notwithstanding the less favourable position of the moon, correcting for the moon's motion, the measured arcs in photograph No. 5, reduced to miles, are as follows :—

* 'Roy. Soc. Proc.,' vol. 64, p. 37.

Proto-calcium (K)	7800 miles.
Hydrogen	7000 ,,
Helium, 4471·65	5800 ,,
,, 4026·34	5000 ,,
Strontium, 4077·89	4800 ,,
,, 4215·70	3800 ,,

The Spectrum of the Corona.

Coronal rings are shown on photographs 5, 6, and 7.

The green ring at 5303·7 is the brightest, but that at 3987·0 is also very distinct and more continuous than the green ring. The rings generally appear to be less bright than in 1898, and many of the fainter rings recorded in 1898* have not been detected on the 1900 series of photographs. The following table shows the wave-lengths of the rings which have been noted, with general remarks indicating the distribution of intensity in them.

TABLE of Coronal Radiations.

Wave-length.	Average Intensity. Max. = 10.	Remarks.
3800	2	Brightest from W. to N.W.
3987·0	5	A nearly continuous ring a little brighter in west than elsewhere.
4231·3	3	Brightest in west and south-west, very similar to chief ring 5303.
4359·5	3	Brightest from S. to N.E.
4568·5	3	Very similar to 3987·0 in distribution of intensity.
5303·7	10	Brightest between west and south-west.

The above correspond with the principal rings recorded in 1898. Others are suspected, but they are too indistinct for satisfactory measurement; one of them, not previously recorded, is near λ 5537.

The dissimilarity of form of the rings indicates that they have probably not all the same chemical origin, as I have previously pointed out,† three different substances probably being in question.

Besides the bright rings, the spectrum of the corona shows a considerable amount of continuous spectrum. This is brightest in the parts corresponding to the inner corona generally, as indicated by its being broken up into bands by the elevations and depressions of the moon's limb, but it also has places of maximum brightness agreeing in position with the brighter parts of the green coronal ring. In the eclipse of 1898 the feature last mentioned was also noted, and the opinion was expressed

* 'Roy. Soc. Proc.,' vol. 66, p. 191.

† 'Roy. Soc. Proc.,' vol. 66, p. 191.

that the action which produced a brightening of the green ring also produces a brightening of the continuous spectrum, not only in the region where the gaseous mass is rendered more luminous, but in the region immediately overlying it. It is only in the large-scale photographs of 1900 that the effects of lunar irregularities have been directly traced, and it is possible that some of the brighter parts of the continuous spectrum in the 1898 series attributed to concealed elevations of the green ring should be ascribed to these irregularities.

A detailed examination of the photographs has further shown that some of the brighter streaks of continuous spectrum correspond with polar rays of the corona, more particularly with those extending outwards in a direction nearly coincident with the plane of dispersion.

Comparison of the Green Coronal Ring with the Inner and Outer Corona.

The general results as to the distribution of intensity in the coronal rings are the same as those arrived at from the photographs of 1898, namely :—

(1.) The positions of greatest brightness of the coronal rings have apparently no connection with the positions of the prominences.

(2.) The brightest parts of the green ring correspond very closely with the brightest parts of the inner corona, but are apparently independent of the outer corona. This distribution, however, is less marked than in 1898, when distinct prominence-like masses in the inner corona, corresponding to the brightest parts of the green ring, were photographed. Some of the bright parts of the inner corona in the north-east quadrant appear to be unrepresented on the green ring only because of their unfavourable situation with reference to the plane of dispersion.

These results are illustrated in the accompanying diagram (fig. 8).

The Differences between the Coronas observed at the Periods of Sun-spot Maxima and Minima.

My attention was called especially to these differences, because I saw the minimum eclipse of 1878, while the phenomena of that of 1871 (maximum) were still quite fresh in my mind. My then published statements have been amply confirmed during the eclipses which have happened since 1878, but certainly the strongest confirmation has been obtained during the present one, which took place two more spot periods after 1878.

(1.) *Form.*—With regard to form, at the instant of totality I saw the 1878 corona over again, the wind-vane appearance being as then most striking.

This is also the appearance presented by the drawings made by some of the "Theseus" observers and reproduced in Part II. of this report; and also by the photographs obtained with the various coronagraphs.

Great equatorial extensions corresponding with those observed by NEWCOMB, in 1878, were not seen by any of the observers, either with or without the aid of discs.

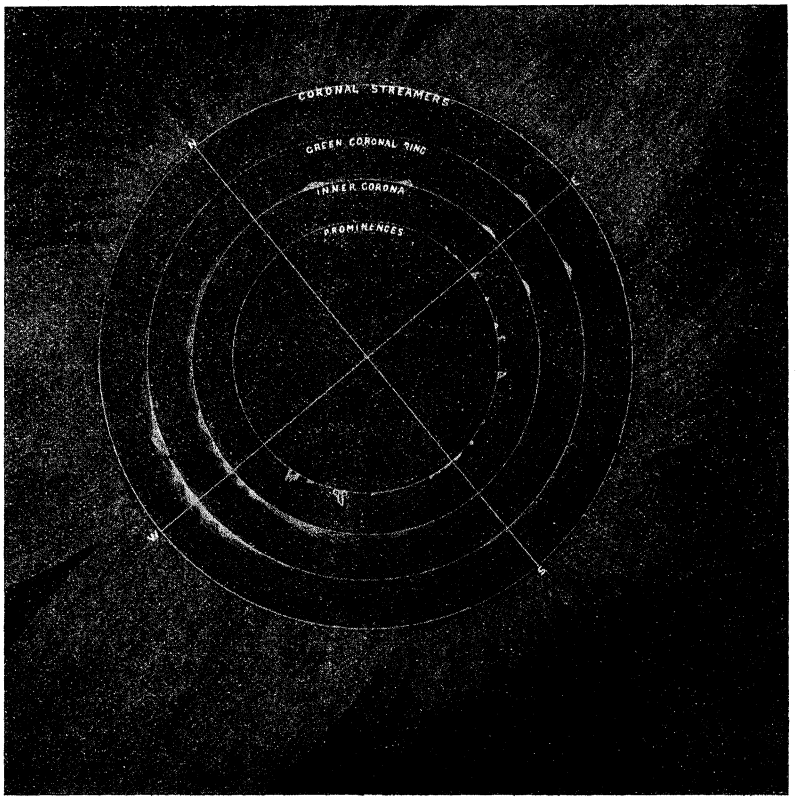


FIG. 8. The green coronal ring compared with prominences and inner and outer corona.

The atmospheric conditions at the time of eclipse were excellent, and it may be therefore that the feature observed by NEWCOMB, in 1878, was exceptional.

(2.) *The Spectrum.*—In connection with the eclipse of 1878 (minimum), I pointed out that, whereas in 1871 (maximum) the spectrum of the corona viewed by small dispersion was remarkable for the brightness of the lines, in 1878 they were practically absent, and the continuous spectrum was remarkably brilliant.

I determined therefore to make a similar observation in this year of minimum, and, as in 1878, used a grating-first-order spectrum placed near the eye. The result was identical with that recorded in 1878. I saw no obvious rings or arcs, but chiefly a bright continuous spectrum.

The photographs taken with the prismatic cameras, as already pointed out, confirm this view that the bright rings are feebler near a time of minimum. The green ring was observed visually by Mr. PAYN with a powerful direct-vision spectroscope deprived of its collimator, and by Mr. FOWLER with a prismatic opera-glass.

The latter remarked that the green ring was decidedly dimmer than in 1898, when it was observed by him with the same instrument.

