MEMOIRS

0E THE

KODAIKÁNAL OBSERVATORY

O. MIOHIE SMITH
Director

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THE SPECTRUM OF STJNSPOTS

BY

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THE SPECTRUM OF STINKPOTS.

INTRODUCTORY.

Visual observations of spot spectra have been carried out at this observatory on a definite plan since the year 1904 and the results have from time to time been published in the observatory Bulletins. In the present memoir I shall discuss the results of several different researches carried out by photographic methods from the "beginning of the year 1907 up to the present time (June 1909).

It will be convenient to arrange the subject-matter under five sectional headings as follows :—

Section I. Description of Instruments employed.

II, *(a)* Discussion of spot spectrum photographs in the region F to D with catalogue of affected lines.

(/>) The weakened lines.

(p) The magnesium hydride lines.

(d) The telluric lines.

(0) The apparent bright spaoes.

III. Pressure in spots.

IV. Radial motion in spots.

V. General conclusions and summary.

SECTION L

.Description of Instruments.

Two grating spectrographs have been employed in these researches.

Spectrograph I. contains a Rowland parabolic grating of 20 feet radius of curvature, used with a colliraating lens of about 5 feet focus achromatised for the region G- to D. The grating has a ruled surface I "8 inches in length, and has 15,028 lines to the inch. This spectrograph is used in connection with a polar sirlerostat and a 6-inch lens of 40 feet focus giving an image of the sun on the slit plate of 4| inches (114 mm.) diameter.

The whole apparatus is mounted on an inclined plane, the common axis of collimator and image-forming lens being directed towards the celestial pole, which has an elevation of 10° 14'.

In photographing spot spectra it is necessary to correct the astigmatism of the grating. This may be accomplished completely by using a perfectly parallel beam from the collimator and placing the camera tube normal to the grating. In. practice it is not convenient to do this excepting for the 1st and 2nd orders, owing to the high angle of incidence necessary which entails serious loss of light.

In all the spectra obtained during 1907, which were in the 3rd order, a sufficiently good correction was obtained by using slightly divergent light, thereby lengthening the focus of the grating from 10 to over 12 feet. The angle of incidence upon the grating was about 53 degrees and the diffracted beam made an angla of 45 degrees with the collimator, more or less, according to the region of spectrum photographed.

8pectrograph II. contains a Rowland plane grating of 3*2 inches ruled surface and 14,428 lines to the inch. The collimator and camera lenses are visual achromatics of 36 and 84 inches focal length respectively. The instrument was mounted on a masonry pier in the spectroheliograph building with tho axes of collimator and camera level. A solar image, 60 mm. in diameter, formed by the 12-inch photo-visual lens of the spectroheliograph, was reflected on to the slit plate by-means of a plane mirror mounted on a hinged iron frame about 12 inches inside the focus. When the spectroheiiograph apparatus was nob in use the frame carrying the mirror could be immediately lowered into position for reflecting the sun's image on to the slit.

With a wide slit the beam of light issuing from tho collimator and falling upon the grating formed a circular patch about 45 mm. in diameter. This was just enclosed by the width of the ruling, but did not illuminate the whole ruled surface^ The width of slit commonly used in photographing spectra was 0*03 mm.., and with this width the beam of light is spread out laterally by diffraction so as to give a perfectly uniform illumination of the entire ruling.

In order to obtain a high linear dispersion with, a comparatively abort camera the angle of diffraction was made large. Most of the photographs of spot and limb spectra have been obtained with the camera inclined. 52 degrees to the ecllimator which gives a linear dispersion in the 4th order of I mm. = 1 Å at X 4270. In the ultra violet near H and K it was found advantageous to increase this angle to 63 degrees in order to realize the greatest possible photographic resolution.

Under these conditions the spectrum is far from normal and the spectrum lines are appreciably curved. These disadvantages are not however of a serious nature and are outweighed by the saving of light resulting from the use of a short camera. The curvature of the lines can easily be computed and allowed for, if neeeasary, by Dr. Walker's formula.*

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* Kodaikánal Observatory Bulletin No. 16.

