**Astronomy.** — *Preliminary Report on the Expedition to Lapland for the Observation of the Total Solar Eclipse of June 29th 1927.* By A. PANNEKOEK and M. G. J. MINNAERT.

(Communicated at the meeting of September 28, 1927).

1. The observation of the total solar eclipse of Jan. 14, 1926 at Palembang having failed through clouds, it was to be feared that in the much more favourable eclipse of 1929 our instruments should have to be used, before by practical experience possible faults could have been detected and corrected. This consideration induced the Eclipse Committee to organize an expedition for observing the total eclipse of June 29th 1927. As the zone of totality traversed England, the South of Norway and the North of Sweden a limited programme could be executed at moderate expense. By the short duration of the eclipse study of the spectrum of the corona would be difficult, but for the observation of the flash a test of the Cooke spectrograph was quite possible. For this reason a request was made to the "Hollandsche Maatschappij van Wetenschappen" at Harlem to destine the "PIETER LANGERHUIZEN fund" for this year for an expedition to observe this eclipse. In its session of May 15th 1927 the Society decided to comply with our request. Immediately the preparation of the expedition, for which preliminary experiments had been made already at the Heliophysical Institute of the Utrecht Physical Laboratory, was taken energetically in hand.

As our place of observation Gällivare in the northern part of Sweden was chosen, chiefly on account of the greater height of the sun (28°, while it was 22° at Aal in Norway), and also, because for our instrumental outfit the vicinity of the technical resources of a large industrial plant was desirable. The instruments which were to accompany us, were the large Cooke spectrograph with moving lens, and the coronacamera with liquid prism. The financial means available allowed to send out only three observers, Messrs A. PANNEKOEK, M. G. J. MINNAERT and N. W. DOORN, the latter assistant at the Leyden Observatory. By special funds Mr. W. BLEEKER, of the Utrecht Physical Laboratory, was enabled to join the expedition ; his wireless apparatus enabled us to compare our chronometers directly with the wireless time signals.

The members of the expedition left on May 26 and arrived at Gällivare on June 1. The same day an observing site was selected and the building of piers and of a shed was begun. The instruments, which had been sent by ship to Stockholm and further by rail, reached our camp on June 13, and their erection was begun immediately.

2. *Observing site.* Most expeditions to Lapland chose their sites in the immediate vicinity of the small towns of Gällivare or Malmberget, at a distance of 7—9 km from the central line. For our work it was necessary to have our observing station in the immediate neighbourhood of the central line; on the accompanying map the central line is drawn and the observing place chosen


is indicated by a cross. The central line has been computed from the elements of the Nautical Almanac, to which corrections $dx = -0.00060$ and $dy = +0.00003$ were applied, communicated to us by Mr. L. J. COMRIE, Deputy Superintendent of the Nautical Almanac Office. The geographical coordinates of our observing site, taken from the map, are

$$\lambda = 1^h\,22^m\,58^s\,\mathrm{E}. \quad \beta = +67^\circ\,3'.5\,;$$

it is situated some kms North of the wayside station Harrträsk of the electrical railway Narvik—Luleå. For this site the moments of $2^d$ and $3^d$ contact were computed $5^h\,46^m\,6^s.8$ and $5^h\,46^m\,48.^s4$ G.M.T., thus giving the duration 41.6 seconds. The points of contact on the solar limb were situated 2° 1′ below the diameter inclined 7° 10′ to the daily motion.

Our camp could only be reached by railway; without the aid of the State Railway Authorities, who ordered four trains to stop there each day, our work would not have been possible. They also had our camp connected with the 4000 Volt cable running along the railway ; the alternating current was transformed down to 220 Volt ; it served so for illumination in our dark room and, converted to continuous current of 200 Volt by means of a motor and dynamo, was used for charging a battery of storage cells and for feeding an iron arc. The storage cells, also put at our disposal by the Railway Authorities, drove the motors for the moving lens and for the rotating cylinder of the Cooke spectrograph. We are indebted for the loan of the necessary instruments for electrical measurements to the Laboratory of the " Technische Hoogeschool" at Delft.