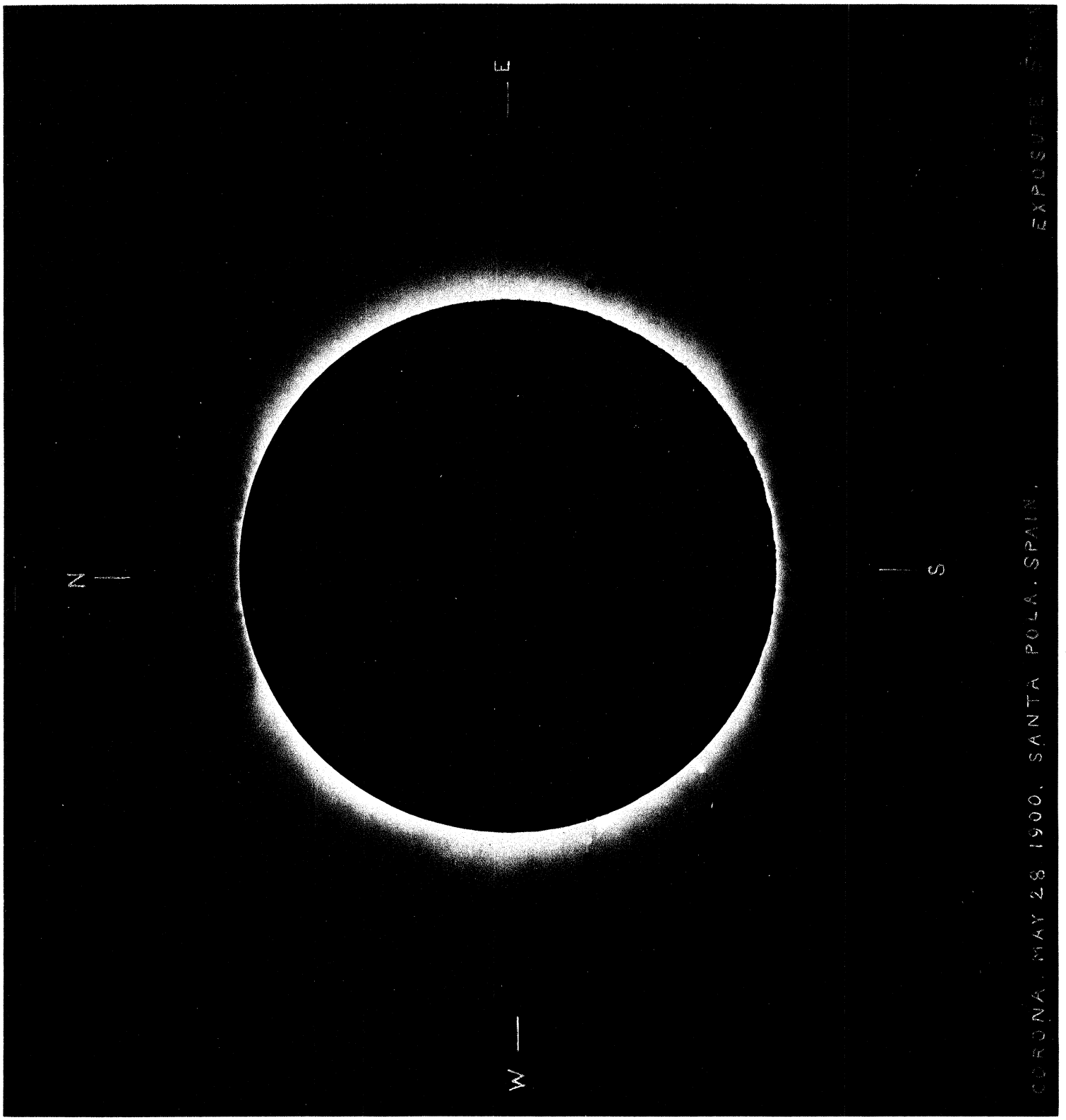
(3.) *The Minute Structure of the Inner Corona.*—Lieutenant DOUGHTY, R.N., and myself made observations on the minute structure of the corona, in order to see if any small details could be observed, and whether they were the same I saw so well and recorded during the eclipse of 1871, at a period of sun-spot maximum. This question was specially taken up this year, as exactly two sun-spot periods have elapsed since 1878.

In 1871 I used a 6-inch object-glass, and distinctly observed marked delicate thread-like filaments, reminding one of the structure of the prominences, with mottling and nebulous indications here and there; some of these distinct markings were obvious enough to be seen till some minutes after totality.*

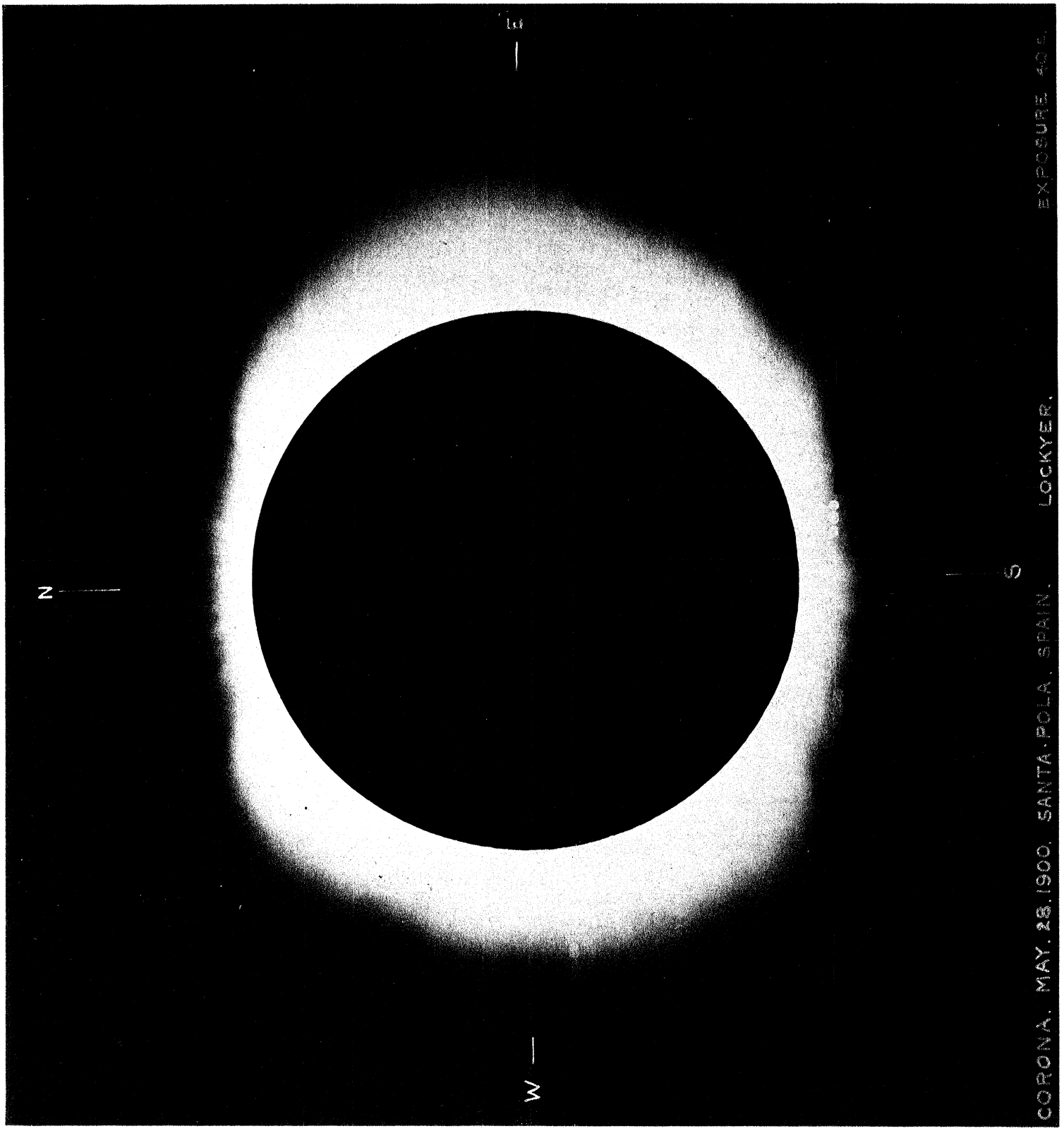
This year, with a perfect 4-inch Taylor lens and a higher power, not the slightest appearance of this structure could be traced; the corona some 2′ or 3′ above the chromosphere was absolutely without any detailed markings whatever.

Lieutenant DOUGHTY duplicated and confirmed these observations with a $3\frac{3}{4}$-inch Cooke. Here, then, is established another well-marked difference between maximum and minimum coronas.

* 'Solar Physics,' p. 372.



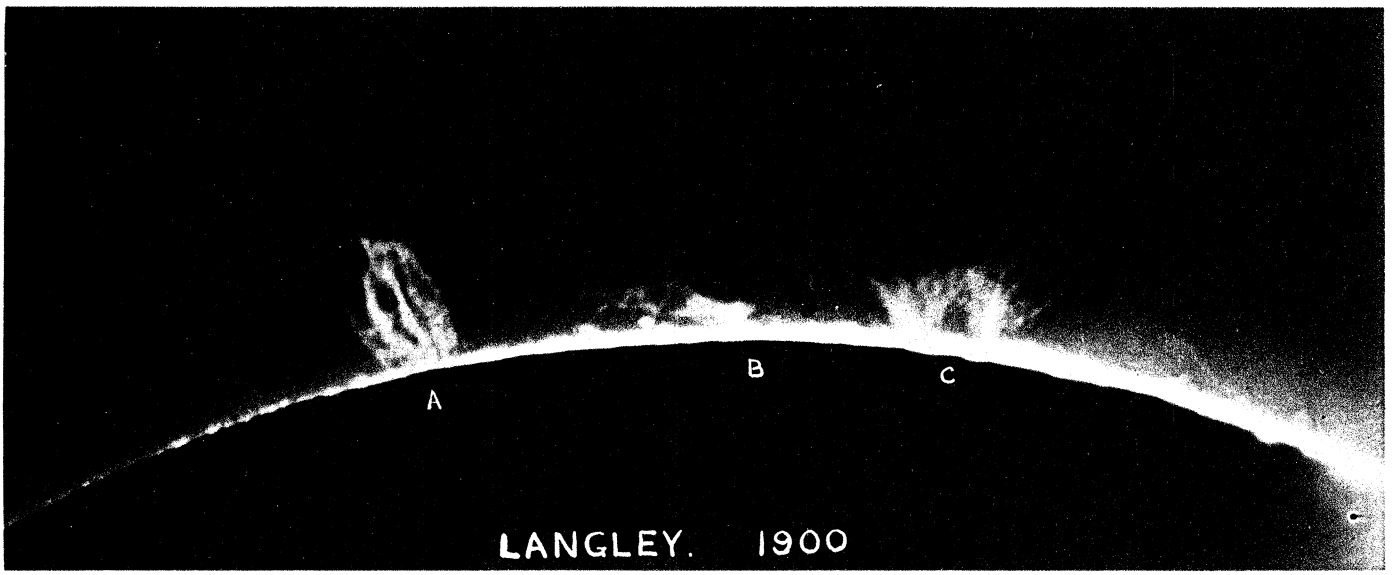
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

