V. *Total Eclipse of the Sun, January* 22, 1898.—*Observations at Viziadrug.*

By Sir Norman Lockyer, *K.C.B., F.R.S., Captain* Chisholm-Batten, *R.N., and Professor* A. Pedler, *F.R.S.*

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[Plates 4–8.]

Contents.

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ILLUSTRATIONS.

PART I.—GENERAL ARRANGEMENTS.

By Sir NORMAN LOCKYER, *K.C.B.*, *F.R.S.*

Objects of the Expedition.

FOR the expedition to Kio Island in 1896 I had arranged an extensive programme of observations which unfortunately could not be completely carried out on account of bad weather,* and I did not find it necessary to materially modify this programme for the expedition of 1898. In view of the large number of observers which was expected to be available in 1898, as in 1896, the observations proposed included records of nearly all the phenomena of a total eclipse, in addition to spectroscopic researches.

Three associated series of spectroscopic observations were provided for :

(1.) Prismatic cameras, to give records of the phenomena with a larger dispersion than any previously employed. The special features of this form of spectroscope, and the important points to be considered in the interpretation of the photographic records which they give, were described in the Report on the Eclipse of 1893.†

(2.) An integrating spectroscope of large dimensions to attempt to get stronger photographic indications of the coronal radiations, by utilising the whole area of the corona, which the prismatic camera cannot do.

(3.) A grating spectroscope, in conjunction with a telescope of large aperture and short focus, for eye observations of the inner corona. The spectrum of the chromosphere, as photographed in 1893 and 1896, showed that the Fraunhofer lines were not completely represented, and it seemed likely that the missing lines would be found above the chromospheric layer photographed, and associated with the coronal layers, of which we had photographed only a few of the brightest radiations. I certainly saw some of them in Egypt in 1882,‡ and it was accordingly decided to attempt to fill the blank in the photographic record by visual observations.

The present Report deals with all the observations except those made with the prismatic cameras, in which case the work of reducing the photographs is very heavy and will not be completed for some time.

* 'Phil. Trans.,' A, vol. 190 (1897), p. 2.
† 'Phil. Trans.,' A, vol. 187 (1896), pp. 551–618.
‡ 'Roy. Soc. Proc.,' vol. 34, p. 297.

In the first part of the Report I give an account of the general arrangements. The second part is Captain CHISHOLM-BATTEN's report on the observations made by the officers and men of H.M.S. "Melpomene."

Professor A. PEDLER, F.R.S., gives an account, in the third part, of his visual observations with the grating spectroscope.

Details of the meteorological observations made at Viziadrug, under the direction of Mr. JOHN ELIOT, M.A., F.R.S., C.I.E., Meteorological Reporter to the Government of India, have already been published.*

The Observing Station and Preparations.

After various inquiries which I had made respecting the suitability of Viziadrug for observations of the total eclipse, I informed the Eclipse Committee that I was prepared to take charge of an expedition to that locality, and it was agreed that the observations at this station should be placed in my charge.

The latitude and longitude of the part of the fort at Viziadrug finally occupied were 16° 33′ 26″ N. and 73° 18′ 58″ E. respectively, and the duration of totality was estimated at 127 seconds.

In connection with the work at this station the Admiralty was asked for a ship of war to convey the observers from Colombo to Viziadrug, and to permit the use of the ship, if possible, as a base, to enable me to repeat the observations attempted in Norway in 1896 with the assistance of H.M.S. "Volage," which ship supplied twenty-four assistants during the eclipse and fifty volunteers for general observations.† As a result of the Royal Society's application, H.M.S. "Melpomene," in command of Captain CHISHOLM-BATTEN, R.N., was told off to join the expedition.

The expedition, which left England on December 10, consisted of Mr. A. FOWLER, Dr. W. J. S. LOCKYER, and myself, together with the Marquis of GRAHAM, who joined as a volunteer. Some little time after reaching Viziadrug Professor PEDLER, F.R.S., from Calcutta, joined the party, and shortly before the eclipse Mr. JOHN ELIOT, Meteorological Reporter to the Government of India, joined from Simla. On arrival at Colombo we found H.M.S. "Melpomene" waiting there, and at once proceeded to the selected spot of observation—Viziadrug.

During the three days' voyage to our station a call for volunteers was made by Captain BATTEN, and 120 came forward. Lectures and demonstrations were therefore at once commenced by Lieutenants BLACKETT, COLBECK, and DUGMORE, Second Engineer MOUNTIFIELD, and myself to the several parties of men who had undertaken to perform special pieces of work. Twenty-two separate groups of observers were formed. On our arrival at Viziadrug we were received very kindly by Mr. BOMANJI, the Collector of Ratnagiri, and an Overseer of the Public Works

* 'Indian Meteorological Memoirs,' vol. 11, Part I. Calcutta, 1899.

† 'Phil. Trans.,' A, vol. 190 (1897), pp. 1–21.

Department, who was on the spot in charge of some most excellent masons and carpenters, picked men from Ratnagiri as we later ascertained, and plenty of material for the construction of the necessary concrete bases and huts. It was important to erect the huts as soon as possible, not only to shelter the instruments, but also the observers, from the sun. Several screens were made which could be moved and placed in any required position; these were found to be invaluable while the instruments were being erected. A considerable number of coolies was also present to do such work as carrying packing-cases, sawing wood, clearing the camp, &c.

In the fort was also a police guard sent from Ratnagiri. The camp was watched, both by day and night, so effectively by them that no damage to any instrument was reported.

On the arrival of the "Melpomene" at Viziadrug, Mr. BOMANJI came on board to report the arrangements which had been made for the expedition by the Government of India. As these were not quite completed, it was necessary for the first few days to return to the ship every evening, but afterwards Mr. FOWLER, Dr. LOCKYER, and myself took up our quarters at the Dak bungalow inside the fort, close to the instruments. Meals were provided at the Collector's camp, which was also inside the fort.

A party was landed at the fort on the afternoon of our arrival to inspect the site suggested by Mr. BOMANJI, and it was at once evident that it would satisfy all requirements, provided the fluctuations of temperature of the great masses of masonry composing the fort had no disturbing influence on the steadiness of the air. In order to investigate this point a $3\frac{3}{4}$-inch telescope was erected, and observations of the surrounding landscape, and, at dusk, of various stars, were made, from which it appeared that the atmosphere was sufficiently steady for the observations.

Next morning the instruments were landed and the concrete bases for them were commenced. The erection of the huts was also begun by the native workmen, and continued without intermission.

The instruments were set up as soon as their bases were ready, and by the end of a week all were practically in readiness for the eclipse. Constant clear skies enabled all the adjustments to be made without difficulty.

A plan of the fort showing the arrangement of the instruments is given in Plate 4.

During the week preceding the eclipse the adjustments were frequently tested, and a complete system of drills was established.

As the number of volunteers was so large, I pointed out to Captain BATTEN, who had volunteered to aid in a special branch of the work, the importance of his taking charge of the whole camp and giving all the necessary orders for conducting the operations during the general rehearsals, and the eclipse itself. He eventually agreed to this, and the procedure and time signals were arranged between us.

The development of the photographic plates was commenced immediately after the eclipse, and it was found that the results were on the whole very satisfactory. No results, however, were obtained with the integrating spectroscope, and the kinematograph films taken by Lord GRAHAM were too badly fogged to serve any useful purpose.

The dismantling of the instruments was commenced very soon after the eclipse, and the packing, together with the development and copying of the negatives, kept the party fully occupied until the morning of January 25, when the expedition left Viziadrug.

Half of the negatives and glass copies of the remainder were conveyed to England in charge of Mr. FOWLER, while the remaining half of negatives and positives were sent home *viâ* Bombay.

Local Conditions of Eclipse.

In response to my request, the Superintendent of the 'Nautical Almanac' office kindly supplied me with the following local particulars of the eclipse for the station which I proposed to occupy :—

Assuming the position of Viziadrug to be 16° 32′ N. and 73° 22′ E., the times of contact will be

		d.	h.	m.	s.	
1898.	January	21	23	12	20	
		22	0	46	9	Duration 125 secs.
		22	0	48	14	
		22	2	14	33	

These are local mean times, and to reduce to G.M.T., 4h. 53m. 28s. must be subtracted.

The position angle of the point of 2nd contact is 51°, and that of 3rd contact 241°, reckoned from the north point towards the east in each case.

On reaching India, however, it was ascertained that, according to the most recent Admiralty chart, the position of the selected station was 16° 33′ 26″ N., and 73° 18′ 58″ E. This being nearer to the central line than the position adopted by Dr. DOWNING, the duration of totality was estimated at 127 seconds, and the programme of work arranged accordingly. The altitude of the sun at mid-eclipse was calculated to be very nearly 53°, and the azimuth nearly 14°.

The apparent semi-diameters of the sun and moon at the time of eclipse were respectively 16′ 16″·4 and 16′ 39″·5, while the relative motion was approximately 0″·36 per second.

The angle between the vertex and the north point at the time of mid-eclipse was calculated to be 14° 9′, the north point of the limb lying towards the west. The position angle of the sun's axis being 8° west of north, the axis would therefore be inclined 22° 9′ from the vertical towards the west. The heliographic latitude of the sun's centre was 5° 20′ S., so that the direct image was oriented as shown in fig. 1, which also shows the points of 2nd and 3rd contact.

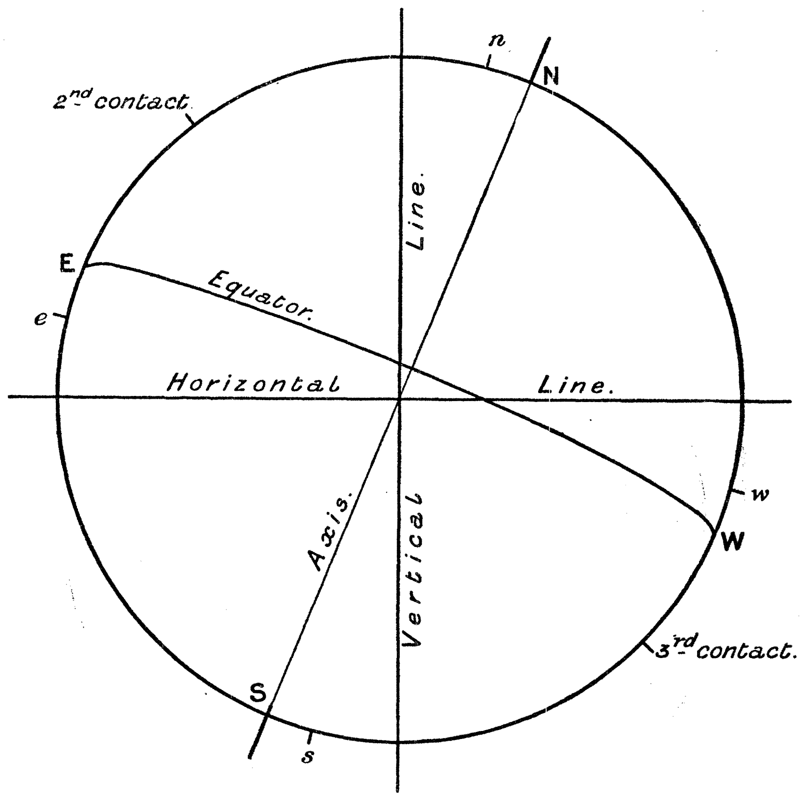


Fig. 1. Orientation of Sun's Disc at Mid-eclipse.

In connection with the instruments using the light from cœlostat mirrors, it was further necessary to calculate the sun's amplitude at the time of rising. This was found to be 20° 31′ south of east.

Time Arrangements.

The general time signals were given by a bugler under Captain BATTEN's orders. The chronometer was in charge of Lieutenant DE WET, R.N.

One of the ship's chronometers was fortunately available for use on shore on the day of eclipse, but previously watches were frequently corrected by means of signals sent by Lieutenant QUAYLE from the ship.

The special signals during totality were given every 10 seconds, beginning at 127—the assumed period of totality—by means of the eclipse clock (which was started at the signal "Go" by cutting a thread, thereby releasing the pendulum), by two timekeepers, one during the first half the other during the second half of totality.

In the system adopted not only was the time left called out every tenth second, but other signals were interpolated to guide the work in the photographic huts. In order that there might be no mistake about the calls, a spiral was drawn on the clock-face and the seconds left plainly marked at the points which the second hand would occupy during its two revolutions (fig. 2). The time calls were repeated by two assistants, who stood about 50 yards from the eclipse clock, for the benefit of the observers in the outlying parts of the camp.

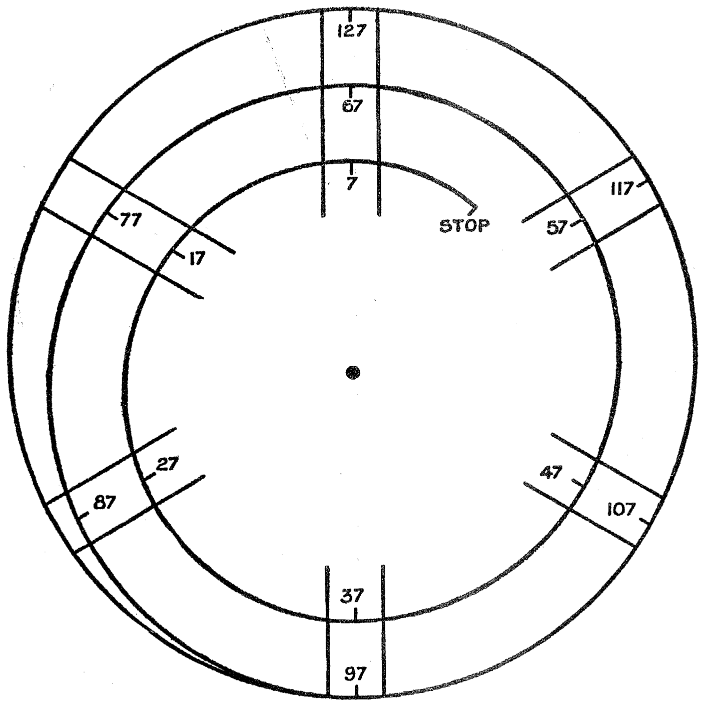


Fig. 2. Dial of Eclipse Clock.

For the work of the prismatic cameras it was important to get a signal as nearly as possible 5 seconds before the beginning of totality, and, in order to eliminate the possible error of the chronometer, it was arranged to determine this by direct observations. Two methods were adopted. In one of them a boat was moored at a distance of 2 miles from the camp, in the direction of approach of the shadow, which would pass this point 5 seconds before totality. This failed because of the indefinite boundary of the shadow.

The other method was to determine when the visible remaining crescent subtended an angle of 45°; calculation showed that this would occur at the desired interval from totality. This method was completely successful.

A signal at 25 seconds before commencement of totality was also given from observations, the cusps then subtending an angle of 90°. These observations of the cusps were made by Lieutenant DE WET.

The chronometer was 5h. 8m. 35·5s. slow on mean time at Viziadrug, and 0h. 15m. 20s. slow on Greenwich mean time, as determined by Lieutenant QUAYLE.

Acknowledgment of Assistance.

The extraordinary interest and the skill displayed by the officers and men of H.M.S. "Volage" under Captain KING HALL in 1896, and of H.M.S. "Melpomene" under Captain CHISHOLM-BATTEN in the present year, prove beyond all question that, in eclipses in which a man-of-war can be employed, the most effective and the most economical means of securing observations is to depend upon the naval personnel, one or two skilled observers being sent out to help in the final adjustments of instruments according to the number it is intended to employ.

At Viziadrug, Mr. FOWLER and Dr. LOCKYER were enabled to report all the fixed instruments and huts, eight in number, erected and all but the final adjustments made after six days' work, a long break being necessary in the middle of the day in consequence of the heat. Such an achievement as this is beyond all eclipse precedent, and was only rendered possible by the help of a large staff of highly trained men. Of the 150 engaged in the operations only three originally formed the expedition.

It is, therefore, quite inappropriate that I, on the part of the expedition, should here tender thanks to Captain BATTEN, the officers and men of H.M.S. "Melpomene" for their assistance, for as matters turned out we assisted them; but we are anxious to place on record the kindness we received from them both afloat and ashore, and since the great success of the recent observations is due almost entirely to Captain CHISHOLM-BATTEN and the ship's company of the "Melpomene," I trust that the President and Council of the Royal Society may be pleased to communicate this fact to the Lords Commissioners of the Admiralty.

Among those to whom thanks are specially due are the following, representing the Indian Government :—

E. GILES, Esq., Director of Public Instruction, in charge of arrangements made by Bombay Government.
K. R. BOMANJI, Esq., Collector of Ratnagiri.
J. L. JENKINS, Esq., Collector of Salt.
E. H. AITKEN, Esq., Assistant Collector of Salt.
F. R. BADER, Esq., Assistant Engineer, P.W.D.
GANGADHAR ANANT BHAT, Executive Engineer, P.W.D.
GOVIND GOSHI, Overseer, P.W.D.
SADASHI GOVIND JOSHI, Clerk to the Overseer, P.W.D.

Thanks are also due to the Officers of the Police, Telegraph, and Customs Departments, and others representing the Bombay Government, for their unceasing efforts to help us in every way.

Everybody was struck by the admirable and smart manner in which the subordinates of the Public Works Department accomplished their respective tasks.

I took upon myself, when leaving Viziadrug, to write an unofficial letter to Mr. Bomanji, thanking him, in the name of the expedition, for his great personal kindnesses to us as well as for the valuable assistance we had received from him and the other local representatives of the Government.

L. Lee, Esq., Collector of Customs for Ceylon, and other Customs officials at Colombo, rendered valuable assistance to the expedition by granting special facilities and providing means for transhipping the instruments.

The Orient Steam Navigation Company very kindly conveyed the instruments free of charge to and from Colombo.

To W. H. Sinclair, Esq., a former Collector of the district (now retired), I was indebted for the supply of much valuable local information before leaving England.

My own personal thanks are due to Mr. Fowler and Dr. Lockyer, who assisted me in the preliminary work of organisation, and who, while at Viziadrug, worked hard both day and night to further the objects of the expedition; and also to Mr. Bourne, Midshipman, attached to me as Aide-de-Camp, who was indefatigable in helping me to carry out the various details of the local organisation.

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

By Captain Chisholm-Batten, *R.N.*

Admiralty Instructions.

H.M.S. "Melpomene" was ordered to receive on board Sir Norman Lockyer and party at Colombo, convey them to Viziadrug, and bring them back to Colombo after the eclipse. During her stay at Viziadrug such assistance as lay in her power was to be rendered to the party. It was to be quite understood that it was very desirable that the officers and men should interest themselves in the work, and be encouraged to come forward as assistant observers, if required, by Sir Norman Lockyer.

By later orders, H.M.S. "Melpomene" was ordered to convey Sir Norman Lockyer from Viziadrug to Goa, instead of returning direct to Colombo.

Diary of the Expedition.

On the arrival of the "Lusitania," the Torpedo Instructor was sent on board to make himself, as much as might be, familiar with the eighty cases of eclipse gear, in order that he might attend to them throughout.

On the 4th January the party and the gear were transferred from the mail steamer and H.M.S. "Melpomene" left Colombo.

On the 5th January Sir NORMAN LOCKYER gave a lecture, with illustrations by lantern slides, on Eclipses in general, and afterwards volunteer observers were called for. All the officers, and over 100 men, gave in their names as volunteers for special work, or for general assistance. The same evening the sketching party were instructed and exercised, and daily afterwards.

Friday, January 7.—The party arrived at Viziadrug. The Collector came on board, and on landing, the party selected a site, a piece of flat ground, the highest inside the old Castle, on which there was plenty of room for the instruments (see Plan, Plate 4), and near which was the Traveller's bungalow, built over the old powder magazine of the pirates, which was used as a dark room, mess room for the men, lecture room when lantern slides were required, and general resting-place, on account of its being cool and shaded.

Saturday, January 8.—All instruments were landed, and a fair start made in setting them up, the leading hand of each party from the ship assisting at his own instrument or job.

Instruction was carried out on board on the spectrum, in corona drawing, and on observing the colours of the landscape.

Sunday, January 9.—During Sunday the native workmen, masons, carpenters, and labourers provided by the Public Works Department of India, prepared cement foundations, shelter huts, and the site generally.

Monday, January 10.—Good work was done in setting up the instruments, which were in place by the evening. Instruction was carried out on board on hand spectroscopes.

A signal-house had been built, and a signal pole set up for communication with the ship. Larger parties every day were now required on shore for setting up gear, and for practice with it. As Viziadrug has the reputation of being a favourite place for snakes, men always landed in gaiters. The dark room for the British party was set up in the magazine, and one for Mr. TURNER, the photographer, sent from Calcutta by the Government of India, was set up in a shady place close to the bungalow on his arrival on Tuesday.

Tuesday, January 11.—Lectures on spectra colours, landscape, and corona drawings were given.

Sir NORMAN LOCKYER, Mr. FOWLER, and Dr. LOCKYER took up their quarters at Norman Castle.

Wednesday, January 12.—Sketching corona, with discs, party were under instruction, and the usual duties of various parties independently.

Thursday, January 13.—Professor PEDLER arrived, and found his telescope in place, and a party ready to assist him.

In the evening, about five o'clock, the first rehearsal took place of the parties ready.

Instruction in colour of landscape, and corona sketching with discs, was carried out on this day.

Friday, January 14.—Instruction was carried out on colours of landscape and the observation of stars during totality.

A second rehearsal took place, and the most important photography was found to be well ahead of time.

Saturday, January 15.—A rehearsal took place, and the usual instruction went on.

Monday, January 17.—The first rehearsal at eclipse time took place, in order that practice might be obtained in directing the instruments to the proper point in the heavens; a second rehearsal took place at 5 P.M. These rehearsals in the evening were at first repeated two, or even three, times the same evening, but later on one drill was found enough.

Instruction by Mr. TURNER on landscape cameras, and lectures on stars, with a view to their observation during totality, took place.

Tuesday, January 18.—Rehearsals took place at eclipse time, at 5 P.M., and after sunset, the latter for the purpose of testing the lighting arrangements, which were found to be sufficient.

Lecture on spectra was given.

Wednesday, January 19.—Mr. AITKEN, who was to take charge of the naturalists' party, arrived but left again before the eclipse, and only returned on the last morning. Professor PEDLER started a thermometer class in readiness for Mr. ELIOT. Lecture was given on spectra, and rehearsal took place at 5 P.M.

Thursday, January 20.—Mr. ELIOT arrived and was supplied with a party for making meteorological observations under his guidance.

Lecture on observations of temperature.

Rehearsal at 5 P.M. The party was now complete.

Friday, January 21.—Rehearsal of duties at eclipse time. Half-holiday.

List of Instruments and Observers.

The observers were as follows :—

1. *Time Signals.*
   - Captain A. W. CHISHOLM-BATTEN, R.N.
   - F. DOWNTON, Leading Seaman.
   - W. WOODS, Yeoman of Signals.
   - W. GROVES, Shipwright.
   - F. T. MAREY, Private, R.M.L.I.
   - G. S. FULLILOVE, Private, R.M.L.I.
   - G. CLEARY, Private, R.M.L.I.

2. 6-*inch Prismatic Camera.*
   - Mr. FOWLER.
   - Lieutenant O. DE WET, R.N.
   - C. IRONSIDES, G.M.
   - J. TURNER, T.I.
   - F. BRADING, A.B.
   - J. INNES, A.B.
   - G. SALT, Boy, 1st Class.

3. 9-*inch Prismatic Camera.*
   - Dr. LOCKYER.
   - Lieutenant PERCIVAL JONES, R.N.R.
   - A. RAMAGE, A.B.
   - W. BRAY, Ch. Arm.
   - A. WILKINS, Shipwright.
   - E. ASHFORD, A.B.
   - F. FENTON, A.B.
   - A. CARR, Boy, 1st Class.

4. *Integrating Spectroscope.*

Lieutenant G. C. Quayle, R.N.
J. Bird, Ch. E.R.A.
G. Travill, P.O., 1st Class.

5. *Coronagraph.*

Staff-Engineer A. Kerr, R.N.
W. Holmes, E.R.A.
C. Moseley, Leading Stoker, 1st Class.
G. Collier, Stoker.

6. *Discs.*

{A. Ruse, Ship's Corporal, 1st Class. G. Pink, Qualified Signalman. J. Henry, Boy, 1st Class.}
{B. Brook, Stoker. A. McDonald, P.O., 1st Class. A. Tull, Ship's Steward's Boy.}
{L. Pettingale, Leading Signalman. W. Brooker, A.B. S. Drew, Ordinary Seaman.}
{R. Sutherland, Leading Signalman. W. Webb, A.B. W. Corney, Stoker.}
{G. Price, A.B. J. Jones, A.B. F. Dibbins, Ordinary Seaman.}
{L. Gates, A.B. R. Davis, A.B. P. McKenna, A.B.}

7. *Sketches of Corona without Discs.*

A. Richardson, P.O., 1st Class. W. Pankhurst, A.B. H. Lack, Boy, 1st Class. } General.
W. Anderson, A.B. E. Wilson, Ordinary Seaman. } N.E.
T. Wells, A.B. H. Brinstead, A.B. } N.W.
E. Dann. W. Evans. } S.E.
W. Clayton. A. Penny. } S.W.

8. $3\frac{3}{4}$*-inch Equatorial.*

Sir Norman Lockyer, K.C.B.
Mr. H. Willmore, Assistant Engineer, R.N.
M. Moore, Stoker.

9. *Observations on Stars.*

Lieutenant Henry Blackett, R.N.
J. McDonald, A.B.
F. Stevens, A.B.
R. Buckland, Plumber's Mate.
T. Sutton, Stoker.
J. FitzRoy, Boy, 1st Class.
G. Russell, Private, R.M.L.I.

10. *Hand Spectroscopes.*

Lieutenant C. E. B. Colbeck, R.N.
C. Kitchingham, Private, R.M.L.I.
C. Woodley, P.O., 1st Class.
P. Manning, Ordinary Seaman.
H. Mitchell, Stoker.
J. Dobson, Sergeant, R.M.L.I.

11. *Prisms for Observations of Ring Spectra.*

Mr. J. Mountifield, Senior Engineer, R.N.
W. Morris, E.R.A.
A. Howe, E.R.A.
C. Stacey, Leading Stoker, 2nd Class.
H. Knight, Leading Stoker, 2nd Class.
R. Coates, Stoker.
G. Tarrant, Stoker.
H. Warren, Stoker.
J. Inch, Stoker.
G. Gray, Chief Stoker.
J. Cross, Stoker.

12. *Polariscope.*

Staff-Surgeon C. L. Nolan, R.N.

13. *Landscape Colours.*

Lieutenant E. N. R. Dugmore, R.N.
G. Farrell, Boy, 1st Class.
W. Jacobs, A.B.
P. Darvil, Boy, 1st Class.
H. Rhodes, Ordinary Seaman.
H. Attree, Signalman.

14. *Landscape Cameras.*
 Mr. TURNER, Survey Department, Calcutta.
 E. GYNGELL, A.B.
 H. CHILDS, Chief Stoker.
 J. COLLINS, Chief Stoker.
 J. KEARNEY, Leading Stoker, 1st Class.
 E. CROSS, Leading Stoker, 2nd Class.

15. *Shadow Phenomena.*
 W. KEENAN, Chief Carpenter's Mate.
 A. REYNOLDS, Stoker.
 W. WEEKS, Shipwright.
 G. RILEY, Stoker.
 B. CRUNDEN, Stoker.
 C. CARPENTER, Stoker.

16. *Observations of Shadow-bands.*
 Staff-Surgeon C. L. NOLAN, R.N.
 C. HESTER, Private, R.M.L.I.
 A. PURKINGTON, 2nd S. B. Steward.

17. *Kinematograph for Eclipse.*
 The Marquis of GRAHAM.
 A. SHILCOCK, E.R.A.
 E. GREEN, Boy, 1st Class.
 C. THOMAS, Seedie.
 P. KING, Ordinary Seaman.
 W. CRONEN, Stoker.

18. *Kinematograph for Shadow.*
 Mr. H. P. BARNETT, Paymaster, R.N.
 A. GIDNEY, E.R.A.

19. *Contact Observations.*
 Lieutenant O. DE WET, R.N.
 C. IRONSIDES, G.M.

20. *Observatious on Natives, Animals, &c.*
 W. J. C. SLOCOMBE, Ordinary Seaman.
 G. WHITTINGSTALL, Ordinary Seaman.
 F. BEAL, Ordinary Seaman.

21. 6-*inch Equatorial with Grating Spectroscope.*
 Sir NORMAN LOCKYER, K.C.B.
 Professor A. PEDLER, F.R.S.
 Mr. R. C. STEELE, Gunner, R.N.
 P. ROSS, Ch. E.R.A.
 G. VANSTONE, Ch. E.R.A.
 H. BROWN, Ship's Steward's Boy.

22. *Meteorological Observations.*
 Mr. JOHN ELIOT, C.I.E., F.R.S.
 J. RUSSELL, Chief Stoker.
 C. BUTT, Leading Stoker, 1st Class.
 H. ROCKETT, Stoker.
 A. WALLACE, Stoker.
 G. PRATT, Stoker.
 H. WALLBURN, Stoker.
 J. BARTLETT, Stoker.
 T. McCARTHY, Stoker.
 E. PERRY, Stoker.
 G. WOOLSTON, Stoker.
 G. GARRARD, Stoker.
 C. MINTRAM, Stoker.
 P. KEEFE, P.O., 1st Class.

Aides-de-Camp to Sir NORMAN LOCKYER, K.C.B., F.R.S.
 Mr. W. H. P. BOURNE, Midshipman, R.N.
 J. HUNT, P.O., 2nd Class.

Integrating Spectroscope.

This instrument was intrusted to Lieutenant G. C. QUAYLE, R.N., the Navigating Officer, who reports as follows :—

"This instrument was erected in the same hut as the coronagraph, and was also fed by the same mirror. It was placed in a horizontal position, bearing S. 70 E., and secured on to a flat board resting on three packing cases filled with stones, the packing cases standing on solid cement bases.

"Three exposures were made—

1st,	15 secs.	127–112
2nd,	90 ,, ...	107–17
3rd,	8 ,, ...	12–4

"This instrument was worked by myself and two assistants, one as exposer and one as timekeeper."

To this it may be added that the instrument had two prisms each, with an angle of 60°, and faces $2\frac{7}{8} \times 5$ inches, and they were set to minimum deviation for H_γ. The focal length of the collimating lens was 72 inches, and its effective aperture $2\frac{7}{8}$ inches, so that a part of the sky, a little more than two degrees in diameter, would be embraced.

