"Total Solar Eclipse of 1898, January 22. Preliminary Report on the Observations made at Pulgaon, India." By Captain E. H. HILLS, R.E., and H. F. NEWALL, Sec. R.A.S. Received May 25, 1898.

(PLATES 1—3.)

CONTENTS.

I. *Origin of the Expedition and General Preparations.*

By Captain Hills and H. F. Newall.

This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The observers are indebted to the Great Indian Peninsular Railway Company for the carriage of the instruments at reduced rates between Bombay and Pulgaon, and for a considerable reduction of fares to the observers for this journey.

Observers.—The party consisted of :—

Captain E. H. Hills, R.E., Instructor in Chemistry and Photography at the School of Military Engineering, Chatham.
H. F. Newall, Sec. R.A.S., Cambridge Observatory.

(In what follows these will be designated by the initials H. and N.)

It had originally been arranged that Dr. E. J. Stone, Radcliffe Observer, Oxford, should be a member of the party. The vacancy caused by his lamented death was not filled, as it was decided to use the skilled assistance which could be obtained locally in order to carry out part of the programme of work that Dr. Stone intended to attempt, namely the obtaining of twelve photographs of the corona with the double tube camera.

Local Arrangements.—When the preparations were being made for this expedition the Surveyor-General of India intimated that his department would be willing to give what assistance they could. This generous offer was gladly accepted by the Joint Permanent

Eclipse Committee, and the Surveyor-General was asked if he could send—

(*a*) An officer who would take general charge of the camp.

(*b*) Six skilled native assistants.

(*c*) A photographer who would bring with him a suitable dark room ready for erection, and photographic materials.

The officer detailed to take charge of the camp at Pulgaon was Captain G. P. Lenox Conyngham, R.E., and the observers feel that they owe much of the success of the expedition to the excellence of all the arrangements made by him.

The thanks of the observers are also due to Lieut.-Colonel St. G. Gore, R.E., Superintendent of the Trigonometrical Survey, for the continuous interest he took in the work, and to Lieut. G. A. Beazeley, R.E., for much help in the observations, and in the developing and copying of the photographic plates.

The observers are also indebted to the local authorities for their kindness in doing everything that was possible to render the time spent in the Eclipse Camp, both pleasant and profitable, in particular to W. A. Nedham, Esq., Commissioner, Nagpur; S. N. Chitnavis, Esq., Deputy Commissioner, Wardha; and A. C. Blennerhassett, Esq., I.C.S., Assistant Commissioner, Wardha. A number of others, whose names are mentioned below, took part in the actual observations, and the observers wish to express their grateful thanks for the valuable assistance thus rendered.

Selection of Station.—In order that the masonry piers to carry the instruments might be built, and that all the arrangements for forming the camp might be proceeded with before the arrival of the observers it was considered advisable that the choice of the actual station, the approximate position of which had been already decided upon, should be left to the Survey officer in charge. The place selected was Pulgaon, on the Nagpur branch of the Great Indian Peninsular Railway, and the camp and observatory were placed on an open piece of ground about a mile to the north of the station. The position proved excellent in every way.

Arrival at Station.—N. arrived at the camp on January 10, H. on January 12. All the instruments, which had been forwarded direct from Bombay, had previously arrived, and the necessary piers and huts for the observatory were found completed in accordance with the plans prepared and sent by the observers to Captain Lenox Conyngham. It was thus possible at once to proceed with the erection and adjustment of the instruments.

Meteorological Observations.—A continuous set of meteorological observations were made from January 16 to January 23, of which it may be interesting to give a summary.

	Wind.	Barometer.			Temperature in shade.								Maximum in sun.	Minimum on grass.
					Dry bulb.			Wet bulb.			Max.	Min.		
		9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.				
Jan. 16	Very light, N. to N.W. ..	29·2	29·4	29·2	66	90	88	58	72	67	95	44	110	42
,, 17	Very light, E. to N.	29·2	29·3	29·2	68	87	89	58	69	69	95	43	110	39
,, 18	Calm	29·2	29·4	29·3	65	86	92	56	69	73	93	41	109	37
,, 19	Calm	29·3	29·4	29·3	68	83	86	58	66	66	89	40	105	36
,, 20	Calm to very light, S.E. ..	29·2	29·3	29·2	64	82	86	55	65	69	90	43	106	39
,, 21	Calm to light, S.E.	29·2	29·3	29·2	65	86	90	57	69	71	94	46	110	42
,, 22	Calm	29·2	*	29·2	69	90	88	59	73	71	92	45	107	41
,, 23	Calm	29·3	29·3	29·3	70	86	93	62	67	74	96	48	113	43

* Eclipse day. Barometer not read at noon.

Total rainfall, nil. Total cloud amount, nil.

The instruments employed were standard ones by Negretti and Zambra.

It is interesting to compare these figures with those given by Mr. Eliot in his meteorological note prepared in connection with the eclipse. No data are given for Pulgaon, but the conditions are practically the same as those found at the two nearest stations for which the figures are given, namely Akola and Nagpur.

We have then—

	Temperature.			Cloud amount (parts in 10).		Rain-fall.
	Max.	Min.	Daily range.	10 A.M.	4 P.M.	
Average at end of January in a few recent years—						in.
Akola	84	53	31	1·00	1·48	0·11
Nagpur	83	55	28	1·41	2·18	0·14
Observed—Pulgaon	93	44	49	Nil	Nil	Nil

The figures exhibit the futility of selecting an eclipse station on meteorological data only.

Departure.—The observers left the camp on January 25.

II. *Totality at Pulgaon.*

By Captain Hills and H. F. Newall.

The preparations for totality as regards the instruction and drilling of the assistants calls for little mention. The skilled native assistants, provided by the kindness of the Surveyor-General, were thoroughly accustomed to observing work, and the preparations and preliminary drills proceeded with the utmost smoothness.

The two men selected as timekeepers were instructed to call out the seconds from the beats of a metronome, which had been previously carefully rated.