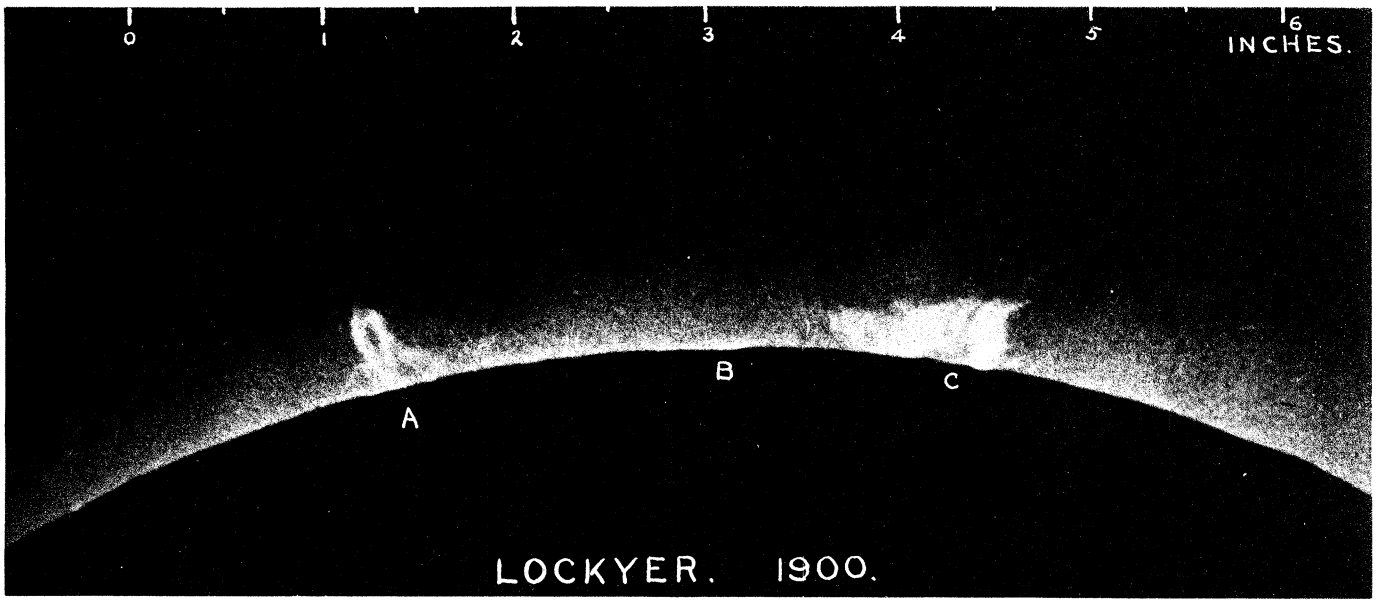


PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

TOTAL SOLAR ECLIPSE.

MAY 28, 1900.



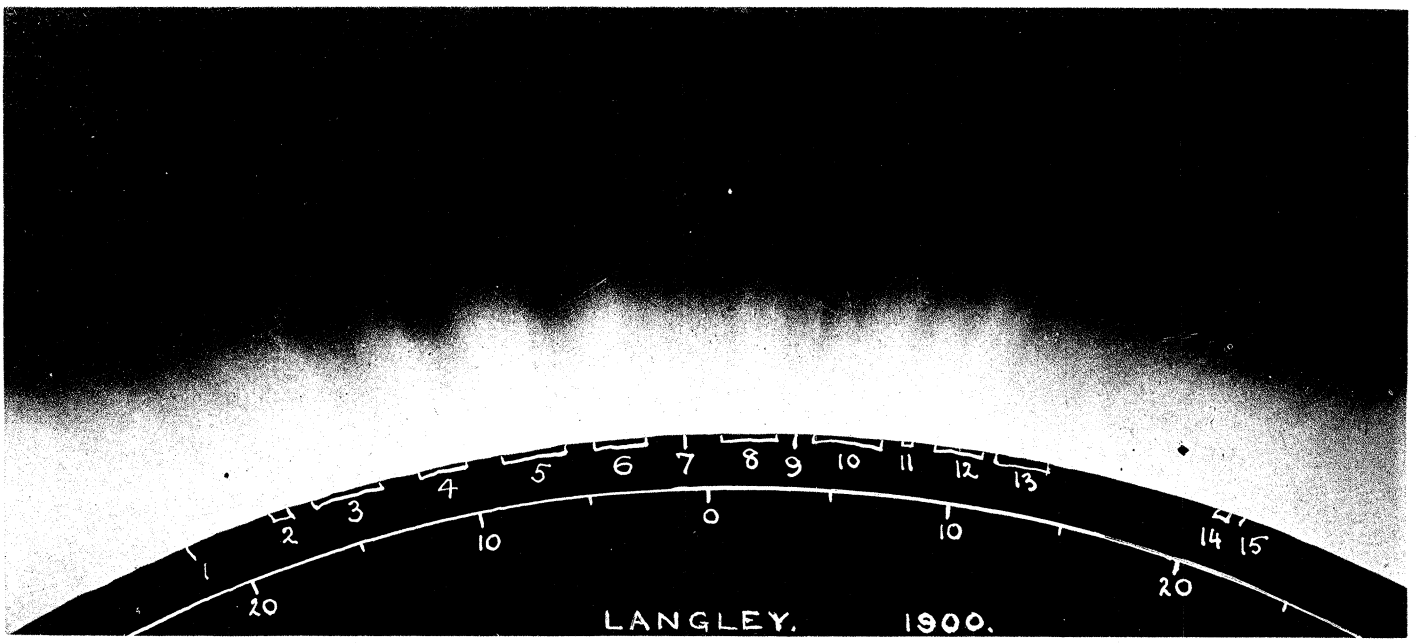


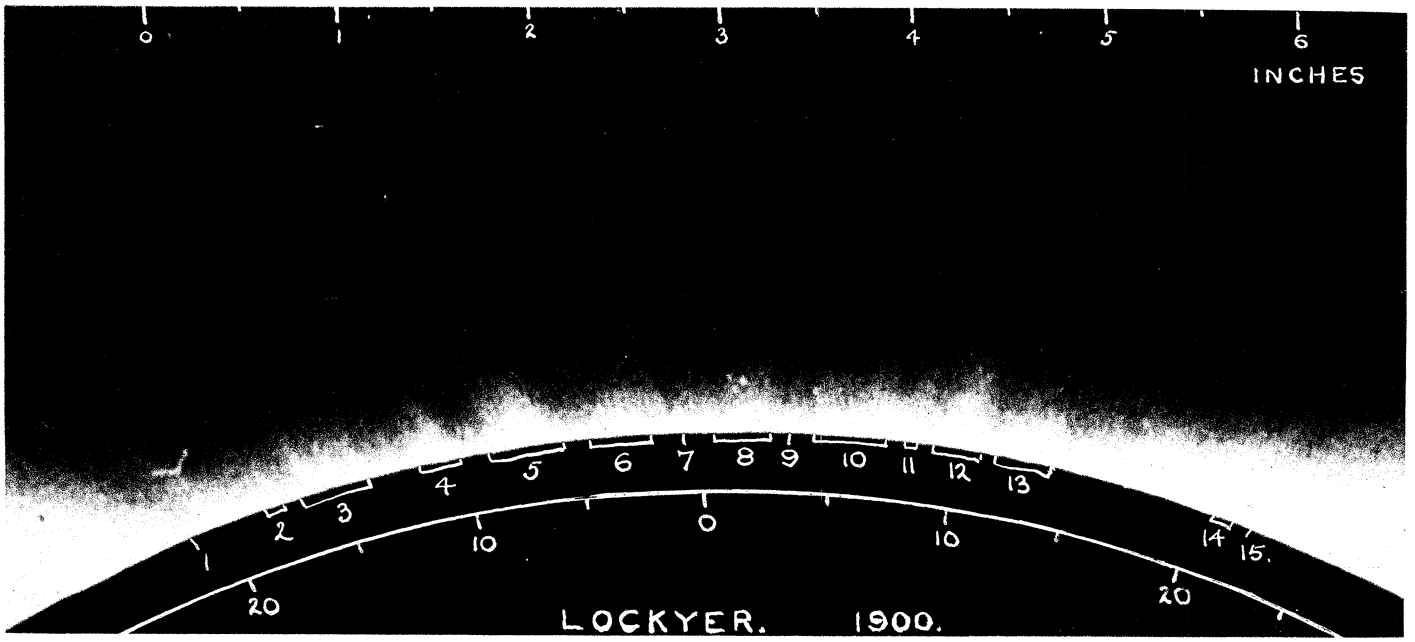
PROMINENCES AT S.W. LIMB.

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

TOTAL SOLAR ECLIPSE.