Light was reflected into the slit by the mirror of a 12-inch cœlostat kindly lent to the expedition by Dr. A. A. COMMON.

The collimator being horizontal, it was set to the bearing S. 70° E. corresponding to the bearing of the sun at rising. Some little trouble was experienced at first with the driving clock of the cœlostat, but owing chiefly to the skill of Engineer MOUNTIFIELD and W. HOLMES, engine-room artificer, it was made to work very satisfactorily a few days before the eclipse.

The adjustments of the instrument were thoroughly tested by Mr. FOWLER on the morning of the eclipse during the partial phases, and successful photographs were taken; but although the three exposures were duly made during totality, no results were secured.

There is reason to fear, however, that the slit was closed before totality, so that we are left in doubt as to the efficiency of a photographic integrating spectroscope.

The Coronagraph.

Staff-engineer KERR reports as follows:—

"During totality five photographs were taken by this instrument. Throughout this time the plates were inserted and exposed continuously, the insertions being as rapidly effected as possible.

"Commencing at totality, the first exposure lasted 5 seconds, the second was a 'snap,' the third lasted 75 seconds, the fourth occupied 22 seconds, the fifth and last was a 'snap' made at 5 seconds before the end of totality.

"Attention to instrumental details precluded observation of the totality phase of the eclipse before and after taking the third photograph, but, during the liberal interval afforded by the comparatively long exposure for the latter, a good view of the eclipse was obtained."

The plates employed were as follows :—

(1.)	MAWSON'S "Castle"	5 seconds.
(2.)	EDWARDS' "Snap Shot" (isochromatic) .	Instantaneous.
(3.)	,, ,, ,, . .	75 seconds.
(4.)	Lumière. Series A	22 ,,
(5.)	,, ,, ...	Instantaneous.

The plates were developed with pyro-soda very shortly after the eclipse by Mr. TURNER and Mr. FOWLER, and very successful results were obtained. Numbers 1, 2, 3, and 4 are reproduced in Plate 5.

The orientation of the photographs may be readily derived from fig. 3, showing the orientation of the sun's image in the cœlostat mirror from calculations made before the eclipse by Mr. FOWLER.

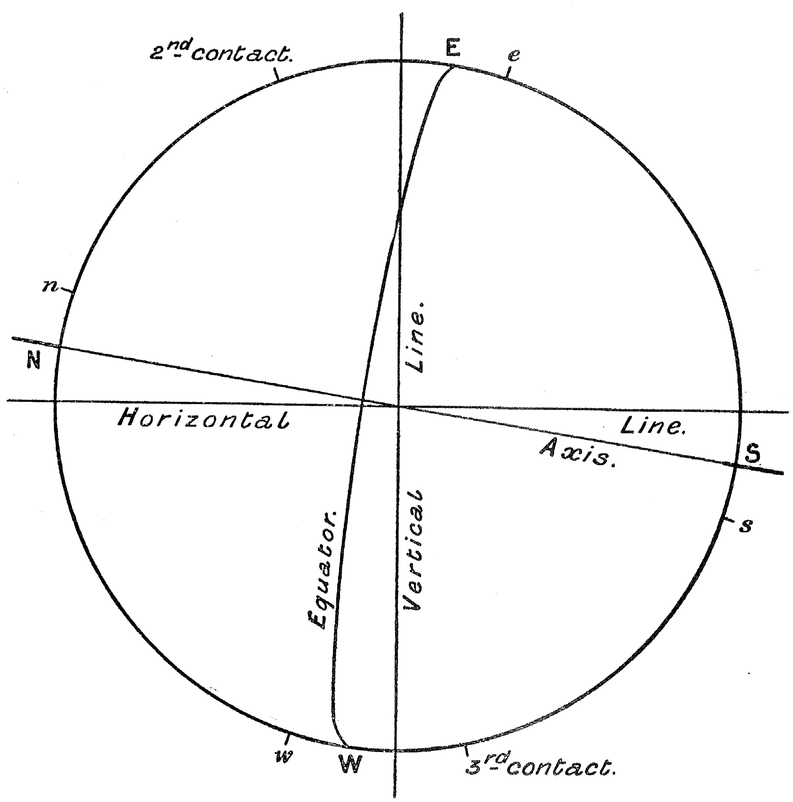


Fig. 3. Orientation of Sun's Image in Cœlostat, reflected along a horizontal S.E. line.

(*n. s. e. w.* = north, south, east, and west points.) N. S. E. W. = points where Sun's axis and equator meet the disc.

Comparing the two shortest exposures with the longer ones, it appears that the brightest parts of the inner corona shown by the former have no obvious connection with the long streamers shown in the latter, and, as was pointed out in Sir NORMAN

LOCKYER's preliminary report,* the green coronal image depicted by the prismatic cameras corresponds very closely with the image of the inner corona.

Discs.

The arrangement introduced by Professor NEWCOMB in 1878, in which a circular disc is used to protect the eye from the glare of the inner corona, was adopted to facilitate the search for faint extensions of the corona.

The six discs were manned by eighteen volunteers. Of each party of three, one was pointer, one was observer, and the third the writer. A convenient seat being arranged for the observer from which he could comfortably get the disc and sun in line through his eyepiece, he made way for the pointer, who kept the eyepiece in line with disc and sun until the last moment.

On the "Alert" being sounded at ten minutes before totality, the observer was blindfolded, and the bandage was only taken off 10 seconds after totality commenced. He then dictated what he saw, taking the most delicate and faintest effects first, and afterwards going round the moon's disc clockwise to ensure nothing was omitted.

After the eclipse was over, the observers, with the aid of the notes, made a sketch from memory.

The observers had been selected from volunteers, and had been trained from the 5th of January, a period of seventeen days. The method of selection and training was to show on the screen a slide of a corona from a previous eclipse, and allow duration of totality for copying it, and a few minutes after the slide had been removed for touching up from memory.

Lieutenant QUAYLE, who adjusted the discs, reports as follows:—

"The discs varied in size from 6 to 2 inches, and were made of thin wood, painted a dead black. Six discs were used, placed at from 40 to 15 feet from the eye, and covering from 7 to 3 minutes of arc.

"As the altitude of the sun at the time of eclipse reached 53°, some difficulty was at first experienced in finding a suitable site so as to give the necessary elevation, but eventually the inner wall of the fort was selected, and out of a varied collection of spars, uprights were chosen; these were either driven into crevices in the wall, or fixed with staples and lashed.

"The correct position of each disc was obtained by means of a sextant, prismatic compass, and a measuring tape.

"The eyepieces were suspended on cross-bars, lashed between two uprights about 3 feet apart, thus giving a considerable horizontal motion, the eyepieces themselves supplying the correction for altitude. Lieutenant COLBECK assisted in erecting the discs."

In order to simplify the orientation, the vertex or "top" of the sun was to be

* 'Roy. Soc. Proc.,' vol. 64, p. 40.

read as north, the "bottom" as south, while the right and left were to be read as east and west respectively, as in ordinary maps. The lengths of the streamers were stated in terms of the diameter of the disc employed in each case.

The Superintendent of the Trigonometrical Branch Survey of India very kindly forwarded six photo-zincographed cards conveniently designed for sketches, and these were used by the disc observers. Each observer was provided with a written form containing the following questions:—

(1.) Longest streamer—
    Length in diameters of disc =
    Bearing =
(2.) Is there a streamer in S.S.W. ?
(3.) ,, ,, ,, N.N.E. ?
(4.) What do you see in N.E. quadrant ?
(5.) ,, ,, S.E. ,,
(6.) ,, ,, S.W. ,,
(7.) ,, ,, N.W. ,,
(8.) What are your impressions as to colours ?
(9.) General remarks.

The records of the observers are sufficiently accordant, but it is not considered necessary to give the details of the observations and drawings, as nothing was noticed which was not photographed.

It is somewhat remarkable that even the longest streamer was only traced to a little more than 2 diameters by any of the observers who were provided with discs, while Sir NORMAN LOCKYER, Mr. FOWLER, and Dr. LOCKYER agreed in estimating it at not less than 4 diameters.

The most important result, however, is the absence of any record of faint equatorial extensions.

Sketches of Corona, without Discs.

Lieutenant DUGMORE reports as follows:—

"The corona party, consisting of ten men, was selected during the 'Melpomene's' passage to Viziadrug from Colombo, and from January 14th to the day of the eclipse they were instructed daily, making sketches in the limited time during which totality would last, viz., 127 seconds, from paintings of past coronas, until they attained a high degree of proficiency. These drills were carried out by exposing the paintings on a screen, and while the timekeeper called out every ten seconds, the men made their sketches.

"For the eclipse the party was stationed close to the meteorological shed, and each man was provided with a large sheet of pasteboard with a disc to represent the moon, and concentric circles of one moon's diameter each marked on it, and also the lines to divide the quadrants. One man, W. PARKHURST, A.B., used the ship's long-distance telescope, and made a sketch of the whole corona. Another man also made a general drawing of the whole corona, using the naked eye only; whilst, of the remaining eight, two sketched each quadrant."

Most of the sketches are excellent, but as they give no certain indications of details which are not shown in the photographs, it is not considered necessary to reproduce them.

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

This telescope was used by Sir NORMAN LOCKYER to observe the exact time of second and third contacts to give the signals "Go" and "Over" to the timekeepers. A diagonal eyepiece was employed, in which a silvered reflecting surface could be substituted for one of plane glass by the simple operation of sliding a frame containing these reflectors. For the first 50 seconds of totality he employed this instrument to minutely observe the structure of the rifts and streamers. In his absence the instrument was used by Assistant Engineer H. H. WILLMORE for the examination of the structure of the corona. Mr. WILLMORE took down the notes of Sir NORMAN LOCKYER'S observations which are included in his report which follows:—

"From 127 seconds to 70 seconds Sir NORMAN observed through the telescope, and I took the following notes at his dictation:—

> "'Distinct structure at poles; many brilliant prominences; much curvature; long horn as in 1896 eclipse; tracery at both poles quite exquisite; four distinct streamers, one of three diameters.'

"At 70 seconds I took Sir NORMAN'S place. The corona appeared very different from anything I had seen in books, appearing more homogeneous and less well-defined in its various parts than any of the illustrations I had practised with. At the solar poles plume-like structures of great beauty were observable, intercepted by darker curved rifts. The inner corona was discernible from both the chromosphere and the outer corona, which latter appeared less bright. I particularly noticed a very bright prominence jutting out at the lower right-hand portion of the sun's limb. The outer corona in its main features appeared to consist of four long conical streamers. I could discern no difference in the structures of these streamers. At 17 seconds Sir NORMAN again observed up till the expiration of totality.

"For some 5 seconds after third contact the corona appeared to lose hardly any of its beauty or brilliance. Then it slowly faded, commencing from its more remote portions towards the sun's limb, this phenomena taking another 3 or 4 seconds."

Observations of Stars during Eclipse.

Lieutenant BLACKETT reports as follows on the drills and actual observations :—

"The star observation party consisted of six observers, in my charge, making seven in all. It was found more convenient to tell them off in different parties, as follows :—

"*Lieutenant in charge.*—To make a hasty sketch of the whole, noting times of appearance and disappearance of planets only.

"*Two observers.*—To take eastern semicircle.

"*Two observers.*—To take western semicircle.

"*Two observers.*—To observe stars near the sun.

"The party was supplied with star atlases and photographic copies of a chart showing the stars (from mag. 1 to 4) and planets which would be in the sun's vicinity during the eclipse.

"After some drills with stars, such as making correct drawings of the different constellations (Orion was found a good subject, the three stars in the belt being used as a base to work on), the observers were found to be quite efficient.

"For the actual eclipse, charts on a larger scale were used and nailed to boards, stars being marked down as they appeared or disappeared. These charts were photo-zincographed at the office of the Trigonometrical Branch, Survey of India, Dehra Dun, and were found handy and most useful.

"It was found that the best position for observing the stars, the sun being at an altitude of 53°, was to lie down full length, the sailor's hat or a round helmet being held up and used to screen the eyes from the bright rays.

"Only a few stars were visible, all of which appeared on the western side of the sun.

"*Venus* was noted particularly both before and after totality, and was the first of the planets to appear and the last to disappear, being seen altogether for 20 minutes.

"*Mars* was visible for a short time during totality, and then disappeared.

"*Mercury* was not seen.

"α and β *Capricorni*, though close to the sun, were not visible.

"θ *Aquilæ*, much higher up, came out before totality for a short period, and then as suddenly disappeared, and was not seen again.

"λ *Aquilæ* appeared and disappeared in the same manner and time as θ, but appeared again, was visible for a short time, and then disappeared.

"*Another star* was seen by all the party, some of whom seemed to find a difficulty in locating it on the charts. It is placed on the chart as being midway between Venus and Mars by two of the observers, and marked as π Sagittarii by the other five; it was seen only for a short time, and that before totality. This star was about second magnitude.

"It is to be noted that the stars that appeared before totality disappeared, as far as could be judged, at totality. No stars except Venus were visible for any length of time after totality. All the observations were made with the naked eye."

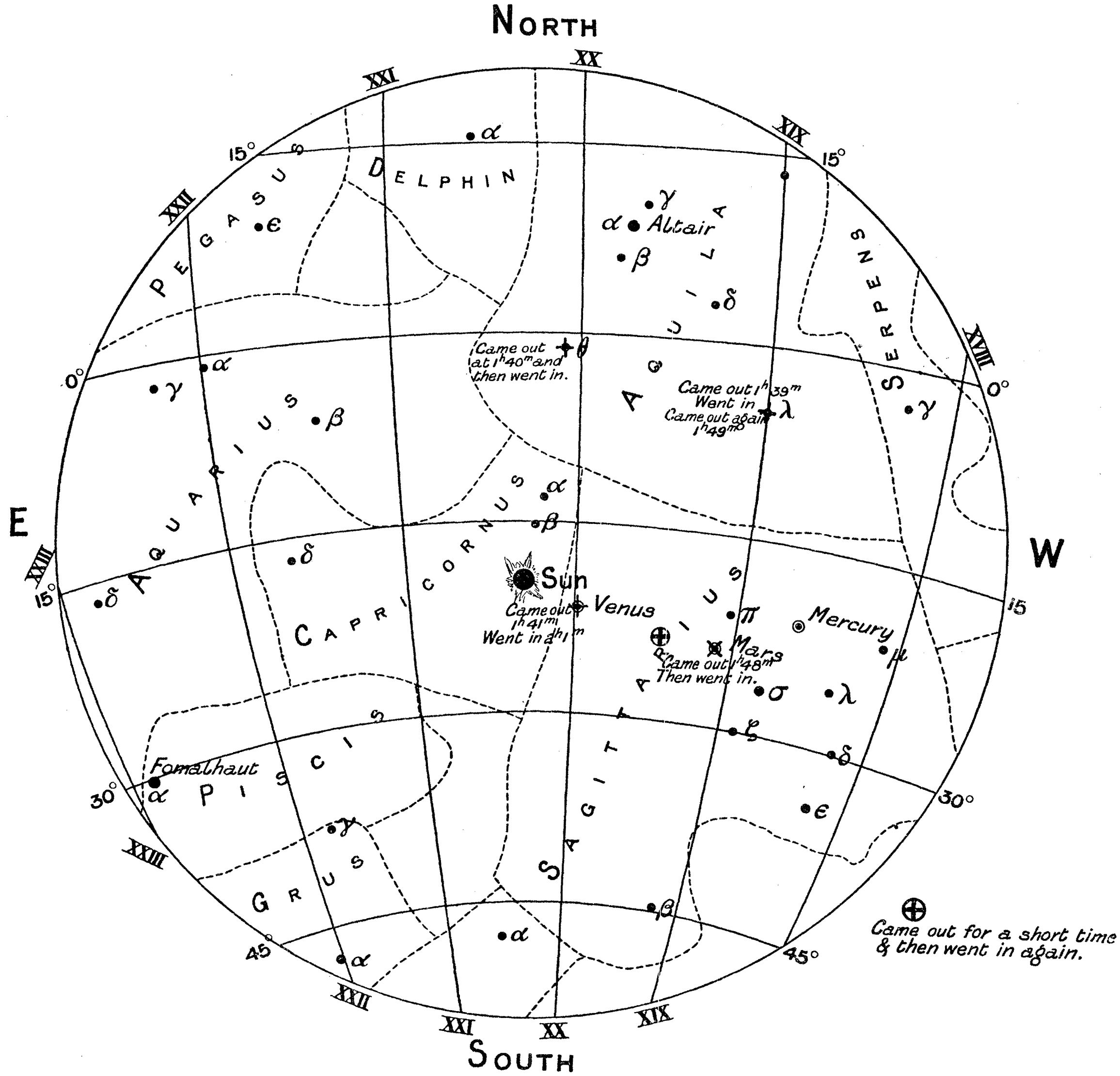


Fig. 4. Chart showing Stars in Sun's vicinity and the Stars actually observed during the Eclipse.

The observations of stars may be conveniently expressed as follows :—

Name.	Appearance.	Disappearance.	Reappearance.
λ Aquilæ . . .	8 m. before totality	Shorly afterwards	At end of totality
θ Aquilæ . . .	7 m. ,, ,,	,, ,,	
Venus	6 m. ,, ,,	12 m. after end of totality	
Mars	1 m. after beginning of totality	Shortly afterwards	
?	Seen only for a short time before		

It thus appears that more stars were seen just before the commencement of totality than during the actual period of totality; that is, they were logged as disappearing just before the total phase commenced. A similar observation was made by Admiral DON ULLOA in the eclipse of 1778.* The body seen between Venus and Mars was certainly not a star, although its behaviour was similar to that of θ Aquilæ. Sir NORMAN LOCKYER has suggested that it may have been a collision of meteor swarms in the sun's neighbourhood.

The chart summarising the observations of stars is reproduced on a small scale in fig. 4 (p. 171).

Hand Spectroscopes.

Three small integrating spectroscopes were provided for eye observations. Two of these were direct-vision pocket spectroscopes, while the third was an ordinary prism of 30° attached to the end of a tube about 10 inches long, which was provided with a slit at the other end.

Lieutenant COLBECK was in charge of these observations, and the preparatory work consisted of observations of the spectra of various salts when burned in a spirit lamp flame, in addition to joining in the general drills.

Sir NORMAN LOCKYER has examined the records, and suggests that Lieutenant COLBECK's observation at 25 seconds before totality possibly indicates a faint continuous spectrum, with the hydrogen C and F bright. Further, that the lines seen during totality were probably:

Yellowish-green, seen by three observers	—	Corona line.
Blue ,, ,, ,, ,,	—	Hydrogen line (F).
Red, seen by one observer	—	He 7065·5. He 6678·2. Hydrogen line (C).
Yellow ,, ,,	—	Helium line (D_3).
Green ,, ,,	—	Mg group (*b*). Iron, 5018.

After totality the Fraunhofer lines reappeared in the following order:—

Line in the orange (D).
Lines in the green (? *b*, *e*).
Lines in the violet and blue (? F, G).

Prisms for observation of Ring Spectra.

These observations were chiefly intended to supplement the photographic work of the prismatic cameras, by providing a record of the phenomena in the green and

* 'Phil. Trans.,' 1799, p. 105.

red part of the spectrum. Two of the chief questions on which such observations might be expected to throw light were (1) whether the green ring image of the corona corresponded with the outline of the corona; (2) whether hydrogen was present or absent from the corona, as indicated by the presence or absence of a coronal ring at Hα.

In addition to the visual observations, an experiment was made as to the efficiency for photographic work of a small camera fitted with a transmission grating.

Senior Engineer MOUNTIFIELD, R.N., who was in charge of this work, reports as follows:—

"The instruments used in these observations were five in number, and consisted of (1) A direct-vision hand spectroscope-prism section only of about $1\frac{1}{4}$ inch diameter, giving a spectrum of about 10° visual angle.

"(2) A 'meteor spectroscope' of about $\frac{3}{4}$ inch diameter, giving a spectrum of about half the length of the first.

"(3) A prism with a refracting angle of 60°.

"(4) and (5) Prisms with refracting angle of 45°.

"Instruction was given during the 14 days preceding that of the eclipse, the general nature of continuous and discontinuous spectra explained and illustrated by means of small, straight, and circular slits in tinfoil placed before the flame of a spirit lamp, and observed through the instruments to be used.

"The probable variations in the actual spectrum to be observed were also explained.

"The observers were instructed to note specially shapes which appeared to be repeated in different parts of the spectrum, and the number of parts in which they were repeated.

"The actual observations were commenced at 12.30, local mean time. Each observer was provided with an assistant, who noted down on a form, ruled in columns —one for each 10 seconds of totality—what was seen.

"At the commencement of observations, the greatest breadth of the sun's crescent was about one-sixth of its diameter, and only a bright continuous spectrum could be seen.

"My own observations were as follows:—At 12.33 the crescent had become so narrow that two curved dark lines appeared faintly in the red.

"Other lines soon appeared, and gradually increased in distinctness, until about 12.43, when those in blue and green began to disappear, followed by yellow, green, orange, and red in the order named. No dark lines were distinguishable by me half a minute before totality.

"At the commencement of totality a number of bright arcs flashed out suddenly —the number could not be estimated reliably, but two arcs in red, one in yellow, one in greenish-yellow, one in green, and one in blue were noted.

"In from 1 to $1\frac{1}{2}$ seconds these had faded, leaving a few irregular bright arcs. These consisted of a patchy arc, extending over about 150° of the sun's circumference, on the N.E. Nearly continuous, but varying in height from about 1′ to $\frac{1}{2}$′, broken near the equator, continued on the S.E., where there was a peculiar whorl-shaped prominence about 2 feet in height. This was shown complete in two red, one orange, and three yellowish-green images (close together). In two greenish-blue images and one blue one, patches only of these arcs were observed, very disconnected in the north-east, and only slightly more continuous in the south-east, where the arcs were broadest, thus appearing to consist of the bases of the greater projections. The yellowish-green arcs were very bright, the red somewhat less so, the remainder being relatively faint. The red arcs appeared to be the most complete, the yellow-green slightly less so, the orange still less continuous, the blue and others very incomplete.

"At about 65 seconds after the commencement of totality, rings were observed, discontinuous, but extending round the whole of the sun's circumference, of the same general character as the arcs before mentioned, but slightly larger in diameter. Two rings in the red appeared broader and more regular than the rest; three in the yellowish-green, very close together, were brighter, but not so extended as the first; and one in the orange was much less complete and fainter, but similar in shape to the red and yellow-green. These rings were represented in the greenish-blue and blue by only a few isolated patches, principally in the north-east.

"Seventy seconds after the commencement of totality, these rings had disappeared on the east side, leaving arcs surrounding the west side, similar in appearance, omitting the whorl-shaped prominence, to those first observed. These arcs gradually became broader and more connected, the blue and green-blue becoming nearly continuous.

"Two minutes after commencement these rings were all much more connected and broader, while preserving their relative breadth and brightness.

"About 125 seconds after commencement a number of bright arcs suddenly appeared, covering the structure of the arcs previously described. The number seen might be estimated at about twenty, but this is not considered reliable, as the arcs rapidly faded; in about one second they were obscured by bright continuous spectrum.

"In half a minute two dark lines appeared in the red, one in the orange, a broad one in the yellowish-green, one in the green-blue, and one in the blue, gradually becoming broader and losing definition until five minutes after totality, when they were not distinguishable.

"During the whole period of totality, a continuous spectrum was observed, faint at the ends, but increasing in brightness about the yellow and green, where it was nearly half as bright as the bright arcs observed in that part of the spectrum. No details of structure were observed in this spectrum, but its width was about twice the apparent diameter of the sun.

"No bright arcs were observed before or after totality.

"The records of the other four observers are similar, though somewhat less complete. The appearance of dark Fraunhofer arcs as the crescent became thinner, their replacement by light arcs at the commencement of totality, the change of the arcs from the east to the west side, and the reappearance of dark arcs was noted by all.

"The half-plate camera, with diffraction grating, was manipulated by G. GRAY, chief stoker. It was supported on a stand near the finder of the 6-inch prismatic camera, a portion of the light from the siderostat of that instrument being intercepted and reflected into the lens of the camera by a right-angle prism. A photographic diffraction grating was fitted to the front of the Cooke lens of the camera, and the whole was so arranged as to show three orders of the spectrum above and one below the image of the sun. Ordinary plates were used, as isochromatic ones of the proper size were not available. The exposures were made by means of a sliding shutter fitted in front of the grating. Four plates were exposed, with varying exposures, namely, 10 secs., 65 secs., 15 secs., about $\frac{1}{4}$ sec. For all the exposures $F/A = 6{\cdot}5$."

Remarks by Sir NORMAN LOCKYER.

In discussing these observations, it is important to distinguish between rings produced by the light of the corona and those produced by the succession of prominences which surround the dark moon. An examination of the photographs taken with the prismatic cameras shows that the conditions with regard to the visibility of the chromosphere and prominences were as follows :—

During first 30 seconds of totality. .	Chromospheric arcs in N.E., prominences in S.E., N.W., and W.
During next 60 seconds	No chromospheric arcs visible, but the succession of prominences appear as dotted rings.
During last 30 seconds of totality . .	Chromospheric arcs in S.W., prominences in S.E., N.W., N., and E.

The green ring of the corona was visible throughout totality, and must have been visible to all the observers. Its variation from the fragmentary rings, due to chromosphere and prominences, however, appears to have almost escaped notice. None of the observations suggest the presence of a red coronal ring, so that there was no indication of hydrogen in the corona.

The flashing out of bright lines at the commencement and end of totality was observed, and also the spectrum of the chromosphere and of the largest prominence. The lines seen in the latter were probably as follows :—

In red .	He 7065 or 6678. H_α (C).
Orange .	He (D_3).
Yellowish-green	Enhanced Fe 5316·79 (1474 K). "Cool" Fe (E). Mg (2).
Greenish-blue	Enhanced Fe 5018. ,, ,, 4924.
Blue . .	H_β (F).

The appearances described by Mr. MOUNTIFIELD in the middle of totality were clearly due mainly to the fragmentary rings of prominences which were then visible, and do not represent the spectrum of the corona. The observations do not give any information as to the relation of the green coronal ring to the form of the corona, but information on this point is given by the photographs taken with the prismatic cameras; these show that the green ring resembles in form the inner corona, and has little or no relation to the longer streamers. The photographs taken with the small camera show the principal chromospheric and prominence lines very distinctly in two orders of spectra, representing on a small scale what was photographed with the larger instruments. No. 2 is especially interesting, as showing in one of the first order spectra a well-defined coronal ring, more refrangible than K, which is probably identical with the line recorded by Captain HILLS at λ 3801. Traces of other coronal rings are also seen. The first order spectrum of No. 3 shows an arc of the coronal ring λ 4231 in a position corresponding to the north-western limb of the sun.

The Polariscope.

The instrument employed for observations of polarisation phenomena was that used by Sir NORMAN LOCKYER in India in 1871. It consists of a telescope having an object glass 1·4 inches in diameter and 14 inches focus, with a double eyepiece; one contains a Savart and the other a biquartz. A simple rotation of the eye end sufficed to readily bring either of the eyepieces into position. The eyepiece of the biquartz, which was alone employed, gives a magnification of about nine times, and a field of about two degrees diameter. Dr. NOLAN states his results as follows:—

"With the junction of the crystals vertical the corona was seen of a uniform bright silvery-steel colour; the large streamer in the S.W. was followed to its end; it became less bright and distinct from the centre. At E.S.E. a prominence was noted, bright glowing red. The interspaces were seen of a dark leaden blue, and were uniform.

"On rotating the crystals through 180°, no change of colour was noted; the contrast between the colours of the streamers and rifts became more marked, and an increase of intensity in the colour of a rift between N.W. and N.N.W. was noticed. Colours, chiefly violet, were noted in the S.W. just at the end of totality."

Landscape Colours.

Lieutenant DUGMORE has supplied the following statement as to the work in this section :—

This party consisted of six—one officer and five men—and was exercised every day from January 12th to January 21st inclusive.

The period during which the landscape most resembled the landscape of an eclipse was between 5 and 10 minutes after sunset, and this was the time selected each day for practice.

For the eclipse four of the party were stationed on a small hill inside the Fort of Viziadrug, and one of them was told off for each quadrant of the horizon, while the other two made notes of landscape in all directions from the "Melpomene."

At the beginning of the eclipse little change took place in the appearance of the landscape. It gradually grew darker till about 5 minutes before totality occurred, when it appeared as in a very bright moonlight night, and continued so up to the instant of the commencement of totality. Then the land became a dense black colour, except the distant hills, which assumed a delicate neutral tint. The heavens darkened to a very deep blue; the sky by the horizon became pink and yellow, with bright blue above the streaks, except in N.W., where a neutral tint appeared under a yellow streak. The sea changed from a bright greenish-blue to a rich dark blue, except the calm spots, which were of a very pale blue tint. The wind changed from east to west at about 8 minutes before totality, it being almost calm during the phenomenon. There were no clouds.

Landscape Cameras.

A number of ordinary cameras being available, it was determined to utilise them in attempts to secure records of a variety of phenomena.

Mr. A. W. TURNER, the photographer sent down by the Survey Office at Calcutta, undertook to give the men the necessary instruction, and himself took charge of one of the instruments.

A 10″ × 8″ camera was placed in position to photograph the corona by using a spare part of the cœlostat mirror, a small diagonal mirror being introduced so that the camera did not interfere with the coronograph and integrator. Two exposures were made by Mr. TURNER during totality, one with an exposure of 100 seconds, and the other with an exposure of 20 seconds. The long exposure gave an excellent result, the great streamer in the south-west being depicted through a distance of three lunar diameters.

A 5″ × 4″ camera, with Zeiss lens, operated by J. COLLINS, Chief Stoker, was also utilised for photographs of the corona. This was fixed in a convenient position, and had no arrangement for following the sun during exposure. Three exposures of 15 seconds each were made during totality, and one photograph shows very clearly the form of the corona and the relative lengths of the four streamers. On this negative the diameter of the sun is 0·05 inch, and the longest streamer, in the south-west quadrant, extends 0·25 inch from the moon's limb. Photographically, therefore, this streamer was five lunar diameters in length. Another exposure of 10 seconds, 5 seconds after totality, shows the crescent strongly solarised, and a faint representation of the corona on the opposite side.