The signal for the beginning of totality was given by Captain Lenox Conyngham who was making the exposures with the double tube camera, but it was also necessary for the spectroscopic work to get a signal at some definite time before totality which was accomplished by the following method :—

The length of the diminishing crescent of the sun was calculated for 15 seconds before totality. The observer in charge of the double tube camera watched the image on his ground glass and gave a signal when the crescent had arrived at the calculated length. The actual interval between the 15 second signal and the beginning of totality was 13 seconds.

Observing Party.—The following is a complete list of the whole observing party :—

Double Tube Camera.

In charge of instrument—Captain G. P. Lenox Conyngham, R.E.

Exposer—Babu S. C. Goha.

Recorder—Babu S. N. Saha.

Handing slides—Kali Din.

Receiving ditto—Mahabri.

Holding bags—Balgar.

Spectroscopic Cameras.

Observer—Captain E. H. Hills, R.E.

Exposer—Quartz spectroscope, Lieutenant F. R. H. Eustace, R.E.

,, —Flint spectroscope, Babu I. C. Dev.

Assistant in charge of slow motion—Lieutenant G. A. Beazeley, R.E.

Recorder—Mrs. Hills.

Spectroscope with Two Slits.

Observer—Mr. H. F. Newall.

Assistants—Mrs. Newall, Babu S. B. Shome.

Grating Spectroscope.

Observer—Mr. H. F. Newall.

Assistant—Mr. A. C. Blennerhassett, I.C.S.

Time Keepers.

Sub-Assistant Superintendent Hanuman Prasad.

Babu Lal Singh.

Recording Thermometers.

Captain G. C. Kemp, R.E.

Observing Magnetometer.

Lieut.-Colonel St. G. Gore, R.E.

Photographing Shadow Bands.

Mr. J. Harrold.

Recording Contacts.

1st and 4th—Captain Hills, R.E.

2nd—Captain G. P. Lenox Conyngham, R.E.

3rd—Mr. E. Batchelor, I.C.S.

Observed Times of Contacts.

Pulgaon—Latitude, 20° 44′ 10″·6 N.

Longitude, 78° 19′ 2″·5 E.

Computed distance from centre line, 4 miles.

The observed local mean times of contacts were :—

1st......	11 hrs.	50 min.	43·0 secs.
2nd	13 „	21 „	3·0 „
3rd	13 „	22 „	58·0 „
4th	14 „	43 „	54·5 „

The chronometer employed was rated by theodolite observations, and was probably correct within 1 sec.

Temperature Observations.—The result of the observations made for the two hours about totality were as follows :—

L.M.T.	In sun.		In shade.		
	Black bulb.	Glass bulb.	Dry bulb.	Wet bulb.	
h. m.					
12 21	99	93	90	73	
12 36	94	93	87	70	
12 51	90	90	85	69	
13 6	84	84	83	67	
13 21	79	78	80	66	Commencement of totality.
13 23	77	77	79	66	End of totality.
13 31	75	74	78	66	Lowest readings.
13 46	81	82	78	67	
14 1	89	86	82	67	
14 16	93	90	85	68	
14 31	97	94	86	69	

Magnetometer.—Colonel Gore made observations with the magnetometer with a view of detecting variation in the horizontal component of the earth's magnetic field during the eclipse. No change was observed.

Shadow Bands.—An attempt was made to photograph these with a small camera provided with an excellent Cooke lens of large aperture (F/6·3). A white sheet was stretched opposite to the sun's position, and a series of exposures was made at beginning and end of totality. Several spectators saw shadow bands, but no trace is discoverable on the photographs.

III.—*The Double-tube Camera.*

By Capt. Hills.

Instrument.—This camera was the one used by Mr. Taylor in Brazil in 1893, and was taken to Norway by Dr. Common in 1896. The tube is of wood, 6 feet long, and 14 × 7 inches in section, divided by a partition into two square tubes of 7 × 7-inch section. In one of these was placed the "Abney" lens of 4 inches aperture and 5 feet 2 inches focal length, giving an image of the sun 0·57 inch in diameter; in the other the photoheliograph objective (used in Transit of Venus expedition), of 4 inches aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of 7½ inches focus placed 5 inches within the focus, the combination giving an image of the sun 1½ inches in diameter. The camera was furnished with six plate-holders, each taking two plates of 160 × 160 mm., as in use for the astrographic chart, both plates being exposed by a quarter-turn of one shutter. The camera was pointed to a 16-inch plane mirror, made by Dr. Common, and mounted as a cœlostat by Mr. Hammersley after a design by Dr. Common, the sun's rays being thus reflected into the telescope.

The camera and cœlostat were not placed in a hut, but a screen of bamboo matting was erected round the whole instrument, to protect it from the wind, to which the cœlostat is particularly sensitive. Another portion of bamboo screen was placed horizontally above the camera, to protect the observer and the wooden body of the camera from the direct rays of the sun.

Mounting and Adjustment.—The cœlostat was placed on a masonry pier level with the ground. As some trouble had previously been experienced with the driving clock, owing to the heavy weight necessary, care was taken on this occasion that it should be very rigidly fixed in position. The method adopted was to screw the clock down on to a stout wooden base-board, which in its turn was firmly bolted to the masonry pier carrying the cœlostat, the driving cord being led off horizontally under one pulley attached to the base-board, and over another pulley hanging from the top of a strong wooden trestle about 6 feet high. Railway fishplates were used as weights. With this method no trouble at all was experienced, and the clock-driving was irreproachable.

In order to carry the camera, two parallel brick walls were built on the west side of the cœlostat, and on the top of each of these a 4-feet length of heavy rail was placed, held in ordinary railway chairs, lent for the purpose by the railway authorities at Pulgaon. A wooden stop or button fixed on the under side of the camera rested against the lower rail and prevented the camera from slipping down towards the mirror.

The angle at which the camera was set was so selected that the slide end should be at a suitable height for working. It was found convenient to direct the camera towards a point about 30° below the horizon, a little to the south of east. The focussing was done by reflection, and calls for no special remark, the final adjustment being accomplished by using the cœlostat mirror.

