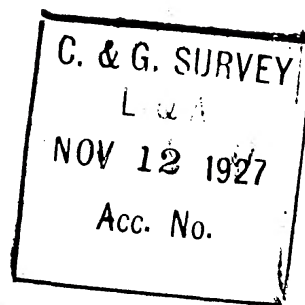




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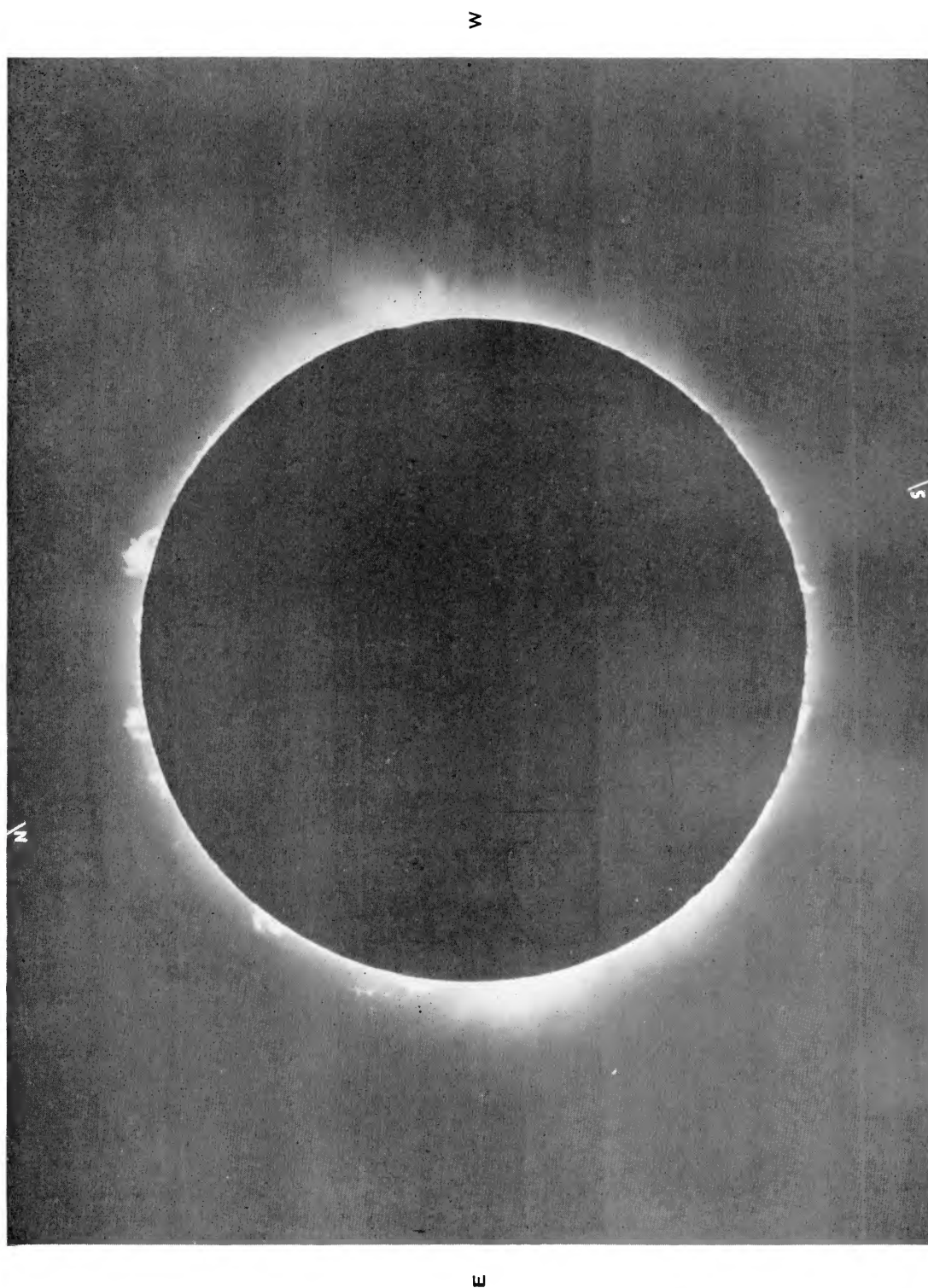
No. 9

Report of the Expeditions from the Royal Observatory, Greenwich, to observe the Total Solar Eclipse of 1927 June 29. (Plates 8-12.)

(Communicated by the Astronomer Royal.)

1. A site in the neighbourhood of Settle was considered desirable as being near the central line, easy of access for large instruments, and where accommodation could be readily found for the observers. The exact position was determined by the offer of the Governors and Headmaster of Giggleswick School to place a field near the school chapel at the service of the Astronomer Royal. From this point the hills to the east rise to a height of 4° to 6° . Though this might be to some extent a drawback, the practical gain of having a place where the instruments would be safe and the observers free from interruption and within easy reach of an hotel in Settle more than compensated for this slight disadvantage.