A 5″ × 4″ folding Kodak, operated by J. KEARNEY, Leading Stoker 1st class, was set in a position to include the corona and a portion of the wall of the fort in the field of view. Three exposures were made for periods of 20 seconds each. The first began just after totality had commenced, and gives a good representation of the corona—the two longest streamers extending only one lunar diameter. The second photograph shows clearly the lower corona, notwithstanding the fact that part of the sun had begun to appear. During the third exposure the camera was slightly shaken, so that the image is duplicated.

Two cameras fitted with instantaneous shutters were set up with the view of photographing the shadow passing over the landscape in case its boundary should be sufficiently well defined. One was a $7\frac{1}{2} \times 5$, and the other a half-plate, and they were operated respectively by E. GYNGELL, A.B., and H. CHILDS, Chief Stoker. It turned out that the shadow on its approach appeared very gradually, so that the plates exposed simply resulted in under-exposed photographs of the general landscape with no features of interest.

The images of the sun seen inside the various observatories which were covered with matting were so striking throughout the preparations that it was decided to attempt to photograph them during the partial phases of the eclipse.

A quarter-plate camera for this purpose was accordingly placed in charge of E. CROSS, Leading Stoker 2nd class. A bamboo screen was erected, with its plane roughly perpendicular to a line directed to the sun, and behind this a white cloth was spread to receive the images. Three successful exposures were made with this instrument.

Shadow Phenomena.

The party which was organised for the observation of the shadow phenomena other than the "shadow bands" was in charge of Lieutenant BLACKETT, who reports as follows :—

"The observers state that the approaching shadow could not be seen, though carefully watched for. During totality the boat with mast and large flag could scarcely be seen; it was anchored 2 miles off, and the height of the eye above sea-level was 70 feet.

"The darkness at totality was of about bright twilight. A cool westerly breeze came in suddenly, which made the air chilly and the temperature fall considerably."

Observations of Shadow Bands.

Staff-Surgeon NOLAN, R.N., observed these phenomena with the help of two assistants. He reports as follows:—

"To observe these a large white tablecloth was spread on a flat piece of ground, and the corner of a wall which gave two planes at an angle of about 115° to each other was whitewashed. The angle of these vertical planes was towards the sun. Two square heavy rods were also provided, 3 feet long, the centre foot being painted black, the ends white. These were to indicate the direction in which the shadow-bands travelled; they were to be placed on the white sheet parallel to the direction of the bands, and their exact position afterwards determined. One, marked 'Before,' was to be used before totality, the other, marked 'After,' was to be used after. The black foot in the centre was to assist the eye in estimating the breadth of the shadows and interspaces.

The bands commenced to appear at $12^h\ 41^m\ 35^s$.
,, ceased ,, at the second contact.
,, reappeared at the third contact.
,, ceased altogether at $12^h\ 51^m\ 42^s$.

None were observed during totality, though looked for. As they continued to the very moment of the second contact, and reappeared as rapidly at the third, it was thought that possibly the darkness rendered them invisible.

"*The Direction of Travelling.*—The rods showed that the general direction of the bands before totality was to the west, and the first rod was placed pointing N. 88° W., but the direction of the course of the bands gradually veered round 40°–45° to the south, and remained in this direction for the last two-thirds, or perhaps a little more, of their duration before totality. It was also noted by Private HESTER, who was specially told off to observe the direction and place the rods, that for a few moments before the marked change in direction took place to the *south*, the bands seemed to waver and changed towards the *north* 10°–15° three or four times. The direction of the bands after totality was to N. 60° E., and was constant. The bands, therefore, for most of the time before totality, travelled in exactly the opposite direction to those after totality. This was observed on the white flame, and noted separately by three observers, S. B. S. PURKINGTON, Private HESTER, and myself. In this connection, note a short report below, given by Mr. MOUNTIFIELD, who incidentally observed the bands.

" *Rate of Movement.*—It is certain that the bands increased rapidly in speed from their first appearance to their disappearance at totality, and decreased as rapidly on their reappearance till they finally ceased. S. B. S. PURKINGTON, who was specially told off for this observation, states that they moved too rapidly for him to count them. The other two observers at the white sheet agreed. An observer who noticed the bands at another part of the camp incidentally gave their speed as 4–6 miles per hour; the exact time of this observation is not known accurately; it was within 10 minutes before totality. Mr. MOUNTIFIELD in his note below seemed to have seen two sets of shadows; these were not observed on the sheet at the time of this observation; I was employed elsewhere.

" *Width of the Bands.*—The three observers at the white sheet agreed in estimating the bands at $\frac{1}{2}$ inch to $1\frac{1}{2}$ inch broad, with one exception (see later). Also that they varied considerably, and were broadest at the commencement of their appearance and when they ceased to appear.

" *Width of the Spaces.*—The observers agreed that these were very variable, much larger, 4 to 6 inches, at the first appearance of the bands, and decreasing to totality when they about equalled the bands. At the end of totality they were small, as at the commencement of totality, and gradually increased in size until the bands were actually intermittent. At about 1 minute after totality there was a long intermittency during which a large band, about 2 inches broad, passed by itself in a most striking manner; this was noticed separately by each of the three observers.

" *General.*—The bands were described as 'narrow mottled shadows,' 'shadows of bands of flocculent wool,' 'ripples of smoke,' 'ripples of water,' &c. They appeared at times to break in two."

Note by Mr. MOUNTIFIELD.—" About 5 seconds after third contact light shadows were observed of a rippling character, comparing with waves, the crests being in a N. and S. direction, the transverse velocity about 6 miles an hour to westward. Superposed, appeared to be a much fainter series drifting eastward. Distance from crest to crest 6 inches to 8 inches. Motion was irregular, as though an oscillating motion were acting in conjunction with the onward speed of 6 miles an hour.

" In compliance with a request for further information on one or two points, Dr. NOLAN states that the bands moved in a direction perpendicular to their lengths, and that the rods were placed in the direction of motion of the bands—pointing in the direction towards which the bands travelled one after the other. In order to remove all ambiguity the accompanying sketch (fig. 5) was appended, in which the arrow indicates the direction of the rod, and the parallel lines show the direction of the bands themselves."

The following further description of the bands themselves was also given :—

" The bands were simply narrow bands of shadow, parallel to each other, and following each other like ripples on water, and seemed to slightly change their direction, as described in the report, as a whole. The shadows were observed on the whitewashed wall, as indeed they were all over the ground, but attention was confined to the sheet."

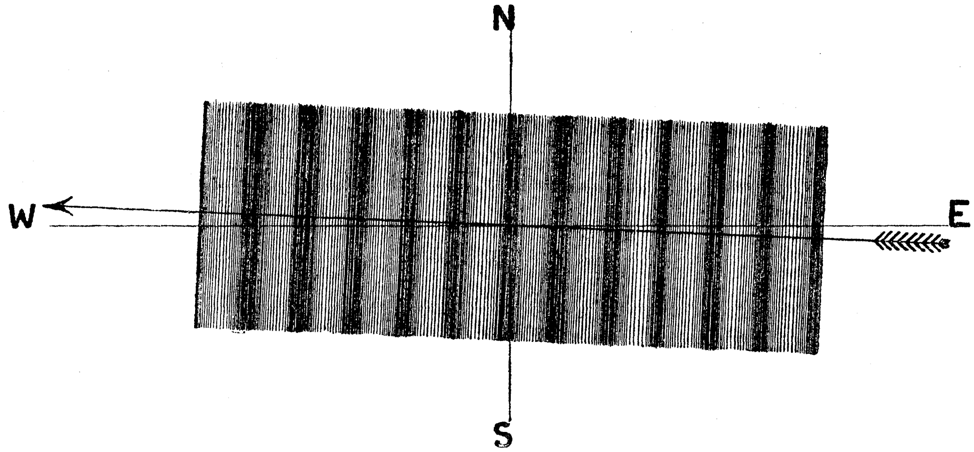


Fig. 5. Observations of Shadow Bands.

It is interesting to note further that Staff-engineer KERR draws attention in his report to the presence of shadow bands during totality, travelling in a westerly direction.

Kinematograph for Eclipse.

The Marquis of GRAHAM has drawn up the following statement with regard to the work of this instrument :—

"By the kind permission of Sir NORMAN LOCKYER and Captain CHISHOLM-BATTEN I was allowed to accompany the eclipse party as a volunteer. I therefore took out with me two kinematographs with which I hoped to secure a record of the eclipse itself as seen by the eye, and one also of the swoop of the shadow across land and sea.

"The eclipse kinematograph was provided by Mr. HILGER with a fine photographic objective 3 inches in diameter and 21 inches focal length. The shutter arrangements were completely altered in order to suit this large aperture, and this also necessitated certain alterations in the mechanism for the film. The handle gearing was altered to provide either for 'time' or 'running' exposures, and a Thornton-Pickard shutter was adapted to the lens. Finally a model cœlostat, with a 4-inch speculum, designed by Mr. FOWLER, was provided to reflect the sun's rays into the lens during the whole eclipse.

"Owing to various delays, I did not receive the instrument until December 9th, so that preliminary experiments were out of the question. During the voyage to Colombo, however, both instruments were examined, and many defects came to light. But for the timely assistance and skill of Mr. HARRIS, Chief Engineer of the

'Lusitania,' and Mr. ROBERTSON, Fifth Engineer, the whole undertaking would have been a disaster from the outset.

"A very suitable site was allotted for the eclipse kinematograph, and its erection and adjustment were proceeded with the day after our arrival at Viziadrug.

"Our plan of work was as follows:—Beginning 5 minutes before first contact, and continuing to the second contact, exposures were made at the rate of four a minute, giving 380 pictures in all. From second to third, that is, during totality, twelve exposures of 10 seconds each were to be made. At third contact exposures at the rate of four a minute were to be resumed, and continued until five minutes after the fourth contact. The estimated total number of exposures was therefore 772, which would use 52 feet of film on the scale of fifteen photographs per foot.

"On the day of the eclipse, the kinematograph was firmly screwed to the table after loading, and, as arranged, work commenced 5 minutes before first contact. About the time of contact, the shutter broke down and 10 minutes were occupied in repairing it. A little later the shutter spring broke, and again a few seconds were lost. All then went well until near the end of the eclipse, when the rubber ball of the shutter began to work irregularly.

"As I had no means of developing the films in India, they were sent to London for development by the Eastman Co. Unfortunately, probably through leakage, the film was too much fogged to be of any use for the purpose for which it was intended. At the same time, several parts of the film were clear enough to show that the exposures had been successfully made, and that the cœlostat performed its work satisfactorily. With an instrument better adapted to the climate and with more precautions for keeping out stray light, there is every reason to look with confidence for a successful result in a future experiment."

Kinematograph for Shadow.

In his general report, Lord GRAHAM further states that this instrument was provided with a new Dallmeyer lens of wide angle, and was set up on three packing cases filled with stones, resting on one of the outer bastions of the fort.

Seventy-two exposures were made, using $4\frac{3}{4}$ feet of film, but as the advent of the shadow was not strongly marked, the film possesses no feature of interest.

Contact Observations.

In addition to the telescope employed by Sir NORMAN LOCKYER for the observation of contacts, two smaller instruments, primarily acting as finders for the two prismatic cameras, were employed for a similar purpose. The telescope working in connection with the 6-inch prismatic camera was in charge of Lieutenant DE WET, and the time records of the contacts, as indicated by the chronometer, were made by Gunner's Mate C. IRONSIDES. The other instrument was in charge of Lieutenant PERCIVAL JONES, the times by a deck watch being recorded by A. WILKINS, Lieutenant DE WET reports as follows on the instrument and observations :—

"The instrument used for observing the contacts and cusps was a 2-inch telescope, which acted as finder for and was fed by the same mirror as the 6-inch prismatic camera. A screen, 10 inches in diameter, formed by pasting paper on a copper disc, was fixed inside a box in such a way that the disc could be turned round. On the paper a circle 4 inches in diameter was drawn, and also lines marking 90° and 45° of arc. This screen was placed in such a position, that, when focussed, the finder would throw an image coincident with the circle on the screen. It was calculated that the cusps would form an arc of 90° 25 seconds before totality, and an arc of 45° 5 seconds before totality, when the 6-inch and 9-inch prismatic cameras were to commence taking their series of photographs. The observations of contacts and cusps were very difficult to take accurately, owing to the excessive 'boiling' of the sun's crescent as shown on the screen, especially when nearing totality. This 'boiling' seemed to increase simultaneously with the springing up of the sea breeze.

"The observed times of contact, corrected to local mean time, were :—

1st contact . . .	21 d.	23 h.	12 m.	31 s.	Long. of Viziadrug 4 h. 53 m. 16 s. E."
90° (cusps) . . .	0	0	45	31	
45° ,, . . .	0	0	45	50	
2nd contact . . .	0	0	45	53	
3rd ,, . . .	0	0	47	57	
4th ,, . . .	0	2	14	30	

No separate report has been received from Lieutenant PERCIVAL JONES, but shortly after the eclipse a memorandum of the recorded times was made by Mr. FOWLER.

The two sets of observations, corrected to Greenwich mean time, may be summarised as follows :—

Phase.	DE WET.			JONES.			Mean.		
	h.	m.	s.	h.	m.	s.	h	m.	s.
1st contact . . .	18	19	15	18	18	50	18	19	25
Cusps, 90°	19	52	15						
,, 45°	19	52	34						
2nd contact . . .	19	52	37	19	52	36	19	52	36·5
3rd ,, . . .	19	54	41	19	54	42	19	54	41·5
4th ,, . . .	21	21	14	21	21	0	21	21	7

It will be seen that, according to Lieutenant DE WET, totality lasted 2 minutes 4 seconds, and according to Lieutenant PERCIVAL JONES 2 minutes 6 seconds.

The experience gained during this eclipse indicates that the determination of definite intervals before totality by the observation of the cusps is of great value.

Observations on Natives, Animals, &c.

Three observers were told off to note the behaviour of the natives, animals, &c., during the eclipse. The notes were collected by Lieutenant BLACKETT, who has summarised them as follows :—

"The natives, so far as was observed from the fort, were not much disturbed by the eclipse. They had been previously warned not to light fires, the smoke of which might interfere with the observations, and also not to make a noise. On the beach a few—according to a matter-of-fact observer thirteen—ran into the sea, and bathed, as is their custom on these occasions; they also set up a discordant yell for 3 minutes. It was ascertained afterwards that a large proportion of the natives retired to another beach about 3 miles away out of sight and hearing of the fort, and here, undisturbed by the local police, were able to bathe and howl *ad infinitum*.

"This district being particularly devoid of land birds, owing to the barren nature of the soil, not much was gained from observations. A few small birds twittered a good deal during the partial phase, and especially about 10 minutes before totality, but at 7 minutes before totality a sudden silence fell on them all. Some crows (*Corvus hiemalis*) were observed to roost, and martins were seen to be flying unusually high. Bats were not observed to be disturbed in any way, though carefully looked for in likely places. A few snakes came out as they usually do towards dusk."

A snake was also seen by Mr. BARNETT about 7 minutes before totality.

Lieutenant DUGMORE states that "the gulls, which seemed somnambulant soon after first contact, rose at the commencement of totality and flew off silently towards the light in the south, returning, however, in a few seconds while totality was still on, and again settling on the water, where they remained until about 45 minutes after, when they grew more lively and commenced fishing operations. The live-stock on board did not take much apparent notice."

Observations on animal life, &c., were also undertaken by Mr. E. H. AITKEN, Assistant Collector of Salt, who was good enough to supply the following notes for insertion in this Report :—

"The darkness was neither so intense nor so sudden as I had anticipated, and the effects which it produced on living things were less striking than those described in accounts of former eclipses. At 12.40 a cock began to crow, and it continued doing so at intervals till some minutes after totality was over. Up to 12.42 kites and swallows were flying about as usual, and little birds of several species were chattering. I especially noticed the toot of the little barbet, commonly known as the 'Coppersmith' (*Xantholæma*), and the shrill cry of the little striped squirrel. About 12.45 several butterflies began to settle in sheltered nooks about a haystack near me, and I saw a pair of kites plainly seeking a place to roost.

"At this time my attention was attracted by a rapidly undulating shadow on the ground. The general effect was like that produced by the shadow of hot, ascending smoke, but more regular. The undulations ran from east to west. I did not at the time note the apparent distance between them, but should say from memory that it was about half a foot. I think this lasted till put out by the darkness, but I am not sure, as I was attending more to other things.

"During the period of totality I heard the voices of birds, but immediately after it there was a striking silence for a short time. This was noticed by a friend as well as myself. Then a large number of crows which had collected to roost in one tree, after their manner, started into the air with much cawing and flew off, and in a few moments everything was going on as if nothing had happened.

"A man whom I set to watch a roosting tree of bee-eaters (*Merops*) reports that the birds gathered to the tree as the darkness came on. Another reports that the fowls in his yard went about all the time as if nothing unusual were happening. A third, who was fortunate enough to find a troop of monkeys (which I had specially directed them to look for), says that they went about feeding until the darkness came on, when they stopped suddenly and sat motionless and silent, each in its place, until the light returned."

PART III.—SPECTROSCOPIC OBSERVATIONS MADE WITH A 6-INCH SHORT FOCUS LENS AND A GRATING.

By Professor A. PEDLER, *F.R.S.*

Introductory.

The Government of Bengal, having been informed that Sir NORMAN LOCKYER, the head of one of the Eclipse Expeditions coming from England, would be glad if it could be arranged that I could be deputed to Viziadrug to help in the observations of the Total Eclipse of the Sun, permission for my deputation was very kindly and willingly given. Hence I left Bengal on January 7th, and arrived in Bombay on the 9th, but I was detained there until the 12th in connection with certain arrangements required by the Expedition.

I left Bombay on the 12th, and arrived at Viziadrug on the 13th of January.

After my arrival, Sir NORMAN LOCKYER placed in my charge the 6-inch equatorially mounted refracting telescope with a grating spectroscope attached, the Rowland grating having about 16,000 or 17,000 lines to the inch. This instrument had been erected in position under the superintendence of Mr. FOWLER previous to my arrival.

Four assistants were detailed to help in working the instrument. Mr. STEEL, R.N., was deputed to work the fine adjustments of the telescope, so as to bring the desired portion of the image of the sun on to the slit of the spectroscope. Mr. ROSS, who had helped in the erection of the telescope, was selected as time keeper; VANSOME was deputed to have charge of the lamp, and give light when required, and BROWN acted as clerk, and recorded all observations that were dictated to him.

Drills were commenced from the day after my taking over charge of the instruments, and they were repeated five or six times each day so as to give smoothness and quickness in the work, and confidence to those employed in it.

At Sir NORMAN LOCKYER'S suggestion, it was arranged that during the eclipse an attempt should be made to repeat certain observations made by him during the total eclipse of 1882 in Egypt, when what are called the enhanced lines of iron, due to iron vapours under the influence of exceedingly high temperature (as given by a powerful spark) were seen short and bright 7 minutes before totality, while 2 minutes before totality some iron lines usually found in the spectrum of sunspots (*i.e.*, due to iron vapour in a cooler condition) were observed long and thin. During totality it was also arranged to examine the spectrum of the corona, and specially to search for any evidence of the existence of carbon, iron, magnesium, hydrogen, &c.

It was arranged that the spectrum of the *first order* should be worked with, and it was of course necessary that only a portion of the spectrum should be observed. The portion selected, which was well visible in the field of the observing telescope of the spectroscope, included easily from 1474 K to beyond "F," both being well within the field of view.

The Reference Spectrum.

Previous to the instrument being brought out from England, some excellent photographic reference spectra had been prepared by Mr. FOWLER under Sir NORMAN LOCKYER'S direction, and these showed the bands of carbon, the quartette of iron lines rather less refrangible than F, the triple magnesium lines *b*, and also F very distinctly. This reference spectrum was fitted into the eye-piece of the observing telescope of the spectroscope, and the lines acted as the means for absolutely identifying these elements should these lines be visible in the corona, and also were used for reference to decide the position of any other lines which might be observed in this part of the spectrum.

Programme of Work.

The spectroscope being rigidly attached to the telescope, it had to remain in one position in relation to the telescope throughout the time of observation during the eclipse. Hence the following was the programme of work adopted for the eclipse, and this programme was practised daily in the numerous drills before the day of the eclipse.

At 25 minutes before totality, the image of the crescent of the disappearing sun was to be thrown by Mr. STEEL, R.N., on the slit of the spectroscope, so that the north edge of the sun was on the slit, and the cusp just cut the slit, which was placed almost perpendicularly to the limb of the sun. The cusp was then kept by the driving clock and by the use of the fine adjustments by Mr. STEEL on the desired part of the slit until the call of "totality." During this period the time keeper, Mr. ROSS, was to give the time, calling 10, 7, 5, 3 and 1 minutes before totality, so that BROWN, the recorder, could note the time against every observation which was made by myself at the observing telescope, and dictated to him.

At the call of "127 seconds," or the commencement of totality, Mr. STEEL was to work the fine adjustments of the telescope to bring the slit of the spectroscope gradually round the edge of the dark moon, and to place the slit tangentially to the east of the equator of the sun at a distance of about one-twelfth to one-tenth of the diameter of the dark moon from its edge. A card with lines marked on it at fixed distances was placed over the slit of the spectroscope to enable this position to be judged with considerable accuracy. This one-tenth to one-twelfth of the diameter of the moon was taken to the position of the "*inner* corona."

Thirty seconds after, or at 97 seconds call, the slit was to be moved slightly outwards from the edge of the moon, so that it was about one-sixth or one-fifth of the moon's diameter away from its edge, and this was taken as the position of the "*outer* corona."

At 67 seconds call I was to leave the observing telescope, and Sir NORMAN LOCKYER was to observe any spectrum of the outer corona from 62 seconds to 32 seconds call, and at 32 seconds call Mr. STEEL again had to move the slit on to the inner corona within about one-tenth or one-twelfth of the diameter of the moon from its edge, when Sir NORMAN LOCKYER would observe the spectrum of the "inner corona."

At the call of "totality over," Mr. STEEL was to place the slit perpendicularly on the north point of the cusp of the reappearing crescent of the sun, and was to keep it at the cusp so long as observations were required, the calls of time after totality being similar to those before totality.

Mr. STEEL did his work very successfully, and so did all the other three assistants, and BROWN took down every word I dictated to him.

The Observations made.

The following is a statement of the notes written down by BROWN during the time of observation at the eclipse. These I recopied and made complete on the afternoon of the day of the eclipse, so that no details should be lost by allowing any interval of time to elapse between the observations and their full record.

12 *hrs.* 20 *min.*—Commenced observing edge of the sun close to the point of disappearing crescent. Shortly after "F" came into view, bright and short.

12 *hrs.* 23 *min.*—" F " line bright and short. Confirmed by Sir NORMAN LOCKYER. " F " line commenced to extend over bright limb of sun, and continued well visible.

At call—10 *minutes before Totality.*—" F " bright and short, beyond the edge of moon, " F " becoming much longer; seen clearly also over the bright crescent of the sun. No other bright lines visible. " F " long and bright.

7 *minutes before Totality.*—" F " bright and shorter on faint continuous spectrum, with usual Fraunhofer lines. No other bright lines visible.

Iron lines looked for particularly, but not seen. Carbon-green bands looked for particularly, but not seen.

" F " can be seen bright on the disappearing crescent of the sun.

" F " becoming decidedly brighter.

" F " long and bright.

No other bright lines visible.

Call 5 *minutes before Totality.*—" F " bright; also distinctly bright on crescent of the sun.

" F " brighter near the sun, also bright beyond the moon. At this time the bright " F " line was again confirmed by Sir NORMAN LOCKYER, and was the only bright line seen by him.

4 *minutes* (*about*) *before Totality.*—" F " bright and long.

Magnesium (" *b* ") distinctly bright.

" F " is much brighter than " *b*."

Call 3 *minutes before Totality.*—" F " bright and long.

Magnesium (*b*) bright and long.

Magnesium and " F " continue bright and long.

From 2 *to* 1 *minutes before totality* close to point of disappearing crescent.

4871	Iron line	(ÅNGSTRÖM)	rather long and bright.
4890	,,	,,	bright.
4918	,,	,,	not clearly seen, but apparently a line at that place.
4956·5	,,	,,	bright.

Just before call of—

1 *minute before totality* I saw 4871, 4890, and 4956·5 iron lines distinctly bright at point of disappearing crescent of sun. No enhanced iron lines at 4924 and 5018 could be seen.

At call 1 *minute before totality* I reported " F " continues very bright.

Call of " *Go* " *for totality,* or 127 seconds call, the slit was removed from its former position, and placed tangentially on the " inner " corona east of equator of the sun by Mr. STEEL. In passing along the edge of the dark moon eight or nine bright lines at least flashed into the spectrum between " F " and " *b*," most of them being in the half of the field nearer to " F." They were, however, visible for only a few seconds, and appeared to " flash " in rather than remain steady, and they practically disappeared when the slit was brought to rest on the inner corona. No measurements could therefore be made with the reference spectrum. When at rest on the inner corona in the spectrum, "F" was seen long and bright; 1474 K (judged by iron lines 5323 and 5327 in reference spectrum) longer and brighter than "F," and practically filled the whole length of the slit; four, or possibly five, bright lines very feeble, very close to, if not identical with, the positions of iron quartette, but not sufficiently bright to measure very accurately, and there was not sufficient light to give very good indications of the reference spectrum. I could see no enhanced iron lines. No carbon bands were visible.

At 97 *seconds call*, Mr. STEEL put slit tangentially on "*outer*" corona east of equator, when "F" was seen long and fairly bright; 1474 K was seen long and bright; "*b*" was seen very faint, with a faint continuous spectrum. No carbon bands were visible. No iron lines were visible.

At 67 *to* 62 *seconds call*, I gave place to Sir NORMAN LOCKYER, who reported he was unable to detect any lines in the spectrum.

47 *seconds call.*—Again took my place at the spectroscope. Slit still on "outer" corona, east of equator of sun, and I reported no spectrum visible.

Afterwards, faint continuous spectrum, too feeble to make any measurements.

32 *seconds call.*—Slit placed tangentially on "inner" corona (east of equator of sun). "F" line long and bright; 1474 K line longer and brighter than "F."

Iron lines looked for, but not visible.

Carbon bands looked for, but not visible.

17 *seconds call.*—Slit placed tangentially on "inner" corona* (east of equator of sun). Only "F" and 1474 K visible.

Iron lines looked for, but none visible.

Carbon bands looked for, but none visible.

Call "Totality over."—Slit placed perpendicularly at north edge of the reappearing crescent of the sun.

"F" long and bright.

Magnesium ("*b*") rather long and bright.

No carbon bands visible.

No iron lines visible.

Call 1 *minute after totality.*—Working near the point of the crescent.

"F" long and bright.

Magnesium ("*b*") bright.

1474 K rather faint.

Carbon bands looked for, but none visible. 4871, 4890, 4956·5 (ÅNGSTRÖM) lines of iron flashed in. A bright iron line about 4956·5 of iron (ÅNGSTRÖM) distinctly bright.

* In this case the position of the slit must have been outside that occupied at the commencement of totality.

About 2 minutes after totality.—"F" long and bright.

Magnesium ("*b*") short and bright.

Call 3 minutes after totality.—Only continuous spectrum with Fraunhofer lines.

Call 5 minutes after totality.—Ordinary continuous spectrum, with dark lines "F" again coming in brightly for a short time.

Call 7 minutes after totality.—"F" bright but faint, and very short.

No other bright lines.

Only ordinary continuous spectrum with Fraunhofer lines.

Note.—The portion of the spectrum observed was from "F" to just beyond "1474 K."

It will therefore be seen that in the spectrum of the corona the arc lines of iron were seen, and also magnesium and hydrogen, together with the coronal line 1474 K, all of them bright. On the other hand, I was unable to repeat the observations made by Sir NORMAN LOCKYER in the eclipse of 1882. A further point which may be noticed is that I was able to observe distinctly the coronal line 1474 K bright beyond the cusp of the sun one minute after totality. No carbon bands could be detected at any time.

Remarks on the Observations.

The preceding observations of bright lines may be conveniently summarised as follows :—

At cusp before totality	10 min.–4 min.	F.
	4 min.–2 min.	F, *b*.
	2 min.–1 min.	F, *b*, Fe arc quartette.
Chromosphere	Beginning of totality	8 or 9 bright lines between F and *b*.
Inner corona (3′ from eastern limb)	About 120–97 secs. calls by time keeper.	F, 1474 K, and 4 or 5 feeble lines, possibly identical with iron quartette.
	Signal.	
Outer corona (16′ from eastern limb)	97–67	F, 1474 K, trace of .
	67–47	No lines seen.
Inner corona (3′ from eastern limb)	32–17	F, 1474 K.
	17–	F, 1474 K, no Fe lines.
Cusp after totality	0 min.–1 min.	F, *b*.
	1 min.–2 min.	F, *b*, 1474 K, three members of iron quartette.
	2 min.–3 min.	F, *b*.

As regards the attempt to repeat the observations of 1882, it may be remarked that the want of complete success was probably due to faintness of the spectrum as seen with a grating, and the difficulty of observing the shorter lines in consequence of the small size of the image projected on the slit. So far as they go, however, the observations are in accordance with those of 1882. Thus, at 7 minutes before totality in 1882, in the region of the iron quartette to which reference is frequently made, short lines were noted at 4924 and 4934, and at three minutes before totality only 4957 was added as a line of moderate length; these may be supposed to have escaped my notice at the corresponding intervals from totality on account of their shortness. At 2 minutes before totality in 1882 the same lines were observed with the addition of long and fainter lines of the other three members of the arc quartette at 4872, 4891, 4919, and a titanium line at 4933; with the exception of the titanium line, therefore, my observation of the arc quartette at 2 minutes to 1 minute before totality agrees, supposing that I was only able to see the longer lines.

In the chromosphere as ordinarily observed, and as photographed with the prismatic camera, the enhanced Fe lines 4924 and 5018, and the Ba line at 4934, are more easily visible than the arc quartette, and it thus results that the arc quartette as observed before totality by me in 1898 and by Sir NORMAN LOCKYER in 1882, proceeds not from the chromosphere, but from a region above it.

In connection with the observations during totality, it must be remembered that when a slit spectroscope is employed, lines may appear in the coronal spectrum which belong only to the chromosphere and prominences, on account of the light being scattered by our atmosphere.