3. *Adjustment of the instruments.* In the report on the Sumatra expedition the mounting of the Cooke spectrograph has been described. To reflect the sun beams horizontally in such a way that the daily motion of the solar image would be horizontal, reflection by two mirrors was necessary then. The first, a coelostat mirror parallel to the earth's axis, reflected the solar image to a point of the meridian with opposite declination ; the second mirror then reflected it to the southpoint of the horizon. As, however, for the eclipse of 1927 the sun's declination was $+23^\circ 17'$ and the latitude $67^\circ 3'$, one reflection on a coelostat mirror threw the image to a point $20'$ below the southern horizon ; hence one mirror sufficed here. The adjustment of the mirror was made in the same way as described in the former report, by means of the same two altazimuths from Delft and Wageningen, once more kindly lent us by Prof. SCHERMERHORN and Prof. DIEPERINK. The adjustment was more difficult here than in the Indias, because the azimuth of the polar axis and the inclination of the mirror to the axis are interdependent with a factor $\sin \beta$. For the azimuth pointings we could make use of a landmark on the top of the Dundret, 7 km distant, for which an azimuth $136^\circ 34'$ was found from observations of the sun.

The reflected sunbeams were collected by the Steinheil objective of the Utrecht Observatory into a solar image of 3 cms on the slit plate. This objective was moved by a motor with clock regulation ; its velocity was regulated the preceding days so that on the eclipse day the daily motion was exactly compensated. The slit was set perpendicular to the relative movement of the moon, hence it was inclined $7^\circ$ to the vertical, and in the same way the prism train, which was traversed twice by the light, and the spectrum in the focal plane were inclined $7^\circ$. The prisms were set at minimum deviation for $\lambda\, 4380$ ; the spectrum extended from $\lambda\, 4150$ to $\lambda\, 4700$, but the extreme wave-lengths were not exactly in focus. For the first flash the slit cut an arc of $8^\circ$ of the sun's limb ; in this position also the exposure for the corona spectrum was made, and then the mirror, by means of a lever between two pins, was turned through a small angle to bring the place of 3d contact upon the slit. The distance of the pins had to be regulated accurately the preceding days ; but through lack of sunshine this could not be performed wholly satisfactorily.

In order to throw the sunlight into the coronacamera we could, by the kindness of Prof. R. SCHORR, make use of a coelostat of the Hamburg Observatory, provided with our 20 cm mirror, and adapted to this high latitude. The mirror was placed at a distance of 6 m. North of the liquid prism ; the adjustment was made in the same way as for the other instrument. This large distance was chosen in order that only the immediate surroundings of the sun could send light into the camera ; by surrounding the mirror and the light path with black screens, also other spurious light was excluded. The liquid prism, with its refracting edge set horizontally, was packed tightly in cotton wool to prevent any variation of temperature. To get the whole spectrum an ordinary and a panchromatic plate (Lumière Opta 68 $\times$ 59 mm, and Ilford Panchromatic 68 $\times$ 40) were put into the plate holder beside each other in such a way that the division fell between $\lambda$ 4900 and $\lambda$ 5000. On this double plate two exposures were made, a short one of 3 sec. lasting from 5 to 8 seconds after the beginning of totality, and a longer one which should end 5 sec. before the end of totality ; between them the plate was displaced 33 mm. Then a second pair of plates was exposed 5 sec. to the solar crescent, weakened by an evenly blackened photographic plate.

The mirrors were resilvered some days before the eclipse.

The adjustment of the instruments was hampered very much by rains ; at the eclipse hour the sun was visible only on 5 days between June 13$^{th}$ and 27$^{th}$. On June 28$^{th}$ began the Lapponian summer, a period of constant bright weather — often however with occasional clouds — with high temperature, which made the work increasingly difficult, especially by the increasing multitudes of gnats.

4. *The time service.* After the radiomasts had been erected the chronometers were compared regularly with the wireless time signals, for so far as the strong perturbations by the electric railway currents allowed this. The first days at 20$^h$ G.M.T. a time signal from Djetskoe Selo was received ; afterwards we could hear at 12$^h$ G.M.T. the signal of Nauen, transmitted by Stockholm and Boden. The last days, however, it was inaudible in our camp, and we were obliged to compare one of our chronometers at Gällivare with those of the German expedition. That Bordeaux had sent extra signals in the morning of the eclipse, but therefore omitted its regular signal at 7$^h$ G.M.T., we learnt by chance only some days after the eclipse.