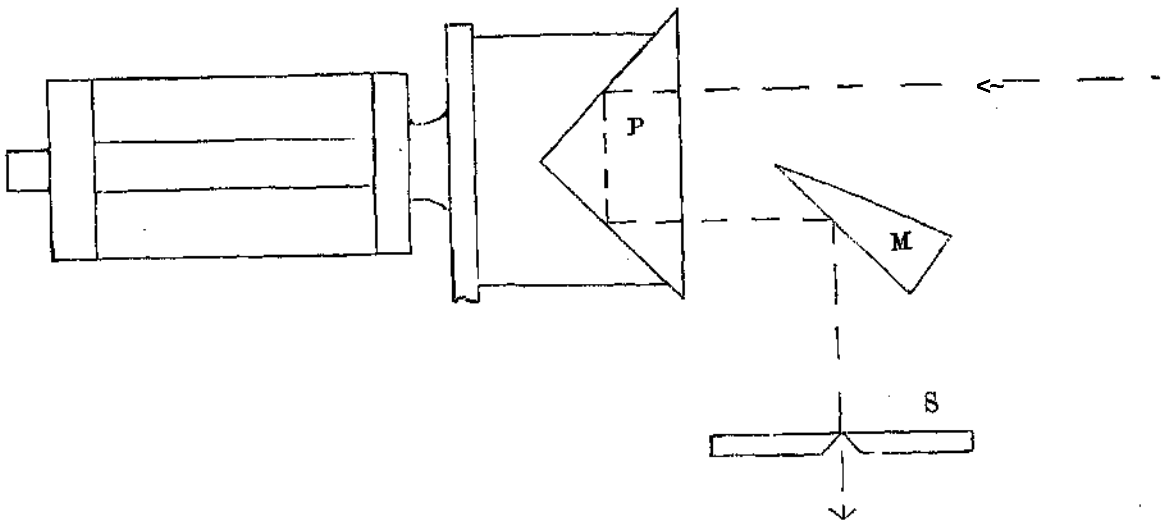
Both spectrographs have been fitted with devices for equalising the density in the photographic images of the spectrum of a spot, and of the surrounding photosphere. In the earlier work this consisted of a sliding V-shaped shutter attached in front of the slit, by means of which the length of the slit could be rapidly altered from that just necessary to include the umbra of a spot, to the length required to give a considerable extent of photosphere spectrum, on each side. An exposure of long duration could thus be made on the umbra, followed by a short exposure on the entire spot and surrounding photosphere. In practice the ratio of exposure times needed to give equal densities for spot and photosphere varied from 6 to 1 in the yellow, to 10 to 1 in the violet. If smaller ratios than these were fonnd to give equal densities it generally implied the admixture of photospheric light in the umbral spectrum, either from bad guiding or from the effects of a diffusive sky.

In the later work another equalising device was used. This consists of a frame fixed a few millimeters in front of the slit and carrying a neutral tinted plane parallel glass plate transmitting about 15 per cent, of the incident light. This plate is divided by a straight cut along the centre- and the two halves can be separated a, few millimeters so as to form a wedge-shaped aperture placed at right angles to the spectrograph slit. In making an exposure it is only necessary to adjust the distance separating the plates and guide the spot into the aperture so that its light falls unobstructed upon the slit. A single exposure is then made sufficient to give a suitable density for the spot spectrum and for the much enfeebled spectrum of the surrounding photosphere.

This method is far superior to the sliding shutter when determinations of line displacements are intended as there can be no spurious displacement arising from a changing temperature in the grating or other parts of the apparatus, and the danger of infinitesimal movements of the slit in working the shutter are avoided. In future work it is intended to use compensated wedges of neutral tinted glass instead of the uniformly tinted plates at present employed. It will then be possible to exactly equalise the densities in all parts of the spectrum.

Both spectrographs are also fitted with Rowland's device for photographing a comparison spectrum on each side of a narrow central strip of spectrum. In spectrograph II. this is small enough to admit of use in photographing spot spectra in the middle strip, and has been so used for some large spots. It consists of a metal bar 165 mm. long, 11 mm. wide, 3 mm, thick, having along its centre a slot 3 mm. wide and 150 mm. long. The bar is provided at the ends with bearings and can be rotated on these through a right angle. It is fitted in the camera immediately in front of the photographic plate. It was designed principally for limb and centre comparison spectra for which it is admirably adapted.