The brightest chromospheric lines in the F–*b* region are those of iron at 4924 and 5016, and the barium line at 4934. These were, no doubt, among the lines which I observed at the beginning of totality, and are the lines which I should have seen in the inner corona if the lines noted were due to glare. As I did not see these lines, it would appear that glare was ineffective except in the case of F and *b*, and that the lines which I saw between F and *b* really belong to the corona. Here, again, we have an indication that the region above the chromosphere shows cool lines of iron, and, in connection with other lines of inquiry, this points to a region above the chromosphere as the source of some of the Fraunhofer absorption.

PART IV.—THE PRISMATIC CAMERAS.

By Sir NORMAN LOCKYER, *K.C.B., F.R.S.*

The Instruments employed and Photographs obtained.

The Instruments employed.

The success which attended the use of the prismatic cameras in the eclipses of 1893* and 1896,† led me to attempt to obtain photographs on a still larger scale in the eclipse of 1898. Two instruments were employed on this occasion,

* 'Phil. Trans.,' A, vol. 187 (1896), pp. 551–618.

† 'Phil. Trans.,' A, vol. 189 (1897), pp. 259–263.

each more powerful than any previously used. One of them had an aperture of 6 inches, and a focal length of 90 inches, with two prisms of 45° each; the other had an aperture of 9 inches, and a focal length of 120 inches, with one prism of 45°. Both were fixed, and sunlight was reflected into them by siderostats. The 6-inch instrument was placed in a horizontal position, but the 9-inch was set up at such an angle that the direction of the moon's motion across the sun was coincident with the direction of dispersion.

To obtain this result in the case of the 9-inch instrument, the position of the telescope was previously carefully calculated by Dr. LOCKYER, and it was found that to gain the desired object, the tube had to be deviated 28° to the east side of the meridian, depressed at the object glass end 24° 40′, and twisted about its optical axis 41° in the opposite direction to the hands of a watch. To secure this accurate position at the eclipse camp, suitable packing cases were chosen and special wooden tops were made, the whole being erected at Kensington previous to its departure for India. For the information of future observers, the following diagram (fig. 6), is given showing a perspective view of the method of supporting the square tube.

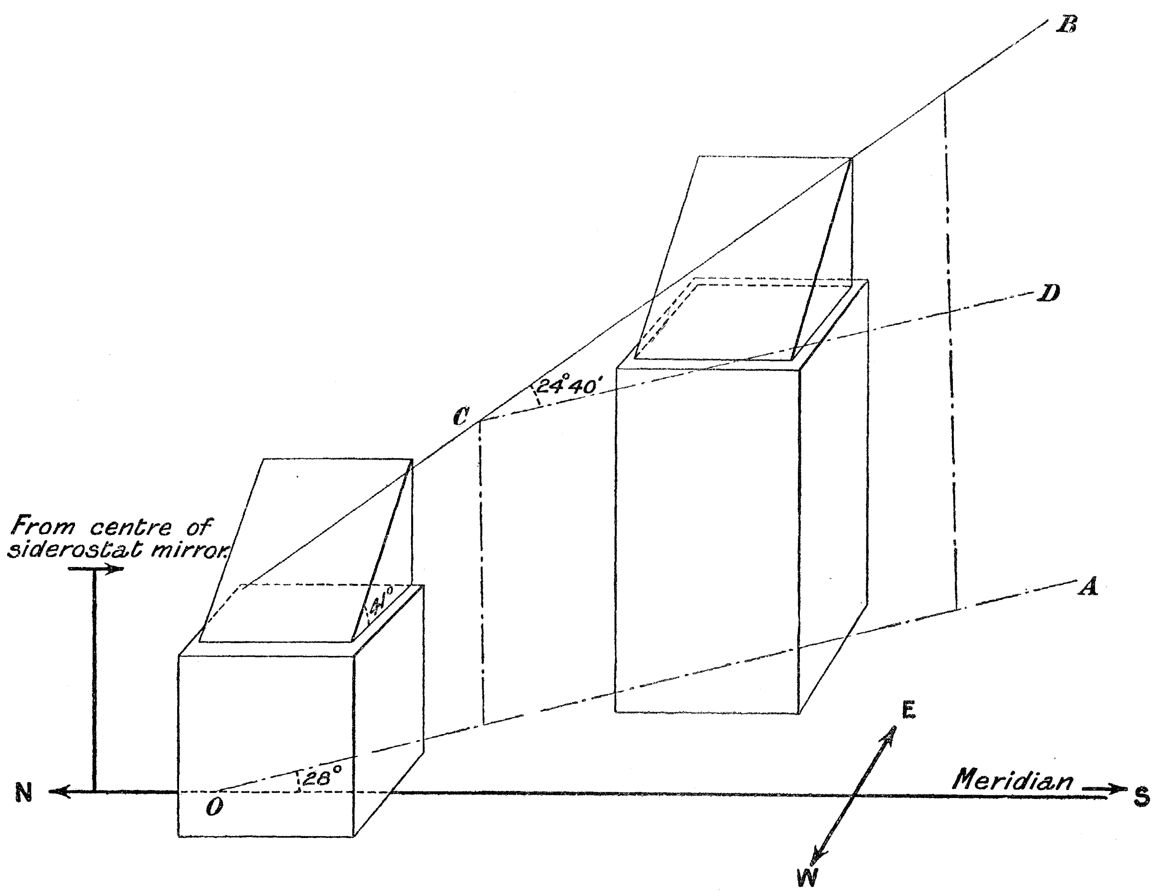


Fig. 6. Illustrating position of 9-inch prismatic camera.

In each case, some of the spare light from the mirror was utilized for a small telescope adjusted to act as a finder to the prismatic camera. The one used with the 9-inch instrument was arranged to view the image directly with an eye-piece, but that employed with the 6-inch was arranged to give an enlarged image on a white screen.

Each instrument was provided with plateholders similar to those employed in Brazil in 1893.* Four slides were used with the 6-inch, two holding plates 12″ × 10″, and two holding four plates each 12″ × 2″. For the 9-inch two of the plateholders carried plates 16″ × 6½″, and three carried three plates each 6½″ × 2″.

The instruments were focussed by taking trial photographs of stellar spectra.

Mr. FOWLER and Dr. LOCKYER, who were in charge of the 6-inch and 9-inch respectively, were each assisted by a number of volunteers from H.M.S. "Melpomene," who were distributed as follows :—

	6-inch.	9-inch.
In charge of finder and chronometer	Lieutenant DE WET, R.N.	Lieutenant PERCIVAL JONES, R.N.R.
In charge of siderostat and to make exposures	J. TURNER, I.I.	W. BRAY, Ch. Arm.
Recorder of exposures	C. IRONSIDES, G.M.	A. RAMAGE, A.B., L.T.O
To hand and receive dark slides	T. BRADING, A.B. J. INNES, A.B.	A. WILKINS, Shipwright. E. ASHFORD, A.B. F. FENTON, A.B.
In charge of lamp	E. SALT, Boy, 1st Class.	A. CARR, Boy, 1st Class.

The duty of the observer in charge of the finder was to keep the image in the centre of the field of view, which corresponded by previous adjustment with the centre of the plate in the prismatic camera; records of the moments of contact were also made.

The exposures were made by means of a piece of cardboard which was used to cover or uncover the front of the prism from directions given by Mr. FOWLER and Dr. LOCKYER respectively.

In the two prismatic cameras fifty-seven photographs were secured, the exposures varying from 1 to 50 seconds. Such a result as this could only be obtained by a minute subdivision of labour.

Local Conditions of Eclipse as affecting the Prismatic Cameras.

The small difference in the apparent diameters of the sun and moon (see Part I., p. 156) was a very favourable circumstance in connection with the work of the prismatic cameras relating to the chromospheric spectrum, for the reason that the arcs of chromosphere visible at the beginning and end of totality would be

* 'Phil. Trans.,' A, vol. 187 (1896), p. 571.

comparatively long ones. A layer 10 inches in depth, for example, would be exposed over a length of 112° at the instant of contact, and a layer 1 inch in depth over a length of 34°.

Calculations showed that, after reflection from the mirror of a siderostat along a horizontal meridian line, the north point of the sun's axis, as seen by an observer looking into the mirror, would be 7° 13′ to the left of the top of the image; the east and west points were to the right and left respectively.

It was evident then that with dispersion in a horizontal direction there would be a little overlapping of adjacent chromospheric arcs, but still it was considered desirable that in one of the instruments at least the dispersion should be arranged so as to give the arcs quite symmetrical.

Photographs taken with the 6-inch Prismatic Camera.

Mr. FOWLER's programme was to begin taking a series of ten snapshot pictures 5 seconds before the commencement of totality, to obtain a record every second or thereabouts of the spectrum of the chromosphere. After this he exposed eight other plates to secure photographs of the coronal rings, the exposures being of various lengths. It was also arranged that at 5 seconds before the end of totality he should commence another series of ten snapshots, exposing the last of these some few seconds after totality. The actual times of exposure, &c., are shown in the following table :—

TABLE of Exposures for 6-inch Prismatic Camera.

Number.	Kind of plate.	G.M.T. of exposure, A.M.	Exposure.	Remarks.
		h. m. s.		
1. *a*	EDWARDS' snapshot, isochromatic	7 52 35	Inst.	
b	,, ,, ,,	36	,,	
c	,, ,, ,,	37	,,	
d	,, ,, ,,	38	,,	
e	,, ,, ,,	40	,,	
f	,, ,, ,,	41	,,	Beginning of totality.
g	,, ,, ,,	42	,,	
h	,, ,, ,,	43	,,	
k	,, ,, ,,	45	,,	
l	,, ,, ,,	46	,,	
2. *a*	EDWARDS' snapshot, isochromatic	7 52 50 to 53 40	50 secs.	Slide changed.
b	,, ,, ,,	7 53 41	Inst.	
c	,, ,, ,,	7 53 44 to 50	6 secs.	
d	,, ,, ,,	7 53 51	Inst.	

TABLE of Exposures for 6-inch Prismatic Camera—*continued.*

Number.	Kind of plate.	G.M.T. of exposure, A.M.	Exposure.	Remarks.
		h. m. s.		
3. *a*	Lumière	7 53 58 to 54 10	12 secs.	Slide changed.
b	,, ...	7 54 11	Inst.	
c	,, ...	7 54 13 to 20	7 secs.	
d	,, ...	7 54 22 to 30	8 secs.	
4. *a*	Lumière	7 54 42	Inst.	Slide changed.
b	,, ...	43	,,	
c	,, ...	45	,,	End of totality.
d	,, ...	46	,,	
e	,, ...	47	,,	
f	,, ...	48	,,	
g	,, ...	49	,,	
h	,, ...	50	,,	
k	,, ...	51	,,	
l	,, ...	52	,,	

On developing the plates it was found that everything had gone satisfactorily. The large plates containing the ten snapshots give the whole story of the chromosphere during 12 seconds, the time taken to make the ten exposures.

The last set of ten exposures did not come out quite as expected, for the reason that the duration of totality was a few seconds shorter than had been provided for in the time-table, so that only two of the exposures were made before the end of totality. The very last exposure, however, taken about 8 seconds after totality, shows many bright lines.

Some of the more important photographs are reproduced, without enlargement, in Plates 6 and 7. Plate 6 shows the series of ten exposures taken near the beginning of totality; the diagonal streak of light is due to a leak in the plate-holder, which did not exist on the day preceding the eclipse, when all the slides were tested. Plate 7 includes photographs 2*c*, and 3*d*; in each case the brightest and most conspicuous features are the images of the chromosphere and prominences, while the rings representing the spectrum of the corona are relatively faint.

The succession of changes in the spectra throughout the eclipse requires but little explanation. In the first few exposures (top of Plate 6) the bands of apparently continuous spectrum were produced by the last remaining parts of the visible crescent, which was broken up by the irregularities of the moon's limb; in these bands the Fraunhofer lines are clearly seen in the region more refrangible than K, but in the violet and blue the Fraunhofer lines are not seen, probably in consequence of over-exposure. These bands gradually disappeared as totality approached, and the spectrum of the chromosphere, which before showed its bright lines as short arcs at the cusps, then exhibits them as complete arcs broken up by the lunar irregularities. Later, the spectrum of the upper chromosphere appears alone, the lines being then relatively few in number (bottom of Plate 6).

As the middle of totality approaches, the chromospheric arcs lose their importance, and the principal features of the spectra then are the continuous spectrum of the corona and the coronal rings; at this time relatively long exposures are required to secure adequate photographic records. The continuous spectrum is not of uniform intensity on account of the unequal distribution of coronal light round the limb (Plate 7).

As the end of totality approaches, the chromospheric arcs reappear, now in the part corresponding to the sun's south-western limb, and the phenomena shown on Plate 6 are repeated in inverse order. It has not been thought necessary to reproduce the ten photographs taken at these stages.

The prominences visible throughout the eclipse were neither large nor numerous, and their spectra show comparatively few lines. One, in the south-east quadrant, appears in all the photographs.

The principles governing the interpretation of photographs taken by the prismatic camera, both in and out of totality, are fully described in my report of the photographs obtained in 1893.*

Photographs taken with the 9-*inch Prismatic Camera.*

The programme adopted was similar to that of the 6-inch, there being two large plates ($16 \times 6\frac{1}{2}$) for recording a series of ten snapshots at and near the times of second and third contacts, and nine smaller plates for exposure during totality. All the exposures were successfully made, but the lines in the spectrum are not very sharp, owing to warping of the wooden tube by the heat and the consequent disturbance of the focus.

As has been previously stated, this instrument was so mounted that the arcs should appear symmetrical about the direction of dispersion. It is satisfactory to state that the photographs showed that the experiment was very successful, the arcs coming out exactly as calculated. Although this instrument was capable of only giving about half the dispersion of the 6-inch, the optical parts were better adapted for recording the ultra-violet region of the spectrum.

Particulars as to the photographs taken are given in the following table :—

* 'Phil. Trans.,' A, vol. 187 (1896), pp. 551–618.

TABLE OF EXPOSURES for 9-inch Prismatic Camera.

Number.	Kind of plate.	G.M.T. of exposure, A.M.	Exposure.	Remarks.
		h. m. s.		
I. *a*	Lumière	7 52 35·5	Inst.	
b	,,	37·5	,,	
c	,,	38·5	,,	
d	,,	39·5	,,	
e	,,	40·5	,,	
			→	Beginning of totality.
f	,,	42·5	,,	
g	,,	44·5	,,	
h	,,	45·5	,,	
i	,,	46·5	,,	
k	,,	48·5	,,	
II. *a*	Lumière	7 52 54·5 } 53 4·5 }	10 secs.	Slide changed.
b	,,	7 53 6·0 } 15·0 }	9 ,,	
c	,,	7 53 16·5	Inst.	
III. *a*	Lumière	7 53 21·5 } 25·5 }	4 secs.	Slide changed.
b	Edwards	7 53 28·5 } 54 4·5 }	36 ,,	
c	,,	7 54 6·5	Inst.	
IV. *a*	Edwards	7 54 10·5 } 24·5 }	4 secs.	Slide changed.
b	,,	7 53 28·5 } 54 4·5 }	36 ,,	
c	,,	7 54 37·5	Inst.	
V. *a*	Edwards	7 54 43·5	Inst.	Slide changed.
b	,,	45·5	,,	
			→	End of totality.
c	,,	46·5	,,	
d	,,	47·5	,,	
e	,,	48·5	,,	
f	,,	49·5	,,	
g	,,	50·5	,,	
h	,,	51·5	,,	
i	,,	52·5	,,	
k	,,	54·5	,,	

The photographs show the same succession of phenomena as those taken with the 6-inch, the chief differences being that the diameter of the rings is in greater proportion to the length of the spectrum, and that the chromospheric arcs are symmetrical. The series of ten spectra taken near the beginning of totality is reproduced without enlargement in Plate 8. Two other spectra taken with longer exposure nearer mid-eclipse are reproduced in Plate 7, namely, photographs $2a$ and $4b$.

Reduction of the Photographs.

The Determination of Wave-lengths of Chromospheric Lines.

When we come to determine the wave-lengths of lines in a spectrum of the eclipsed sun, taken by means of a prismatic camera, it is found that the problem is not quite the same as in the case of the slit spectroscope, in which care must always be taken only to utilise the centre of each of the lines for micrometric measurements, no matter how broad they may be.

In the prismatic camera pictures, in which arcs take the place of lines, not only must great care be taken to measure the distance between them in the direction of dispersion, but these measurements must always be made from the side representing the limb of the moon. Now the question has arisen, does the inner portion of these arcs in all cases represent the limb of the dark moon? If it does, then all measurements for wave-length made from it would be correct.

I have shown previously* that there may exist arcs which would be brighter some distance from the moon's limb, and these would decrease in intensity as this limb was approached, such an arc being due to a shell of vapour concentric with the photosphere, but some distance from it. It is quite easy to understand that a photograph of such an arc, especially if it were under-exposed, would give us a record of the brightest part of the arc in the line of sight, but this fainter portion extending down to the dark moon would be missing.

In such a case the measurements for wave-length made from the inner edge would not then be justifiable, and if the arc in question were of unknown origin, its deduced wave-length would be, and the suggested origin might be, erroneous. Theoretically all arcs which represent layers high up above the photosphere should be more intense where the line of sight of the observer meets the layer in question tangentially. Thus arcs that represent layers which are lowest should be brightest nearer the moon's limb, while the opposite should be the case with those at higher levels.

It appears, however, from the photographs taken during the last three eclipses that such a gradation of light has not been recorded, but this is owing probably to the small size of the solar image used.

An idea of the sizes in the 6-inch and 9-inch prismatic cameras, and the thickness of some of the arcs, may be of interest in this place. In these two cameras the solar images were 0·85 and 1·12 inches in diameter respectively. Considering a layer at the sun to extend 5000 miles above the photosphere, this is equivalent at the mean distance of the sun to 11·1 seconds of arc; taking the sun's diameter as subtending an angle of 32′ 3″·6, then the ratio of this layer to the diameter is as 11·1 to 1923·6,

* 'Roy. Soc. Proc.,' vol. 187, p. 587.

which is as 1 to 173·2. The image of the sun in the 6-inch prismatic camera being 0·85 inch, this layer would be represented at the moment of totality by an arc equal in thickness to ·0045 inch, or nearly one two-hundredth of an inch. In the 9-inch prismatic camera its breadth would be ·006 inch. In the case of the 6-inch spectra a displacement of $\frac{1}{200}$th of an inch corresponds at Hγ to a shift of 1·2 tenth-metres, while in the case of the 9-inch spectra the corresponding shift would be smaller. As the majority of the chromosphere vapours do not reach so high as 1000 miles above the photosphere, as indicated by the lengths of the arcs, the possible displacements due to the above cause are generally too small to be taken into account. Distinct displacements, however, have been noted in some of the arcs of helium and carbon, and in these cases the known wave-lengths have been adopted.

Another possibility of error is introduced in the case of the brightest arcs by irradiation. The depth of the hydrogen stratum, for example, as indicated by the *thickness* of F(Hβ) arc is in some cases nearly three times as great as that indicated by the *length* of the arc. Accordingly if the arc be supposed to have expanded equally in both directions, the true position of the moon's edge will be nearly one-third the thickness of the arc from its inner edge. For this reason the hydrogen arcs Hβ, Hγ, Hδ, Hϵ, as well as the K line of calcium, have not been used as fiducial lines in reducing the chromospheric spectra. The ultra-violet series of hydrogen lines, however, are much finer, and have been used for plotting the curve for the reduction of that part of the spectrum.

The actual procedure was as follows :—

For the purpose of reduction the spectrum has been divided into two parts, one extending from Hα in the red to λ 3900 in the violet, and the other from λ 3900 to the limit of the photographic impressions in the ultra-violet, about λ 3663.

In the first part the wave-lengths were determined by direct comparison with a photograph of the solar spectrum taken with the same instrument provided with a slit and collimator, the latter being a 4-inch Cooke triplet of 6 feet focal length.

For the ultra-violet part of the spectrum, this direct method could not be used, as in consequence of the absorption of ultra-violet rays by the dense prisms, satisfactory photographs of the solar spectrum beyond λ 3900 could not be obtained. Some of the photographs of metallic arc spectra, however, show a considerable number of lines in this part of the spectrum, and these have been used to confirm wave-lengths determined in other ways. In the first instance, the wave-lengths were determined by the use of an interpolation curve, adopting well-known lines of hydrogen, titanium, magnesium, and iron as fiducial points. Besides this, Dr. HARTMANN's interpolation formula for prismatic spectra* has been employed for the reduction of the ultra-violet part of the spectrum. The wave-lengths adopted for the ultra-violet hydrogen lines Hζ to Hγ are those of AMES,† from Hξ to Hρ.

* 'Publicationen des Astrophysikalischen Observatoriums zu Potsdam,' No. 42, vol. 12, 1898.

† 'Phil. Mag.,' vol. 30, 1890, p. 33.

HALE'S* values have been assumed. The values of the lines $H\sigma$ to $H\chi$ are those computed from the measurements of the photographs: these agree closely with those deduced from BALMER'S law. The direct measures of the lines for the use of both interpolation curve and formula were made by means of an ivory scale divided to $\frac{1}{100}$th of an inch. The positions of the fiducial lines for the interpolation formula were checked with a stage micrometer reading to $\frac{1}{10000}$th of an inch, but the majority of the lines were too broad or too faint to permit the use of this instrument with satisfactory results in all cases. The reduction of the wave-lengths of the lines and the assignment of origins were, in the region between 3900 and D, mainly done by Mr. BAXANDALL. For the region more refrangible than 3900 Mr. SHACKLETON is chiefly responsible.

Determination of the Wave-lengths of Coronal Rings.

The wave-lengths of the coronal rings have been determined by direct comparison with a photograph of the solar spectrum on the same scale, utilising the well-known lines of the chromosphere and prominences for properly superposing the photographs. In the case of the coronal rings, the wave-lengths may be affected in the same way as those of the chromospheric arcs, if all the radiations are not photographed quite down to the moon's edge, and an additional slight error may be introduced by the movement of the moon during the comparatively long exposures required to photograph some of the rings. One cannot be certain that the inner edge of the ring corresponds to the same position of the moon's edge as that adopted in the case of the chromospheric arcs used as references, since the chromospheric arcs are bright enough to register their total thickness in view, throughout the exposure, while the fainter coronal rings might only be shown in those parts having the maximum exposure. Thus, in Photograph $2a$ of the 6-inch series, which was exposed for 50 seconds, the movement of the moon relatively to the sun during the exposure would be $18''\cdot5$, corresponding at $H\gamma$ to a displacement in wave-length of nearly two tenth-metres. The measured wave-length of a line will be different, according as the inner edge is taken to represent the moon's position at the beginning or end of the exposure, the inner edges of the chromospheric arcs at this stage representing essentially the moon's position at the beginning of the exposure. It is probable that the inner edge of a photographed ring will correspond to the positions of the moon at some time intermediate between the beginning and end of the exposure, so that the error, even in the case of an exposure as long as 50 seconds, would not amount to two tenth-metres. The more useful exposures for coronal rings were those of 6 to 8 seconds, and in these the possible errors due to the moon's motion will be smaller than those which may be introduced by imperfect settings on such indistinct appearances as those presented by most of the coronal rings. Hence no attempt has been made to make such corrections of the wave-lengths.

* 'Astro-Phys. Jour.,' vol. 11 (1892), p. 618

Determination of Origins.

In the report on the eclipse of 1893, to which reference has already been made, I pointed out, p. 557, that the chemical part of the investigation could not be satisfactorily conducted until much more inquiry had been made, "(*a*) into the old observations, (*b*) into the spectra of stars and nebulæ, and (*c*) into certain questions for which new observations are necessary." Since 1896 great progress has been made in our knowledge of the spectra of the heavenly bodies, and of the changes in the spectra of chemical substances with different conditions of temperature, and the chemical part of the inquiry is now placed on a much firmer basis.

The origins of the various lines have been determined partly by direct comparison with the arc and spark spectra of the elements, photographed with the same instrument fitted with a collimator, as described above, and where such comparison spectra were not available by reference to existing records of the arc and spark lines of the elements. The list of chromospheric lines has also been compared with the lists (published and unpublished) of enhanced lines of many of the elements observed at Kensington.

THE SPECTRUM OF THE CHROMOSPHERE.

Distribution of Substances in the Chromosphere.

I first deal with the determination of the heights of the various absorbing vapours so far as they can be gathered from the photographs, which, of course, only record for us the brightest lower portions of the different arcs, and not their complete extension.

The following table shows the results obtained in the case of some of the most typical lines :—

Lines.	Length of arcs.	Height.	
		In miles.	In secs. of arc.
Ca(K)	130°	6000	13·3
Hydrogen	112°	4500	10·0
He 4471·25	105°	4000	8·9
He 4026·3; Sr 4077·9, 4215·66	86°	2700	6·0
Ca 4226·9; Sc 4247 Mg ultra-violet triplet	72½°	2000	4·4
Fe triplet (4045) Strongest arc lines (4307·96, 4325·92, &c.) Al 3944·16 and 3961·67	60°	1450	3·2
Fe enhanced lines 4584, 4233 Mn quartet (4030·9, &c.)	51°	1100	2·4
Fe enhanced quartet (4523·0, &c.) and many other lines	40°	650	1·4
Carbon fluting and many lines, including some arc lines of iron	35°	475	1·05

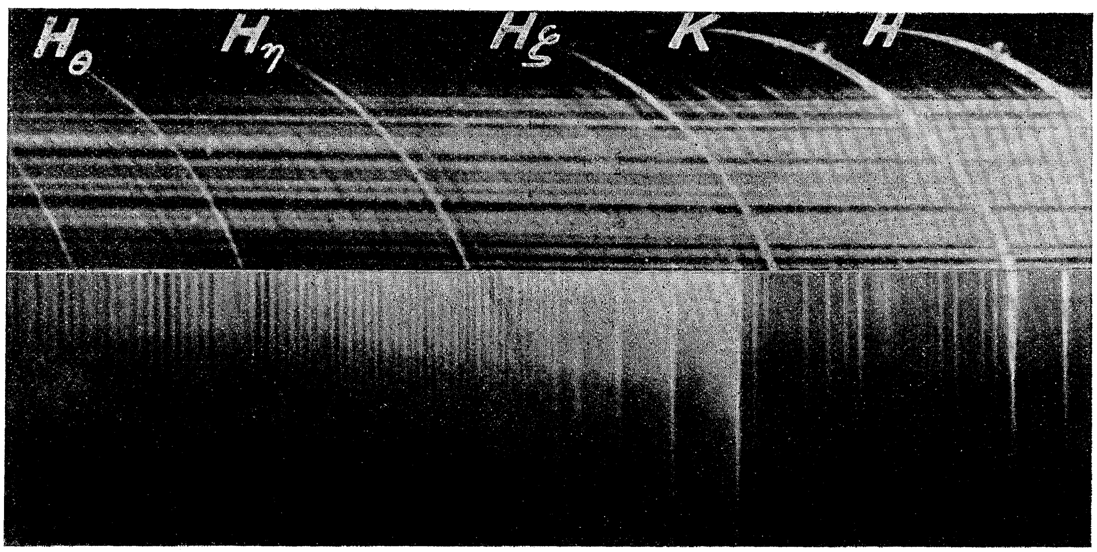
A very noticeable feature of the chromospheric spectra, which the photographs enable us to investigate at different elevations, is the difference in the behaviour of the gaseous and metallic lines. In the spectrum taken very near the moment of second contact, representing that of the lower strata with the spectra of higher ones superposed, the metallic arcs are relatively short and very bright, while in later photographs representing the spectra of successively higher strata free from admixture with lower ones, the metallic arcs are relatively feeble. This is also indicated in another way by the varying effects seen over the tops of lunar mountains and through indentations in the moon's limb.

Some of the lines are seen to be relatively much brighter in the upper strata than in the lower, such lines showing no notable increase of brightness at the points where lower strata are revealed through lunar valleys. Chief among these lines are those of hydrogen, helium, and calcium (H and K), but there is an additional line at wave-length 4686·2 or thereabouts, which behaves in the same way.

This line does not appear in YOUNG's list of chromospheric lines, and all attempts to trace it in known spectra have failed. A line apparently coincident with it, however, has been found in the photographed spectrum of a tube containing helium, which is one of the series of comparison spectra taken with the 6-inch prismatic camera to facilitate the reduction of the eclipse photographs.

The only recognised impurity in the vacuum tube used is oxygen, but besides the line to which reference has been made, there are a few faint lines for which no origins can at present be assigned.

It is worthy of remark that this line falls very near to the first line of the principal series in the spectrum of hydrogen, recently calculated by RYDBERG to have a wave-length of 4687·88.*



.Fig 7. Comparison of Chromosphere and Carbon Fluting at λ 3883.

* 'Astro-Phys. Jour.,' vol. 6, p. 237.

Among the shortest arcs are those corresponding to the carbon group at λ 3883. The perfect correspondence of the five heads of the carbon band with the chromospheric arcs is demonstrated by the comparison given in fig. 7, in which the coincidences of K and a few other lines are also shown.

Comparison of Chromospheric and Fraunhofer Lines.

As in the case of the photographs taken with the prismatic cameras in 1893 and 1896, the spectrum of the chromosphere in 1898 is very different from the Fraunhofer spectrum, so that we have not to deal with a mere reversal of the dark lines of ordinary sunlight into bright ones. (See fig. 8.)

Many very strong chromospheric lines, as the helium lines for example, are not represented among the Fraunhofer lines, while many Fraunhofer lines are absent from the chromospheric spectrum.

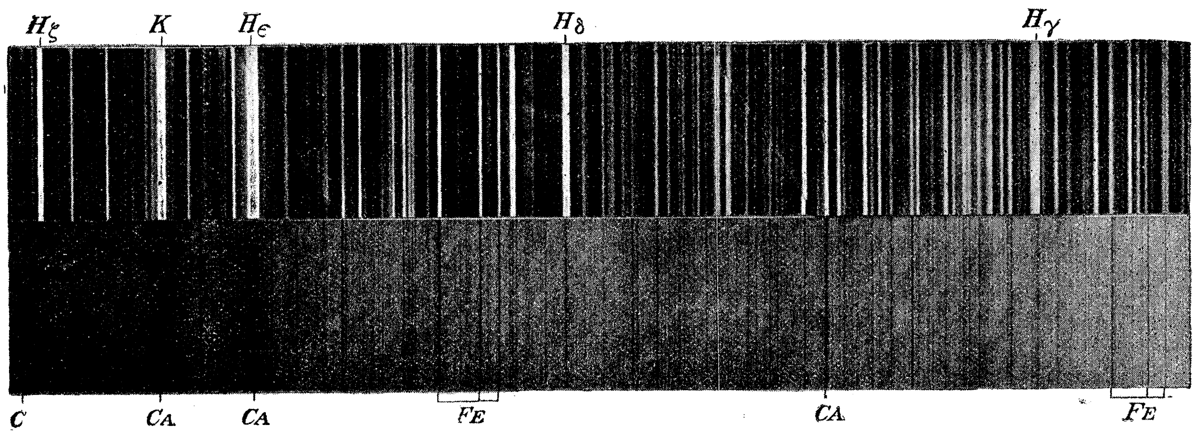


Fig. 8. Spectrum of Chromosphere as photographed during Eclipse compared with Fraunhofer lines.