The programme of observations included a large-scale photograph of the corona, observations of the extreme-red end of the chromospheric spectrum, and a comparison of the intensities of the calcium lines in the infra-red with those at H and K. An addition to the programme was made by the offer of the Editor of the *Daily Mail* to place an aeroplane at the disposal of the Astronomer Royal. This practically ensured that a photograph would be obtained giving the general form of the corona in the event of clouds covering the whole zone of totality at the time of the eclipse. A further addition to the observatory programme was made by the offer of the Hydrographer of the Navy to find accommodation for observers on the survey ship H.M.S. *Fitzroy*, which was engaged at the time of the eclipse in the North Sea near the zone of totality. This added another chance in the event of cloudy weather.



Solar Corona photographed at Giggleswick. Exp. 19^s. Royal Observatory, Greenwich.
The letters N and S refer to the Sun's axis.

2. The instruments taken to Giggleswick were—

(a) A 6-inch lens of 45-feet focus, made by Alvan Clark and kindly lent by Mr. J. H. Worthington. This was mounted horizontally in a long tube of steel lattice-work, covered with black cloth and Willesden canvas. It was fed by an 8-inch cœlostæt belonging to the Royal Irish Academy. The plates employed were Ilford Special Rapid of 15×12 inches.

(b) A spectroscope of small dispersion for direct comparison of the intensity of the ionized calcium lines in the infra-red with those at H and K. This was of a reflecting Littrow type. The light, after passing the slit, was directed by a diagonal reflector on to a $6\frac{1}{2}$ -inch concave mirror of 38-inch focus. From here it was sent back as a parallel beam to a 30° prism silvered on the back. This, after refraction and reflection, returned it to the mirror from whence it was reflected to focus on the photographic plate at a point just above and beyond the prism. Good definition was secured from $\lambda 3900$ to $\lambda 8600$.

The sun's image was formed on the slit plate by a 9-inch concave speculum mirror of 10-feet focus, which was filled with light from a 16-inch cœlostæt.

The complete optical train thus consisted of three disconnected parts—the cœlostæt, the image-forming mirror, and the spectroscope—which must be brought into simultaneous adjustment. As their relationship is changing with the varying declination of the sun, under the weather conditions prevailing this adjustment proved most difficult.

By means of a coarse wire grating which could be slipped in front of the prism, an intensity scale was placed on the plate by exposures on the solar spectrum, made just before and just after totality.

Specially prepared infra-red sensitive plates were used, but although on experimental plates before and after the eclipse $\lambda 9000$ was reached without difficulty, yet the plate exposed during the eclipse proved insensitive beyond $\lambda 8000$. Consequently the observation failed in its purpose.

(c) A spectroscope of greater dispersion for more detailed examination of the chromospheric spectrum in the extreme red. This also was of Littrow type. The prism was of 40° angle and 7 inches height, whilst the collimating lens was of $7\frac{1}{2}$ inches aperture and $11\frac{1}{2}$ feet focal length.

As with the small spectroscope, the image on the slit plate was formed by a 9-inch concave speculum mirror, kindly lent by Sir John Herschel, filled from a 12-inch cœlostæt. On experimental photographs excellent definition was obtained from $\lambda 5000$ to $\lambda 8000$, but owing to the unfavourable conditions obtaining at the time of the eclipse no results of value were obtained with this instrument.

The instruments were all set up at Greenwich a few weeks before the eclipse.

3. The observers were Dr. Jackson, Mr. Davidson, Mr. Melotte, and Mr. Woodman. They saw the instruments duly dispatched on an Admiralty lorry on June 13. Mr. Davidson and Mr. Woodman left the following day, and arrived at Giggleswick in time to choose the positions for the various instruments and developing hut. Dr. Jackson

and Mr. Melotte followed the next day, and reached Giggleswick about the same time as the lorry with the instruments. Mr. Greaves and Mr. Horrocks joined them on June 17 in order to give assistance and gain experience. The lorry was unloaded on June 16, and with the help of Mr. Brassington, a local contractor, whose services were engaged, the instruments were carried into the field in small loads and got under cover. The instruments were erected under difficult conditions owing to rain and wind. Still more difficult was the adjustment, as there were few occasions on which the sun was visible for many minutes consecutively. At the hour of the eclipse the sun was visible in a clear sky on June 15. For 13 consecutive days clouds obscured the sun at this time.

The 45-foot telescope was focussed visually by an autocollimating method. A plane mirror—the mirror from its own cœlostæt—was set just in front of the objective and normal to the optical axis of the lens. By observing, through cobalt glass, the reflected image of a lamp placed near the focal plane the focus could be determined with great certainty.

The focus of the spectroscopes was determined by photographing the calcium spark obtained with a coil and storage batteries which had been taken for the comparison spectra. The final focussing adjustments were made on the night of June 28.

The party was joined at Giggleswick by M. Maxime de Saussure, for whom a 3-inch telescope, fitted with a direct-vision prism placed before the object-glass, had been provided. He proposed to observe the times of beginning and end of totality by disappearance and re-appearance of the absorption lines of the chromosphere.