In the work on radial motion in sun spots apparatus had to be devised for rotating the sun's image on the slit plate. This was accomplished in a simple, if not entirely satisfactory, manner by the aid of a large right angle prism having-a hypotenuse surface 70 mm. by 60 mm. The prism is mounted in a block of wood at the end of a horizontal steel axle supported in brass bearings. A movement of rotation can thus be given to the prism, which is adjusted so as. to revolve in the plane of the hypotenuse surface, the axis of revolution passing normally through the centre of this face. A plane mirror (the silvered face of a quartz prism of small angle) covering one half of the prism face is placed in front of the latter in the position shown in the accompanying diagram in which the letters P, M, S, denote the prism, mirror, and slit respectively. The other half of the face receives light from



the large object glass of the speotroheliograph. The course of the rays when the prism is placed with its ground glass ends level is shown in the diagram by a broken line; a rotation of the prism through any angle, 0, produces a rotation of the image on the slit plate of 2 9, without changing the direction of the axis of the pencil of rays, provided that the axis of rotation is carefully adjusted parallel to the incident rays.

The movement of the prism is controlled by a spring catch falling into notches cut at 5-degree intervals on one side of the metal flange to which the wood block is screwed. The other side of the flange is turned smooth. By this means the spectrograph slit can be made to bisect a sunspot in a series of directions differing by 10 degrees, or, by rotating the prism 180 degrees so that the spring catch falls on the uncut portion of the flange, the spot can be bisected either exactly radial to the limb or in any other direction.

The defect of this method of rotating the image is the displacement of the pencil of rays falling upon the mirror and slit when the prism is rotated. This in practice is corrected by using the slow motions of the heliostat, but it obviously limits the angle through which the prism, can be moved. Practically the prism can 'be moved through 30 degrees in either direction without loss of light, and this produces a total rotation of the image of 120 degrees, which is generally sufficient for the purpose in view.

SECTION II.

(<?) Dismission of spot spectra in the region F to D.

The first really satisfactory photographs of the spot spectrum were obtained in May and June 3907 by the then third assistant Mr. GK Nagaraja Aiyar using spectrograph I. In these the density of silver deposit is practically the same in the spot band as in the photosphere spectrum on each side, an essential condition in estimating correctly ihe relative intensities of the lines in the two spectra.

Since the above were taken numerous photographs have been obtained with both instruments of all the larger spots which have appeared. The fine quality of the earlier series of plates however (which has scarcely been exceeded since) amply justified the considerable time which has been spent in an exhaustive study of the whole region covered by them, this extends from X 4850 to A, 6042 and includes over 1000 affected lines.

This series of plates has been copied on an enlarged scale with a special apparatus designed by the writer for lengthening the short lines in the spot band and photographing at the same time a comparison spectrum of the adjoining photosphere. A cylindrical lens of long focus is used for lengthening the lines, a device which, like others, is liable to produce false lines in the resulting spectrum ; these however have been almost entirely avoided owing to the considerable width of the original spot band and the freedom of the plates from accidental defects.

Wave-length scales appropriate to the different plates were constructed by the Director on a dividing engine, and a working map of the spot spectrum with wave-length scales attached was made with silver prints of the enlargements. In the reproductions which accompany this memoir a large portion of this map is given in plates 1 and 2. This includes, in 8 sections, the region between 4838 and 5723. The upper spectrum in each section is the spot spectrum, and the lower the normal solar spectrum.

The original negatives were obtained on the following dates :—1907, May 11, 12, June 20, 21, and 22. The May spot (Greenwich No. 6184) was in south latitude 14° and was 18 degrees west of the central meridian on May 11. The June spot (Greenwich No. 6205) was in south latitude 15° and was 10 degrees west of the central meridian on June 20.

The plates of the May spot selected for measurement cover the regions 4b51-5054 and 5244-5772 ; and the June spectra were measured in the regions 5026-5283 and 5682-6042. In the overlapping portions of the spectra of the two spots no differences were detected and the separate measures gave as a rule very accordant values of wave length.

The results of the measures and estimates of intensity are given in the following catalogue (Table I.). In this the two spots are not treated .separately, and in the regions which overlap the mean values from the two seta of measures are entered. The section of spectrum between 5027 and 5255 contains a grout amount of detail and this portion was gone over twice, the mean values from the two independent estimates of wave-length and intensity being entered in the fourth and fifth columns.

In this catalogue only those lines which could with certainty bo distinguished from the corresponding photosphere lines by an increase or decrease of intensity

TABLB I.

Lines affected in sunspots.