To know the moment of 2$^d$ contact we made use of two methods described already in the Sumatra report. A telephone connection could be made at no shorter distance, because of the rough inaccessible ground between, than at Jokkmokk, 60 km to the S.W., at $\lambda$ 1$^h$ 19$^m$ 0$^s$, $\beta + 66^\circ 36'.1$, where the computed time of 2$^d$ contact was 5$^h$ 45$^m$ 5$^s$.3 G.M.T., 61.5 seconds ahead of the time at our site. We found Messrs WESTERLUND and VÄSTFELD, resp. surgeon and photographer at that place, willing to observe the beginning of totality and give us a signal by telephone. The State Telegraph Authorities provided for a continuous connection of their observing place via Jokkmokk—Murjek—Gällivare with our camp every morning $5\frac{1}{2}$ to $6^h$ G.M.T. from June 25th to 29th. One observer was to watch the appearance of Bailey's beads or the disappearance of the sun, the other would observe the passage of the shadow over the country. The telephone connection worked well all those days.

The other method consisted in the projection of a solar image of 12 cm by means of a telescope of 8 cm aperture. The length of the chord of the crescent $20^s$, $12^s$, $8^s$, $6^s$ before $2^d$ contact was computed 0.865, 0.778, 0.695, 0.635 diameters. On the screen lines were drawn at these distances parallel to the moon's motion. The projecting telescope was placed between the Hamburg coelostat and the liquid prism ; hence $5^s$ before $2^d$ contact it had to be removed by an assistant.

5. *The eclipse day.* The arrangement for the eclipse was :

Cooke spectrograph : Dr. M. G. J. MINNAERT, assisted by Mr. W. BLEEKER for the moving lens and the mirror ; coronacamera : Mr. N. W. DOORN ; time service Prof. A. PANNEKOEK, assisted by Magister J. L. H. MOOSBERG, teacher at Malmberget, who also during the preparations had given us valuable aid. Several rehearsals had taken place on the preceding days.

In the morning of June 29 the sky was nearly clear ; during the partial phase some thin clouds passed before the sun. During totality the sun was quite cloudless. On the projected image the sun's limb was seen strongly boiling.

The telephone signals from Jokkmokk were received $5^h\ 45^m\ 6$—$7^s$ (observation of the sun) and $5^h\ 45^m\ 11$—$12^s$ (observation of the shadow); probably in consequence of the small difference in diameter of the sun and the moon the decrease of illumination was not so sudden as in other eclipses. The $2^d$ contact was thus assumed to take place at $5^h\ 46^m\ 9^s$, and in this way the seconds —$20^s$, —12, 11, 10 ...... were called out. The projected thin crescent — of which one cusp was broken up into separate specks — was somewhat too short, i.e. the counting was $1^s$ too late ; thus in counting the number 6 was omitted and the numbers 8, 7, 5, 4, 3, 2, 1, 0, 1, 2 ...... were called. The disappearance of the sun's light was not observed ; from the observations of the crescent $5^h\ 46^m\ 8^s$ G.M.T. was the time of $2^d$ contact. At 38 the place of $3^d$ contact was seen brightening, and after 40 the sunlight reappeared ; $5^h\ 46^m\ 48^s.5$ G.M.T. may be taken as the end of totality.

At the Cooke spectrograph the moving lens was started at $5^h\ 44^m\ 17^s$. In the finder 70 sec. before $2^d$ contact several Fraunhofer lines ($H\ \beta$ and surroundings) were seen to be reversed. At count —$5^s$ the circuit for the motor of the rotating cylinder was closed, and the first plate was exposed ; on account of the slipping of the driving cord the cylinder had to be displaced at first by hand, so that a somewhat too long time elapsed before the second exposure. At count $+7^s$ the circuit was broken, the 6th plate was exposed before the occulting sector stopped, and the 7th plate was exposed for the coronal spectrum from $+17^s$ till $+34^s$, the moment that the mirror was turned. A faint orange ring was visible on the slitplate; the slit seemed to stand outside the moon's limb. The motor was again put into action between $+36^s$ and $+37^s$, and was stopped after the exposure of the 12th plate.

With the coronacamera the first exposure lasted from $+5^s$ till $+8^s$, and after moving the plate, the second exposure was given from $+11^s$ till $+37^s$. Then the plateholder was changed and an exposure on the sun's crescent was made from $+18^s$ till $+28^s$.

6. *The comparison spectra.* Photographic negatives, which will be used for photometric purposes are standardized, as a rule, by putting comparison spectra of known intensity upon them. In our case these spectra, for fear of spurious light on the eclipse plates, were taken on other plates, which were cut from the same piece, and were developed together with the eclipse plates. The taking of these comparison spectra occupied us several days after the eclipse in increasingly difficult conditions.