At their request, representatives of four cinematograph firms were permitted to take stations in the field assigned to the observatory party, viz. Gaumont, Pathé Frères, Topical Budget, and British Polychromide Ltd. (a colour process). We were very pleased to give these facilities in view of the educational value of the films. An object-glass was lent to Pathé Frères to give a large-scale image, and a second mirror, kindly lent by Captain Ainslie, was mounted on the cœlostæt supplying the 45-foot telescope. The use of the cœlostæt mirror was suggested as it admitted of greater stability for the cinema apparatus, but there was too little time before totality to get this mirror into adjustment, so the photographs were taken directly.

4. On the evening of June 28 the weather showed some signs of improvement. Mr. Davidson and Mr. Melotte went to the field after dinner on that day and stayed there the night, bathing plates and filling plate carriers, and verifying some of the adjustments of the spectroscopes. They were joined in the early morning by the Astronomer Royal, Dr. Jackson, Mr. Woodman, and Mr. Horrocks. At this hour people were gradually collecting in the neighbourhood. The field assigned to us was guarded by the School O.T.C. and a few policemen, and none was allowed in except those to whom passes signed by the Astronomer Royal and the Superintendent of Police had been given. These included, besides the official party, several parties of amateur astronomers, cinematograph operators, press representatives, and photographers. There were a few breaks in the clouds, but it was

not till about 10 minutes before totality that the sun was more than momentarily visible. Mr. Horrocks with a chronometer, whose error had been determined from the B.B.C. signals, called out from the calculated times 10^m, 5^m, 2^m, 1^m, 50^s, 40^s, 30^s, 20^s, 10^s before totality. Mr. Davidson gave the word "Go" as the crescent broke into beads, and Mr. Horrocks took up the counting of seconds, and the plates of the several instruments were duly exposed.

The rapidity with which the crescent disappeared and the brightness of the corona were generally noted. Red prominences particularly near the vertex of the sun were visible to the naked eye. The duration of totality was generally estimated at 23^s, though no precise observation was attempted.

The time of second contact was observed, and for comparison with the computed time Col. Jack, Director-General of the Ordnance Survey Office, Southampton, has kindly communicated the position of the site at Giggleswick as follows :—

Latitude	.	.	.	54°	4′.2	N.
Longitude	.	.	.	2°	17′.7	W.
Altitude	.	.	.			570 feet.

The sun was at an altitude of 12°.1 in azimuth 23°.2 N. of E., so that the shadow reached the camp at the same time as it reached sea-level in

Latitude	.	.	.	54°	4′.0	N.
Longitude	.	.	.	2°	18′.4	W.

This position is only about 0.2 of a mile north-west from the central line as given by Dr. Comrie in *M.N.* **87**, 496. From Dr. Comrie's data the computed time of mid-totality was 5^h 24^m 28^s.9 G.M.T., so that if we take the duration of totality as 23^s.4, the computed beginning was 5^h 24^m 17^s.2. When Mr. Davidson said "Go" the chronometer showed 5^h 25^m 0^s. The correction to the chronometer was -44^s.5, so that this corresponded to 5^h 24^m 15^s.5 G.M.T. The Astronomer Royal with the chronometer before him noted that the beginning of totality was at 5^h 25^m 0^s. This agreed with Mr. Davidson's "Go," which he estimated might be as much as 0^s.5 early. The Astronomer Royal's observation, therefore, indicates that the eclipse commenced 1^s.7 early and Mr. Davidson's 1^s.2 early. The photograph of the corona was taken from 5^h 24^m 17^s to 5^h 24^m 36^s.5 G.M.T. It is clear that the eclipse took place at least one second before the computed time. M. de Saussure, as seen from the following paragraph, made the eclipse begin 1^s.1 early, so that the mean may be taken as 1^s.3 early.

M. de Saussure's report is as follows :—

"I observed the eclipse with the Greenwich party, in the chapel field at Giggleswick, and used a 3-inch refractor kindly put at my disposal by the Royal Observatory; in front of the object-glass a direct-vision prism was mounted. I had to observe inner contacts by means of the flash spectrum (with Nardin stop watches to be compared with the chronometer). The observations were made in the green part of the

spectrum. I saw the first reversal, from the dark to bright lines, at $5^h 24^m 16^s.1$ G.M.T., which must be the time of second contact. The time of third contact could not be determined, because the lines showed the interesting feature of remaining bright several seconds after totality.

"During totality I looked at the corona with a field-glass and noted its type as nearly corresponding to maximum of sunspots, with an outline showing several projections finishing in points."

No meteorological observations were made by the Greenwich party. As the eclipse occurred in the early morning when temperature would normally be rising there was nothing sufficiently large to notice without a thermometer. The darkness during totality was just sufficient to necessitate the use of a flash-light in reading the chronometer.

Among the minor observations the visibility of the corona before and after totality may be noted. Dr. Jackson with the naked eye saw it extending along 90° of the limb opposite to the crescent 25^s before the total phase without having specially looked for it.