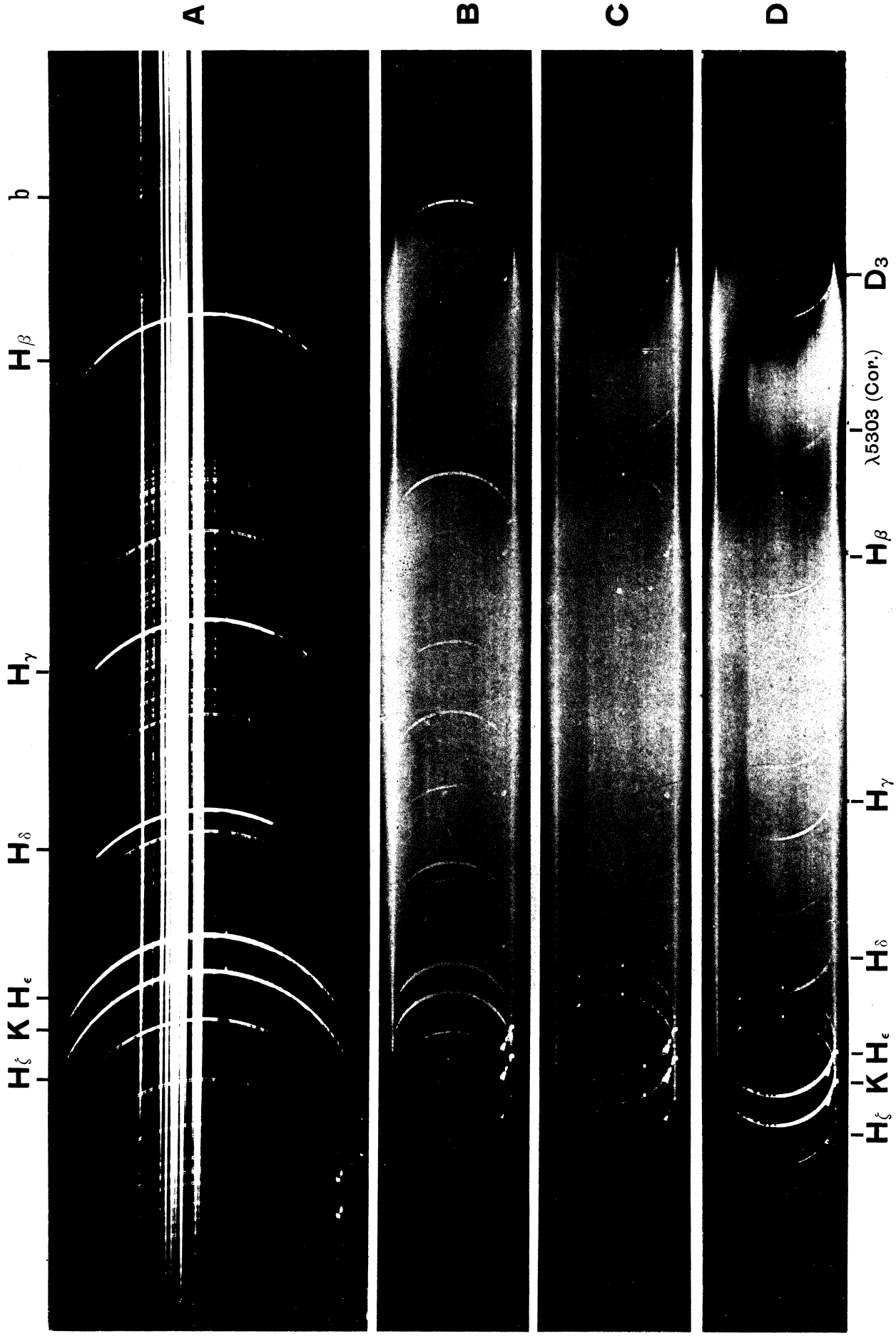
MAY 28, 1900.





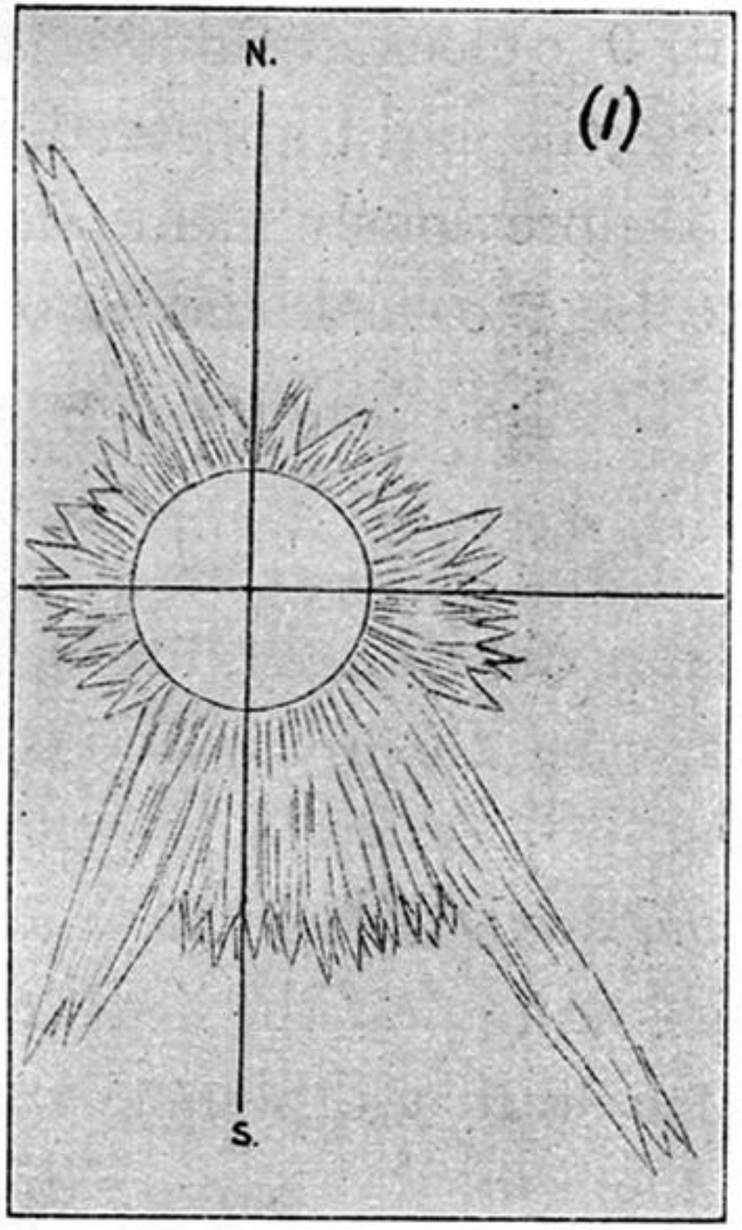
NORTH POLAR REGION.

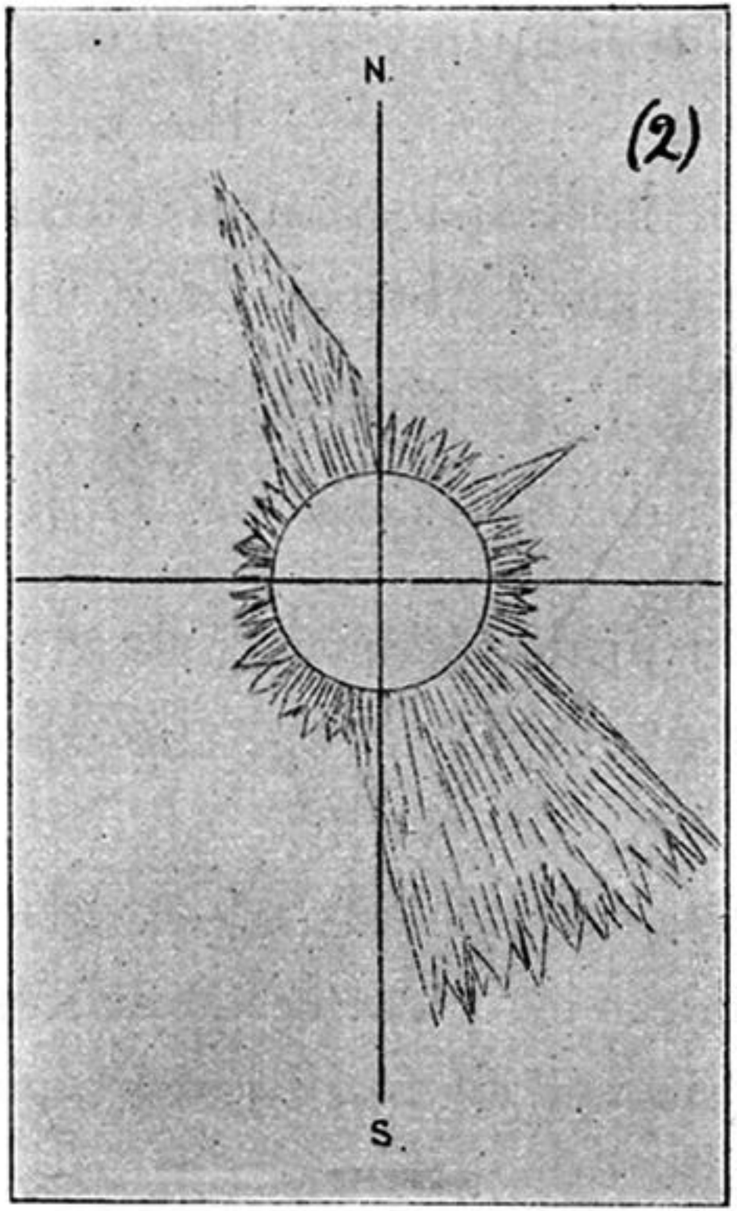
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