For each of the 12 plates taken with the Cooke spectrograph 3 sister-plates were exposed: one to the solar spectrum, one to the spectrum of an iron arc, and one to the continuous spectrum of a Nitralamp of known temperature and distribution of energy along the spectrum. In all these cases the slit was equally illuminated by the source, and a reducer, consisting of a thin glassplate, half silvered in equal steps of decreasing transparency (Stufenfilter) was placed before the slit. By this means every comparison spectrum was divided into homogeneous strips, for which the relative intensities were exactly known.

For the plates taken with the coronacamera also two kinds of standardizing spectra have been taken on sister-plates; a broad slit with collimator was set before the liquid prism and illuminated one time by a Nitralamp shining on a piece of chalk, another time by a Neonlamp giving a series of monochromatic rectangles. Also in this case the stepped absorbing screen was set before the slit.

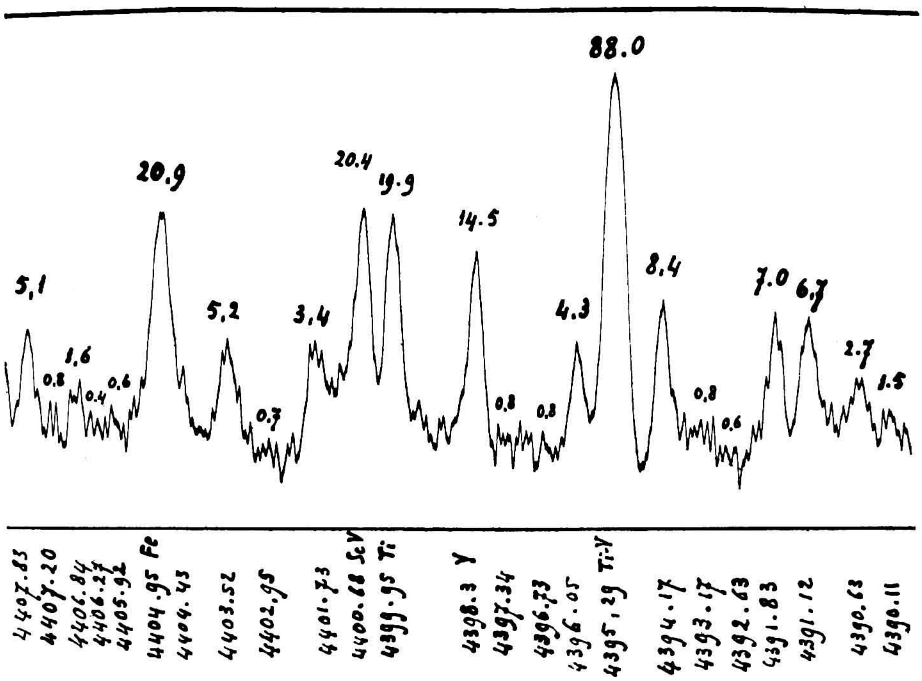
The plates were developed (always eclipse plates and sister plates together) by Messrs MINNAERT and DOORN; here unexpected difficulties arose by the tropical temperature in our dark room for nearly the whole 24 hours of the day. Therefore as a developer metol-hydrochinon-borax, which is of much use in the Indias, and which gives weak contrasts and little fog, was used. The panchromatic plates were at first desensitized in pinakryptol and then developed as ordinary plates. Distilled water was supplied by the laboratory of the Iron Works at Malmberget, which had also procured us nitric acid for silvering the mirrors.

After the plates had been developed the instruments were packed on

July 5th ; part of them, which was wanted for the observations on Gornergrat, Mr. MINNAERT took with him to Utrecht ; the rest was conveyed by the steamer "Wallrat Tham" from Luleå to Rotterdam.

7. *Results.* The first plate of the Cooke spectrograph shows the flashspectrum consisting of lines of nearly 3 mm, superposed on a somewhat narrower strip of continuous spectrum of the sun's border. Between λ 4150 and 4700, a number of 300 emission lines may roughly be estimated; on the continuous strip they are combined in a varying degree with absorption lines of the border. The next plates only contain, with decreasing intensity, some of the brightest chromospheric lines of H and He ; probably by the slow starting of the motor the 2d plate was exposed only after 2d contact. The 7th plate, which was exposed 17 seconds, does not show any coronal line. The other plates, which should have been exposed to the second flash, contain no lines ; probably the slit stood far beyond the sun's limb.