Rowland.	Origin.	Intensity in sun.	λ Measured.	Intensity in spot.	Remarks.
4851-69	Ca. V	1	—	3	Plate of May llt.li, UK)7, logins horo;
4855-06		1	—	1	Slightly reduood in spot.
4856-20	Ti	1	—	a	
4859-93	Fe	4		6	Widonod.
4861-17	—	0		0	("Perhaps nna/rectod, tiho line in well separated from IJ/3 in spot.
4861-53	H	30	4861-53	15	Width in sun 0'7oA (Kowlund), In H]iot, 0'25A'
4862-43	Or	0		2	
4862-55	—	0000	4862-45	00	
4864-50	—	1		0	
4864-92	Y	0		2	
4868-45	Ti	0		1	
4870-32	Ti	1		2	
4873-63	Ni	2		0	
4873-93	—	0(1		2	
4874-93	Ni	o		00	
4875-67	Y	1		2	
4876·59	—	1		(l	
4881-74	Y	IN		2	
4882-34	Ke	3		3	
4882-52	Ti	000	4882-51	0	Shading extending to 82-fi.
4882-67	—	000	4882-77		
4882-89	—	000		0	Band,
4883-09	—	0000N	4882-97		
4883-31	—	0000N	4883-27	00	
4883-65	—	000N	4883-61	0000	
4883'-87	Yt	2		2	
4884-24	Mn	000	4884-32	000	Shading to Yt line more marked on red aid©.
4884-78	—	0	—	000	
4885-12	—	000	4885-10	00	Not. separated from Ti lino,
4885-26	Ti	2	—	3	
4886-13	Or	00	—	0	Broadened.
4894 00	—	00		—	Obliterated iajspot,
4894-74	—	CO		0000	
4894-98	—	0000	4895-00	00	
			4895-61	0	

TABLE I.—cord.

X Bowland.	Origin.	Intensity in sun.	A Measured.	Intensity in spot.	Remarks.
4896-02	Fe	1	4896-60		
			4896-69	0?	Probably a line on red side of Fe line.
			4897-19	0	
			4898-29	0	
			4898-59		
4900-09	Ti	2	—	3	
4900-65	—	0000	4900-76	00	
4900-81	—	00			
4902-03	—	000N	4902-06		A band or group including the solar lines.
4902-26	—	0000		0	
490-2-42	—	000	4902-87		
4902-66	—	000			
4905-01	—	0000	4905-01	00	
4906-58	—	0000	4906-57	000	
4900-28	*	000	4909-29	0	
4912-67	Or	000		0	
4913-80	Ti	2	—	3	
			4915-11	0	
4915-41	Ti	000		1	
			4915-70	00	
4916-66	—	00		—	Obliterated.
4918-19	Fo	1		0	
4921-96	La Ti	1	—	3	
4924:11	Fe			3	p Fe.
4925-45	Ee	5		?	Probably reduced in intensity, a shading extends to 4925-80.
4925-75	Ni	00			
4926-33	—	1		1	
4928-51	Ti	000		1	
		0	4929-08	00	
			4929-40	00	Group of ill defined lines.
			4929-79	00	
49S0-24	—	000	4930-36	00	
4930-66	—	0000	4930-82	0	
4980-98	Ni	00			
			4931-68	00	
			4934-81	0	
			4935-21	0	
				0000	
4937-24	—	€0			
4937-52	Ni?	3		2	
4937-90	Ti	000		1	
4941-13	—	0000	4941-15	00	Band with these limita.
4941-50	—	0000	4941-50		
494i-75	—	0000	4941-70	00	
4942-00	—	0000	4942-02	1	
4944-09		0000	4944-07	0	
4948-12	—	000U	4948-10	00	
4950-55		0000N	4950-58	00	
4950-80		OOOON	4950-70	00	
			4950-87	000	
			4958-96	00	
			4960-81	000	
			4961-46	00	
4961-56		0000	4961-74	00	
4963-24		0000	4963-22	000	Very narrow line,
4964-90	Ti	000	4961-89	0	