The adjustment of the axis of the cœlostat was effected very quickly by means of the attached declination theodolite. The level attached to the telescope makes it possible to adjust in altitude without any astronomical observation, for the latitude of the place can be taken from the map with sufficient accuracy; and setting the telescope to the south declination equal to the co-latitude, and in the meridian, the level should indicate horizontality. Index errors of the circle and level are eliminated by reversal of the instrument. There is a slight uncertainty attending the placing of the telescope in the meridian, but this does not seriously affect the adjustment in altitude. If a cross-level were made for the pivots of the telescope, this uncertainty could be removed.

To adjust in azimuth we must have an observation of the sun (or a star) at a distance from the meridian. Observing his declination (in reversed positions of the instrument and taking the mean), the instrument must be moved in azimuth until this observed declination agrees with that given in the 'Nautical Almanac.' A very few trials, if the sun can be seen for half an hour, will soon indicate the true azimuth without any calculations, within a minute or two of arc, though if the instrument be moved much in azimuth the altitude observation must be repeated.

After the initial adjustment of the cœlostat it was not disturbed, but the adjustment was re-tested at intervals, with the following results. The individual readings were only taken to minutes of arc, but both limbs of the sun were observed in both positions of the instrument, and the mean of the four set down:—

Cœlostat. Observer H.

Date.	Hour angle of sun. hrs.	Observed decl.	Tabular decl.	O.—C.
Jan. 15	−3·0	21° 7′	21° 7′	0′
16	−3·0	20 55	20 56	−1
17	+2·0	20 40	20 42	−2
19	−2·5	20 18	20 20	−2
20	+3·0	20 6	20 7	−1

From this general watch kept on the instrument it is clear that the adjustments remained good within 1′ or 2′, which is more than sufficient for the purpose. The only other adjustment required is the setting of the face of the mirror parallel to the polar axis of the instrument. This was easily effected by reversing the mirror in the Ys and observing if the sun's image in the two cases crossed the same position on the ground glass when the mirror was moved in right ascension.

Three screws are provided in the base of the mirror cell for correcting this error should any be found.

Programme of Observations.—The six slides were filled and intended to be exposed as follows :—

No. of slide.	Exposure.	Plate.
1	2 secs.	Ilford "Empress."
2	8 ,,	Ditto, ditto.
3	12 ,,	Ditto, Special Rapid.
4	24 ,,	Ditto, ditto.
5	12 ,,	Ditto, "Empress."
6	4 ,,	Ditto, ditto.

Plates 2, 3, 4, 5 were backed with a solution of asphalte in benzol and had the Abney standard squares impressed on them. If the rapidity of the Special Rapid be taken as twice that of the Empress plates, the above programme gives a series of equivalent exposures of

2, 4, 8, 12, 24, 48 seconds.

No exposures of less than 2 seconds were made, because it was considered that the detail of the inner corona would be better shown by the large scale pictures, of which at least four separate sets were being taken by independent observers at other stations.

The orientation of the corona was determined by the following method: After the last exposure had been completed the clock was stopped and the whole instrument was left untouched, with the slide still in the camera, till night. The Abney lens was then uncovered for about $2\frac{3}{4}$ hours, the mirror being left stationary, and a series of star trails were thereby drawn across the plate.

A recorder was employed whose duty was to note the exact time of each exposure made during the eclipse. They were as follows :—

Slide No.	Exposure according to programme.	Actual exposure.				
		Shutter opened.		Shutter closed.		Duration.
		Beginning of totality = zero.				
	secs.	min.	sec.	min.	sec.	sec.
1	2	0	5·0	0	7·5	2·5
2	8	0	14·0	0	22·0	8·0
3	12	0	27·5	0	39·0	11·5
4	24	0	47·0	1	11·0	24·0
5	12	1	18·5	1	30·5	12·0
6	4	1	37·0	1	41·0	4·0

All the above plates were successfully developed the night after the eclipse, and positive copies on glass were made to guard against loss.

A reproduction of one of the best photographs (No. 3, Dallmeyer lens, 12 secs. exposure), is given in Plate 1 (frontispiece).

IV.—*The Spectroscopic Cameras.*

By Capt. Hills.

Instruments.—The details of the two spectroscopes used were as follows:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke achromatic, $4\frac{1}{2}$ in. aperture, 5 ft. 10 in. focus.	Single quartz lens, 5 in. aperture, 4 ft. 9 in. focus.
Collimator and camera lenses.	Single quartz lens, $2\frac{1}{2}$ in. aperture, 30 in. focus.	Single quartz lens, 3 in. aperture, 36 in. focus.
Slit	$1\frac{1}{2}$ in. by 0·0018 in.	2 in. by 0·0014 in.
Prisms	Two dense flint prisms of 60°, $4\frac{1}{2}$ in. base, $2\frac{1}{2}$ in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), $3\frac{1}{2}$ in. base, $2\frac{3}{4}$ n. height.
Prisms at min. deviation for	H_γ.	H_ϵ.
Position of slit with respect to sun's image.	Parallel to meridian through sun's centre, cutting limb at point of second contact.	Vertically diametral.

The slits were in each case adjusted to such a width as to realise one-seventh of the theoretical maximum resolving power of the prisms. In the case of spectroscope No. 1 which, as will be shortly seen, was used for most of the work, this amounted to about 0·3 of an Angström unit in the violet. It may be noted that any higher degree of resolving power would have been wasted owing to the coarseness of grain of the photographic plate, the above figure representing not only the calculated resolving power of the instrument, but that actually realised on a trial plate.

The length of the spectrum on the plate was $3\frac{1}{4}$ inches from H_β to K.

Both spectroscopes were mounted in an approximately horizontal position, and were supplied with light by a heliostat, furnished with a 12-inch flat mirror.

Erection and adjustment of Instrument.—The heliostat and spectroscopes were placed on masonry piers, and a hut of bamboo matting was built up round the latter. The heliostat was left in the open, and, such was the dryness of the air, that it was found that a sheet tied over it at night was more than sufficient to protect it from any damp.

The adjustment of the polar axis of the heliostat was carried out by means of an attached theodolite in precisely the same manner as has been described above in the case of the cœlostat. As it was not possible to reverse the instrument when the slow motion in right ascension was attached, the position of the axis when once adjusted was not retested. This, however, was of little importance, as great accuracy in the driving is not required for this work.

The adjustments of the spectroscopes call for no special mention.