The first plate, part of which has been reproduced in fig. 1 of Plate I renders it possible, by means of the comparison spectra, to deduce values for the intensities of the chromosphere lines. As an instance of the procedure followed we give below for a small part of the plate, a registrogram made with a MOLL registering microphotometer ; the straight




lines at the top and the bottom of the figure denote black (transmission 0) and clear film. In the same way registrograms have been made from the strips of the continuous comparison spectrum, from which the transmission was read for each strip of known intensity. This gives the relation between the transmission of the silver deposit and the intensity of the light for a number of values ; they were represented by a curve, which was used to deduce the intensities in the flash registrogram for the tops of the curve, rendering the emission lines, and the lowest points indicating the background ; by subtraction a value for the intensity of each line was found and has been inscribed in the figure. All lines in this part of the spectrum, contained in MITCHELL's large catalogue, are visible in our curve.

On the plate taken with the corona camera, (of which fig. 2 Table I shows a reproduction to scale) both exposures (of $3^s$ and of $26^s$) contain a strong continuous spectrum, strongest of course in the tangential bands, and a number of monochromatic rings too. For the greater part they are chromospheric emissions ; they may be identified with the following lines :

3889 ($H\zeta$), 3934 ($Ca+$), 3969 ($Ca+$, $H\varepsilon$), 4026 (He), 4078 ($Sr+$) 4102 ($H\delta$), 4216 ($Sr+$), 4341 ($H\gamma$), 4472 (He), 4861 ($H\beta$), 5876 (He), 6563 ($H\alpha$).

Furthermore three coronal rings are visible at $\lambda$ 6375, $\lambda$ 5303 and $\lambda$ 3987. In figs. 3 and 4 Plate I, a five times enlarged reproduction of parts of the exposure of 26 seconds, these rings are easily visible. Perhaps a trace of the emission $\lambda$ 4231 is to be found on the negative, but quite uncertain. If we compare this with the intensities, given by STRATTON and DAVIDSON (for these lines 5, 20, 10, 10) then it follows that the 4231 emission in this eclipse was fainter than 1926 Jan. 14th and in other eclipses. This explains at the same time why the 7th Cooke plate does not show any coronal line. The small number of coronal rings on the corona camera plate is chiefly due to lack of contrast with the continuous background, which in this eclipse was very strong because the lowest and brightest parts of the inner corona were not covered by the moon. A still greater dispersion would have been needed to weaken the background so much that more rings could be visible. We will try, by measuring the blackness of the rings on this plate, to derive values for the intensity of the monochromatic light of the corona by means of the comparison spectra.

*Acknowledgments.* In concluding we wish to express our best thanks to all who have by their assistance contributed to the success of our expedition :

to the "Hollandsche Maatschappij van Wetenschappen" at Harlem, for granting the financial means, by which the expedition was made possible ;

to the Swedish State Railway Authorities, who gave a reduction of 50 % on the freight of the instruments to all expeditions, and who by many facilities made it possible for us to occupy a site near the central line ;

to the Swedish State Telegraph Authorities, who connected our camp with Gällivare by telephone, and provided for a direct telephonic connection with the Jokkmokk observers on the eclipse day ;

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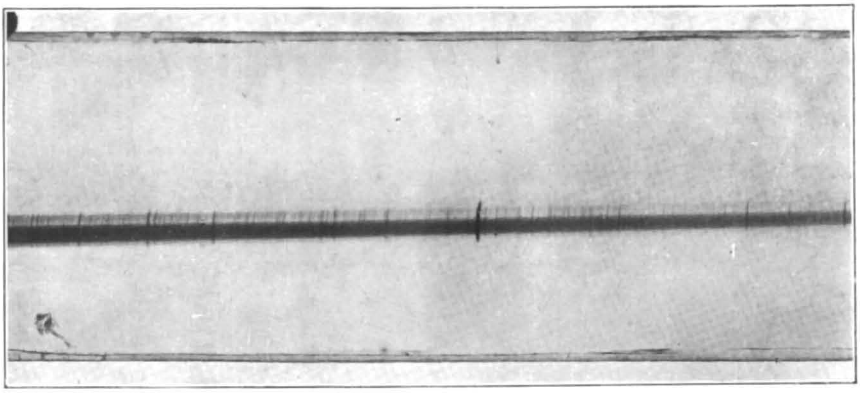

Fig. 1. Spectrum of Chromosphere ($\lambda$ 4210 to $\lambda$ 4530) photographed with the COOKE-spectrograph.