TABLE I.—*coni.*

A Rowland.	Origin.	Intensity in sun.	Measured.	Intensity in spoc.	Remarks.
4965-11	Or	1		2	
4965-35	Ni	0		—	Obliterated.
4966-98	—	0000	4966-97	0	
4967-45	—	0000	4967-48	0	Continuous With 4967*70.
4967-70	Ni	00			
			4969-36	0	
			4969-57	0	
4972-10	—	OO00N	4972-02	0	
4972-36	—	0000	4972-35	00	
4973-83	—	0000	4973-75	00	Very narrow line.
4974-43	—	000			
4974-54	—	0000	4974-13		
4974-64	—	0000		0	Band with these limits.
49T4-72	—	0000	4974-69		
			4975-04	1	
			4975-99	0	
4976-51	Ni	1		1	
4976-67	—	0000		?	
4976-87	—	000		?	Shading oxtending to 4977"04,
4977-06	—	0000	4977-04	0	
4977-83	Fe	0		0	Widened.
4978-37	Ti	00		1	
4979-39	—	000		00	
4980-35	Ni	4		3?	Slightly weakened.
4981-91	Ti	4		5	
			4986-68	00	
4987-09	—	00		—	Obliterated.
4988-03	—	0000	4987-99	0	
4989-73	—	0000	4989-68	00	
			4995-01	00	
4995-21	—	OOOONd ?		?	
4995-59	—	00	4995-48	00	
4997-02	Ni	1		0	
4997-28	Ti	0		1	
4998-41	Ni	1		0	
4999-21	Fe	0		000	
5009-83	TiOo	00		2	
5010-40	—	00		—	Obliterated.
5011-12	Ni	0		0	Slightly weakened.
			5013-20	000	
5013-48	Or,Ti	2		2	
5016-34	Ti	2		3	
5018-63	Fe	4		2	p Fe.
5020-21	Ti	2		3	
502'2-H	Or	000		0	
5023*05	Ti	2		3	
5023-37	Fe	0		00	
5025-03	Ti	3?		3	Rowland's intensity seems too great, the line is stronger in spot than outside.
5025-26	Ni	00		000	
5025-48	—	00		0000	Plate of Juno 20th, 1907, begins here.
5025-75	Ti	1		2	
5027-94	Fe	1		0	
			5029-10	0	
5029-66	—	0000	5029-67	0	
5029-81	Fe	1		1	

TABLE I.—*cont.*

X Rowland.	Origin.	Intensity in sun.	A Measured.	Intensity in spot.	Remarks.
5080*22	—	0000	5030-23	000	
			5030-57	00	
508V20				2	
5081/36	—	000	6081-80	?	
			5031-65	0	
5032-09	—	00	5032-04	0	
5082-56	—	000N	5032·48	0	
5032-91	Ni	00	5032-92	0	
5083-81	—	0000 N	5033-41	00	Groap of perhaps 3 lines poorly defined.
5033-71	—	000	5033-75		
6084-35	—	000	5034*42	00	
5034-53	—	0000	50-34-66	00	
			5035'05	0	
503:")-5'1	Ni	5		4	
50SG-45	3?e	0		0000	
5086-64	Ti	2		5	
6037*11	Fo	00		1	
5038-58	TI	2		3	
5039-43		3		2	A wide diffuse line in spot. Including 5039'54.
5039-54	Ni	00			
5040-14	**Ti**	3		5	
5040-79	Ti	00	5040-81	2	
5041-07		3 d ?		2 ?	Intensity difficult to estimate.
			5043-04	0	
			5043-28	0000	"*Very* narrow line*
504348	—	000	5043-47	0	
5043-76	Ti	00		1	
5044*80	Ni, Oo, ⊕	3		4	Widened.
5044-95	—	0000 N	5044-98	000	Exceedingly fine lines.
5045-45	—	00	5045-36	000	
5045-5P	Ti	00	5045-61	0	Diffuse.
			5046-11	0000	
5046-38	—	000 N	5046-44	000	
			5046-73	000	
5047-11	—	000	5047-15	00	
5047-48	—	000 d	5047-57	00	
6048 12	—	00		00?	
5048-24	Ni	0		000	
5048-41	—	00 Nd		00?	
5048-61	**Fe**	3	5018-64	2	This line is displaced to red 0-03A on plate of June 20th, not displaced May 11th. Diffuse on -violet side.
				2?	
5049-04	Ni	2	5049-42	00	
5049 88	—	0000			
5049-77		00001	5049-79	000	
5049-86		0000	605C-85	000	
5050-32	—	000		000	
5050-63	—	000	5050-65		
5050-92	—	0001	5051-05	000	
5051-15	—	00		1	Widened in spot.
5052-08	Or	0	5052-08	—	Obliterated,
5052-34	—	0	**5053·08**	1	
5053*06	Ti	0	**5053·35**	00	
5053-30	—	0000			