Programme of Exposures.—Two separate lines of work were undertaken:—

(1) The recording of the spectrum of the corona—using for this purpose both spectroscopes, and giving only one exposure of as long a duration as possible.

(2) The recording of the "flash" or spectrum of the sun's limb at both the beginning and end of totality.

For this purpose, spectroscope No. 1 only was used, the camera being provided with a sliding plate, by which means a large number of successive exposures could be made at short intervals.

It was intended to begin the exposures about 10 seconds before second contact, and to continue them till 7 seconds after it, and to expose a similar series at third contact.

In order to get the latter series, it was necessary to shift the image on the slit, which was done by the slow motion of the heliostat, an assistant being stationed at the latter, watching the sun through the theodolite telescope attached to the polar axis.

All the available time during totality, was employed in the long exposure for the corona spectrum.

The complete programme of exposures as drawn up, was as follows, the expected duration of totality being 115 seconds:—

Spectroscope.	No. of slide.	Exposures.	Time in totality.	Plate.
No. 1...	1	10 of 1 sec.	−10 to +7 secs.	Lumière "green sensitive."
	2	1 of 85 secs.	15 to 100 secs.	,, ,, ,,
	3	10 of 1 sec.	108 to 125 secs.	,, ,, ,,
No. 2...	1	1 of 98 secs.	7 to 105 secs.	Ilford Special Rapid.

All the essential points of this programme were carried out The actual time of each exposure was as accurately as can be ascertained,

2nd contact: −10, −8, −6, −4, −2, 0, +2, +4, +6, +8, seconds.
3rd „ −3, −1, +1, +3, +5, +8, +10, seconds.
Corona: Spectroscope No. 1. Exposed 79 seconds from 21−100.
„ „ No. 2. „ 98 „ „ 7−105.

The second series did not begin quite as soon as had been intended, and between the fifth and sixth exposures there was rather a longer interval than between the others, owing to a slight mistake on the part of the exposer. This is, however, of no consequence, as all the interest centres about the photographs taken within 5 seconds of the contact.

The Corona Spectrum.—A reproduction of the corona spectrum as obtained by the two-prism flint spectroscope is given in Plate 2. It is obvious that the photographic intensity of the continuous spectrum fell off very rapidly on receding from the limb. No trace of it is seen at a greater distance than 4′.

Five strong bright lines of unquestionably coronal origin are to be seen. Their wave-lengths, and relative intensities may be provisionally given as—

λ (Rowland).	Photographic intensity.
3987·0	5
4233·5	10
4360·0	3
4567·9	8
5316·9	8

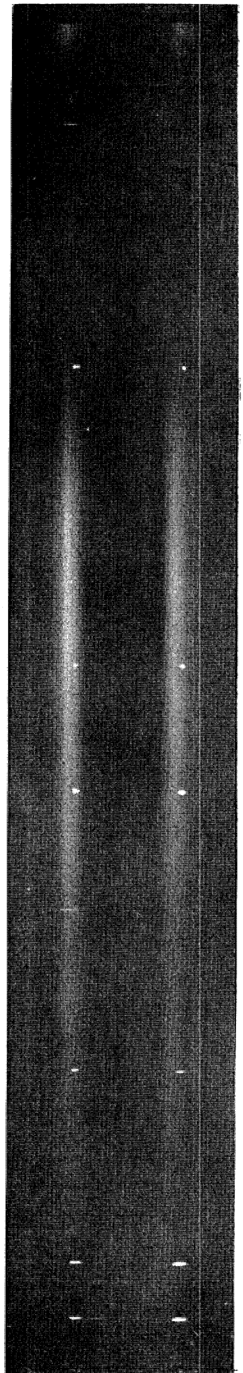
There are other fainter lines whose wave-lengths have not yet been determined.

Spectroscope No. 2, with the quartz train, gave a corona spectrum stretching a considerable distance into the ultra-violet, but of feeble intensity. A strong bright line occurs at λ 3801·0, and the lines given above are also to be plainly seen with the exception of the well known line in the green which was outside the plate.

Spectrum of the limb.—The two series of spectra of the limb contain an immense amount of detail, and will take a considerable time for complete examination. As an indication of the character of the results obtained, reproductions of portions of the two spectra taken at second and third contacts are given in Plate 3.

As considerable interest attaches to the question of the connection between the bright line spectrum of the limb and the solar spectrum, a reproduction of the latter, taken with the same instrument is appended.

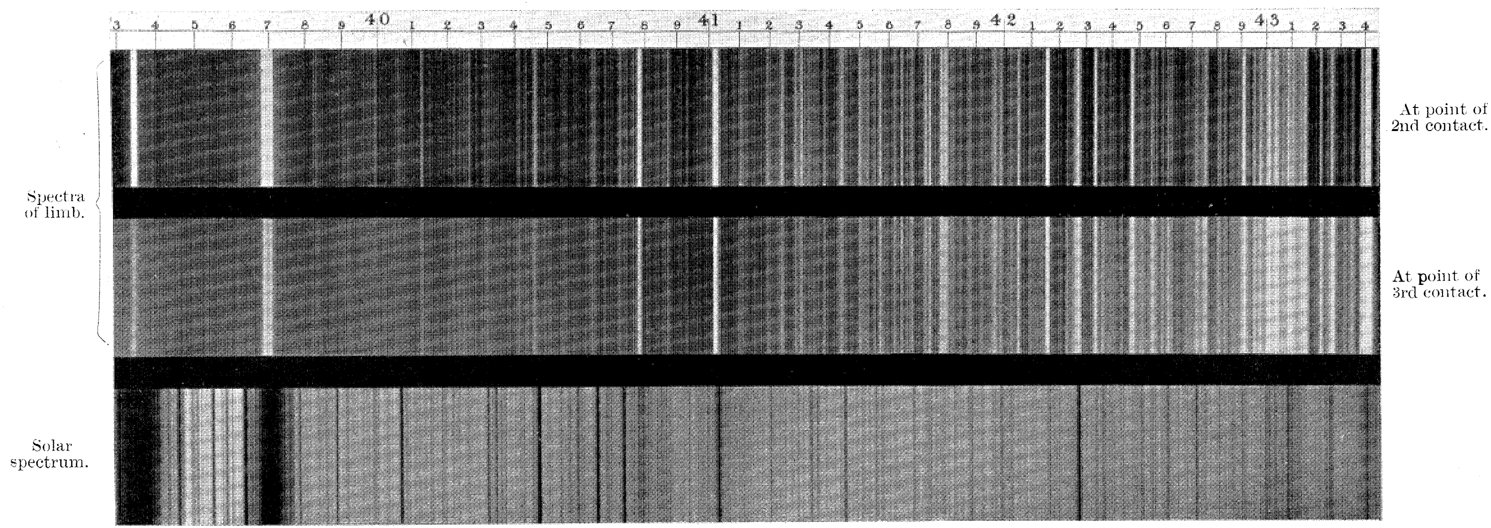
CORONA SPECTRUM.