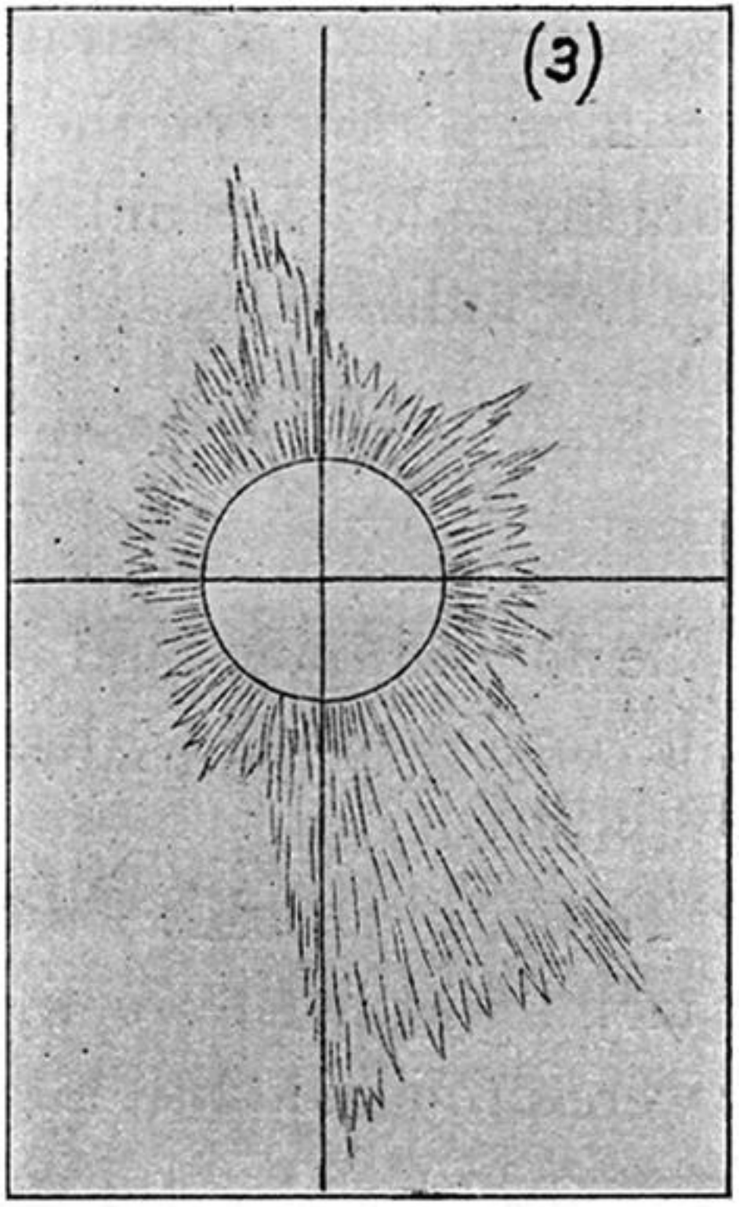


A.—20 foot prismatic camera, near beginning of totality. B. C. D.—7 foot 6 in. prismatic camera, near beginning, middle and end of totality respectively.

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







ig. 3. Sketches of Corona. (1) With discs covering 3 minutes round Sun's limb; (2) with discs covering 6 minutes; (3) without discs.

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

Direction.		Sky.			Clouds.			Land.			Sea.			Observer.
		Before totality.	During totality.	After totality.	Before totality.	During totality.	After totality.	Before totality.	During totality.	After totality.	Before totality.	During totality.	After totality.	
N.E.	On ship.	Light blue, softened off to the horizon.	Indigo, with a dull coloured zone near horizon.	Light blue, softened off to the horizon.	Nil.	Nil.	Nil.	Distant hills grey, showing colour in patches.	Very dark grey.	Distant mountains grey with purple, and very distinct.	Light slate colour.	Dark slate, with green tinge.	Light indigo.	Fleet Paymaster A. W. Aspham, R.N. Staff Engineer, F. T. George, R.N. Lieutenant, W. J. Fraser, R.N.
	On shore.	Blue	...	...	Nil.	...	...	As usual, or copy getting darker brown as totality approaches.	...	...	Nil.	...	...	Captain Whitmarsh, R.M.L.I.
		3.43 P.M., blue; 4 P.M., pinkish on horizon; 4.12 P.M., slate colour.	As at day break.	Slate colour.	Nil.	Nil.	...	Same as on an ordinary clear day.	Dark brown, and hill blue.	Normal.	Nil.	Nil.	Nil.	G. Burnett, Writer.
S.E.	On ship.	Light blue, softened away to the horizon, slight tinge of warm colour near horizon.	Indigo, with a crab colour on the lower portion.	Light blue, softening away to a warm tinge.	Nil.	Nil.	Nil.	Nil.	...	...	Slate colour.	Very dark slate colour, greenish tinge in foreground.	Indigo green tinge in distance.	Fleet Paymaster A. W. Aspham, R.N. Staff Engineer F. T. George, R.N. Lieutenant W. J. Fraser, R.N.
	On shore.	Yellowish pink hue on horizon, and blue overhead.	...	...	Nil.	...	...	Nil.	...	...	Dark blue, and getting still darker blue near totality.	...	...	Captain Whitmarsh, R.M.L.I.
		3.41 P.M., light blue; 3.45, yellow streaks appeared on horizon; 3.55, changed into pink.	Horizon from pink to yellow.	Slate colour.	4.3 P.M., slight horizontal streaks of clouds appeared on horizon.	Nil.	Nil.	Same as on an ordinary clear day.	Dark brown.	Light brown.	3.41, blue. Yellow shadow coming across from S.; 3.57, sea very blue; 4.10, horizon like early dawn.	Dark blue to light blue.	Light blue.	Lance-Corporal Ware, R.M.L.I.
S.W.	On ship.	Light blue, softened away to the horizon, slight tinge of warm colour near horizon.	Indigo, slight crab colour on lower portion.	Light blue, softened away to a warm tinge.	Nil.	Nil.	Nil.	Nil.	Mountains dark purple, looking greyish in distance, and foreground very dark grey.	Mountains purple grey. Foreground similar colours, but darker.	Slate colour.	Dark blue (indigo), with a green tinge.	Blue, with touches of indigo and cobalt green.	Lieutenant W. J. Fraser, R.N. Fleet Paymaster A. W. Aspham, R.N. Staff Engineer F. T. George, R.N.
	On shore.	Yellow shadow extending across from W. to S.	...	...	Horizontal grey streaks over the hills S. of W.	...	...	Normal, with grey haze creeping over.	...	...	Yellow shadow extending from S. to W.	...	...	Captain Whitmarsh, R.M.L.I.
		Horizon light grey, shading off to blue overhead.	As at day-break.	Blue.	Nil.	Nil.	Nil.	Hill in the distance W.S.W. almost obscured. Brownish hue.	Dark fawn. Hills blue.	Normal, as would usually appear after a shower.	Horizon S., yellow shade; 4.10 P.M., dark blue.	Dark blue.	Blue.	Dennis Gibbs, Ship's Steward.
N.W.	On ship.	Light greenish blue.	Indigo, with a faint red tinge on lower portion.	Very light blue.	Slight streaks of cloud near horizon.	Nil.	Nil.	Distant hills hazy grey.	Distant hills grey, foreground darker grey.	Distant hills purple, foreground normal colour.	Blue, with a slight green tinge.	Indigo, with a green tinge.	Light slate blue tinged with green.	Lieutenant W. J. Fraser, R.N. Fleet Paymaster A. W. Aspham, R.N. Staff Engineer F. T. George, R.N.
	On shore.	Blue overhead, distance grey, similar to early dawn.	Very dark blue overhead, and like day breaking over the hills.	Not so blue as during totality; over the hills, light grey.	Horizontal grey grey streaks over the hills.	Nil.	Nil.	Greyish blue haze creeping over the hills.	Hills slate colour, foreground dark brown.	Hills brown, foreground various colours.	Nil.	Nil.	Nil.	Captain Whitmarsh, R.M.L.I.