The conclusion at which I had already arrived, that the chromosphere is not the seat of the Fraunhofer absorption, thus receives further confirmation.

Table of Chromospheric Radiations.

A complete list of the lines which have been measured in the spectrum of the chromosphere, with their origins, so far as they have at present been investigated, is given in the table at the end of this report.

The distribution of the lines throughout the spectrum may be summarised as follows :—

More refrangible than K	265
K to Hγ	190
Hγ to Hβ	178
Hβ to D	223
Total number . . .	856

The intensities are on a scale such that 10 indicates the strongest and 1 the faintest lines.

The suggested origins have been tabulated in two columns, one in which there is considerable certainty as to the origins suggested, and the other in which the evidence is not so complete. The general results with regard to the origins of the chromospheric lines are indicated by the following table.

TABLE showing the probable Presence or Absence of some of the Chemical Elements in the Chromosphere.

Element.	Whether any of the strongest arc lines are represented in the chromospheric spectrum.	Whether any of the enhanced lines are represented in the chromospheric spectrum.
Aluminium	Yes	Doubtful
Antimony	No	Not investigated
Arsenic	No arc lines to compare	Not investigated
Barium	Yes	Not investigated
Bismuth	No	Doubtful
Boron	No arc record	No enhanced lines to compare
Cadmium	No	Not investigated
Cæsium	No	Doubtful
Calcium	Yes	Yes
Carbon	Yes	Doubtful
Cerium	Doubtful	Not investigated
Chromium	Yes	Yes
Cobalt	Doubtful	Doubtful
Copper	Doubtful	Doubtful
Gold	No	Doubtful
Indium	Doubtful	Doubtful
Iridium	No	Not investigated
Iron	Yes	Yes
Lanthanum	Doubtful	No
Lead	Doubtful	Doubtful
Lithium	Doubtful	No enhanced lines to compare
Magnesium	Yes	Doubtful
Manganese	Yes	Yes
Mercury	No	Not investigated
Molybdenum . . .	Doubtful	Doubtful
Nickel	Yes	Yes
Osmium	No	No enhanced lines to compare
Palladium	No	No enhanced lines to compare
Platinum	No	Not investigated
Potassium	Doubtful	Doubtful
Rhodium	Doubtful	No enhanced lines to compare
Rubidium	Doubtful	Doubtful

TABLE showing the Probable Presence or Absence of some of the Chemical Elements in the Chromosphere—*continued.*

Element.	Whether any of the strongest arc lines are represented in the chromospheric spectrum.	Whether any of the enhanced lines are represented in the chromospheric spectrum.
Ruthenium	No	Doubtful
Scandium	Yes	Enhanced lines not investigated
Selenium	No arc record	Enhanced lines not investigated
Silicon	No	Doubtful
Silver	No	Not investigated
Sodium	Yes	No enhanced lines to compare
Strontium	Yes	Yes
Tantalum	Doubtful	No enhanced lines to compare
Tellurium	No arc record	Not investigated
Thallium	No	Doubtful
Thorium	No	Not investigated
Tin	No	Doubtful
Titanium	Yes	Yes
Tungsten	No	Doubtful
Uranium	No arc record	Not investigated
Vanadium	Doubtful	Yes
Yttrium	No	Doubtful
Zinc	No	Doubtful
Zirconium	No	Doubtful

The word "doubtful" signifies that though some of the lines agree approximately in position with chromospheric lines, there is considerable doubt as to whether such lines are really due to the presence of the element in question in the chromosphere. In the tables, coincidences with enhanced lines are indicated by the prefix *p*, signifying the presence of the corresponding "proto-metal"; thus *p* Ti indicates a coincidence with an enhanced line of titanium.

THE SPECTRUM OF THE CORONA.

Differentiation of Coronal Rings.

One of the chief results which, in my opinion, would be secured by the use of the prismatic camera in eclipse work was the differentiation between chromospheric and coronal phenomena. The photographs taken during the eclipses of 1893, 1896, and 1898 all enabled this distinction to be made very clearly, and various radiations formerly attributed to the corona have been shown to belong to the chromosphere alone. The photographs taken in Africa in 1893 showed eight rings in the spectrum of the corona; in Novaya Zemlya, in 1896, with a less powerful instrument, a smaller number was secured; but those taken with increased dispersion in India, in 1898, show a much greater number.

The coronal rings not only differ from the chromospheric ones in regard to the heights to which they extend above the photosphere, but also in appearance.

The outlines of these rings are distinctly not connected with the configuration of the chromosphere and prominences. In photographs taken near the beginning and end of totality, the green ring is brightest on the same side of the moon, although the chromosphere and prominences are first visible on one side and then on the other. None of the rings give any indications of increased brightness at the places occupied by prominences. The green ring, which is the brightest of the rings seen, can be traced completely round the limb, and while in some parts it is very feeble, in others it is bright enough to show the brightest projections of the inner corona as photographed with short exposures with the coronagraph. The other principal rings at 3987 and 4233 can also be traced completely round the limb, but they are fainter on the average and of much more uniform intensity than the green ring.

The Wave-length of the Chief Line in the Green.

The reasons which led to a re-examination of the wave-length of the chief coronal radiation in the green, and the result of the new measurement, have already been stated in a preliminary note communicated to the Society.* The main point of this communication was that two of the chief coronal lines, one in the blue about λ 4231, and the other in the green, had been supposed coincident with two bright chromospheric lines which my investigations had shown to correspond to enhanced lines of iron. The absence of other prominent enhanced iron lines from the corona spectrum, and the improbability of there being a sufficiently high temperature in the corona to produce enhanced lines, suggested a more complete investigation of the supposed coincidences of the coronal and chromospheric lines. The non-coincidence of the coronal line 4231 with the chromospheric line 4233 which was indicated by the measurement of the photographs of 1893† was fully confirmed, and it was also found that the green line was by no means coincident with the chromospheric line 1474 K. Its wave-length was, in fact, estimated as 5303·7, or about 13 tenth-metres more refrangible than 1474 K (5316·79). This result has since been confirmed by CAMPBELL‡ and EVERSHED.§

The Coronal Radiations.

In another preliminary communication to the Royal Society,‖ I gave the results of a more general investigation of the coronal spectrum. The main points may be briefly summarised as follows :—

* 'Roy. Soc. Proc.,' vol. 64, p. 168.

† 'Phil. Trans.,' A, vol. 187 (1896), p. 593.

‡ 'Astro-Physical Journal,' 1899, vol. 10, p. 186.

§ "The Indian Eclipse, 1898," publication of the Brit. Astronom. Assoc., 1899, p. 79.

‖ 'Roy. Soc. Proc.,' vol. 66, p. 189.

(1.) The coronal rings may be divided into three groups, defined by the position angles in which they have their greatest brightness. The typical rings are at wave-lengths 5303·7, 3987, and 4359·5.

(2.) The different forms of the coronal rings indicate that they are not all due to the same substance, at least three being in question.

(3.) The origins of the rings have not yet been traced.

(4.) There are possibly feeble indications of some of the chromospheric gases in the inner corona.

(5.) The chief coronal ring in the green is very closely associated with the form of the inner, and appears to have no distinct connection with the outer corona.

(6.) The outer corona gives no indications of bright rings in photographs taken with the prismatic cameras.

Further examination of the photographs has shown that some of the most minute detail of the inner corona is represented in the green ring. Near the equator, on the eastern limb, for instance, there is a well-defined loop-shaped structure in the inner corona, which presents almost the appearance of a prominence, and this is faithfully reproduced in the corresponding part of the green ring; its spectrum, however, has nothing in common with that of the prominences. A similar relationship is shown at other position angles, but as the Viziadrug photographs were all exposed too long to clearly separate the inner from the outer corona in all parts, a complete discussion of this point must be deferred until photographs taken with shorter exposures by other observers become available for comparison.

The table of coronal radiations is reproduced at the end of this report in order to facilitate comparisons with the chromospheric radiations.

The Continuous Spectrum.

The coronal rings are superposed upon a continuous spectrum which is broken up into bands of various intensities (see Plate 7), and it is important to note that each bright part of the green ring is accompanied by one of these bands. In some of the photographs a few bands of continuous spectrum are seen apparently without corresponding brightenings of the green ring, but an examination of the other photographs generally reveals the brightening in a lower reach of the corona. One or two of the bands appear in places which correspond to the points on the sun's limb about 90° degrees from the points of second and third contact, and in these cases the corresponding brightenings of the green ring are probably hidden by the moon throughout the eclipse.

These facts indicate that the action which produces 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. The continuous spectrum of the outer corona exhibits no definite structures in the photographs which are traceable to individual streamers, but simply appears brightest at the edges of the spectrum where the light of the corona is grasped tangentially by the prisms.

TABLE I.—Lines in the Spectrum of the Chromosphere.

Eclipse 1898.

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
	3663·0	3663·2	<1	—	—	Ti	3662·38	The λλ of these lines for curve were deduced by extrapolation.
	65·6	66·2	<1	—	—	—	—	Very hazy line
	66·3	66·9	<1	—	—	—	—	Very diffuse line
	67·0	67·6	1					
	68·0	68·5	1					
	69·1	69·5	<1	—	—	Ti	3669·11	
	69·6	70·0	1	—	—	Fe	3669·67	
	71·0	70·9	1	—	—	—	—	Very hazy line
	71·7	71·7	1	H	3671·7	—	—	H_χ Very hazy line.
	74·2	74·2	1	H	3674·2	—	—	H_ϕ (fiducial line for curve).
	75·0	75·2	1		—	—	—	
	76·4	76·3	<1		—	Fe	3676·46	
	76·7	76·7	1–2	H	3676·7	—	—	H_υ (fiducial line for curve).
	77·4	77·6	1	—	—	Fe	3677·76	
	78·0	78·1	1–2		—	—	—	
	79·0	79·1	1		—	—		
	79·6	79·6	1–2	H	3679·6	—		H_τ (fiducial line for curve).
	81·6	81·6	1–2	—	—	—	—	Very hazy line.
	82·9	82·9	2	H	3682·9	—	—	H_σ (fiducial line for curve).
3685·3	85·3	85·3	3	*p* Ti	3685·34	—	—	Fiducial line for curve and computation.
	86·7	86·7	2–3	H	3686·7	—	—	H_ρ (fiducial line for curve.)
	87·9	88·0	1	—	—	Fe {	3687·61 3687·80	
	89·0	89·1	1					
	90·2	90·4	1					
	91·0	91·1	1	—	—	Co	3690·87	
	91·5	91·7	3	H	3691·5	—	—	H_π (fiducial line for curve).
	92·4	92·6	1					
	93·5	93·5	1–2	—	—	Co {	3693·26 3693·62	
	94·0	93·9	1–2					
	95·0	94·9	1–2	—	—	Fe	3695·19	
	96·0	95·9	1	—	—	V	3696·01	
	96·6	96·6	1					
	97·4	97·4	3	H	3697·4	—	—	H_o (fiducial line for curve).
	98·3	98·1	1–2					
	99·3	99·3	1					
	3700·2	3700·1	2	—	—	—	—	Double ?
	02·4	02·3	1	—	—	Co	3702·38	Probably several lines
	03·2	03·1	1					

Table I.—*continued.*

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
	3704·1	3703·9	3	H	3704·1	—	—	H_ξ (fiducial line for curve).
	04·7	04·4	1–2	—	—	Fe	3704·60	} Hazy double.
	05·1	04·9	2	He	3705·15	—	—	
	05·7	05·7	2	—	—	Fe	3705·71	
	06·2	06·2	2	Ca	3706·18	*p* Ti	3706·36	
	07·2	07·0	1	—	—	Fe	3707·19	
	07·7	07·6	1	—	—	Co	3707·60	
	08·8	08·9	1–2	—	—	Co	3708·96	Double ?
	10·2	10·1	2	—	—	Ti	3710·09	
	11·5	11·4	1					
	11·9	11·9	4	H	3711·9	—	—	H_ν (fiducial line for curve).
	13·0	12·9	2					
	13·8	13·7	1–2					
	14·9	14·9	1–2					
	15·6	15·3	2	—	—	V	3715·70	
	16·6	16·4	1–2	—	—	Fe	3716·59	
	17·5	17·3	1–2	—	—	Ti	3717·54	Mush of lines.
	18·4	18·3	1–2	—	—	Fe	3718·55	
	19·2	19·1	1–2					
3720·1	20·1	20·1	2	Fe	3720·08			
	20·6	20·6	1–2	—	—	—	—	Thick line.
	21·8	22·0	4	H	3721·8	—	—	H_μ (fiducial line for curve).
22·7	22·7	22·6	2	Fe	3722·73	Ni	3722·64	
	23·7	23·6	2					
	24·6	24·6	2	—	—	Ti	3724·72	
	25·3	25·3	2	—	—	Ti	3725·30	
	26·1	26·0	1					
	26·6	26·6	1–2					
27·1	27·1	27·1	2–3	Fe	3727·06			
27·8	27·9	27·8	2–3	Fe	3727·78			
	28·8	28·7	1					
	29·2	29·1	1					
	30·0	29·9	1	—	—	Ti	3729·95	
	30·6	30·5	1					
	31·5	31·4	1					
	32·5	32·6	2	Fe	3732·55	Co	3732·55	
	33·5	33·5	1–2	—	—	Fe	3733·47	
	34·2	34·2	4	H	3734·15	—	—	H_λ (fiducial line for curve).
35·0	35·0	35·1	1–2	Fe	3735·01		—	
	36·0	36·0	1–2	—	—	Co	3736·04	
37·0	37·0	36·9	3	Ca	3737·06	Fe	3737·28	
	38·5	38·5	1–2	Fe	3738·45		—	
	39·4	39·4	1–2		—	Ni	3739·37	
	40·3	40·3	1–2		—			
	41·0	41·0	1–2		—	Ti	3741·21	
41·8	41·8	41·8	3	*p* Ti	3741·78	—	—	
43·5	43·5	43·3	2	Fe	3743·59	—	—	
	43·7	43·7	2			—	—	
	45·7	45·6	3	Fe	3745·72	—	—	
	47·0	47·0	1–2		—	Fe	3747·07	

Table I.—*continued.*

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
	3747·7	3747·7	2					
3748·4	38·4	48·4	3	Fe	3748·41	*p* Ti	3748·14	
	49·6	49·6	1–2	Fe	3749·63			
	50·2	50·1	4	H	3750·2	—	—	H_κ (fiducial line for curve).
	51·5	51·5	2					
	52·5	52·5	1–2					
	53·7	53·9	1–2	—	—	Fe	3753·73	
	55·6	55·6	1–2	—	—	Co	3755·59	
	56·4	56·5	1–2					
57·8	57·7	57·8	2	*p* Ti	3757·82			
58·4	58·3	58·4	2	Fe	3758·38			
59·4	59·4	59·5	4	*p* Ti	3759·45	—	—	Fiducial line for curve.
	60·2	60·3	1–2	—	—	Fe	3760·20	
	60·7	60·7	1–2	—	—	Fe	3760·68	
61·5	61·5	61·5	4	*p* Ti	3761·46	—	—	Fiducial line for both curve and computation.
	62·6	62·6	1					
	63·7	63·7	1					
63·9	63·9	64·1	2	Fe	3763·95			
65·7	65·7	65·7	1–2	Fe	3765·69			
	66·8	66·8	2					
67·3	67·3	67·4	2	Fe	3767·34			
	68·4	68·4	2					
	69·4	69·4	1–2					
	70·7	70·8	4	H	3770·7	—	—	H_ι (fiducial line for curve).
	72·0	72·1	1–2	—	—	Ti	3771·80	
	73·2	73·4	1–2					
	74·4	74·6	2–3	—	—	Y	3774·47	Long line.
	75·3	75·4	1–2	—	—	Ni	3775·72	
	76·2	76·3	1–2	*p* Ti	3776·20			
	76·7	76·7	1–2	—	—	Fe	3776·60	
	77·8	78·0	1–2					
	78·6	78·8	1	—	—	Fe	3778·65	
	79·8	80·0	1					
	81·0	81·1	1					
	81·8	81·9	1					
	82·7	82·9	1					
	83·7	83·7	1–2	Ni	3783·67			
	84·1	84·1	1–2					
	85·4	85·6	1	—	—	Ti	3786·20	All diffuse lines.
	85·8	86·0	1	—	—	Fe	3786·09	
	86·6	86·8	1	—	—	Fe	3786·82	
	87·2	87·4	1–2	*p* V	3787·34	—	—	
	88·6	88·7	2–3	—	—			
	90·0	90·1	1	—	—	Fe	3790·24	
	90·8	91·0	1–2					
	92·3	92·5	1–2					
	93·1	93·3	1–2					
	94·1	94·3	1–2	—	—	Fe	3794·49	

Table I.—*continued.*

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
	3795·1	3795·2	1–2	Fe	3795·15			
	96·0	96·1	1–2					
	96·6	96·8	1–2					
	98·0	98·1	5	H	3798·0		—	H_θ (fiducial line for curve).
3799·4	99·4	99·3	1–2	Mn	3799·39			
99·7	99·7	99·8	2	Fe	3799·69			
3800·7	3801·0	3801·2	2	Mn	3800·68			
02·1	02·1	02·3	2	Mn	3802·05			
	03·6	03·7	2					
	04·7	04·8	1–2					
	05·5	05·7	1–2	—	—	Fe	3805·49	
	06·7	06·8	1–2	Mn-Fe	3806·86			
	07·7	07·8	2	—	—	Fe	3807·68	Double?
	09·9	10·0	2					
	10·8	10·9	2	—	—	Fe	3810·90	
	12·1	12·1	2	—	—	Fe	3811·95	
	13·1	13·3	2	Fe	{ 3813·10 3813·22			
	13·4	13·6	2	*p* Ti	3813·54			
	14·1	14·3	1	—	—	*p* Cr	3814·07	
14·7	14·7	14·8	3	{ *p* Ti Fe	3814·70 3814·67	} —	— {	Agrees with Fe line, but relatively stronger.
	15·6	15·7	2	*p* V	3815·50			
16·0	16·0	16·1	3	Fe	3815·99			
	17·5 17·8 }	17·8	1–2	—	—	—	—	Double?
	19·4	19·5	2					
19·3	19·8	19·9	1–2	He	3819·75			
20·6	20·6	20·7	3	Fe	3820·59			
	21·9	21·9	1					
	22·4	22·5	1					
24·6	24·7	24·7	3	Fe	3824·59			
26·0	26·3	26·4	3	Fe	3826·03			
	27·6	27·5	1–2	—	—	*p* V	3827·30	
28·0	28·2	28·3	3	Fe	3827·98			
	29·2	29·1	1–2					
29·5	29·5	29·5	4	Mg	3829·50	—	—	Fiducial line for curve and computation.
	30·7	30·7	2–3					
	31·2	31·0	2–3					
	31·8	31·8	1–2	—	—	Ni	3831·84	
32·5	32·5	32·3	4	Mg	3832·45	—	—	Fiducial line for curve.
	33·0	32·9	2	—	—	*p* Y	3833·10	
	33·8	33·6	3	—	—	Fe	3833·46	Line only low down.
34·4	34·2	34·2	2	Fe	3834·36			
	35·6	35·5	6	H	3835·6	—	—	$H\eta$ (fiducial line for curve).
38·4	38·4	38·3	4	Mg	3838·44	—	—	Fiducial line for curve.
39·4	39·2	39·1	1	Fe	3839·40	—	—	Long faint line.
	39·6	39·5	1	—	—	*p* Fe	3839·76	
40·6	40·6	40·6	3	Fe	3840·58			

Table I.—*continued.*

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
3841·2	3841·2	3841·1	3	Fe	3841·19			
	42·0	42·0	1	—	—	Co	3842·19	
43·4	43·5	43·5	2	Fe	3843·40			
	44·5	44·5	2	—	—	V	3844·59	
45·3	45·4	45·4	2	Fe	3845·31			
46·9	47·0	47·0	2	Fe	3846·94			
	47·9	47·9	2					
	49·0	49·1	2					
50·1	50·1	50·1	3	Fe	3850·12			
51·0	51·0	51·1	2	Fe	3850·96			
51·4	—	—	2–3	C	3851·4	—	—	5th edge of C band.
52·7	52·8	52·9	2	Fe	3852·71	Ti	3853·18	
55·0	54·8	54·8	3	C	3855·0	—	—	4th edge of C band.
56·5	56·5	56·6	4	Fe	3856·52	—	—	(Fiducial line for curve.)
	57·1	57·2	2					
	58·1	58·1	2	Ti	3858·26			
	58·4	58·5	3	Ni	3858·44			
	59·3	59·4	2					
60·1	60·1	60·2	4	Fe	3860·06	—	—	(Fiducial line for curve.)
61·8	61·4	61·5	3	C	3861·85	—	—	3rd edge of C band.
	62·9	63·0	2	—	—	Ti	3862·98	
	63·6	63·6	2	—	—	Fe	3863·89	
	64·4	64·5	2					
65·7	65·7	65·6	2	Fe *p* Cr	3865·67			
	65·9	66·0	1					
	66·6	66·6	2	*p* Cr	3866·60	Ti	3866·60	
67·4	67·3	67·3	2	Fe	3867·36			
67·6	—	—	1	He	3867·61			
	68·0	67·8	2					
	68·9	68·7	2					
	69·5	69·3	2					
	70·5	70·5	2					
71·5	71·4	71·4	4	C	3871·53	—	—	2nd edge of C band.
	72·0	72·0	2	—	—	{ Fe { *p* Y	3871·96 3872·30	
72·6	72·6	72·5	4	Fe	3872·64			
73·9	73·4	73·5	2	Fe	3873·90	—	—	Broad hazy line
	74·5	74·3	1					
	75·0	75·0	1	—	—	{ V { Ti	3875·22 3875·44	
	76·2	76·1	1–2	—	—	Fe	3876·19	
	76·8	76·8	2	—	—	Co	3876·98	
78·2	78·2	78·1	2–3	Fe	3878·15	*p* Y	3878·40	
78·7	78·7	78·7	3	Fe	3878·72	*p* V	3878·80	
	79·3	79·3	2					
	79·9	79·9	2					
	80·9	80·8	2					
	82·5	82·5	2					
83·6	83·4	83·4	4	C	3883·55	—	—	1st edge of C band.
	84·4	84·3	2	—	—	Fe	3884·52	

Table I.—*continued.*

Wave-lengths.			Intensity.	Chemical origin.				Remarks.
				Probable.		Possible.		
Comparison.	Curve.	Computed.		Origin.	λλ.	Origin.	λλ.	
	3885·6	3885·6	3	—	—	Fe	3885·66	
3886·4	86·4	86·5	3	Fe	3886·43			
87·2	87·2	87·2	2–3	Fe	3887·20			
	89·2	89·1	8	H	3889·15	—	—	H_ζ (fiducial line for curve).
	91·5	91·4	2					
	92·3	92·2	2	—	—	Fe	3892·07	
	94·1	94·0	2	Co	3894·24			
	94·9	95·0	3	Co	3895·12			
	95·4	95·3	3	—	—	Ti	3895·38	
	95·8	95·7	3	Fe	3895·80			
	96·6	96·5	2					
	98·0	98·0	2	Fe	3898·03			
	98·3	98·2	2					
	99·3	99·2	2	*p* V	3899·30			
	99·9	99·8	2	Fe	3899·85			
3900·7	3900·7	3900·7	4	*p* Ti	3900·68	—	—	Fiducial line for curve and computation.

Wave-lengths.	Intensity.	Chemical origin.				Remarks.
		Probable.		Possible.		
Comparison.		Origin.	λλ.	Origin.	λλ.	
3903·1	2–3	Fe	3903·09	*p* V	3903·42	
05·3	2	—	—	*p* Cr	3905·66	
06·1	2–3	*p* Fe	3906·04			
06·8	2	—	—	Fe	{ 3906·63, 3906·89 }	
07·4	1					
08·4	1					
09·6	<1					
10·6	<1					
13·6	6	*p* Ti	3913·61			
16·2	3	—	—	*p* V	3916·55	? double.
18·6	3	—	—	Fe	{ 3918·46, 3918·56, 3918·79 }	
20·4	3	Fe	3920·41			
23·1	3	Fe	3923·05			
25·9	2	—	—	Fe	{ 3925·79, 3926·09 }	Probably double.
28·1	4	Fe	3928·08			

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
3930·4	3–4	Fe	3930·45			
32·2	2	*p* Ti	3932·16			
33·8	10	Ca	3933·83	—	—	K.
35·4	2					
36·5	1–2					
38·2	3					
38·9	1					
40·4	1					
41·9	1–2					
44·2	5	Al	3944·16			
45·2	2	—	—	*p* Y	3944·94	
47·2	1–2	—	—	*p* Co	3947·27	
48·6	2–3	—	—	Ti Fe	3948·82 3948·93	
50·3	2–3	—	—	Fe *p* Y	3950·10 3950·50	
51·8	1					
52·3	3–4	—	—	*p* V	3952·07	
56·6	4	Ti Fe	3956·48 3956·82			
58·2	4	Ti	3958·36			
61·7	6	Al	3961·67			
63·3	1	—	—	Fe	3963·25	
64·7	2	—	—	Ast	3964·88	
66·3	1					
68·6	10	Ca	3968·63	—	—	H.
70·2	10	H	3970·18	—	—	H_ϵ.
71·4	1	—	—	Fe	3971·48	
73·5	2	—	—	Ni *p*V	3973·70 3973·85	? double.
76·7	1	—	—	Fe	3976·77	
77·8	2	Fe	3977·89			
78·1	trace					
79·3	1	—	—	*p* Cr	3979·66	
80·4	trace					
82·0	6	Ti	3981·92	Fe	3981·87	
83·1	1	—	—	*p* Y	3982·79	
83·8	1					
86·3	1–2	Fe	3986·32			
88·3	1					
89·9	2–3	Ti	3989·91	Fe	3990·01	
91·3	3	—	—	—	—	? double.
95·2	3–4	—	—	Co	3995·46	
97·7	3	—	—	Fe	3997·55 3998·16	
98·8	4	Ti	3998·79			
4000·4	1–2	—	—	*p* Y	4000·70	
03·3	1	—	—	*p* Cr	4003·55	
05·4	5	Fe	4005·41			
06·8	1–2					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
4009·5	2–3	—	—	Ast Fe	4009·42 4009·86	
12·5	5–6	*p* Ti *p* Cr	4012·54 4012·63			
14·5	3	—	—	Fe	4014·68	
16·7	1					
17·5	2					
18·5	1					
20·6	<1					
21·6	3					
23·1	1					
24·7	3	—	—	Ti	4024·73	
26·3	4–5	He	4026·34			
28·5	2–3	*p* Ti	4028·50			
30·9	5	Mn	4030·92			
33·2	3–4	Mn	4033·22			
34·6	3–4	Mn	4034·64			
35·9	1	Mn	4035·88	*p*V	4035·80	
37·7	1					
40·8	4	—	—	Fe	4040·79	
42·4	1					
43·4	1					
44·4	1					
45·9	7	Fe	4045·98			
49·0	3	*p* Fe	4048·82	Mn	4048·91	
51·0	1					
53·8	3	*p*V *p*Ti	4053·80 4053·98			
55·6	2	*p*Fe	4055·63	*p*Ti	4055·19	
57·4	1–2	—	—	Fe	4057·50	
58·2	1–2	—	—	Pb Fe	4058·04 4058·37	
59·2	1–2					
61·2	1–2					
62·7	1	—	—	Fe	4062·60	
63·7	6–7	Fe	4063·76			
67·3	3	*p* Ni	4067·30			
68·1	1	—	—	FeMn	4068·14	
71·8	6	Fe	4071·91			
73·9	1	—	—	Fe	4073·92	
75·3	1					
77·9	10	Sr	4077·89			
80·3	1–2	—	—	Fe	4080·37	
83·1	2	—	—	Mn	4083·10	
84·0	1	—	—	Fe	4083·72 4083·92	
85·0	1–2	—	—	Fe	4084·65 4085·16	
86·7	3					
89·7	1					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	λλ.	Possible. Origin.	λλ.	Remarks.
4092·5	2	—	—	Fe	4092·43 4092·67	
96·2	1–2	—	—	Fe	4096·13 4096·26	
98·2	1	—	—	Fe	4098·34	
4101·9	10	H	4102·00	—	—	H_δ (AMES' λ 4101·85).
07·6	2	Fe	4107·65			
09·9	3	Fe	4109·95	V	4109·91	
11·9	1	—	—	V	4111·94	
14·6	1–2	—	—	Fe	4114·61	
18·7	3–4	Fe	4118·71	Co	4118·93	
21·1	3	He	4120·97			
23·0	3					
28·0	3	—	—	Fe	4127·77	
29·6	2–3					
32·4	3	Fe	4132·24	Li	4132·44	
34·8	3	Fe	4134·84			
37·5	3					
40·1	1					
42·3	1					
43·8	5–6	Fe Ast Fe	4143·57 4143·92 4144·04	—	—	? double.
46·0	1	*p* Cr	4145·91	Fe	4146·22	
47·5	1	—	—	Mn Fe	4147·65 4147·84	
49·4	3–4	—	—	Fe	4149·53	
52·1	2	—	—	Fe	4152·34	
54·8	2–3	—	—	Fe	4154·67 4154·98	
56·5	3					
57·8	1	—	—	Fe	4157·95	
58·9	1	—	—	Fe	4158·96	
61·7	3–4	*p* Ti	4161·70			
63·8	4	*p* Ti	4163·82			
67·5	2–3					
72·1	3–4	*p* Ti	4172·07	Fe	4172·30	
73·5	4–5	*p* Fe	4173·52	*p* Ti	4173·70	
75·8	1	Fe	4175·81			
77·8	5	—	—	*p* Y	4177·75	Straight enhanced line of yttrium.
79·0	4–5	*p* Fe	4178·95			
81·9	3	Fe	4181·92			
84·6	2–3	*p* Ti	4184·40			
87·6	4–5	Fe	4187·20 4187·94			
89·7	1					
91·7	3–4	Fe	4191·60			
94·4	<1					
95·5	1	—	—	Fe	4195·49	
96·4	2–3	—	—	Fe	4196·37	