The photograph of the corona was developed on the spot by Mr. Melotte, and at ten o'clock was photographed by a representative of the *Evening News*. It was taken to London by aeroplane and appeared in the *Evening News* the same day, and in several of the London morning papers on June 30. A number of photographs on a small scale were taken by amateur observers and by the press photographers. Among these are excellent ones by Dr. Waterfield and by Mr. Warhurst of the *Times* photographic staff. These show the type of the corona and its extensions. By the courtesy of the Editor of the *Times* the latter is reproduced in this paper (Plate 11).*

5. *Aeroplane Observations.*—With the object of ensuring some observations of the corona in the event of cloudy weather, the *Daily Mail* placed an Imperial Airways twin-engined, fourteen-seater aeroplane at the disposal of the Astronomer Royal, and Mr. Greaves and Mr. Witchell, together with Mr. F. J. Hargreaves, formed the observing party. Two cameras were installed in the machine; one being a Ross portrait lens of 16 inches focus, working at $F/4.5$, and the other an Aldis lens of 20 inches focus, working at $F/5.6$. The latter camera was kindly lent by Dr. G. Merton. Mr. Witchell was in charge of the Ross camera, which was mounted on the roof of the machine and manipulated from the passenger saloon through an emergency safety-hatch, the cover of which had been removed. The Aldis lens was manipulated by Mr. Greaves and was mounted on a table installed in the saloon and operated through one of the windows, the glass pane of which had been removed. These arrangements were decided on as the result of a trial flight and were effected in the shops of Messrs. Imperial Airways, Limited, at Croydon Aerodrome. Shock-absorbing material was used to deaden as far as possible the vibration due to the engines.

The machine with the observers and two *Daily Mail* representatives left Croydon on the evening of June 28, under the pilotage of Captain F. L. Barnard, and proceeded to Catterick Aerodrome. The eclipse flight commenced at 4.20 a.m. (Greenwich Mean Time) on June 29.

* Dr. Waterfield's photographs are reproduced on Plate 16.

Captain Barnard flew to Hartlepool, and, having from this flight obtained his allowance for wind-drift, climbed above the clouds and flew by dead reckoning south-west along the eclipse track. The altitude at the time of totality was 11,700 feet.

Mr. Witchell secured an exposure on the corona at $1/50$ th second, and Mr. Greaves one at $1/30$ th second. These are reproduced (Plate 11). The first has "trailed" slightly and shows the general form of the inner corona very well. The second, although badly shaken, shows an extended corona up to over a diameter from the limb. The plates used were hypersensitized panchromatics, with a speed of about H and D 1300, prepared by Mr. Thorne-Baker of the Imperial Dry Plate Co. They had been obtained from Mr. Thorne-Baker by Mr. Hargreaves. Mr. Witchell also obtained an exposure at $1/15$ th second, using a backed Ilford Special Rapid plate. This is not reproduced but clearly shows eight or nine prominences. Mr. Hargreaves had planned to photograph the shadow on the ground, but was frustrated by clouds which extended up to over 10,000 feet. He obtained, however, a photograph showing the near cloud clear of the approaching shadow and distant clouds in it, and clear sky on the far side of the shadow.

There was a large amount of cirrus cloud about at a high altitude, but Captain Barnard by skilful navigation placed the aeroplane at the time of totality in such a position that the view of the sun was unobscured.

The two photographs reproduced have been studied carefully by Mr. Hargreaves, who has made a drawing from them. This is also reproduced (Plate 12).

It appears very probable that, as a result of the experience gained, better photographs could be obtained on a future occasion. It would seem that a suitable type of camera to use would be one of about 20 inches focus, working at about $F/3$, and using exposures of $1/100$ th second or even less on hypersensitized plates.

Any success that has been achieved is largely due to the splendid piloting of Captain Barnard, and the assistance received during the preparations from the staff of Messrs. Imperial Airways, Ltd.

6. *Observations in North Sea.*—Rear-Admiral H. P. Douglas, C.M.G., Hydrographer of the Navy, having found it possible for observers to be accommodated on one of H.M. surveying ships operating in the North Sea, Messrs. Edney and Chamberlain proceeded on board H.M.S. *Fitzroy*, commanded by Commander J. R. Harvey, O.B.E., R.N. They were accompanied by Lieut.-Comdr. C. P. Christie, R.N.

Their equipment consisted of two cameras, one fitted with the 6-inch Franklin-Adams lens of 27 inches focus; and the other with an Aldis lens of 20 inches focus, working at $F/5.6$, kindly lent by Dr. Merton. Each camera was fitted with gun-sights and specially mounted so as to allow a rapid setting on the sun to be made.

About midnight on June 28 the *Fitzroy* anchored in a position on the central line of totality in Lat. $54^{\circ} 45' 0''$ N., Long. $1^{\circ} 8' 36''$ W. On account of misty weather it was not possible to fix with any degree of accuracy a position further seaward. It also appeared advisable to anchor moderately close to the shore in order that the ship might remain

as steady as possible during the eclipse. At this time there was a slight northerly swell, sea calm, light airs, and mist over the land, Heugh Light being visible at a distance of about 3 miles.