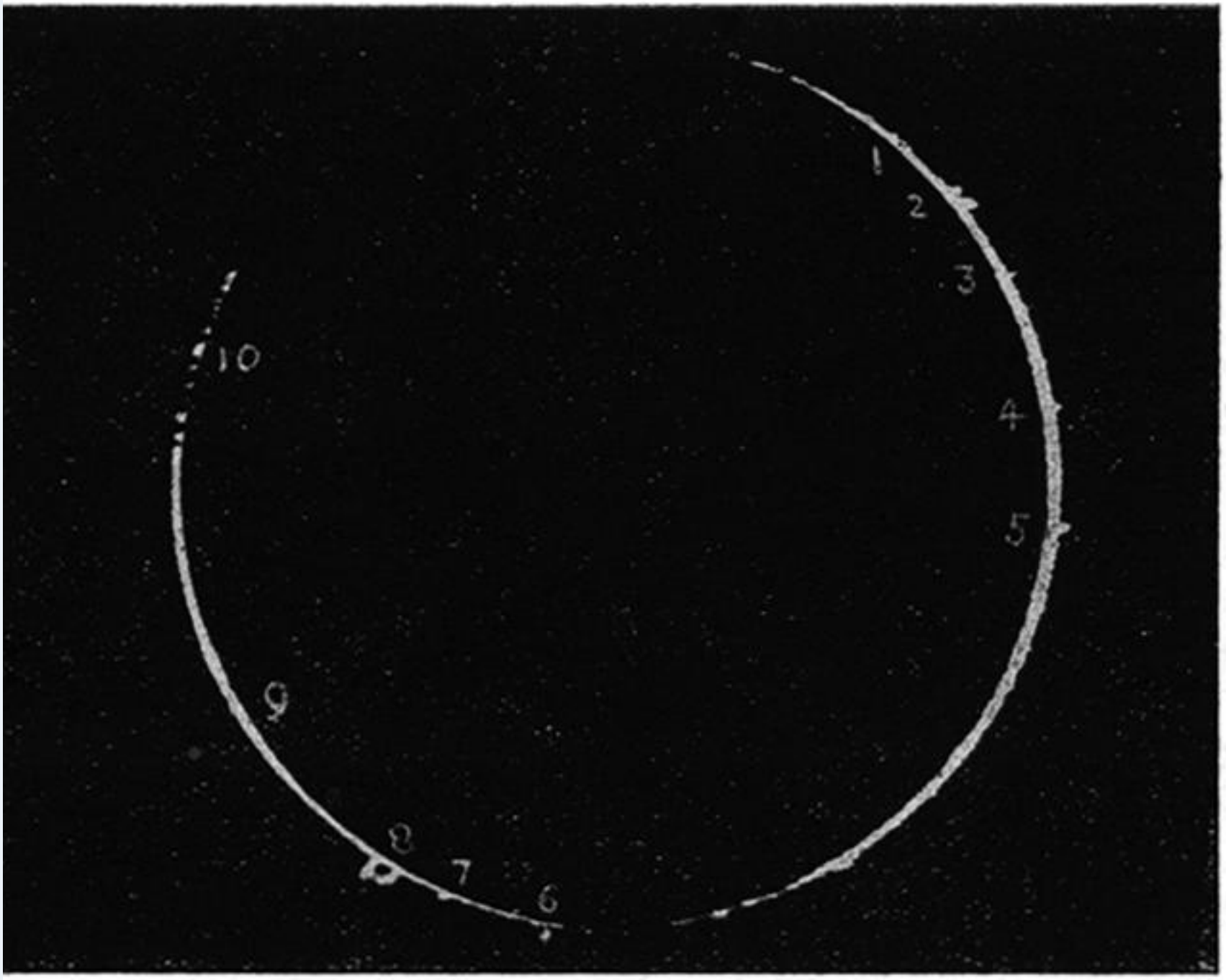
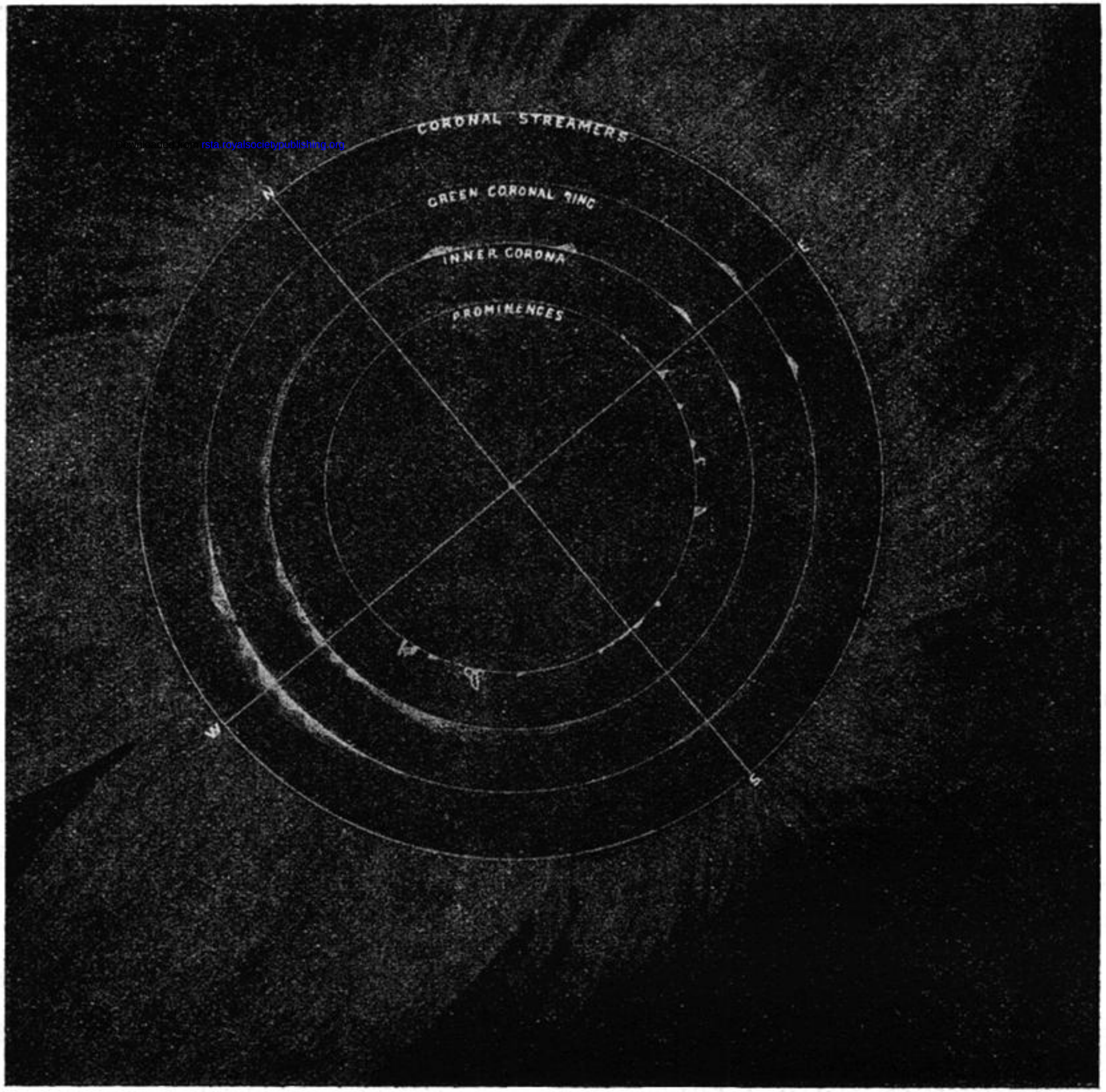
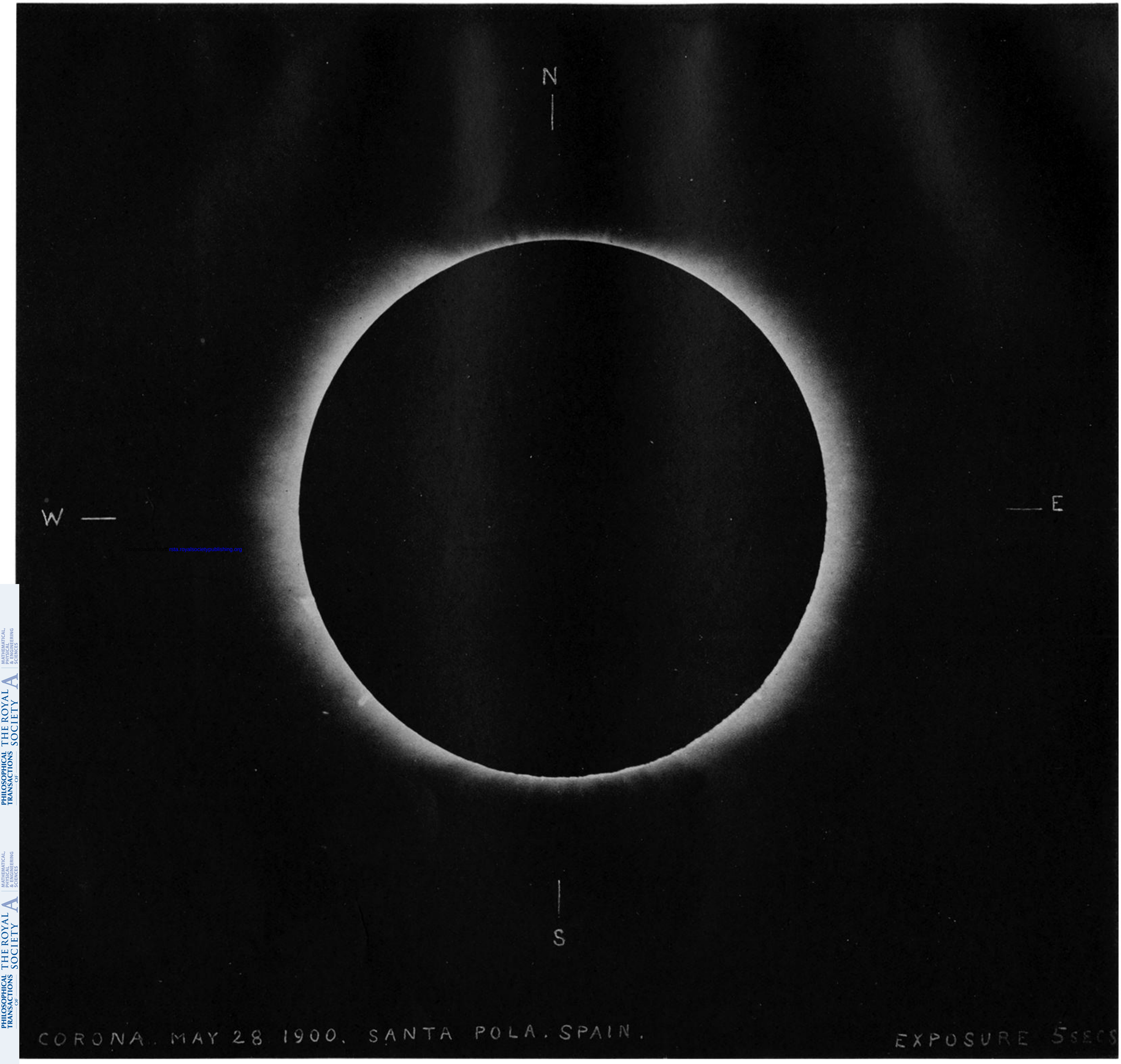