From photograph taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged $1\frac{1}{3}$ times.

SPECTRUM OF SUN'S LIMB.

(Region H_γ to K.)



From photographs taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged $3\frac{1}{2}$ times.

V.—*The Spectroscope with Two Slits.*

By H. F. Newall.

It was intended to attempt (i) to determine by a spectrographic method, the difference in velocity in the line of sight in the eastern and western equatorial regions of the corona, (ii) to utilize the same material, as was obtained for the first research, for a comparison of the spectra of widely separated parts of the corona, and (iii) to use the same instrument in securing photographs of the bright line spectrum of the sun's limb at the end of totality, to be used for the accurate determination of the wave-lengths of the bright lines.

The instrument provided for these purposes is a four-prism spectroscope with two slits.

The train of prisms is of such dimensions and construction, as to transmit a 2-inch beam of light, and to produce a minimum deviation of 180° for H_γ. The collimator and camera are set parallel to one another.

The whole spectroscope is mounted so as to turn about an axis, parallel to the collimator. The axis is rotated (with a period of 24 hours) by clockwork, and is tilted so as to be parallel to the earth's axis. In this position the collimator points to the north pole.

The tube of the collimator is prolonged beyond the plane of the slit, and is arranged to carry at its end a mirror of speculum metal and an object glass, by means of which an image of the sun can be thrown upon the slit.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown upon the slit does not rotate relatively to the slit. Furthermore, the mirror is mounted in such a manner that the axis about which it can be tilted—namely the declination axis—can be oriented relatively to the collimator tube, so that any diameter of the sun may be set parallel to the slit.

The two slits with which the collimator is provided are parallel to one another in the focal plane of the collimator lens, and are separated by such a distance that when the image of the eclipsed sun is thrown between the slits, one is illuminated by the eastern, the other by the western equatorial region of the corona. The top half of one slit is covered, and also the bottom half of the other. The exposures for the two sides of the corona are made simultaneously, and the resulting photograph should give two spectra side by side on the same plate, one slightly displaced, relatively to the other, by an amount depending on the separation of the two slits and the construction and adjustments of the spectroscope.

It was decided that certain coronal lines in the neighbourhood of λ 4233 would be the best available for the determination of displacement due to velocity.

The linear dispersion in the photographed spectrum is about 15 tenthmetres per millimetre at H_γ. The relation between the velocity in the line of sight and one complete revolution of the micrometer to be used in the measuring the plate is about 260 kilometres per second for one revolution.

The scale of the photograph is such that one degree on the sky corresponds to about 9 mm. on the plate.

The effective aperture of the combination regarded as an instrument for producing monochromatic images of a slit-shaped region of the corona is $\frac{1}{12}$.

The adjustment of the axis of the instrument to parallelism with the earth's axis, was accomplished in the same manner as that adopted for adjusting the cœlostat. A theodolite with declination circle was attached to a part of the frame of the spectroscope, specially prepared for it, between the camera and the collimator. The adjustment was very easily and satisfactorily made: in altitude by observations made with the spirit level attached to the theodolite-telescope, and in azimuth by observations of the sun made some hours before or after noon.

Programme of Exposures and General Results.

I. *Spectra of the Corona.*—A set of five photographs, from which the relative velocity in the line of sight of the eastern and western equatorial regions of the corona could be deduced, was to be taken with the spectroscope with two slits.

The programme of exposures was carried out completely successfully, as follows:—

Thirty minutes before totality, plate A was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Fifteen minutes before totality, plate B was exposed for 20 seconds for a duplicate of plate A taken in falling temperature.

During totality, plate No. 1 was exposed for 100 seconds for the spectra of the eastern and western regions of the corona.

Fifteen minutes after totality, plate C was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Thirty minutes after totality, plate D was exposed for 15 seconds for a duplicate of plate C under different temperature conditions.

Result.—On development, the photographic plate No. 1 showed no trace of any impress of the coronal spectra, though the development was pressed as far as possible.

It is clear that the failure is due to the faintness of the corona in the region photographed. Captain Hills was successful in photographing the spectrum of the corona at the same station, but the radial extension of the bright lines and also of the continuous spectrum is unexpectedly small. In neither of his photographs is the spectrum traceable further than about 4′ from the limb of the sun. N., basing his attempt on the results obtained by Deslandres in 1893 and by Abney and Thorpe, had tried to photograph the spectrum at nearly 8′ from the limb of the sun. The apparatus used on the present occasion was of such design and construction, that it was expected to give considerably brighter images than those used by Deslandres in 1893.

II. *Spectrum of the Sun's Limb.*—With the same spectroscope, photographs were to be taken of the bright line spectrum of the sun's limb at the end of totality.

Ten seconds before the end of totality, the exposure referred to in the preceding paragraph was completed; and whilst another plate-holder was being placed in the camera of the spectroscope, the adjustments in R.A. and Declination were changed so that the image of the chromosphere, which was being disclosed near the point of third contact, was adjusted on one of the two slits. Four exposures were then made in rapid succession.