A comprehensive programme had been drawn up and Comdr. Harvey had allotted each member of his staff some share in it. The items included observations of the second and third contacts, approach of the shadow, drawings of the corona, and meteorological observations. A watch was to be kept also for any planet or stars which might become visible during totality.

On the 29th the sun rose behind heavy banks of massed cloud and it soon became apparent that the expedition was doomed to failure. The *Daily Mail* aeroplane was observed manœuvring over Hartlepool, and during totality Jupiter was seen, through a slight break in the clouds, by Comdr. Harvey and by one of the crew who had been especially deputed to keep a look out for it. A glimpse of the partially eclipsed sun was obtained at 5^h 46^m and at 6^h 6^m G.M.T.

The thermometer readings taken between 4^h 20^m and 5^h 40^m G.M.T. showed a range of only 7/10ths degree Fahrenheit.

The observers wish to acknowledge their indebtedness for the great kindness shown to them by Comdr. Harvey and his staff and for assistance rendered them in every possible way.

7. *The Large-scale Photograph.*—The exposure of the large-scale photograph of the corona extends from one or two seconds after the commencement of totality to within one or two seconds of its termination. The picture it gives of the chromosphere and corona reaches to at least 1" of the sun's photospheric limb in the equatorial regions and 6" at the poles. It is thus of special value in showing the chromosphere all round the sun and the relationship of the lower corona to the prominences. All round the limb prominences are shown, the largest ones being near the north. The indentations on the limb indicate a large number of smaller prominences even where they are not distinctly shown in the photograph. Near the south point concentric arches in the corona are shown over a group of prominences. The brightest arch, about 30" broad and of 2' radius, is of approximately semicircular form with its centre near the limb. Inside this a smaller arch is shown, and outside, with radius of about 3½', a fainter arch can be seen on the negative.

The most remarkable features are near the east and west points. Here thin streaks and detached portions of prominences are shown and the corona has its greatest intensity. It would seem that the ionization found in the chromosphere is in these regions carried to a greater degree and forms coronal matter. The guess may be hazarded that strong bright lines in the corona spectrum would have been strongly shown in these regions. This may be inferred from the results of previous eclipses, that emission lines in the coronal spectrum do not extend far above the sun's limb and vary in different parts. Reference may be made to the green line as found in the spectrum taken in 1905 when the slit ran across a large prominence (*Phil. Trans.*, 206, 403), and to the strength of the coronal rings in the neighbourhood of prominences in the eclipses of 1898 and 1926 (*Phil. Trans.*, 197, 151; *R.A.S. Memoirs*, 64, part 4). Attention may also be directed to the development of a bright patch of

corona in the position of a prominence in 1901 in the 100 minutes elapsing between photographs taken in Mauritius and Sumatra. These all confirm the view that the emission lines in the corona arise from matter in the neighbourhood of prominences possibly more ionized than the chromospheric material. The rest of the corona, possibly including the arches, gives a continuous spectrum, and probably arises from light reflected and scattered from small particles.

Patches of prominence matter which have been shot high above the photosphere and are detached from the main chromosphere can be seen in several places. The highest part is in position-angle 58° and is $3'0$ above the sun's limb. In a slightly smaller position-angle, 53° to 45° , is a narrow circular arc of prominence matter reaching $1'2$ above the photosphere. A fine vertical prominence is in 11° position-angle, the extreme height being $1'2$. This height of $1'2$ appears to be reached by prominence material in quite a number of places. The coronal matter in many places, especially near the equator, in position-angles 75° and 260° , is so bright that it cannot be readily differentiated from the prominences. Direct photographs of the sun taken at Greenwich on June 30 indicated a large spot on the sun near the position-angle 75° and a large amount of faculæ both there and at 260° .

8. *Small-scale Photographs.*—The corona is of maximum type, and the photographs show fairly strong extensions of the corona to a distance of one radius of the sun from the limb. The strongest of these is on the west side from position-angles 215° to 300° . At about 300° another branch of the corona can be seen whose edge makes an angle of about 120° with the last streamer. This branch extends from 300° to 20° and includes the large prominences near the north pole. Then follows another bright portion of corona, as bright as but not extending as far as the part from 215° to 300° . This extends from 30° to 115° . Two comparatively narrow streamers are prominent at 120° and 130° . Round the south pole between 135° and 215° there is a fairly uniform extension with the eastern edge more definitely marked than the western.