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
4198·8	4	Fe	{ 4198·49 4199·27			
4202·2	3	Fe	4202·20	*p* V	4202·55	
05·1	3	—	—	{ *p* Y *p* V	4204·89 4205·24	
07·1	1	—	—	Fe	4207·29	
09·6	2–3					
10·9	1					
12·4	1					
15·7	10	Sr	4215·70			
17·0	<1					
19·4	2	Fe	4219·52			
22·4	3	Fe	4222·38			
23·5	<1					
26·9	7	Ca	4226·90			
29·4	<1					
30·7	<1					
33·3	6–7	*p* Fe	4233·33			
35·9	4	Fe	4236·11	*p* Y	4235·88	λλ difficult to determine accurately as the three lines merge into each other.
38·0	1–2	—	—	Fe	4238·19	
39·0	2–3	Fe	4238·97	—	—	
40·3	1					
42·0	<1					
42·8	2–3	—	—	*p* Cr	4242·54	
45·0	1–2	*p* Ni	4244·9			
47·0	7	Sc	4247·00	—	—	Strongest spark line of scandium.
50·4	4–5	Fe	{ 4250·29 4250·95			
54·5	6	Cr	4254·51			
55·6	1–2					
58·2	2					
60·6	4	Fe	4260·64			
61·6	1–2					
62·8	1					
64·6	1–2					
65·5	<1					
67·7	2–3	*p* C	4267·5			
69·8	1					
71·6	4–5	Fe	{ 4271·33 4271·93 }	—	—	Probably compound line.
72·8	1					
75·0	5	Cr	4274·96			
80·2	1–2					
83·0	2–3	—	—	Ca	4283·17	? double.
85·6	2	—	—	Fe	4285·61	
87·6	1	—	—	Ti	4287·57	
90·2	6–7	{ Cr *p* Ti	4289·89 4290·38 }	—	—	Probably compound line.
94·2	5	*p* Ti	4294·20	Fe	4294·30	
96·7	2–3	*p* Fe	4296·65			

Table I.—*continued.*

Wave-lengths.	Intensity.	Chemical origin.				Remarks.
		Probable.		Possible.		
Comparison.		Origin.	λλ.	Origin.	λλ.	
4300·2	5	*p*Ti	4300·21			
03·0	4	Ca *p*Fe	4302·69 4303·34			
05·8	1–2	—	—	FeSr	4305·61	
08·1	5	Fe *p*Ti	4308·08 4308·10	Ca	4307·91	Probably compound line.
13·0	2	*p*Ti	4313·03			
14·0	2	—	—	Sc	4314·25	
15·1	4–5	*p*Ti	4315·14	Fe	4315·26	
18·3	2					
21·2	5	*p*Ti	4321·20	Sc	4320·91	
22·4	1					
25·8	6	Fe	4325·94			
30·6	2–3	*p*Ti	4330·50 4330·87	—	—	Probably compound line.
33·9	3	—	—	La	4333·93	
38·1	5	*p*Ti	4338·08			
40·7	10	H	4340·63	—	—	Hγ.
44·3	3	*p*Ti	4344·45	*p*Mn	4344·19	
47·4	<1					
51·9	6	*p*Fe	4351·93	Mg	4352·08	
55·0	1–2					
59·2	3–4	—	—	*p*Y	4358·88	
62·0	1	—	—	*p*Ni	4362·40	
64·1	1					
67·8	2–3	*p*Ti	4367·84			
70·2	2–3					
74·9	7	*p*Ti	4374·90	Sc *p*Y	4374·63 4375·10	
79·7	2					
83·7	5	Fe	4383·72			
85·5	3	*p*Fe	4385·55			
88·1	1–2	Ast	4388·10			
91·2	2–3	*p*Ti	4391·19			
95·2	7	*p*Ti	4395·20	*p*Mg	4395·0	
99·9	5–6	*p*Ti	4399·94			
4404·9	4	Fe	4404·93			
08·1	3					
11·2	1–2	*p*Ti	4411·20			
15·3	4	Fe	4415·29			
17·9	4–5	*p*Ti	4417·88			
22·7	3	Fe	4422·74	*p*Y	4422·74	
25·6	1	Ca	4425·61			
27·4	3	Fe	4427·48			
30·1	2–3	—	—	La	4430·07 4430·22	
35·5	4–5	Ca	4435·13 4435·85			
36·6	1	—	—	Mn	4436·52	
41·8	1–2					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
4444·0	7	*p* Ti	4443·98			
47·0	1					
47·9	2	Fe	4447·89			
50·6	5	*p* Ti	4450·65			
52·7	1					
55·0	5	{ Ca	4454·95			
		{ *p* Fe	4455·30			
58·0	<1					
59·9	1–2					
62·3	3					
64·6	2–3	*p* Ti	4464·62			
66·5	<1	—	—	Fe	4466·73	
68·7	6	*p* Ti	4468·66			
71·7	8–9	He	4471·65			
76·2	3	Fe	4476·19			
79·2	1					
80·6	1–2					
82·3	4	Fe	4482·34			
84·4	1	—	—	Fe	4484·39	
85·9	1	—	—	Fe	4485·85	
89·3	3	{ *p* Ti	4488·49			
		{ *p* Fe	4489·35			
91·6	2–3	*p* Fe	4491·57			
93·8	2					
94·3	2					
95·2	2					
96·8	3					
4501·5	7	*p* Ti	4501·45			
05·5	1					
08·5	5	*p* Fe	4508·46			
12·3	1					
15·5	4	*p* Fe	4515·51			
18·3	1	—	—	Ti	4518·20	
20·4	3	*p* Fe	4520·40			
22·7	4	*p* Fe	4522·69			
24·1	<1					
28·8	3	Fe	4528·80	*p* V	4528·66	
31·0	1	Co	4531·12 {	Cr	4530·91	
			{	Fe	4531·33	
34·1	7–8	*p* Ti	4534·14			
35·9	2	—	—	Ti	4535·74	
40·0	1–2					
41·7	3	—	—	*p* Fe	4541·40	
44·8	3	—	—	Ti	4544·86	
49·7	7–8	{ *p* Fe	4549·64			
		{ *p* Ti	4549·81			
54·2	7–8	Ba	4554·21			
56·1	3–4	*p* Fe	4556·10	*p* Cu	4556·10	
58·8	3–4	*p* Cr	4558·83			
61·3	<1					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
4563·9	7–8	*p* Ti	4563·94			
66·3	1					
67·4	1					
72·2	7	*p* Ti	4572·16			
76·5	3	*p* Fe	4576·51			
80·0	2	—	—	Ba	4579·86	? double.
84·0	7	*p* Fe	4584·02			
86·8	<1					
88·4	3	*p* Cr	4588·38			
90·1	3	*p* Ti	4590·13			
92·5	3	—	—	*p* Cr	4592·25	
95·1	2					
96·8	2					
4600·8	3					
03·0	2	Fe	4603·13	Li	4603·26	
05·5	2					
07·2	2	—	—	Sr	4607·51	
09·8	1					
13·3	2	—	—	Fe	4613·39	
15·4	3					
19·0	3–4	*p* Cr	4618·97			
22·0	1					
25·3	2–3	—	—	Fe	4625·23	? double.
29·5	5–6	*p* Fe	4629·50			
32·8	1–2					
34·3	1–2	*p* Cr	4634·25			
37·6	2–3	—	—	Fe	4637·69	
40·0	2	—	—	Ti	{ 4639·83 4640·11	
42·8	1					
46·3	4–5	—	—	Cr	4646·35	
48·4	2					
51·8	3–4	—	—	Cr	{ 4651·46 4652·34	
55·4	2					
57·4	3–4	*p* Ti	4657·38			
62·2	2					
64·5	2					
67·6	3–4	—	—	Ti	4667·77	
70·8	3–4	—	—	Sc	4670·4*	* THALEN'S λ corrected to ROWLAND'S scale.
74·0	1					
76·0	1					
79·0	2–3	Fe	4679·03			
82·5	2–3	—	—	*p* Y	4682·60	
87·0	2–3					
91·6	3	—	—	Fe	4691·61	
94·6	1					
97·0	1					
99·5	2–3					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	λλ.	Possible. Origin.	λλ.	Remarks.
4703·2	3–4	Mg	4703·33	—	—	? double.
07·8	2–3	—	—	—	—	Difficult to measure.
09·6	2–3	—	—	—	—	Difficult to measure.
13·8	6	He	4713·25			
18·5	1	—	—	Cr	4718·60	
21·0	1					
23·0	1					
27·7	2	—	—	Fe Mn	4727·58 4727·68	
31·4	3–4					
33·8	1	—	—	Fe	4733·78	
37·0	3	Fe	4736·96			
40·5	2					
43·0	1–2	—	—	Ti	4742·98	
45·5	1					
48·0	1					
49·0	1					
54·2	2–3	Mn	4754·23			
57·5	3					
62·0	4					
65·5	1					
67·0	2					
69·0	1					
71·5	1					
73·0	2					
75·5	<1					
79·9	3–4	*p* Ti	4780·20			
83·1	2					
86·7	2–3	—	—	*p* Y	4786·80	
89·8	2	—	—	Fe	4789·85	
92·3	1					
98·7	2					
4805·2	5	*p* Ti	4805·25			
11·0	3					
15·5	<1					
20·0	<1					
24·3	6	*p* Cr	4824·33			
26·0	<1					
28·5	1–2					
31·3	1–2					
35·5	<1					
37·3	<1					
40·4	2–3	—	—	Co	4840·45	
43·0	2					
48·5	3	*p* Cr	4848·44			
52·2	1					
55·0	2–3	—	—	*p* Y	4855 06	
61·5	10	H	4861·53	—	—	H_β (F).
66·4	1	*p* Ti	4866·4			
71·8	4–5	Fe	4871·51 4872·33			

Table I.—*continued.*

Wave-lengths.	Intensity.	Chemical origin.				Remarks.
		Probable.		Possible.		
Comparison.		Origin.	λλ.	Origin.	λλ.	
4876·0	1					
78·4	2	Ca	4878·31	Fe	4878·41	
83·9	3–4	—	—	*p* Y	4883·87	
87·0	1					
91·2	4–5	Fe	4890·95 4891·68			
4900·0	3	—	—	*p* Y	4900·25	
04·6	1					
09·5	1					
11·4	2	*p* Ti	4911·38			
13·5	1					
21·0	3	Fe	4919·17 4920·69	Ast	4922·10	Broad and hazy, λ difficult to determine, possibly compounded of Ast and Fe.
24·1	6	*p* Fe	4924·11			
28·5	1					
34·2	5	Ba	4934·24			
38·9	2	—	—	Fe	4939·00	
46·0	1–2					
57·5 57·8	3–4	Fe	4957·48 4957·79			
62·8	1					
66·2	1	—	—	Fe	4966·27	
68·1	1					
70·7	1					
73·3	1	—	—	Fe	4973·28	
78·4	1					
81·9	1	Ti	4981·91			
82·7 to 84·3	3	—	—	Fe Ni	4982·68 4984·03 4984·30	Apparently a group of lines merging into each other.
91·5	1–2					
94·3	1–2	—	—	Fe	4994·32	
99·7	2	Ti	4999·69			
5005·9 06·3	2–3	Fe	5005·90 5006·31			
12·9	1					
15·8	2	Ast	5015·73			
18·6	5–6	*p* Fe	5018·63			
22·4	< 1	—	—	Fe	5022·41	
27·3	1	—	—	Fe	5027·31	
31·2	2					
35·6 to 36·7	2	Ni Ti	5035·54 5036·09 5036·65	—	—	Chromospheric line apparently covers this group of Fraunhofer lines.
41·1 to 41·9	3	Fe Ca Fe	5041·07 5041·26 5041·80 5041·94	—	—	Ditto.
50·5	2					

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
5052·8	2					
56·0	1					
60·2	1					
66·1	2	—	—	Ti	5066·174	
68·9	1	Fe	5068·94			
72·5	1	*p* Ti	5072·50			
73·7	1					
79·2 } 79·9 }	3	{ Fe { Fe	5079·41 } 5079·92 }	—	—	Chromospheric line covers the group of Fraunhofer lines in solar spectrum.
85·5	1–2					
88·5	1–2					
97·2	3	—	—	{ Ni { Fe	5097·04 5097·18	
98·8	2	—	—	Fe	{ 5098·75 { 5098·89	
5105·7	2	Fe	5105·72			
07·6 } 07·8 }	2	{ Fe { Fe	5107·62 } 5107·82 }	—	—	Broad line central with narrow Fe double.
10·6	1	Fe	5110·57			
15·5	1	—	—	Ni	5115·57	
21·8	2–3					
23·9 } 25·3 }	2	Fe	{ 5123·90 } { 5125·30 }	—	—	Chromospheric line covers the position occupied by Fe lines at given λλ.
30·5	2–3					
37·4	2	—	—	{ Ni { Fe	5137·25 5137·56	
43·5	1					
48·2	1	—	—	Fe	{ 5148·22 { 5148·41	
51·0 } 52·0 }	1	—	—	Fe	{ 5151·02 { 5152·09	
54·2	2–3	*p* Ti	5154·24			
56·0	1–2	—	—	Ni	5155·94	
62·4	1	Fe	5162·45			
67·6	6	{ Mg { Fe	5167·50 } 5167·68 }	—	—	b_4.
69·1	6	*p* Fe	{ 5169·07 } { 5169·22 }	—	—	b_3. *
72·9	6	Mg	5172·86	—	—	b_2.
78·0	1					
83·8	8	Mg	5183·79	—	—	b_1.
88·9	2	*p* Ti	5188·87	Ca	5189·02	
91·6 } 92·5 }	2	Fe	{ 5191·63 } { 5192·52 }	—	—	Chromospheric line covers position occupied by Fe double.
5202·5	2	Fe	5202·52			

* This is one of the most enhanced Fe lines, but which of the two arc lines at the given λλ is the real enhanced line it is impossible to say without using much larger dispersion.

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
5204·7 } 06·2 }	4–5	Cr	5204·68 } 5206·22 }	Fe	5204·77	Chromospheric line single, but covers position of double Cr line.
08·6 } 08·8 }	2–3	Cr	5208·60	Fe	5208·78	
15·3 to 17·6	3	Fe	5215·35 } 5216·44 } 5217·55 }	—	—	Chromospheric line occupies the position of the three Fraunhofer lines.
27·0	5	*p* Ti } Fe	5226·70 } 5227·04 } 5227·36 }	—	—	Chromospheric line central with fine triplet in Fraunhofer spectrum.
34·8	4					
44·0	1					
47·2 } 47·7 }	1	—	—	Fe } Cr	5247·23 } 5247·74 }	Line apparently central with Fraunhofer double.
50·4 } 50·8 }	1–2	—	—	Fe	5250·39 } 5250·82 }	Faint line apparently central with Fe double.
54·0	1					
58·0	1					
63·0	2					
65·7 to 66·8	2–3	Ca } Fe	5265·73 } 5266·74 }	—	—	Broad line difficult to measure, and apparently covering solar group of Fraunhofer lines.
69·7 to 70·6	3–4	Fe } Ca } Fe	5269·72 5270·44 5270·56			
75·1 to 76·2	4–5	*p* Fe	5276·17	Cr	5275·31 } 5276·20 }	
83·8	4	Fe	5283·80			
97·0	1	—	—	Cr	5296·87	
5300·0	3	—	—	—	—	Broad hazy line.
03·5	1					
07·6	1	—	—	Fe	5307·54	
09·5	1					
16·8	6	*p* Fe	5316·79	—	—	1474 K.
25·7	2					
28·1 to 28·7	5	Fe	5328·24 } 5328·70 } 5328·75 }	—	—	Chromospheric line central with Fe double.
33·1	1	—	—	Fe	5333·09	
37·0	1	*p* Ti	5336·96			
40·0	2–3	Fe	5340·12			
49·7	2	Ca	5349·65			
53·6	2	—	—	Fe	5353·57	
63·0	4					
65·0	1		—	Fe	5365·07	
70·2 } 71·7 }	4–5	Fe	5370·17 } 5371·73 }	—	—	Chromospheric line central with Fe double.
77·0	1					
81·2	2–3	*p* Ti	5381·22			

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
5383·6	1–2	Fe	5383·58			
91·7	2	—	—	Fe	5391·66, 5391·82	
97·3	3	Fe	5397·34			
5404·4, 06·0	4	Fe	5404·36, 5405·99	—	—	Chromospheric line covers position occupied by Fe double.
10·0	2	Cr	5410·00			
15·4	2	Fe	5415·42			
19·0	1					
22·0	1					
25·5	2					
29·9	3	Fe	5429·91			
32·9	2–3					
34·7 to 36·8	—, 2, —	Fe, —, —	5434·74, —, —	—, Ni, Fe	—, 5436·07, 5436·51, 5436·80	Diffuse line covering Fraunhofer group.
47·1	5–6	Fe	5447·13			
53·0	1					
55·8	5	Fe	5455·83			
59·5	1					
63·5	4	Fe	5463·49			
66·6	1–2	—	—	Fe	5466·61	
70·5	2					
74·1	3	Fe	5474·11			
76·5, 76·8	4–5	—	—	Fe	5476·50, 5476·78	
83·3	1–2	—	—	Fe	5483·31	
90·4	1–2	—	—	Ti	5490·37	
94·0	1–2					
97·7	2	Fe	5497·74			
5501·7	2–3	Fe	5501·68			
07·0	2–3	Fe	5507·00			
11·6	2–3					
14·5	2	—	—	Ti	5514·56, 5514·75	
18·0	1–2					
27·6	6	—	—	—	—	Rather broad and probably double. The strong Mg spark line at λ 5528·64 falls on the less refrangible portion of the eclipse line.
35·6	5	Ba	5535·69	Fe	5535·64	
40·0	1					
43·4, 44·2	2	—	—	Fe	5543·41, 5544·16	
46·7, 47·2	2	—	—	Fe	5546·73, 5547·22	
55·1	1–2	—	—	Fe	5555·12	
58·2	2	—	—	Fe	5558·21	

Table I.—*continued.*

Wave-lengths. Comparison.	Intensity.	Chemical origin. Probable. Origin.	Probable. λλ.	Possible. Origin.	Possible. λλ.	Remarks.
5560·4	1	—	—	Fe	5560·43	
62·9 } 63·8 }	1–2	—	—	Fe	{ 5562·93 5563·82	
65·9	2	Fe	5565·93			
69·8	2–3	Fe	5569·85			
73·1	2–3	Fe	5573·08			
76·3	2	Fe	5576·32			
82·2	1–2	Ca	5582·20			
87·0	6	Fe	5586·99			
89·5	1–2	Ca	{ 5588·99 5590·34			
92·0	2–3					
94·7	1	Ca	5594·69			
98·7	3	Ca	5598·71			
5601·5 } 03·1 }	3	Ca	{ 5601·51 5603·08			
10·0	1					
15·9	5–6	Fe	5615·88			
24·8	3–4	Fe	5624·77			
33·0	1					
37·0	2					
39·5	1					
43·0	2					
55·6	2–3	—	—	Fe	5655·72	
59·1	6	Fe	5659·05			
62·7	3	Fe	5662·74			
69·5	3					
82·9	2					
5701·8	2	Fe	5701·77			
06·2	2	—	—	Fe	5706·22	
09·7	4	Fe	5709·60			
28·0	1–2					
32·0	1–2	Fe	5731·98			
53·3	3	Fe	5753·34			
63·2	3	Fe	5763·22			
80·8	3–4					
91·2	1–2	—	—	{ Cr Fe	5791·17 5791·24	
5809·4	2	—	—	Fe	5809·44	
53·9	1–2	Ba	5853·90			
75·9	7	He	5875·87	—	—	D_3.
90·2	3	Na	5890·19	—	—	D_2.
96·2	3	Na	5896·16	—	—	D_1.
6563·0	5	H	6563·05	—	—	Hα (C).

TABLE II.—Coronal Radiations.

Group I. Typical ring, λ 5303·7.

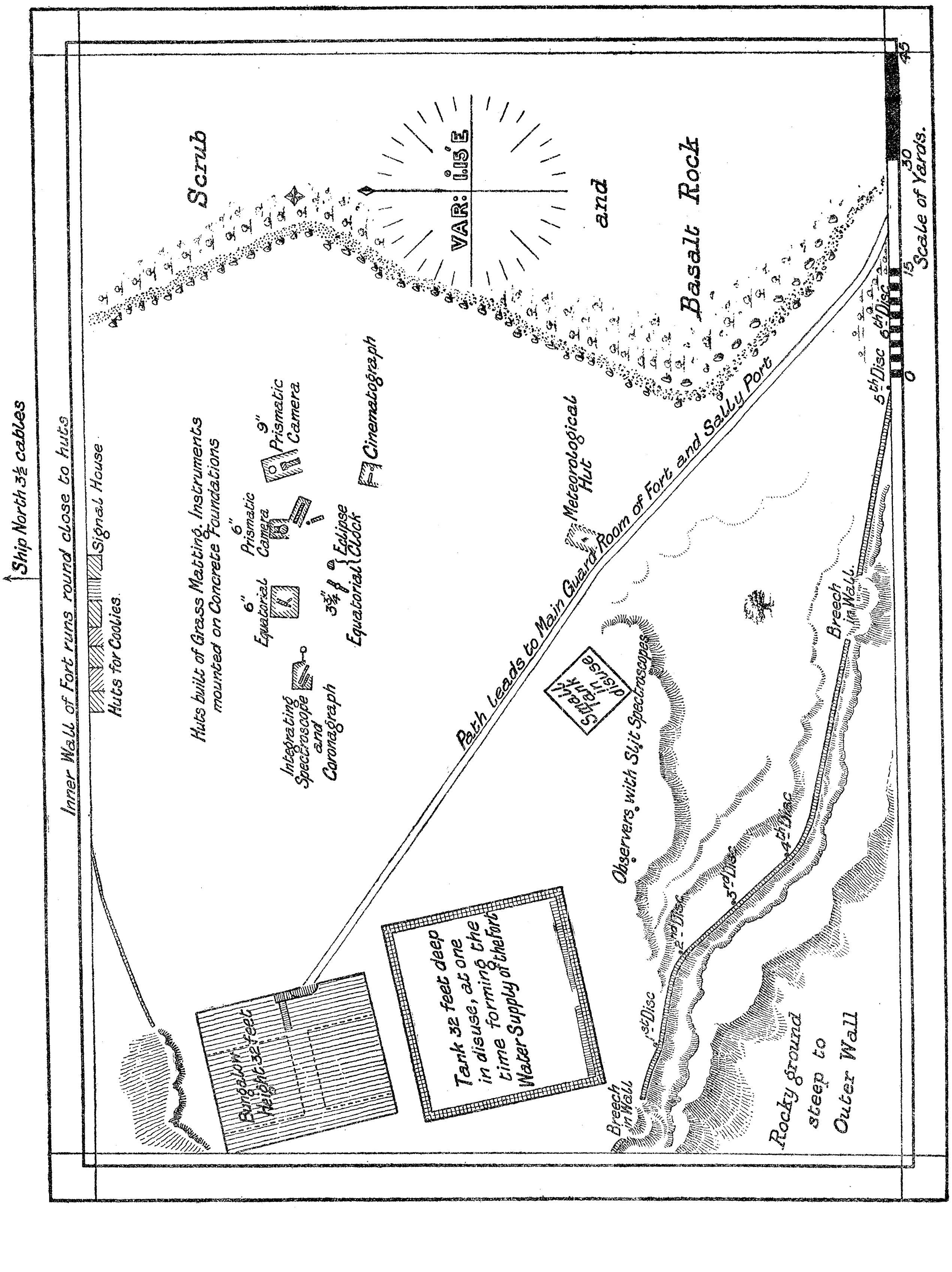
Wave-length.	Brightness. Max. = 10.	Wave-length.	Brightness. Max. = 10.
3952·5	2	4518	1
4007	1	4536	1
4022	1	4588·5	1
4056	2	4657	1
4068	1	4685·5	2
4085	1	4714	1
4121	1	4727	1
4168	1	4737	1
4220	2	4768	1
4231·3	5	4808	1
4248·5	2	4922	2
4262	1	5125	1
4400	1	5137	1
4430	1	5303·7	10

Group II. Typical ring, λ 3987·0.

Wave-length.	Brightness. Max. = 10.
3800	3
3987·0	5
4275	1
4568·5	3

Group III. Typical ring, λ 4359·5.

Wave-length.	Brightness. Max. = 10
4030	1
4192	1
4204	1
4302	1
4323	2
4359·5	3
4485	1
4648	1
4662	1
4788	1
4890	1
5001	1
5255	1



Plan of Fort Viziadrug.

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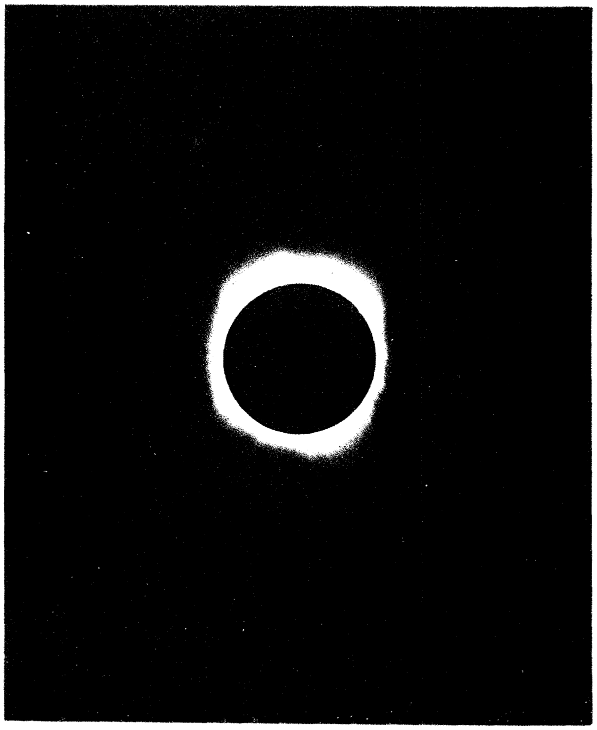

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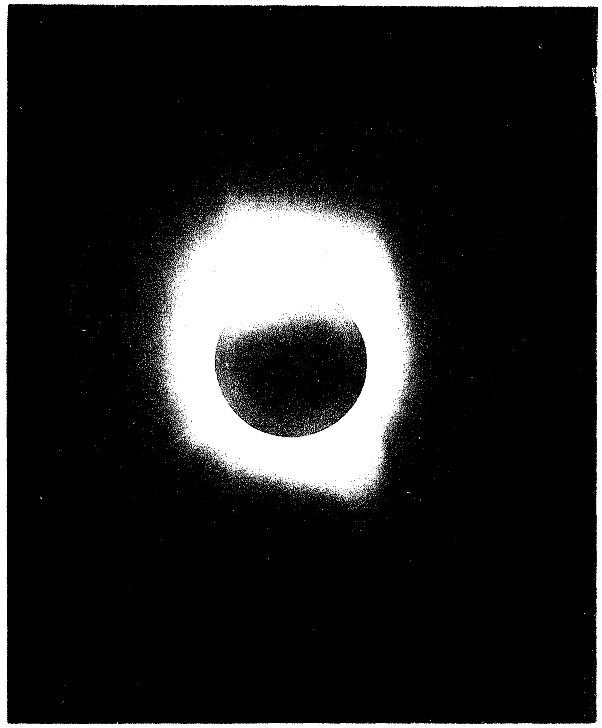

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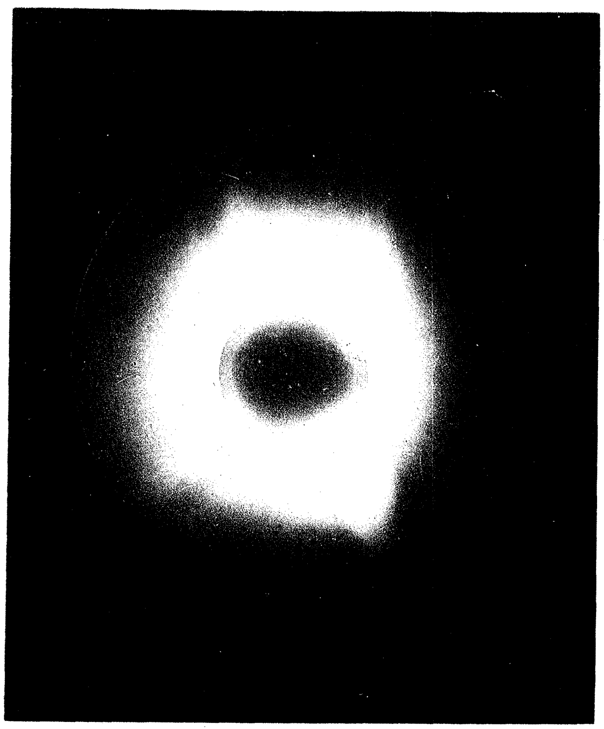

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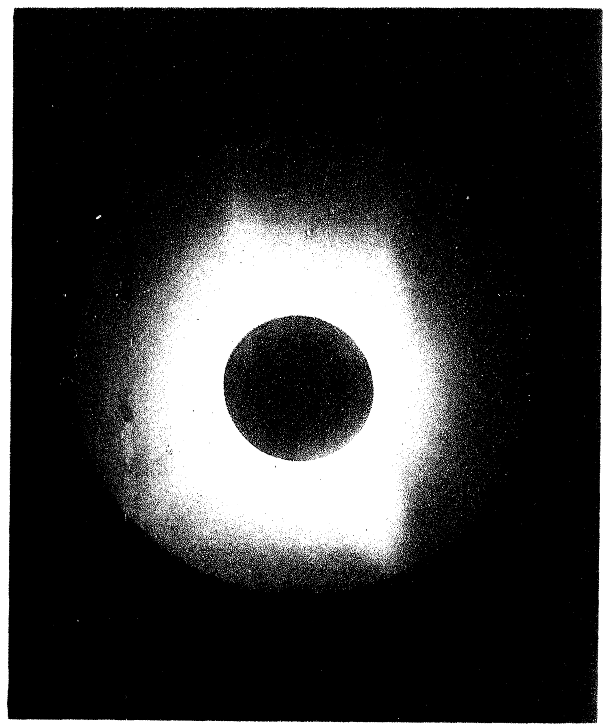
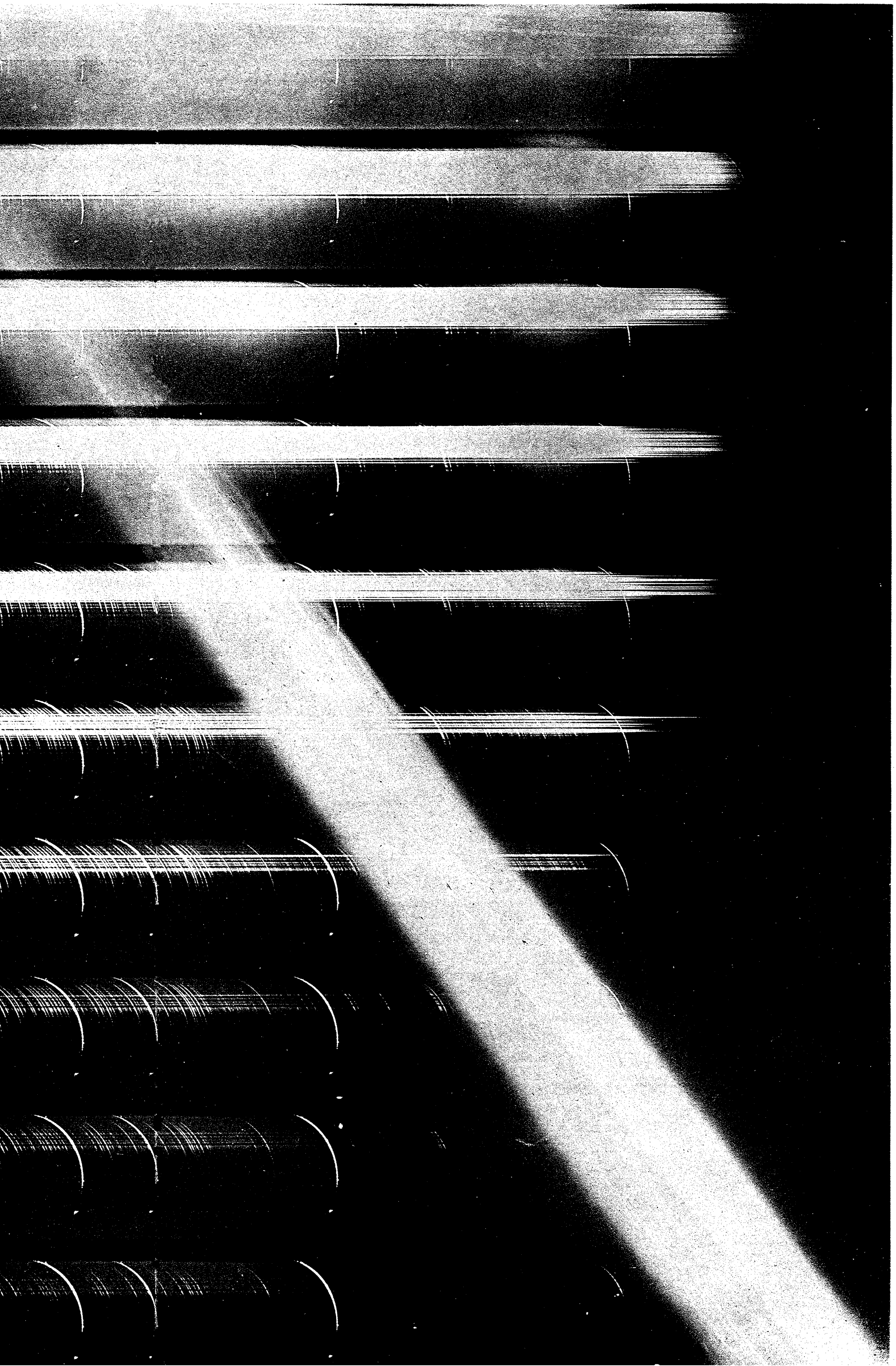


TOTAL ECLIPSE OF THE SUN, JANUARY 22, 1898.