Results.—The photographs thus obtained, give spectra ranging from about λ 3900 to λ 4900; and the first of the series contains a vast number of bright lines, generally similar to those seen in Captain Hills' photographs, and to those shown in the photograph obtained by Mr. Shackleton in Novaya Zemlya, 1896, August 9, and reproduced in Sir Norman Lockyer's Preliminary Report,* and also to those obtained by Mr. Fowler in 1893, and reproduced in Sir Norman Lockyer's Report.†

An additional point of interest in the first photograph of the series is that many absorption lines are also visible. A cursory comparison with the solar spectrum discloses the interesting fact that these lines differ in intensity from the absorption lines in the ordinary solar spectrum.

VI. *The Objective Grating Telescope.*

By H. F. Newall.

An objective grating telescope was used for visual observations of the coronal ring in the green light of wave-length 5316·9 (1474 K).

A plane grating, by Rowland, 14,438 lines to the inch on a ruled surface, $3\frac{1}{2} \times 2\frac{1}{8}$ inches, was fixed on a turn-table in front of a telescope of focal length 29 inches and aperture $3\frac{1}{2}$ inches. A positive eye-piece was used which gave a magnifying power of 19·2, and whose circular field of view was rather more than 1° in diameter.

* 'Phil. Trans.,' A, vol. 189 (1897), pp. 259—263.

† *Ibid.*, A, vol. 187 (1896), Plate 14.

The instrument was mounted so that the telescope was parallel to the earth's axis and pointed towards the north pole. The grating was used in a manner analogous to that in which the mirror of a polar heliostat is used. The light of the corona was incident on the grating at an angle of about 57°, and diffracted beam utilised in the telescope left the grating at an angle of about 13°. In this position of the grating, the green of the second order was used, and the magnifying power of the grating was a little greater than $\frac{1}{2}$, so that the distorted coronal ring was an ellipse, in which the major axis was about twice as great as the minor axis; the minor axis was parallel to the length of the spectrum and perpendicular to the direction of daily motion. No clockwork was used, but a slow motion of a very simple construction was provided and found to work perfectly satisfactorily. The observations were begun 6 seconds after the beginning of totality, and were completed in about 70 seconds.

Results.—The coronal ring was seen in the spectrum of the second order with great distinctness and with such brilliancy as to leave no doubt that it could have been photographed.

None of the fine radial structure of the corona could be seen, though it was especially looked for; but broad patches of light were clearly visible in different positions round the ring.

A drawing of the brighter extensions was made during the eclipse, the observer (N.) keeping himself intentionally in ignorance of the orientation of the image seen in the eye-piece until after the observations were completed so as to avoid bias. A preliminary comparison of the drawing with the direct photographs of the corona has been made, and the following general statements will probably not require much revision on a closer comparison:—

(i) There appeared to be glowing "Coronium" (assuming that the radiation of wave-length 5316·9 is rightly attributed to an element "coronium") at all points round the sun's limb extending radially to distances estimated as ranging between 4′ and 14′.

(ii) The luminosity was not uniform round the limb, but in no position was it entirely absent.

(iii) No *fine* radial streamers comparable with those seen near the poles of the sun in ordinary direct photographs of the corona were observed, though this fine structure was specially looked for.

(iv) In certain positions round the limb patches of increased luminosity were seen; in all, seven patches were noted; in several cases the extension was considerably greater in a radial direction than in a tangential. The bases of the broad streamers on the limb subtended angles ranging from 10° to 30° at the centre of the sun's disc, and the radial extension in three cases was estimated as being greater than 12′.

v) Two of the long streamers referred to in the last paragraph were found to coincide roughly in position with marked broad extensions in the direct photographs of the corona, viz., that to the N.E. and that to the S.W. But the third long streamer to the N. seems to have no connection with any obvious extension in the photographs.

(vi) There was no marked "coronium" luminosity corresponding either to the double-rayed extension in the N.W. quadrant or to the broad extension in the S.E. quadrant.

(vii) As far as it has been possible to pursue the investigation at present, there has appeared no relation between the position of the brighter patches of coronium and the prominences, except perhaps near the three prominences in the N.W. quadrant.

VII. *Polariscopic Observations.*

By H. F. Newall.

It was intended to devote any time that remained over, after providing for the three foregoing investigations during the eclipse, to (i) a search for faint extensions of the corona with the aid of a polariscope, or as an alternative (ii) a general investigation of the nature of the polarisation-phenomena visible during an eclipse. It was expected that results obtained in the latter investigation would probably only be serviceable in suggesting methods of research for future eclipses.

The polariscope used consists of a Nicol prism with a Savart plate attached in front of it. The field of view of the instrument is lozenge-shaped after the manner of Nicol prisms, the long axis being 29° long and the short axis 24°. The width of the central band due to the Savart plate was approximately 1° 25′ between the centres of the first lateral dark bands, the centre being regarded as that part of the dark band where the dusky red meets the steel blue. The plate had been adjusted relatively to the Nicol prism, so that the bands when visible were parallel to the principal plane of the Nicol, and they were kept in this relative position throughout the observations. The instrument was used without telescope or circles.

Observations.—When first the instrument was put to the eye, about 85 secs. after the beginning of totality, bands were visible over the whole field of sky seen through the Nicol prism. Not only were the alternations of brightness seen, but the colours of the bands appeared with unexpected vividness. They were seen at all points within 30° of the sun, with little or no variation in vividness, and as the instrument happened first to be held, the bands were approximately parallel to the sun's axis. These vivid bands are attributed to the polarisation of the light scattered (diffracted) by solid particles in the earth's atmosphere.

The bands were so disconcertingly vivid that a few moments were wasted in inspection of the instrument, but immediately afterwards observations were quietly renewed, the search for faint coronal extensions was abandoned, and attention was confined to the phenomena of polarisation.

The instrument was rotated about its axis, and the bands faded from view and became invisible in a certain position. It was thought immediately after the eclipse that the observations made were enough to prove that the plane of polarisation was neither vertical nor horizontal, but it has since been found that the evidence is not such as to warrant this statement. When the bands had become invisible in the outer part of the field of view, the rotation of the instrument was discontinued for a moment. The eye then gradually became aware of faint colours over the corona, but the distribution appeared to be uneven—rather in patches than in bands. These colours are attributed to the polarisation proper of the corona. The "patchy" distribution is doubtless a result of the nature (presumably radial) of the polarisation of the corona, and of the largeness of the scale of the bands compared with the diameter of the moon (1° 25′ : 33′). The fact that the colours appeared faint in contrast with the vivid sky-bands previously seen may be referred to several alternative explanations which cannot well be dealt with here in detail. It is obvious that the ratio of the brightness of the light scattered by the sky to that of the light of the corona plays as important a part as the proportion of the coronal light that may be regarded as polarised.