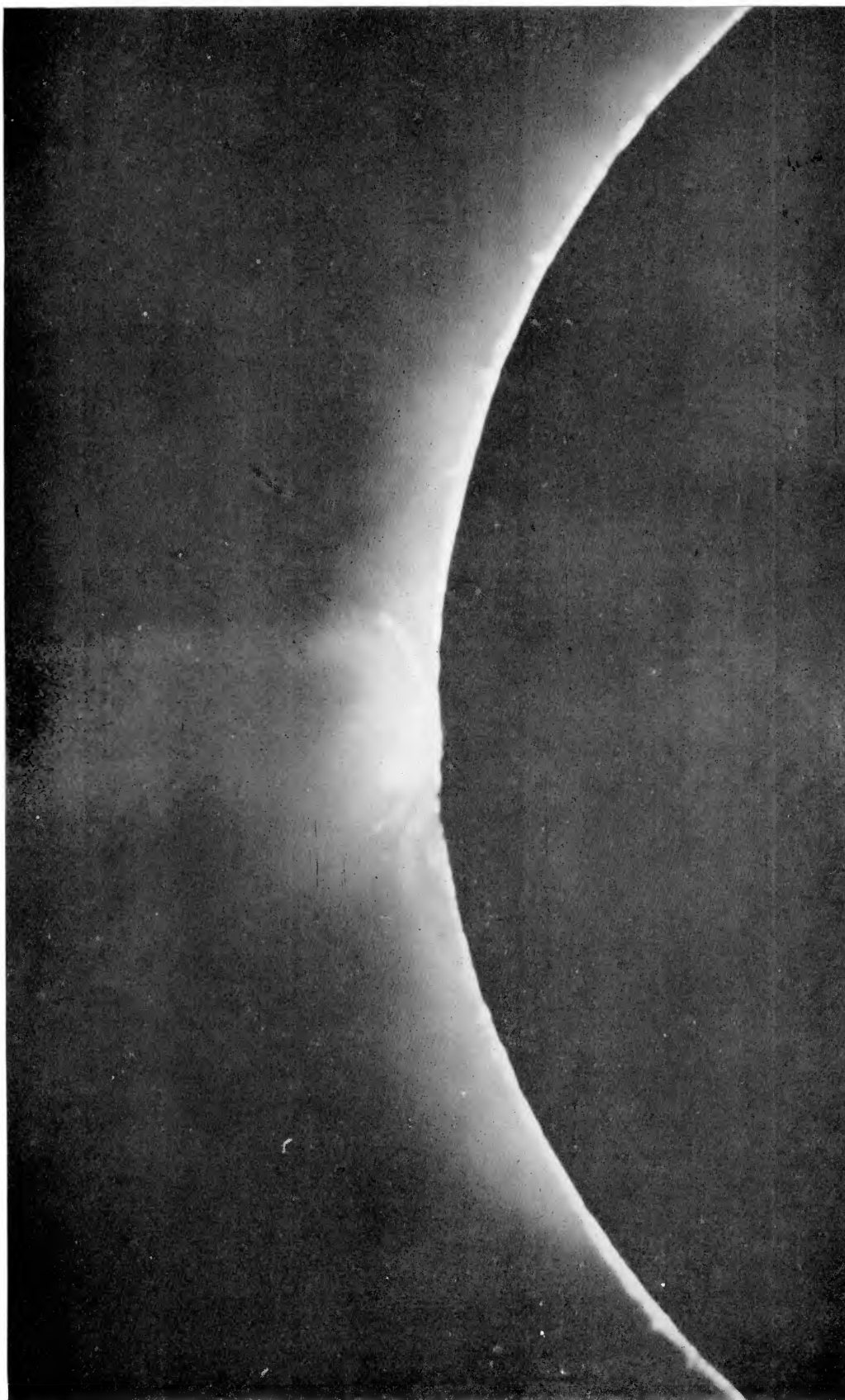
Reproductions are given of (1) the large-scale photograph slightly reduced, (2) east and west limbs on larger scale, (3) the photograph by Mr. Warhurst enlarged $2\frac{1}{2}$ times, (4) two of the aeroplane photographs enlarged 3 times, and (5) the drawing made from them by Mr. Hargreaves.

Although a little outside the scope of this report, it seems desirable to draw attention to the great popular interest taken in this eclipse. This was largely brought about by the press, which drew attention to the rare occurrence of total eclipses and to the splendour and impressive nature of the spectacle. Railway facilities were arranged by the L.N.E.R. and by the L.M.S., so that many thousands were enabled to reach the zone of totality by rail. Many came by car or charabanc. The number who visited the neighbourhood of Settle was estimated by the Superintendent of Police as 100,000. Nearly all of these had a good view of the eclipse.