PHOTOGRAPHS TAKEN AT VIZIADRUG.



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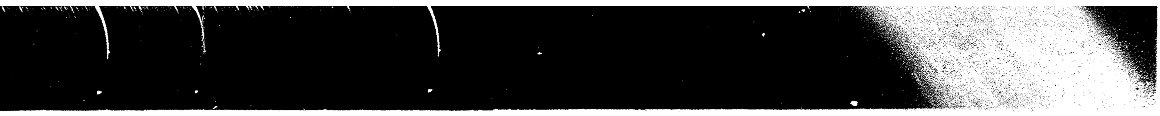

Lockyer (116), 19

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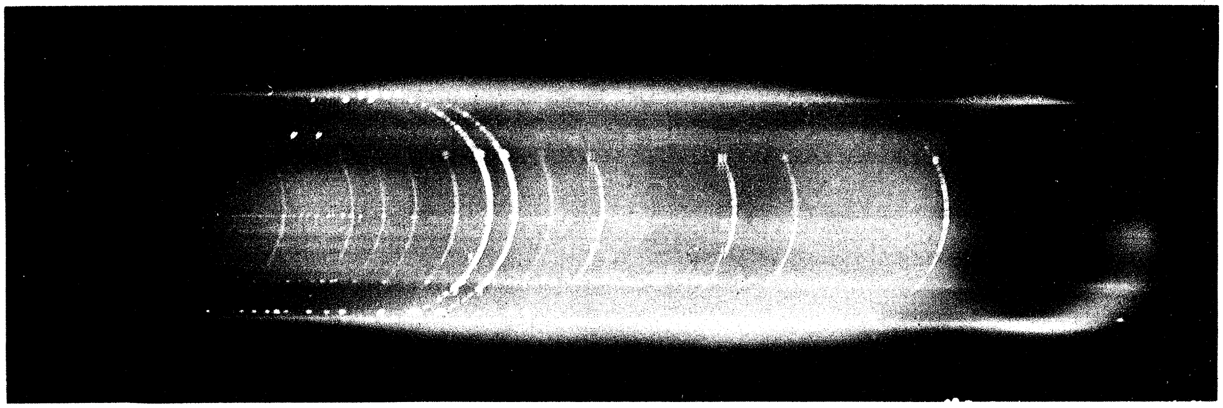

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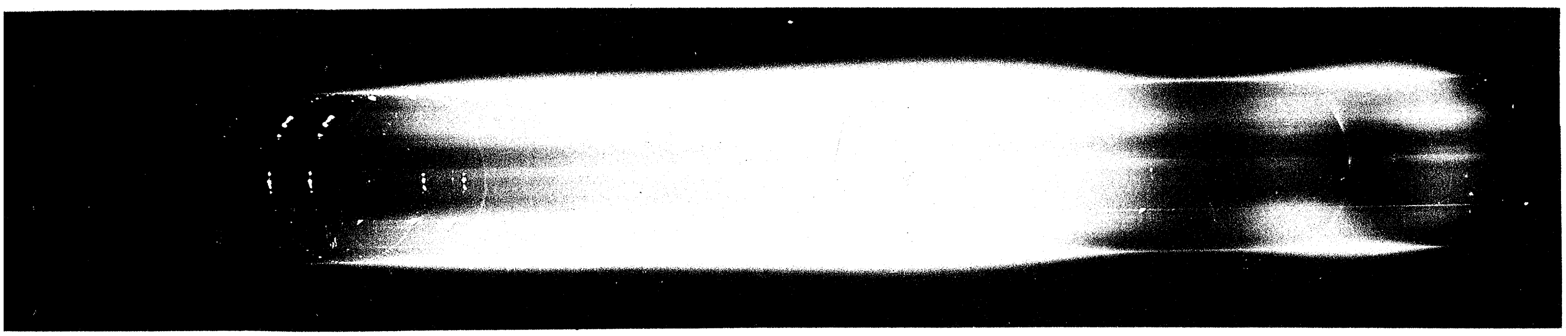

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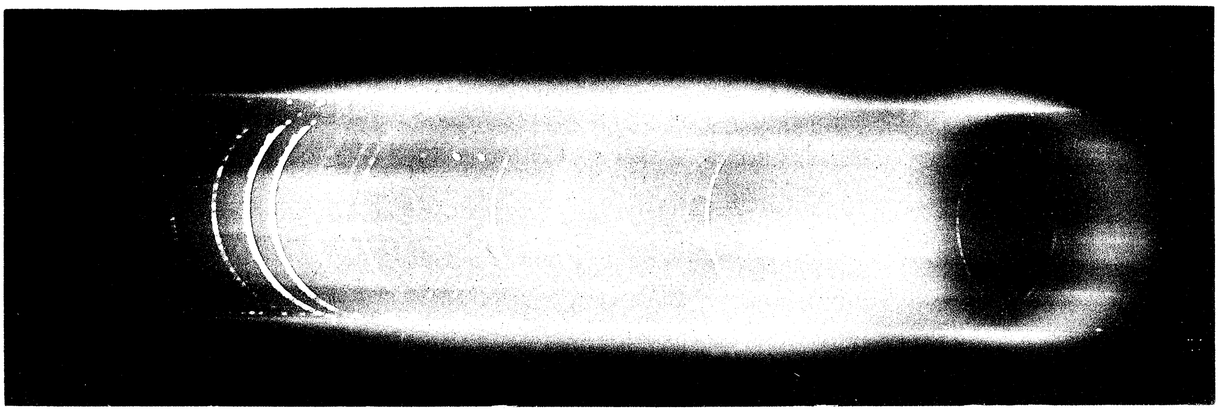

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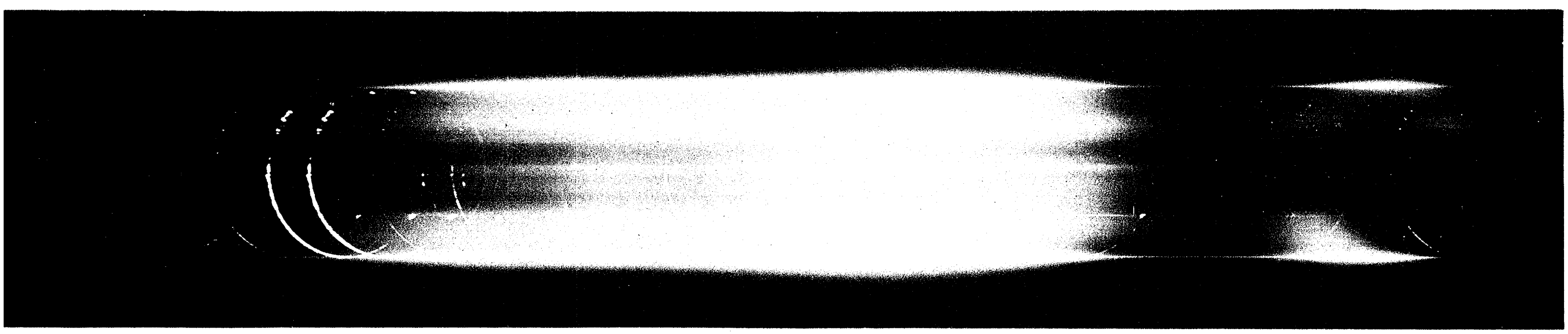

(4)

(1). PHOTOGRAPH 2 A TAKEN WITH 9-INCH PRISMATIC CAMERA.

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(3). ,, 4 B ,, ,, 9 ,, ,, ,,

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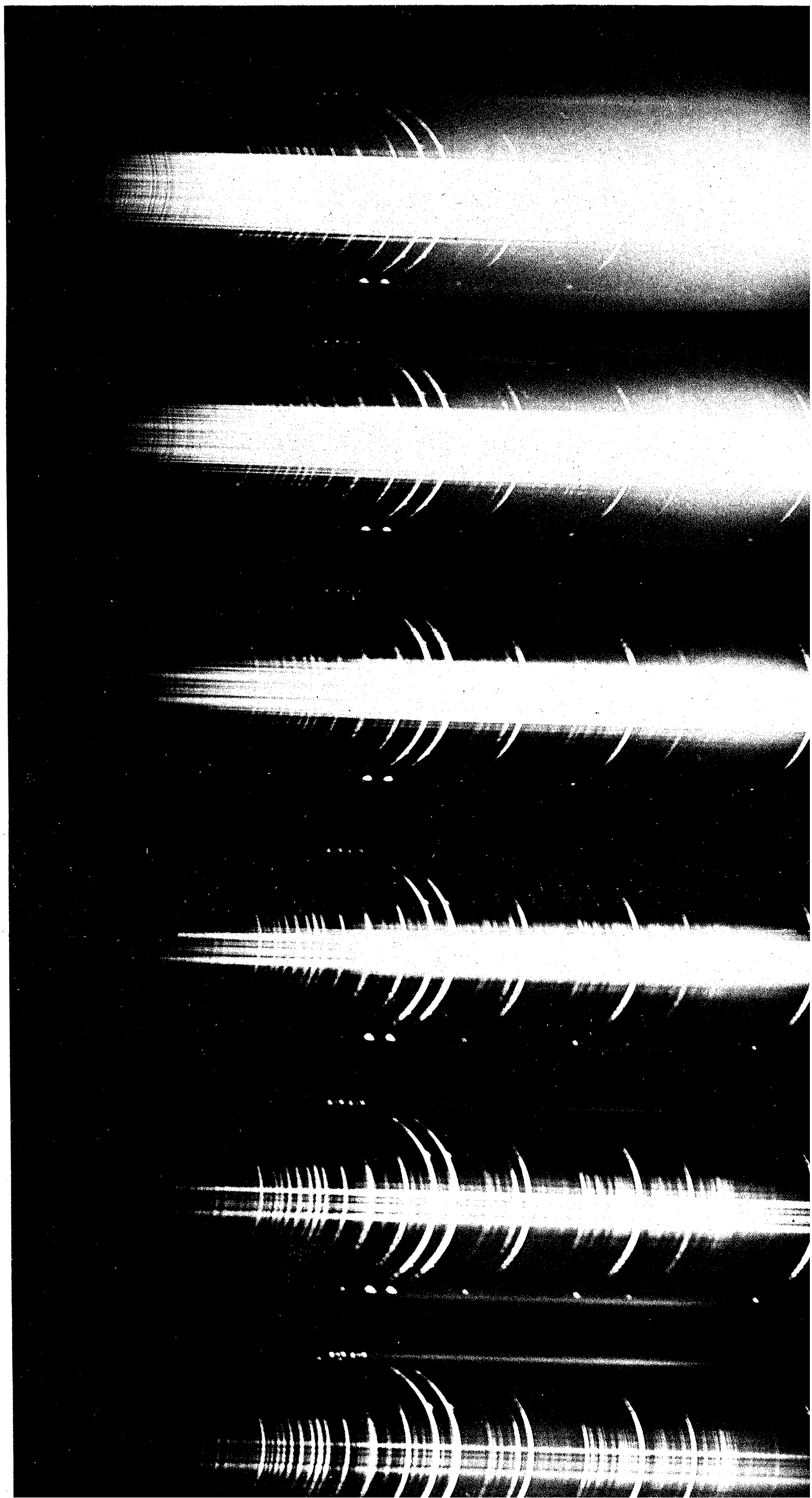

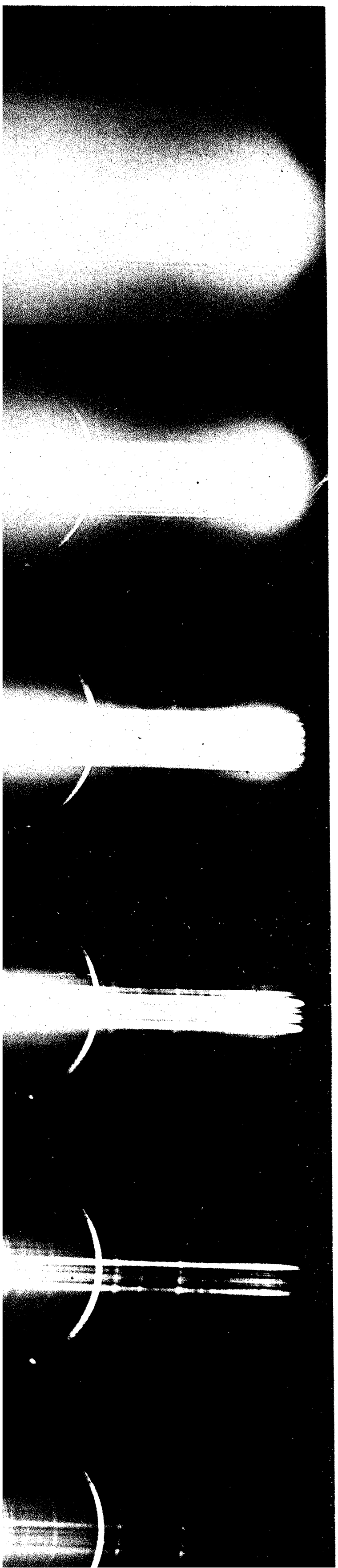

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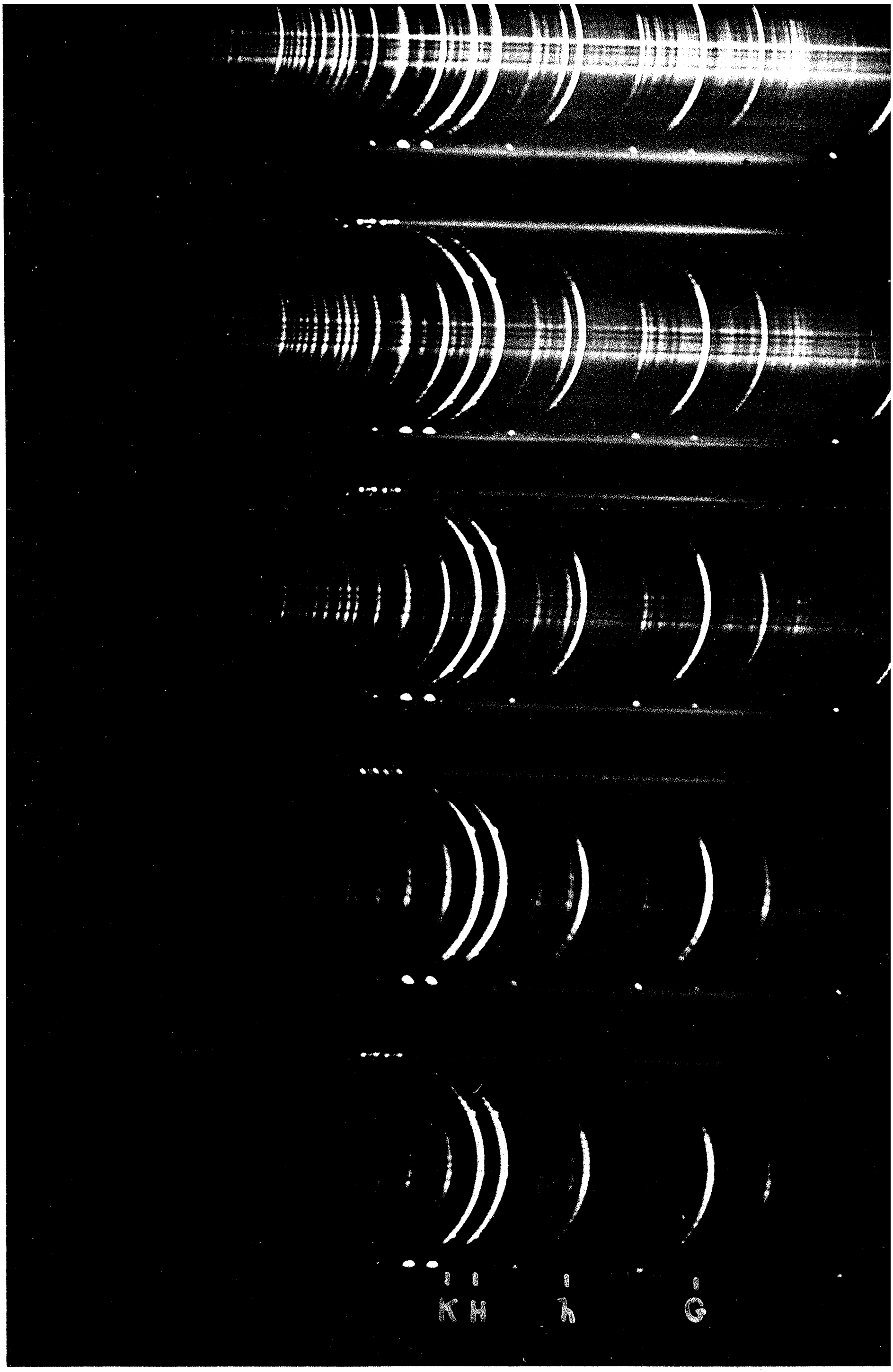
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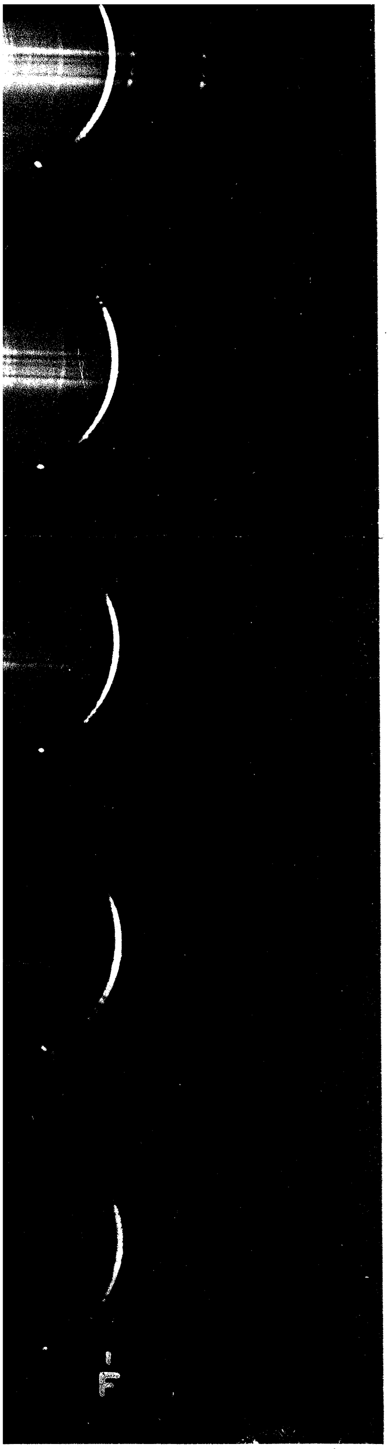

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Lockyer (116), 1900.

ERRATA.

Page 183. In the fourth column of the table, *for* "18 h. 19 m. 25 s." *read* "18 h. 19 m. 2·5 s."

,, 187. 17th line, *for* "taken to the position," *read* "taken to be the position."

,, 190. 27th line, *insert* "*b*" after "trace of."

,, 194. Lines 1 and 2, *for* "inches" and "inch" *read* "seconds of arc."

,, 199. Last line, *for* "$H\gamma$" *read* "$H\nu$"; and after "$H\rho$" read on to next page without stop.

,, 216. In the column "Remarks," opposite λ 4177·75, *for* "Straight" *read* "Strongest."

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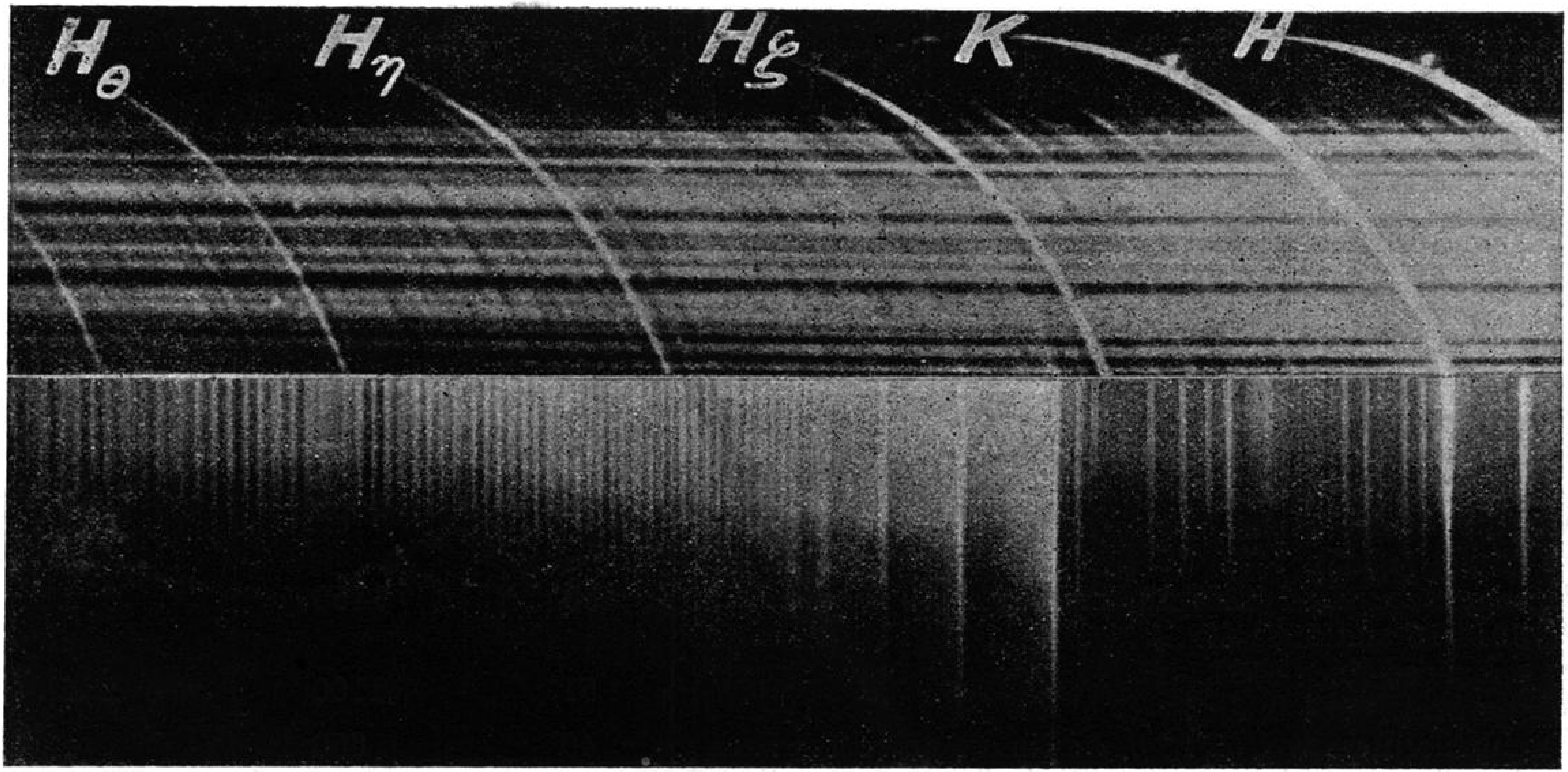


Fig 7. Comparison of Chromosphere and Carbon Fluting at λ 3883.