Next, attention was directed to the corona near the limb, and the central part of the central band was observed while the instrument was rotated, the central band being kept radial to the sun's disc. The observed central part was seen to be bright at all points round the limb on the east side, whether the central sky-band were bright or dark.

Then the bands were set so that one of the first dark lateral bands was tolerably close to the moon's limb, with its centre perhaps half a moon's diameter from the limb. The band was observed to be bright near the limb, and to be dark at a short distance on either side.

Both of the last mentioned observations point to the idea that the light scattered by the atmosphere was comparable in brightness with the corona at points not far distant from the sun's limb.

The incompleteness of the observations is recognised, but on the whole it would appear that their suggestiveness justified the observer in devoting 15 seconds to making them.

The observed intensity of the bands, attributed to sky polarisation, is evidence of the quantity of light reflected by solid particles in the atmosphere. It seems not improbable that the unexpected brightness of the general sky and landscape during totality may have been connected with the amount of light reflected from the dust suspended in the atmosphere and illuminated by the sun-lit plains outside the moon's shadow. The light colouring of the plains, due to the dried herbage at that time of year, is very marked at Pulgaon, but it must not be forgotten that the "sun-lit plains" were in the moon's penumbral shadow for more than an hour both before and after totality.

The observations occupied the 15 seconds, ending 15 seconds before the end of totality.

About 30 seconds after the end of totality, polarisation was again looked for, but no trace could be detected near the sun in any position of the instrument.

"The Skeleton and Classification of Calcareous Sponges." By G. P. BIDDER. Communicated by ADAM SEDGWICK, F.R.S.

Received May 6,—Read May 26, 1898.

I. *Skeleton.*

An element which seems to have been too little regarded in the physiology of sponges is the permanent tension of their walls.* The contours of the surfaces, particularly where they rise over projecting spicules, are alone sufficient to demonstrate that there is surface-tension between the protoplasm of the sponge and the sea-water. Both the outer and the inner surfaces of a cylindrical or of a spherical sponge unite, therefore, in exerting a force which tends to contract its diameter. In many sponges there would appear to be also some form of elastic matter in the tissue immediately underlying the collar-cells; since in teased preparations of the living sponge, fragments of the chamber-wall turn inside out and swim about like ciliate larvæ. While the collar-cells are active, these united tensions are resisted by the pressure of the water in the cavities they line. A broad generalisation of the mechanism of a sponge's currents shows that the velocity in the oscular stream (of comparatively narrow

* I have to thank Mr. G. T. Walker, of Trinity College, Cambridge, for rescuing me from some fallacies with regard to the effects of this tension, and Professor Lewis for most kind patience in mitigating my ignorance of crystallography, and much valuable information.

THE SOLAR CORONA

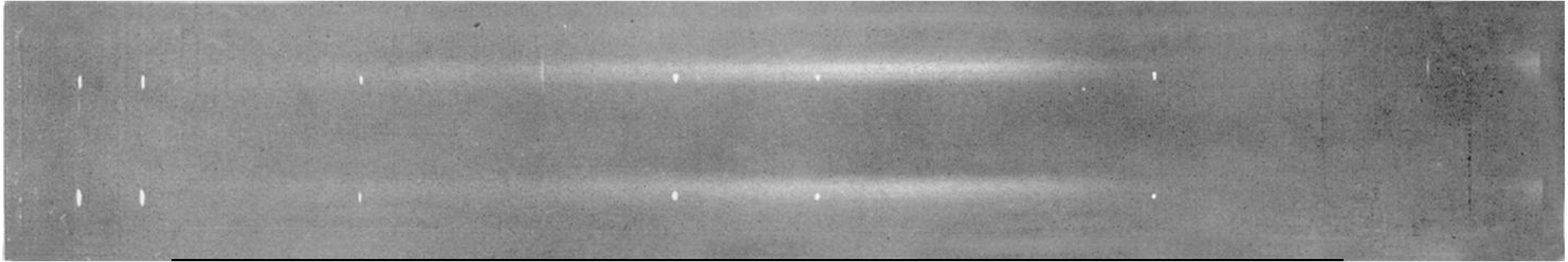
OF 1898.—JAN. 22ND.

Photographed at Pulgaon, Central India, by CAPTAIN E. H. HILLS, R.E.

Dallmeyer Photoheliograph Lens, 5 in. diameter.—Equivalent focus, 15 ft.

Exposure 8 seconds.