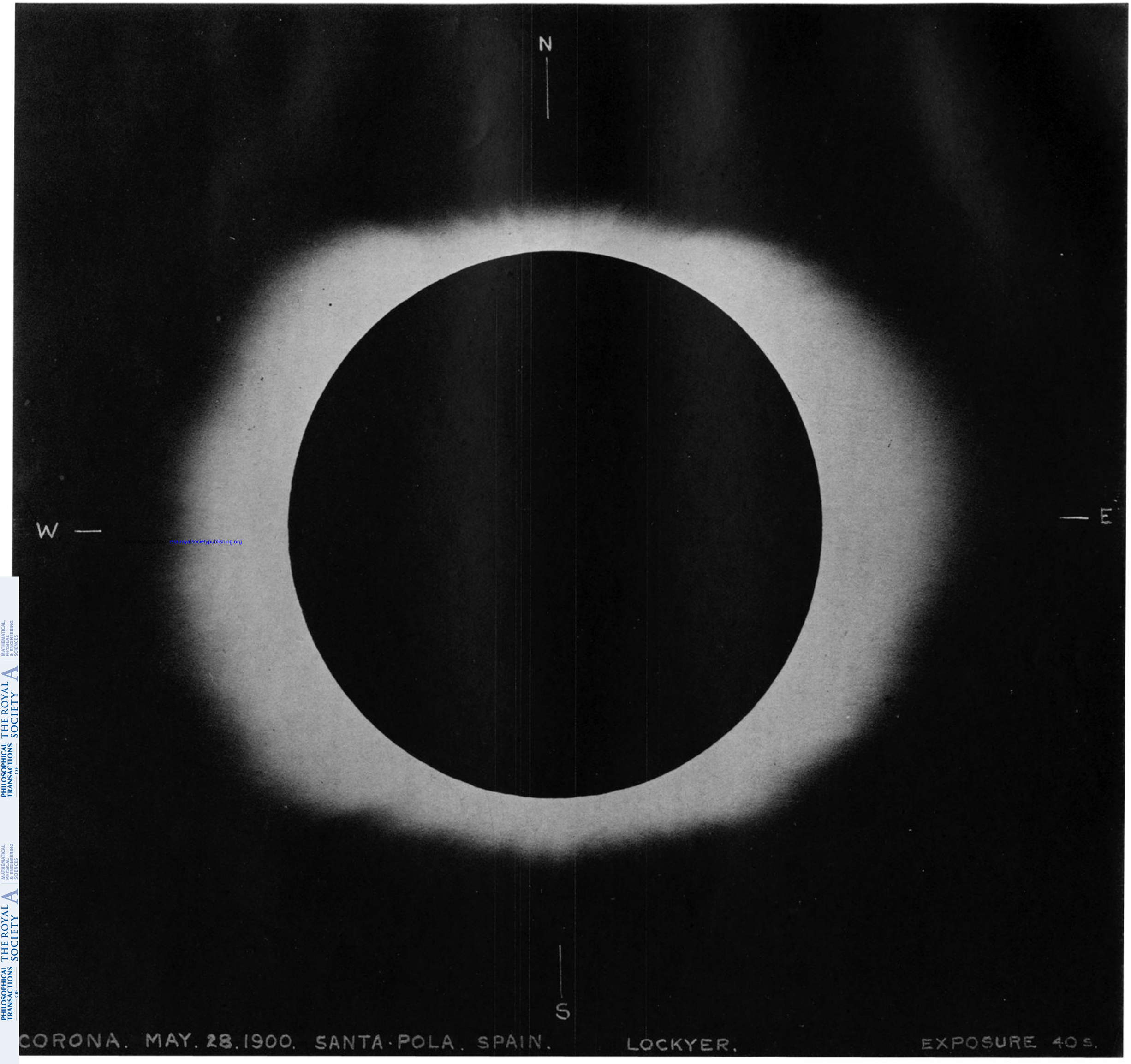
FIG. 7. The chromosphere and prominences in K light.



IG. 8. The green coronal ring compared with prominences and inner and outer corona.