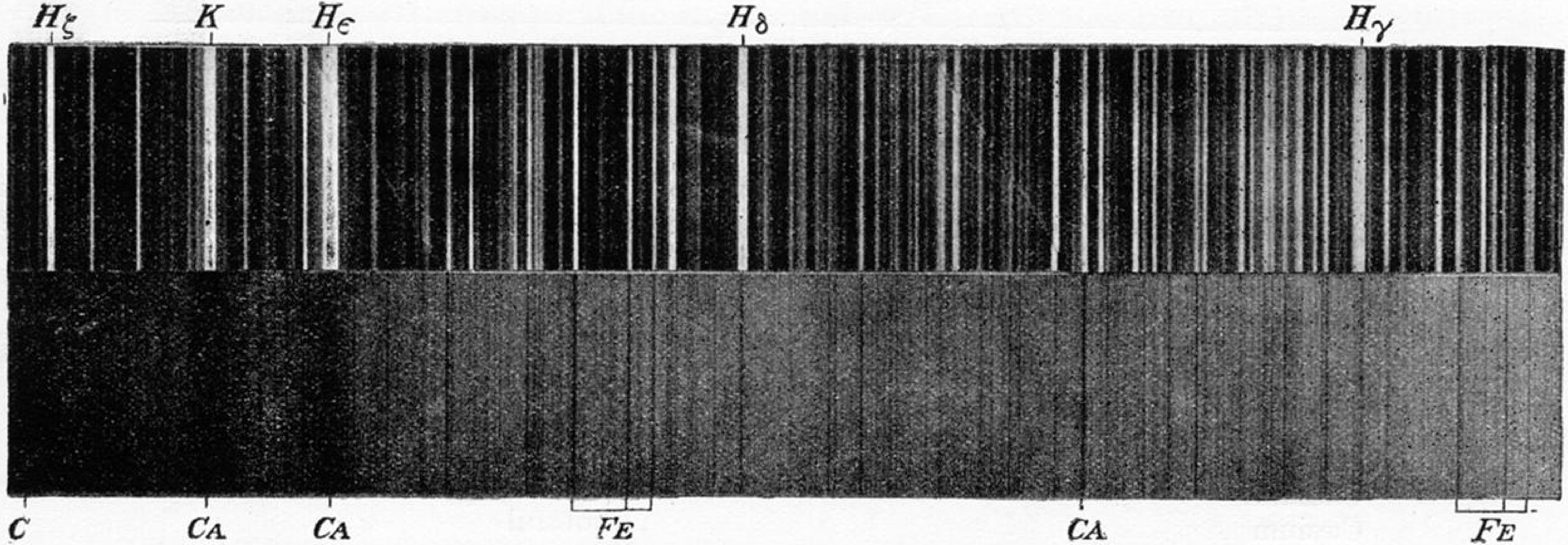
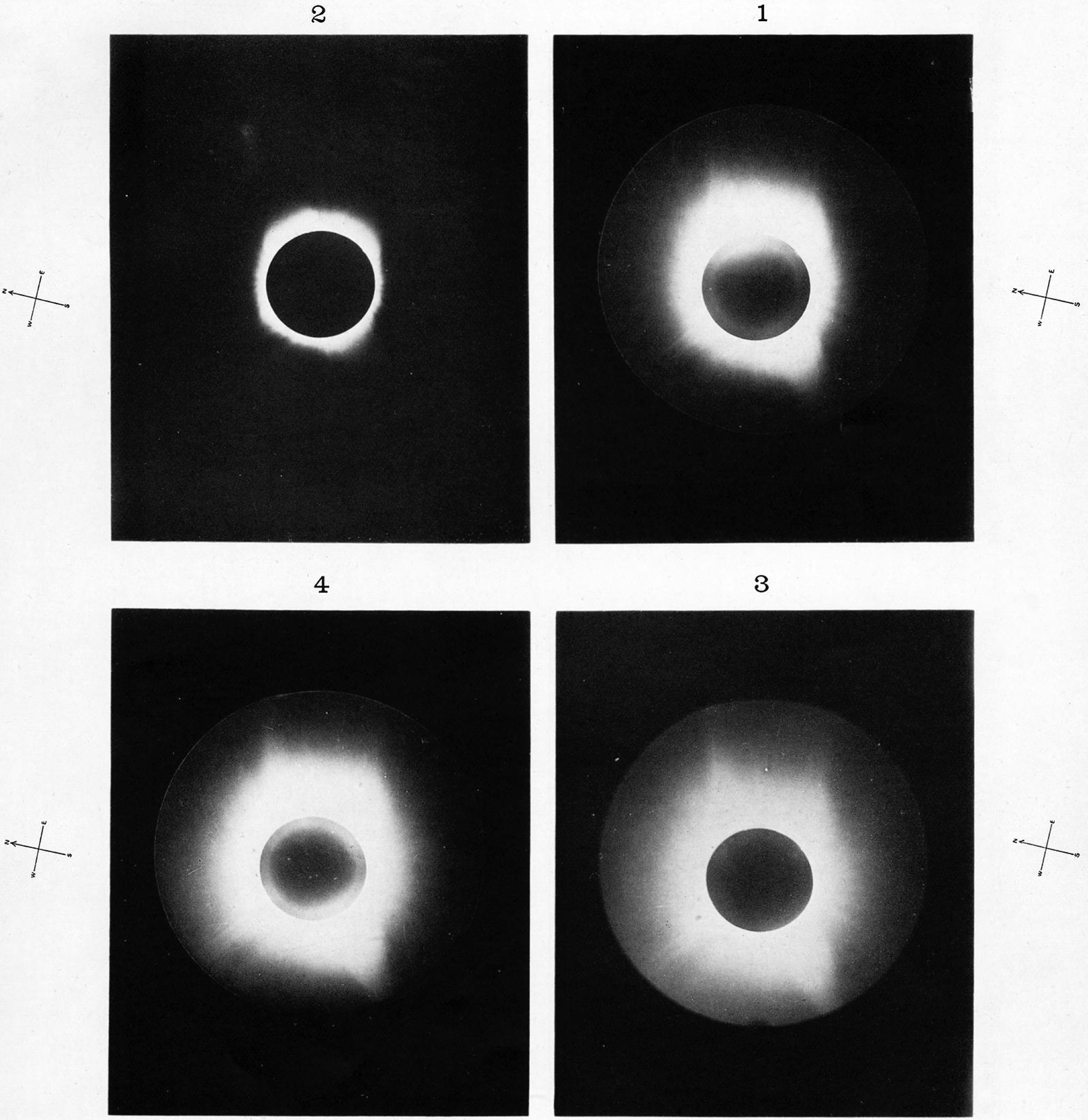


Fig. 8. Spectrum of Chromosphere as photographed during Eclipse compared with Fraunhofer lines.



TOTAL ECLIPSE OF THE SUN, JANUARY *22*, 1898.

PHOTOGRAPHS TAKEN AT VIZIADRUG.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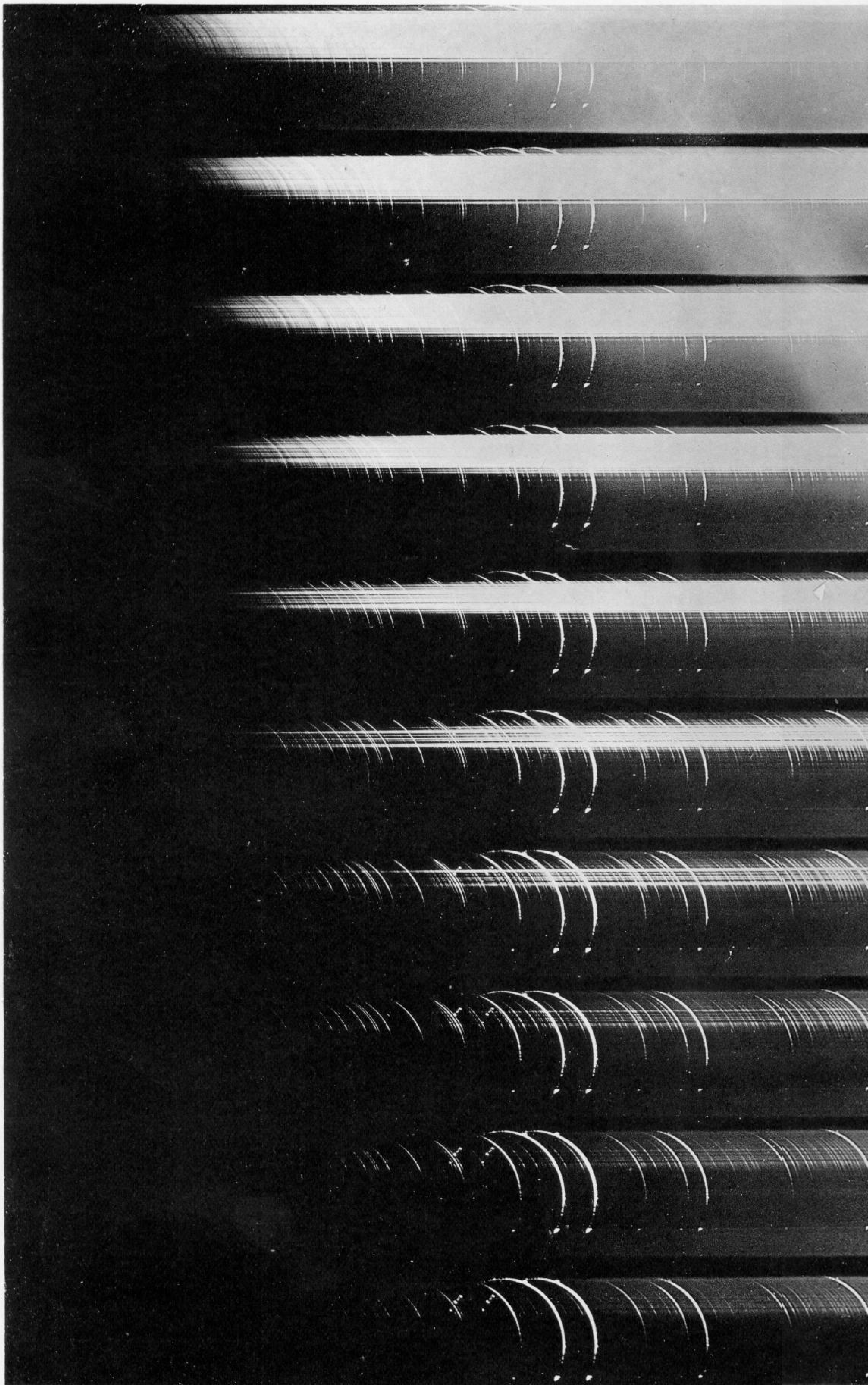

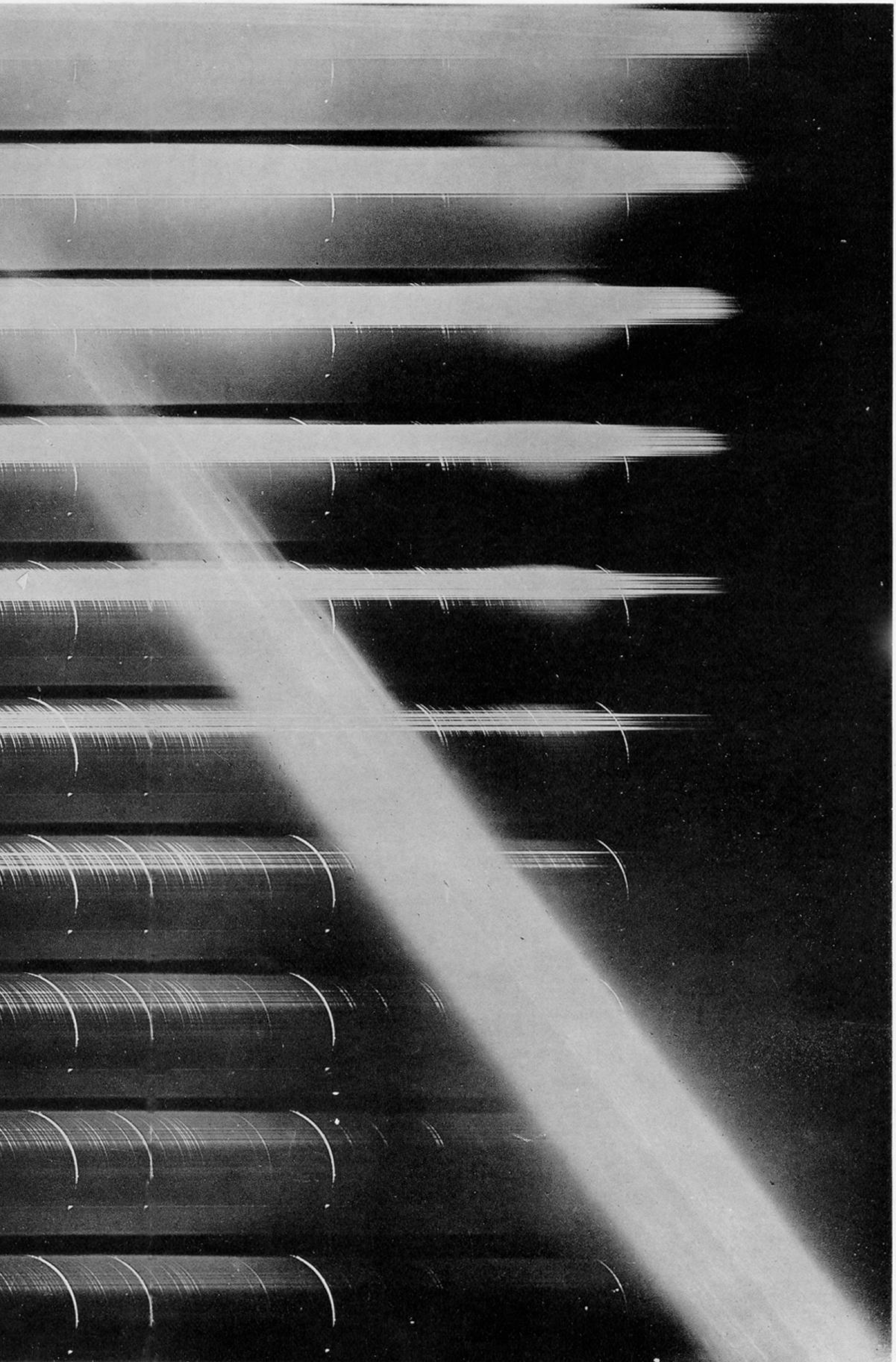

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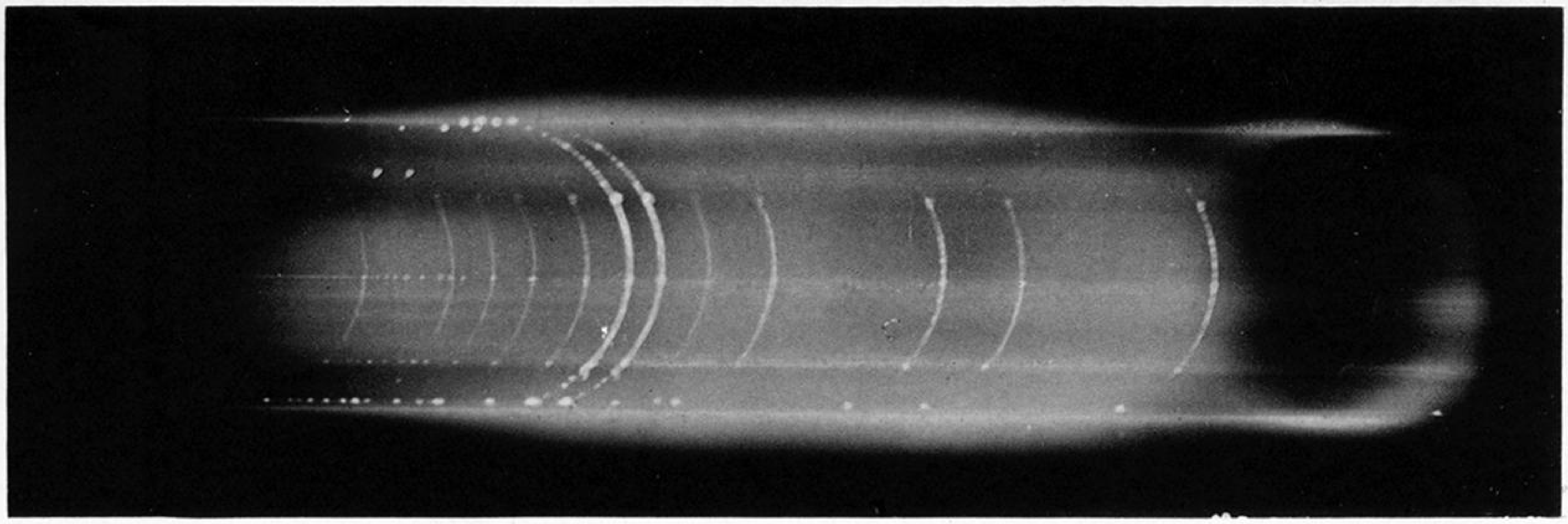
16), 1900.



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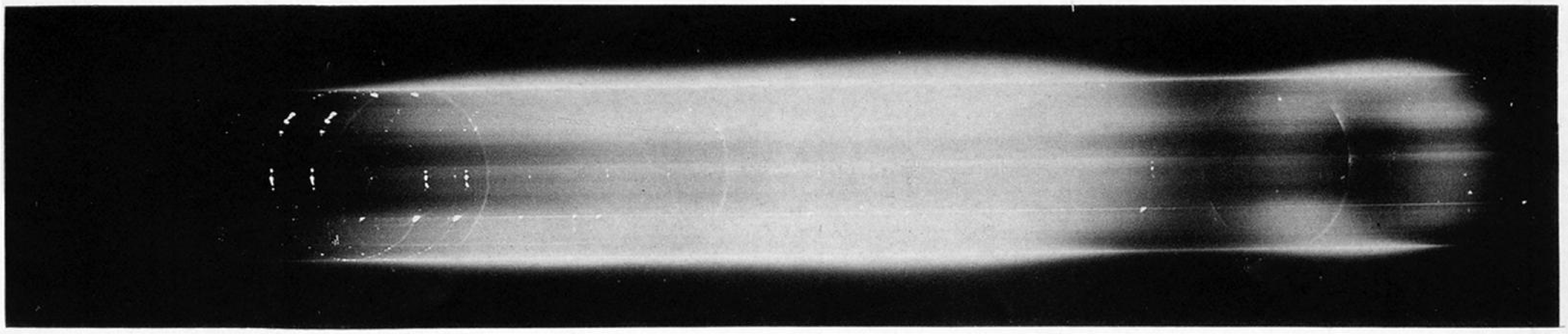

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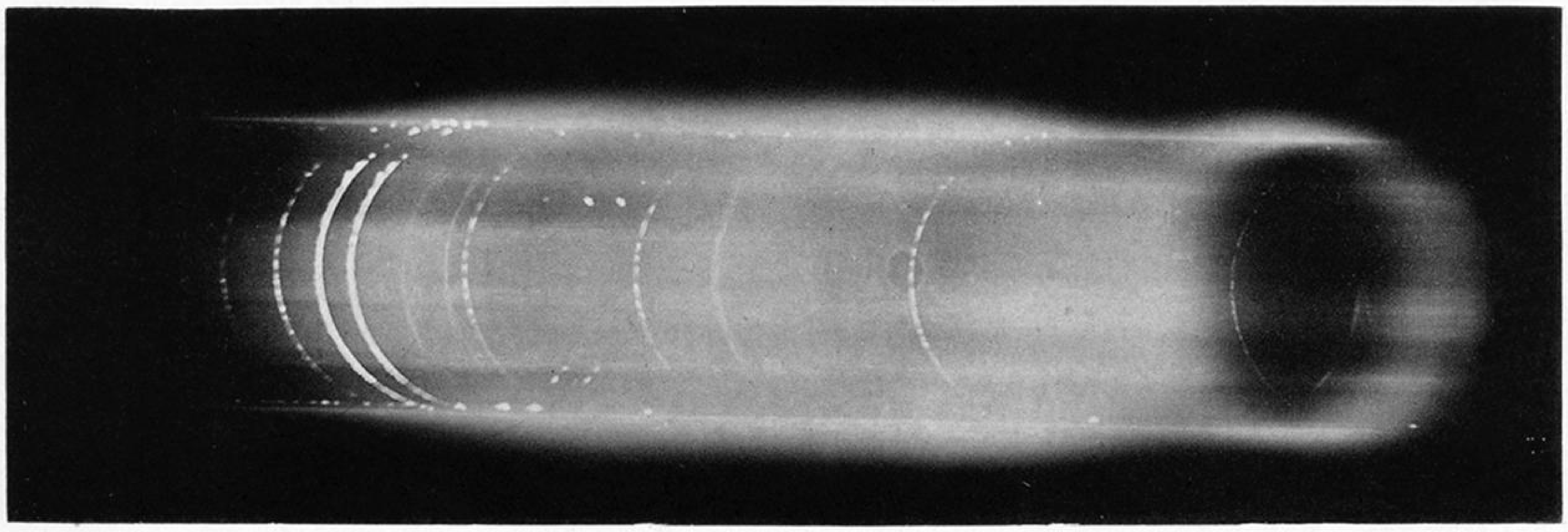

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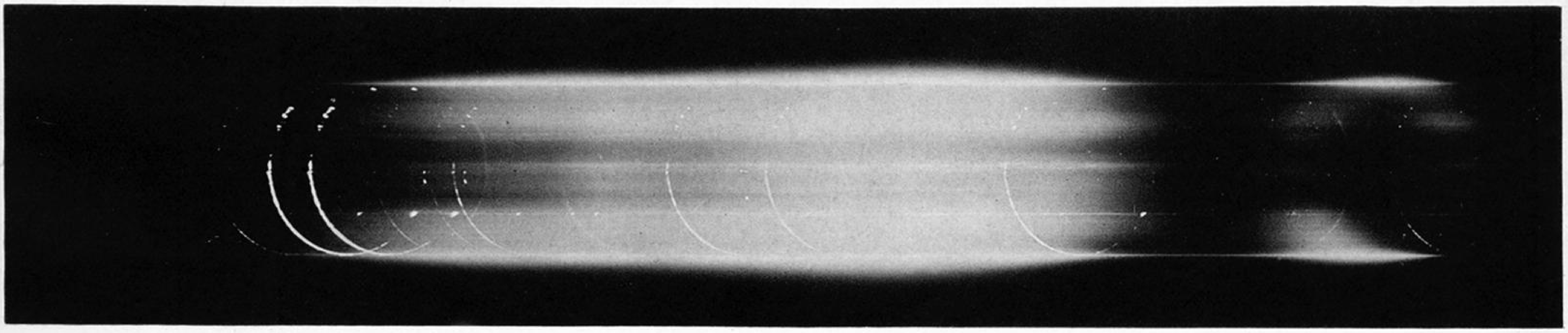

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(1). PHOTOGRAPH 2 A TAKEN WITH 9-INCH PRISMATIC CAMERA.

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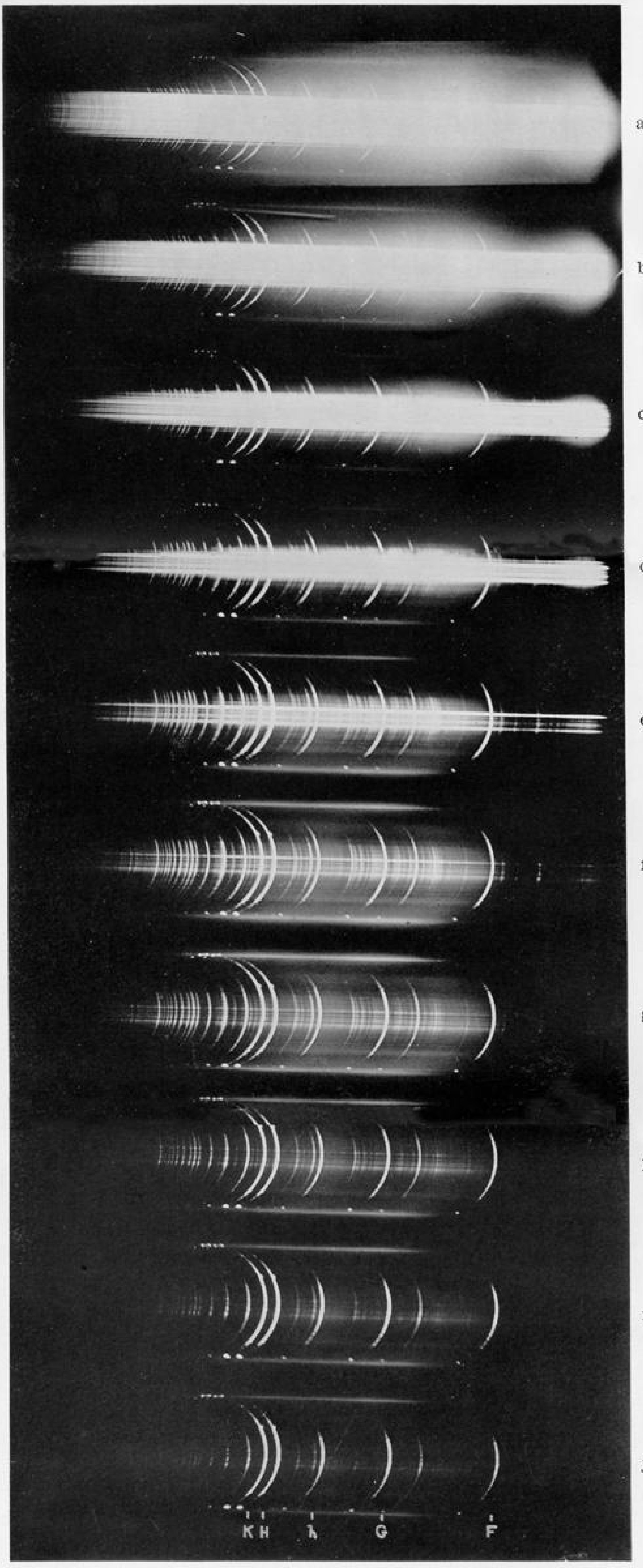
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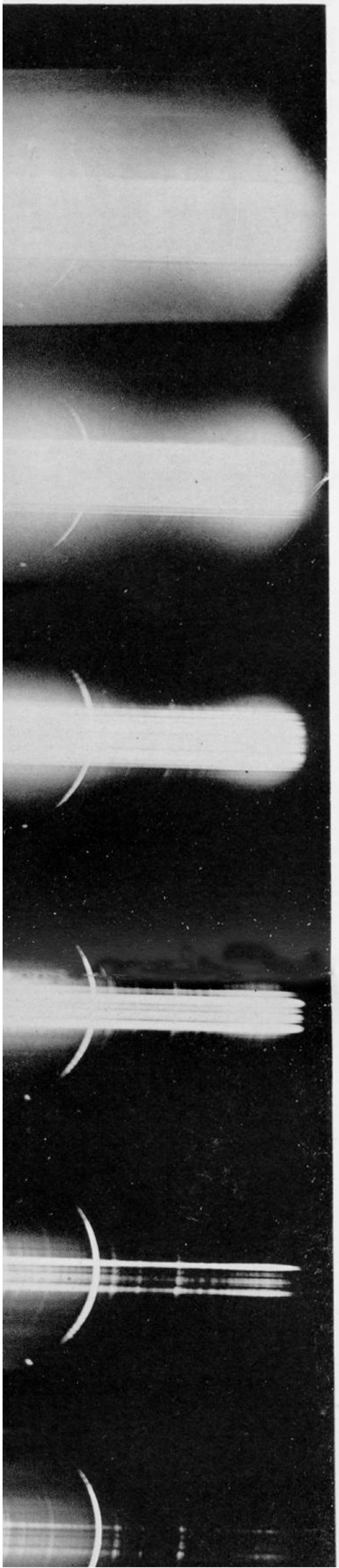

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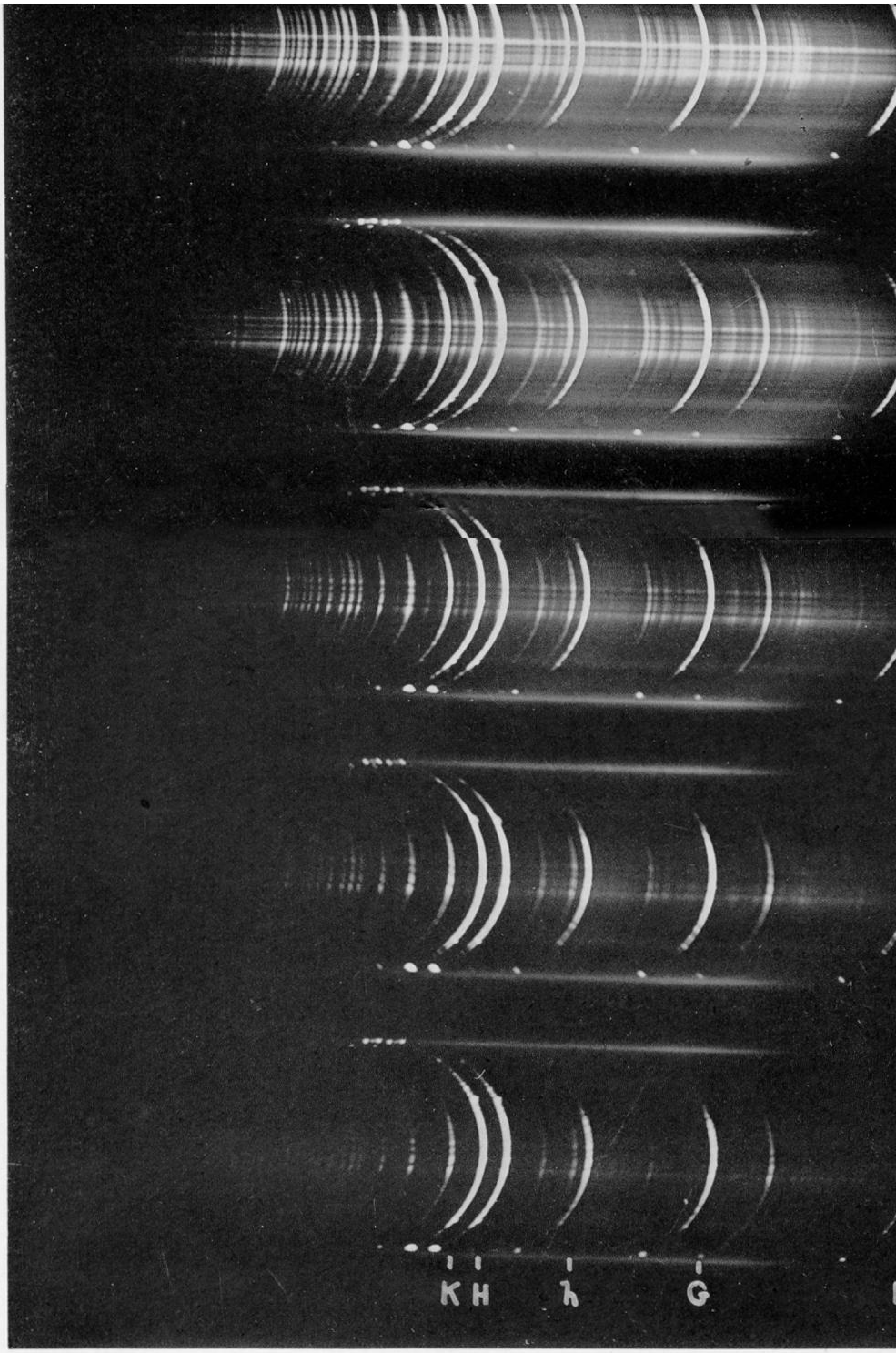
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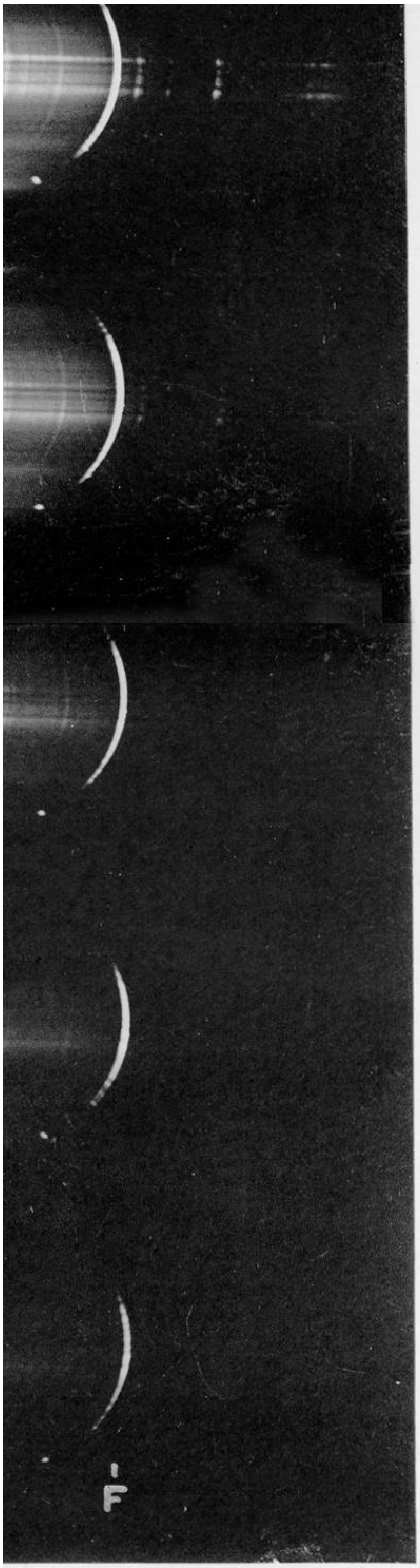

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