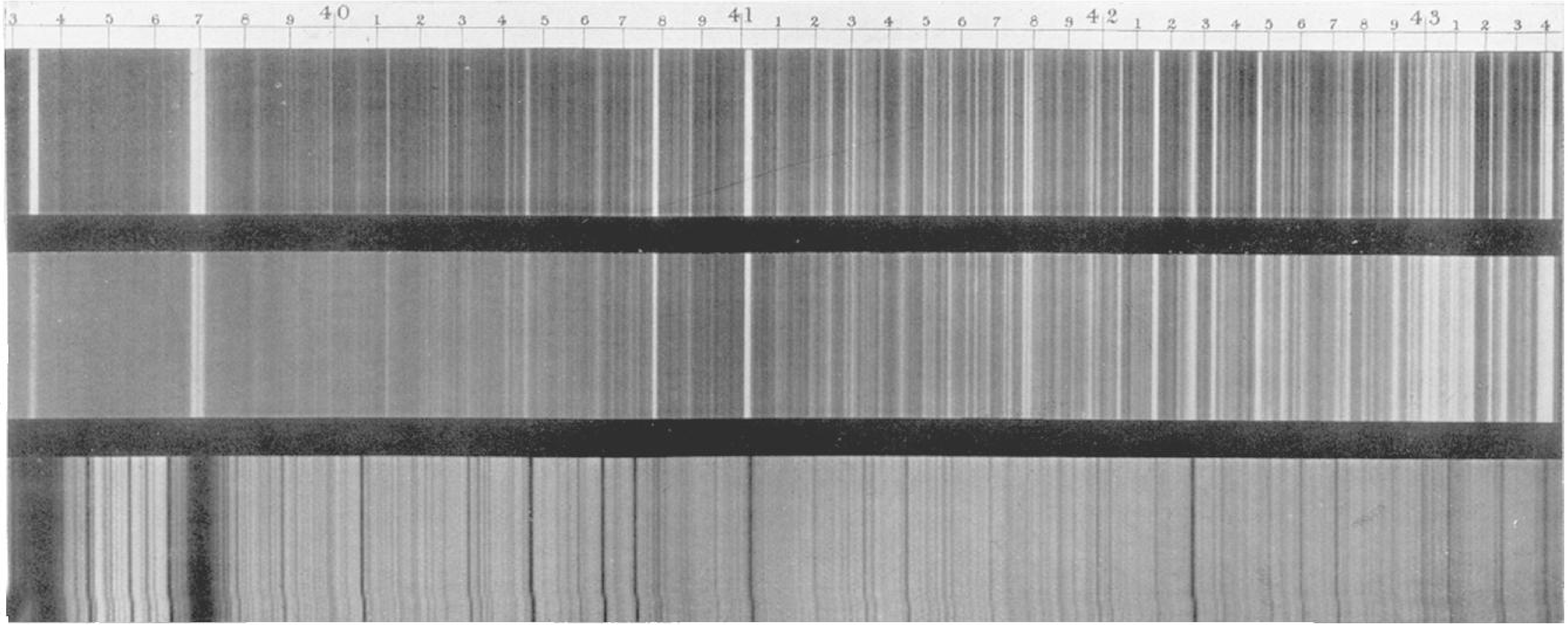
Corona Spectrum.



From photograph taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged 1½ times.

Spectrum of Sun's Limb.

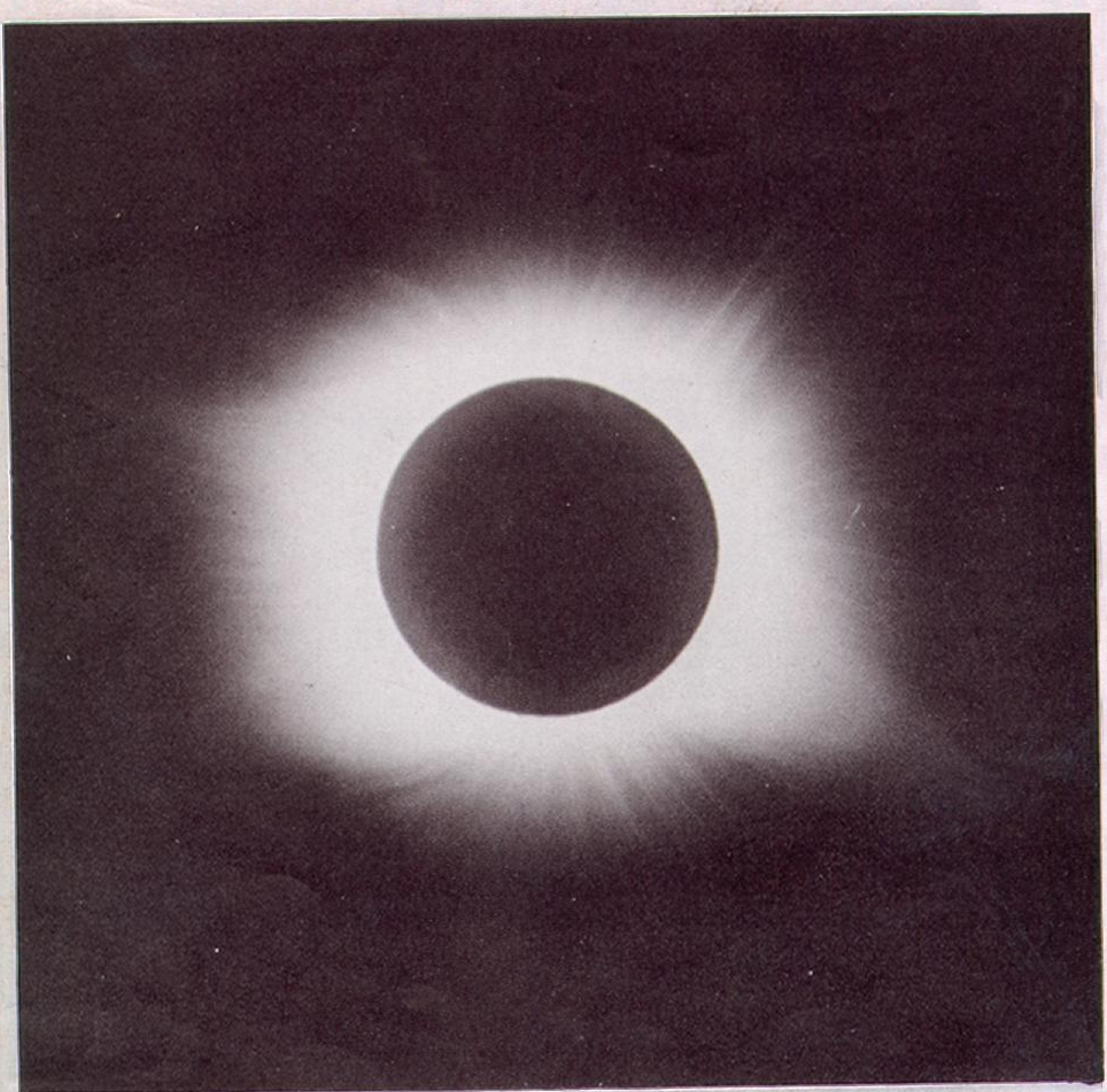
(Region H_γ to K.)



From photographs taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged $3\frac{1}{2}$ times.

THE SOLAR CORONA

Of 1898.—Jan. 22nd.



Photographed at Pulgaon, Central India, by Captain E. H. Hills, R.E.

Dallmeyer Photoheliograph Lens, 5 in. diameter.—Equivalent focus, 15 ft.

Exposure 8 seconds.