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

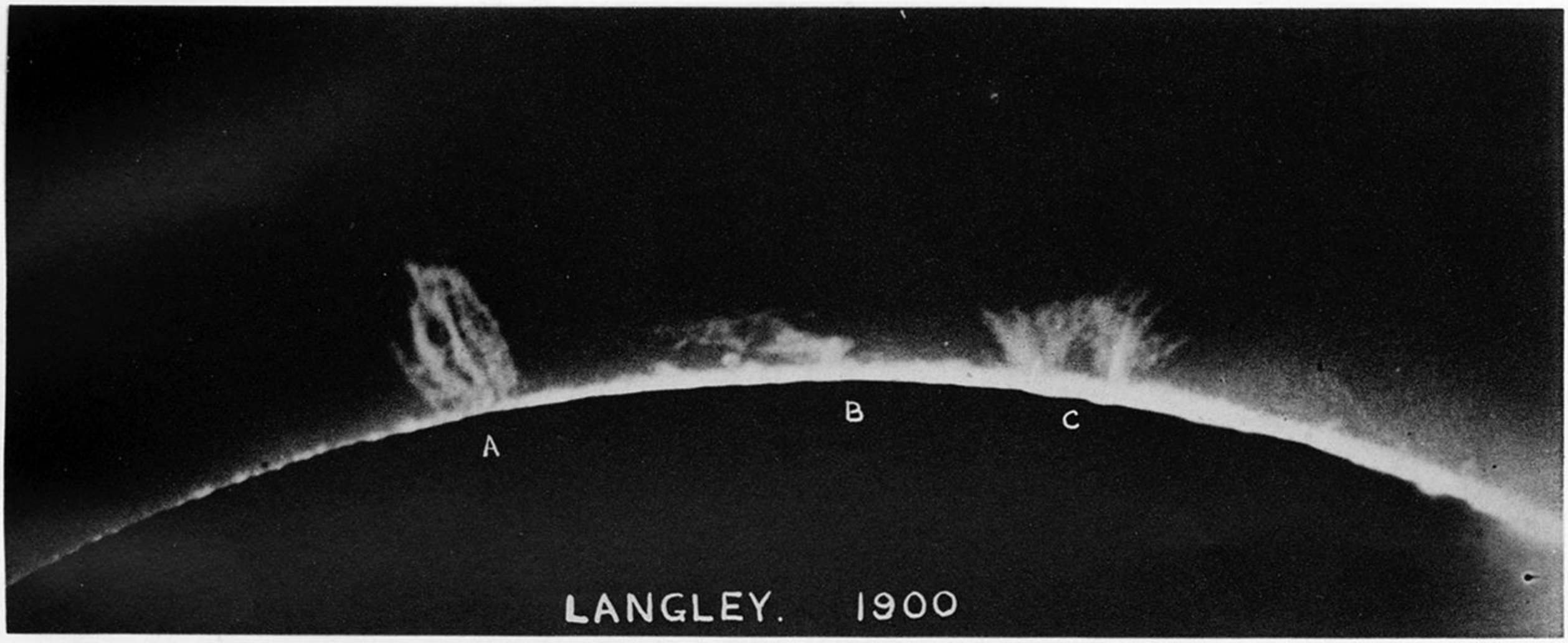


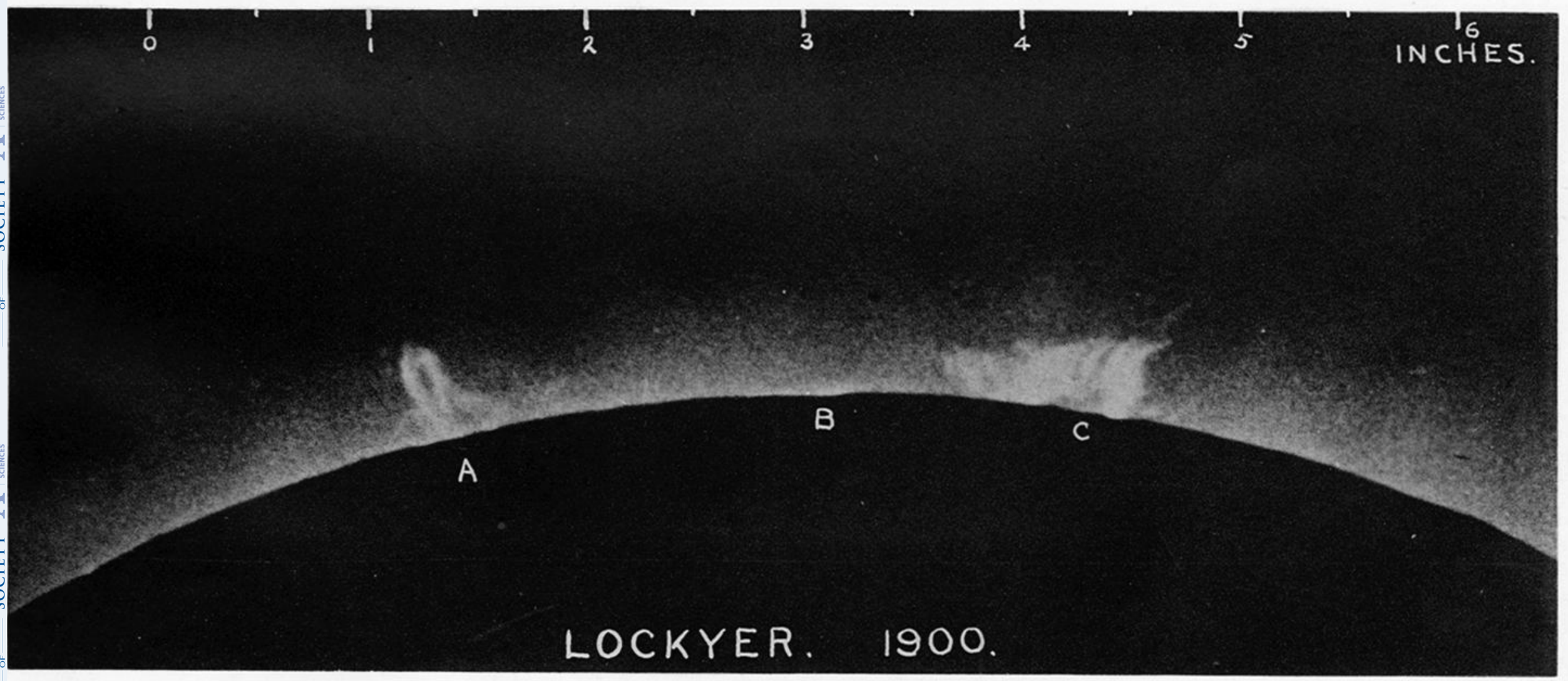


PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

TOTAL SOLAR ECLIPSE.

MAY 28, 1900.

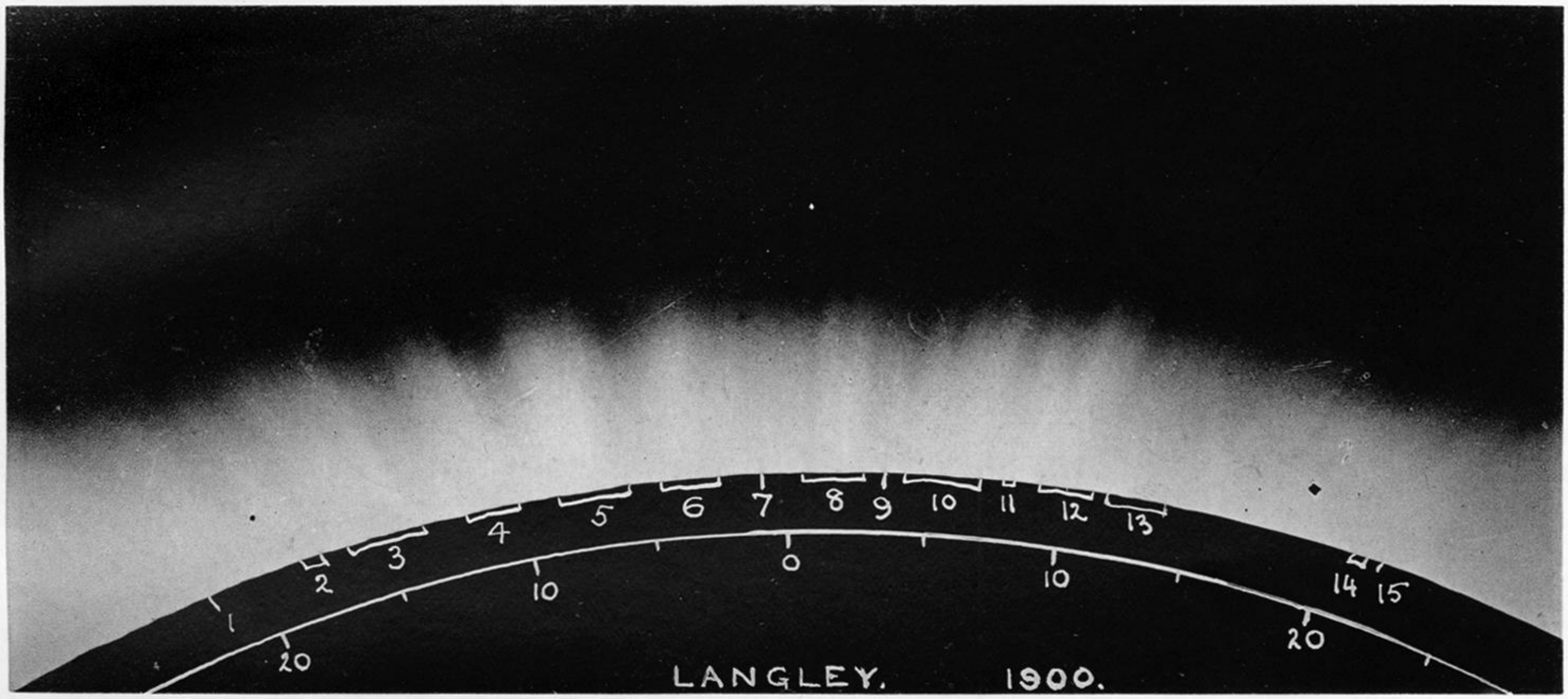




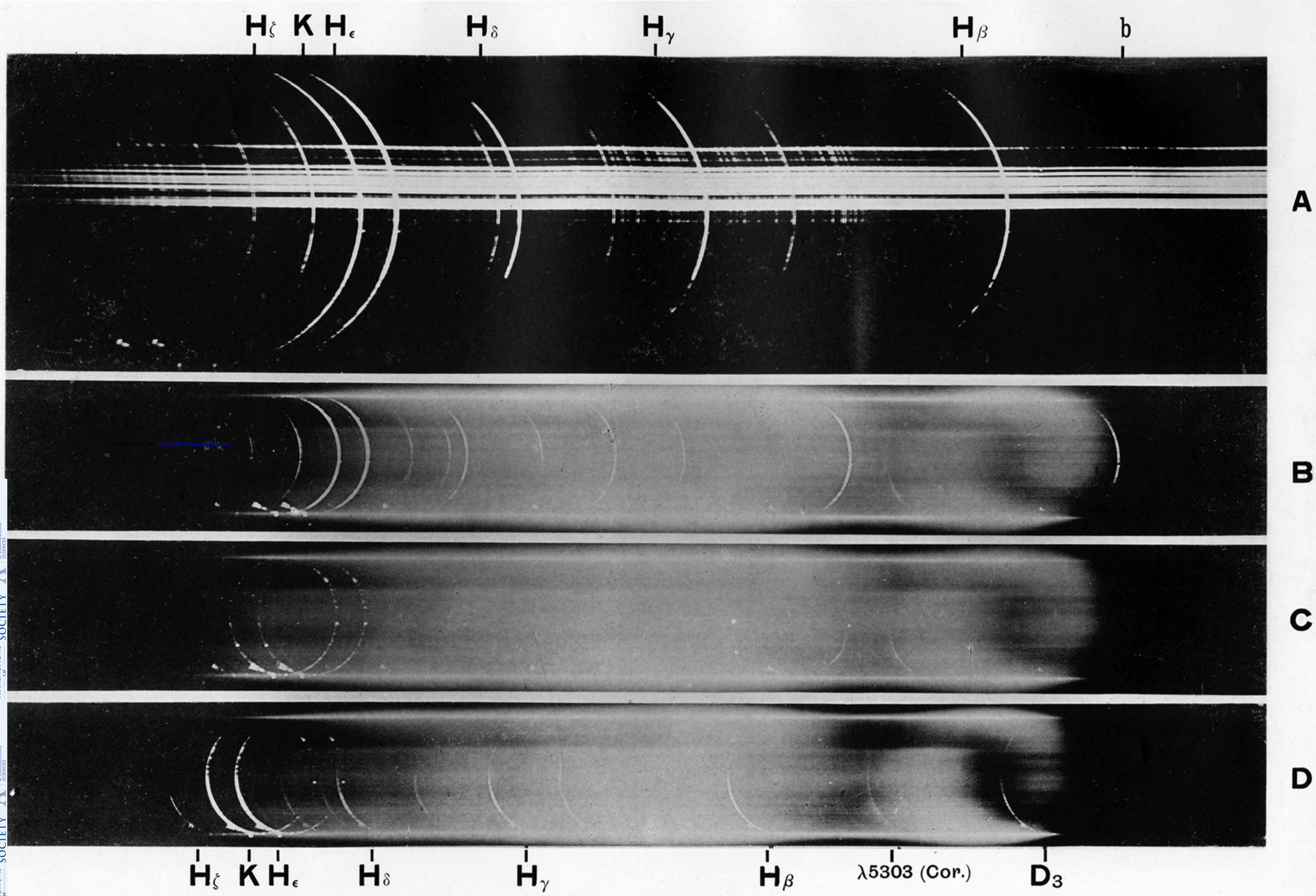
PROMINENCES AT S.W. LIMB.

TOTAL SOLAR ECLIPSE.

MAY 28, 1900.



NORTH POLAR REGION.



A.—20 foot prismatic camera, near beginning of totality. B. C. D.—7 foot 6 in. prismatic camera, near beginning, middle and end of totality respectively.