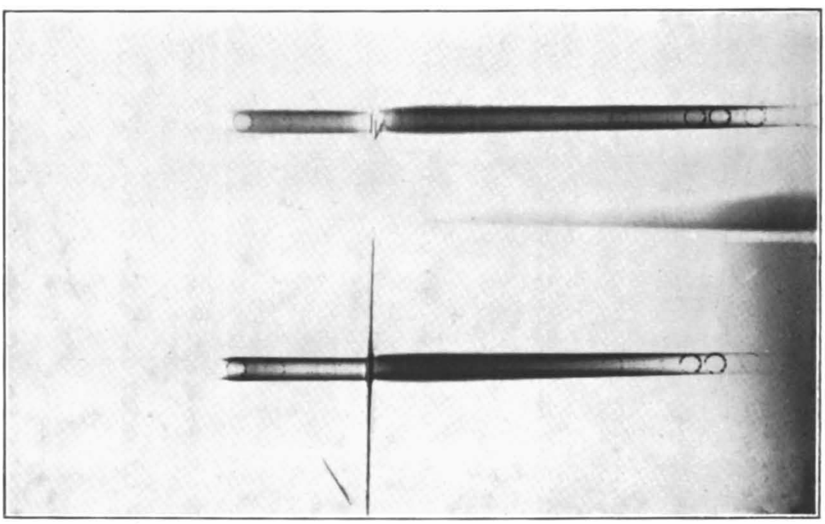

Fig. 2. Spectra of Chromosphere and Corona with the Corona Camera.

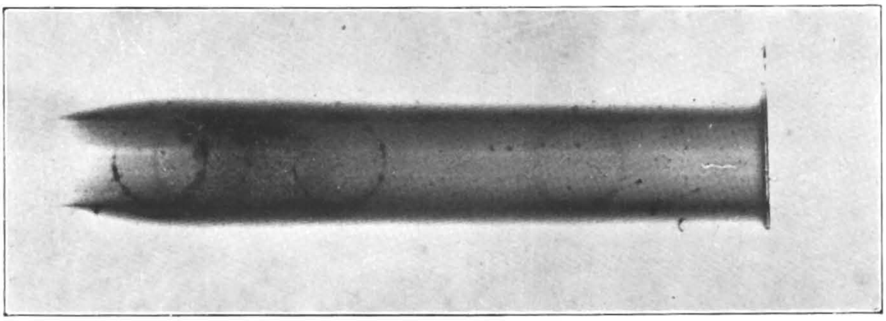

Fig. 3. Red, yellow and green part of Fig. 2 (enlarged 5 times).

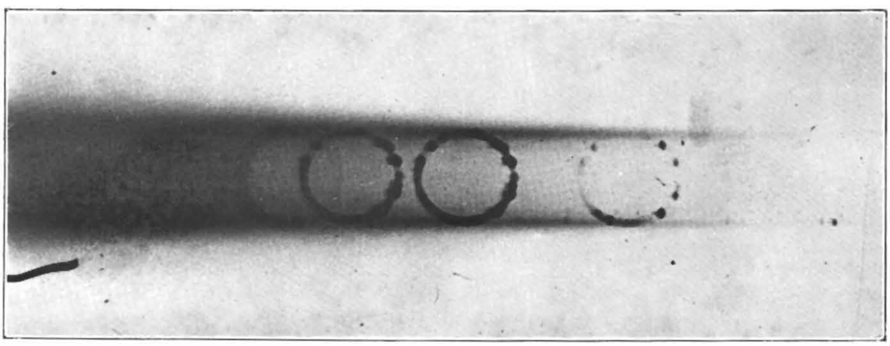

Fig. 4. Violet part of Fig. 2 (enlarged 5 times).

its Laboratory at Malmberget, and for free transport of the greater part of our instruments with one of its oreboats from Luleå to Rotterdam;

further to the officials of the Gällivare railway station, especially to Herr Stationsinspektor AXEL FRIBERG, who with the greatest kindness was always ready to meet our wishes; to Herr Electroingeniör G. SANDVALL at Kiruna, for valuable help in various ways, to Herr Telegrafkomissar LINDGREN at Gällivare; to Magister J. L. H. MOOSBERG, who before and during the eclipse took part in our work as an assistant; to Messrs WESTERLUND and VÄSTFELD, surgeon and photographer at Jokkmokk, for acting as observers at our telephone post, to Mr. C. NOOME, Director of the "Provinciale Utrechtsche Electriciteitsmaatschappij", who supplied us with a motor and dynamo for electric current; to Mr. G. J. IMMINK, Dutch consul at Stockholm, who gave valuable information and help for the transport of our instruments.