In conclusion, I wish to express my thanks to those who kindly lent instruments, particularly to Mr. J. H. Worthington; to the Governors and Headmaster of Giggleswick School for the use of what the exigencies of weather made the best site in England; and to the municipal authori-

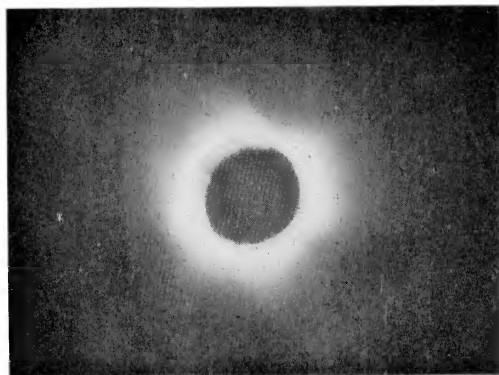
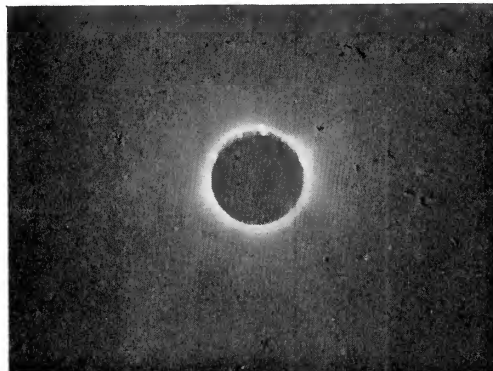
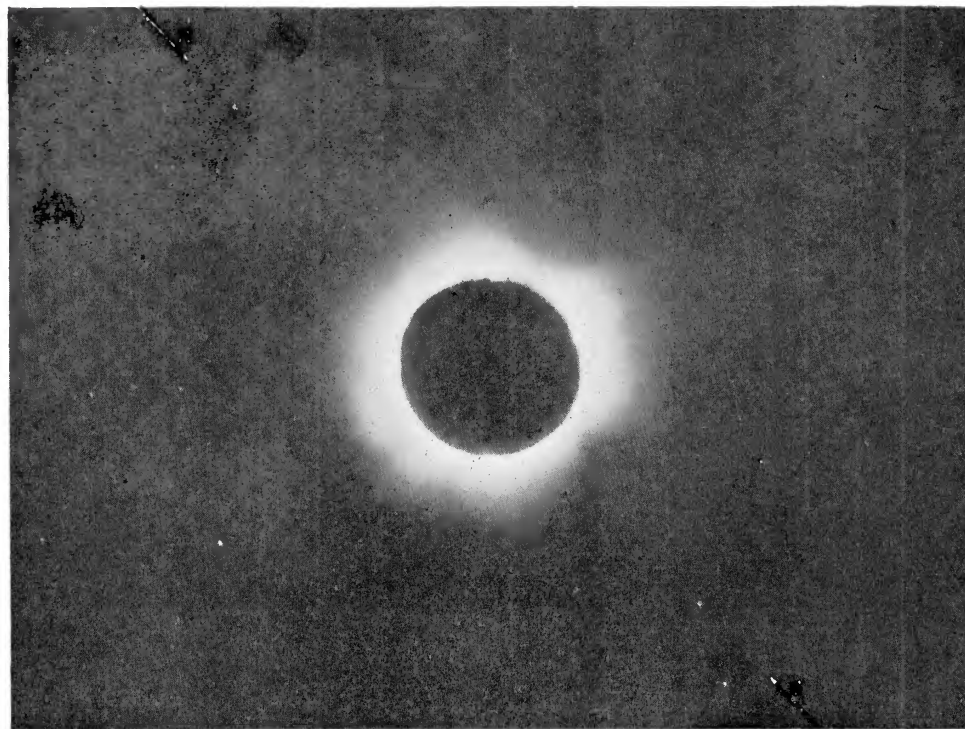


East Limb.

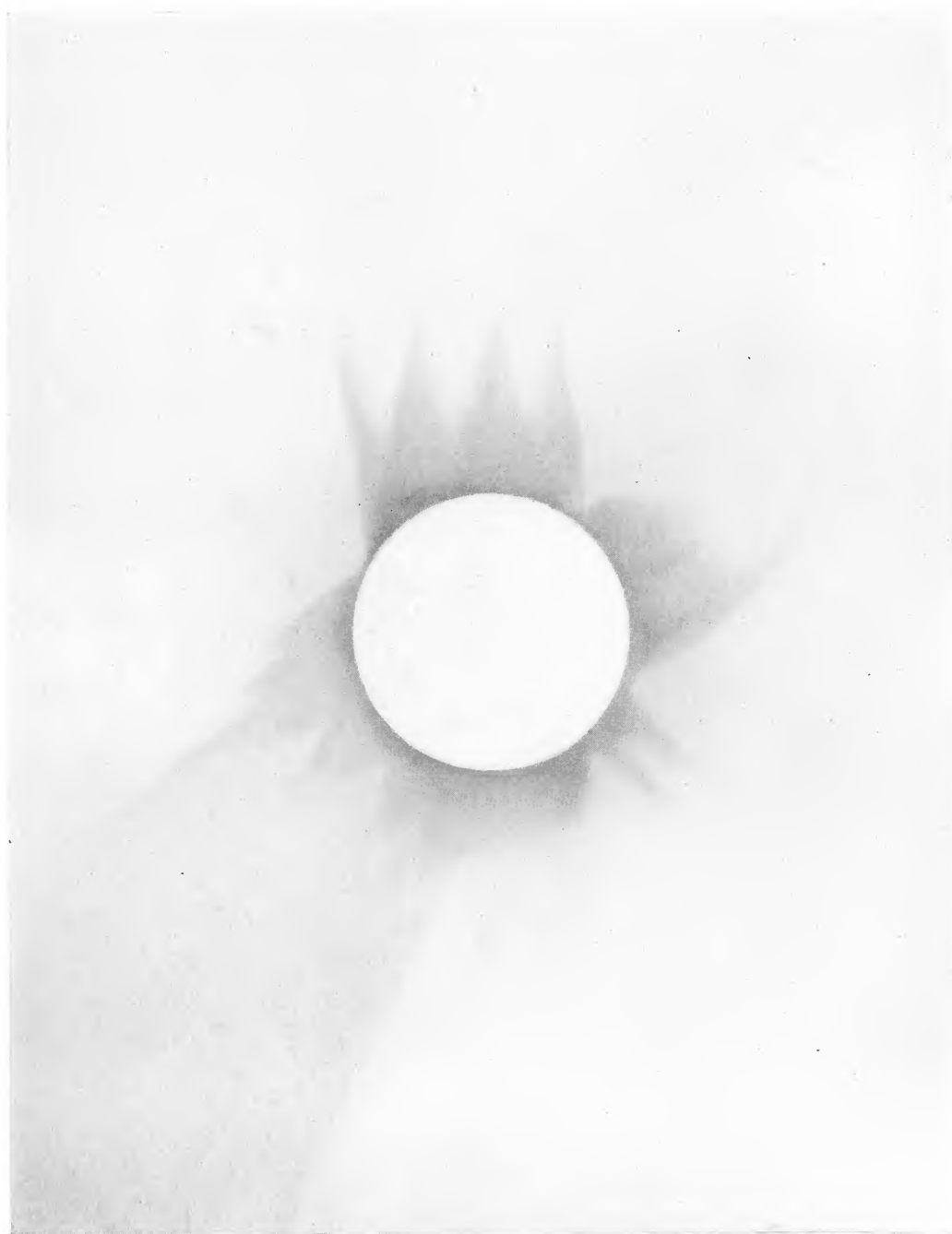


West Limb.

Aeroplane Photographs.

Exp. $1/30^{\text{th}}$ sec.Exp. $1/50^{\text{th}}$ sec.

Photograph taken at Giggleswick by Mr. Warhurst.



Solar Corona, 1927 June 29. Drawn by F. J. Hargreaves, from aeroplane photographs.

ties of Settle and Superintendent of Police for the excellence of their arrangements in securing us from any inconvenience from intrusion on the ground. I also wish to thank the *Daily Mail* for providing an aeroplane, and Imperial Airways, Ltd., for valuable co-operation; and the Hydrographer of the Navy and the Commander of H.M.S. *Fitzroy* for their interest and assistance.

Total Solar Eclipse of 1927 June 29: Report of the Oxford Expedition to Southport. By H. H. Turner, H. Knox-Shaw, and H. G. S. Barrett. (Plate 13.)

1. *Preliminary.*—In the autumn of last year a hospitable invitation from the Mayor and Corporation of Southport to occupy some site in or near the town was transmitted by Mr. Joseph Baxendell to the Eclipse Committee, who asked Professor Turner to organize an expedition in response. Ultimately the expedition was made a joint one of the University and Radcliffe Observatories at Oxford, the personnel consisting of Professor Turner from the former, and Dr. Knox-Shaw and Mr. Barrett from the latter observatory, with much kind help on the day of the eclipse as mentioned below.

On a preliminary visit to Southport, Jan. 19–21 (during the absence of Dr. Knox-Shaw in Egypt), Professor Turner had the kind assistance of Mr. C. R. Davidson of the Royal Observatory, Greenwich, who also materially aided the expedition with advice on several subsequent occasions.

The three members of the expedition arrived at Southport on June 22, and were housed by the Mayor and Corporation in or near the Prince of Wales Hotel, about a mile and a half from King George V. Boys' School, which had been selected as the observing site.

A cycle-shed in the school grounds was quickly adapted as a very convenient shelter for the instruments, and a dark-room in the school buildings was put at the disposal of the expedition.

The only serious difficulties encountered arose from the weather, which was atrocious. One or two passing glimpses of the sun enabled adjustments to be made, so that on the morning of the eclipse all was in readiness, but there was no adequate opportunity of testing the driving clocks.

2. *Instruments.*—(a) *Cœlostats.* One of the 16-inch cœlostats was purchased from the Eclipse Committee (according to Professor Newall's suggestion) by the help of a timely grant from the Lord Leigh Fund, and sent to Messrs. Grubb, Parsons & Co. for overhauling and reconstruction along with other similar instruments. To it was pointed the astrographic 13-inch object-glass of the University Observatory, mounted in the temporary tube, made of gas-pipes surrounded by black cloth and Willesden canvas, which had been used in Egypt in 1905. The horizontal position was adopted for the tube, which was mounted on wooden trestles made by the borough Office of Works. The cœlostat