TABLE I.—*cont.*

λ Rowland.	Origin.	Intensity in sun.	*λ* Measured.	Intensity in spot.	Remarks.
5053-48	—	000	5053-53	00	
5053-76	—	00 N	5053-80	00	; Plate of May lljbh, 1907, ecjds here.
5054-26	—	000	5054-08 6054-40	000	Sroup of perhaps 4 Jines.
			5055-27	00	
			5055-59	00	
5055-76	—	000	5055-78	000	Solar line not visible! on photosphere.
5055-97	—	0000	5055-96	000	Do.; i
5056-17	Fe	00	5U56-13	000	
5056-62	—	000	5056-5i	1	
6057-02	Fe	1		1	Widened.
5057-67	Fe, Ni	0		0000	
5058-17	Fe	1		0	
5068-42	—	000 ST	5058-43	00	
5058-67	Fe	00	5058-68	0	
5059·11	—	0000	5059-07	0	
5059-41	—	000	505^43	0	
5059-581		OdOO")	5059-85	Oo	
5059-96 J		00 J			
5060--26	Fe	3		4	
			5060-64	0	
5061-58	—	000	5061-57	00	
5061-70	—	000	5061-72	0	
5061-88	—	00	5061-89	0	
5062-07	—	000 N	5062-09	000	
5062-29	Ti	0	5062-30	0	Slightly broadened on red side of solar line.
			5063-01	00	
			5063-22	0	Very faiutly visible on photosphere.
5063-86	—	00	5063^3	000	
5063-70	—	0000	5063-71	0	
5064-06	—	0000	5064-06	0	
5064-24	Ti	00	5064-28	00	
5064-84	Ti	3		5	
5065-15	—	1	5065-20	2	
5065-21	Fe	a}			
5065-38	Fe	2	5065-42	2	Widened. Centre displaced to red (not in. plate of May 11).
5065-89	—	0000	5065-92	00	
5066-08	Or	000 1	5066-14	3	
506617	Ti	000]			
5066-91	—	00	5066-87 j	0	Widened.
5067-04	—	000	5067-13 j	2	
5067-34	Fe	3			
			5068-13	000	Poorly defined.
5068-49	Cr,Ti	0000	5068-49	00	
5069-27	—	000	5069-26	00	
5069-59	Ti	000 d		00	
5069-80	—	0000	5069-83	00	[Poorly defined lines.
5069-97	—	0000	5070-00	000	
5070·31	—	000	5070-33	0	Diffuse.
5070-47	—	0000	5070-56	00	
5070-61	—	0000	5070-63	00	
5071-10	—	000	5071-13	00	
5071-31	—	000	5071-36	0	
5071-67	Ti	0	5071-68	1	

TABLE I.—*eont.*

A Rowland.	Origin.	Intensity in sun.	Measured.	Intensity in spot.	Remarks.
5072-26	Fe	3		1	
6072-4K	Ti	0		—	Invisible on spot, or merged in continuous absorption (p. Ti Lockyer.)
5072-85	Fe	2		0	
5073-11	Or	1		2	
5073-64	Ti	00	eo^s-ei	0	
6073-92	—	000	5073-95	0	
6075-99	—	0000	5076-08	0000	
5076-28	—	000	5076-31	00	
507(5-46	Fe	3		1	
5070-67	—	00001			
5076-81	Ti	00	5076-74	00	
			5077-10	00	
5077-56	—	000	5077-51	00	
			5079-03	00?	Probably a line here.
5079-16	Fe	3		1	
5079-41	Fo	4		5	
5079-92	Fe	4		5	
5080*71	Ni	4		2	
6081-76	—	000	508X-75	00	
	—		5081-87		Narrow space like a bright line.
5082*02	—	000	5082-01	00	
5082-58	Ni	2		0	
5082-88	—	0000	50H2-72	?	Probably a line here.
5083-20	—	OOONd?	5083-17	00	
5083-52	Fe	4		5	
6083"8S	—	000	5083-92	0	
6084-28	Ni	3		2	
5084-73	—	000	5084-75	0	
5085-02	—	000	5085-04	0	
5085-18	—	0000	5086-21	0	Separate lines barely distinguishable in this group.
5085-34	Ti	0000	5085*36	0	
6085-67	—	0	5085-67	0	
			5085-74	0	
5086-08	cd?	0000 N	5086-05	000	
5086-42	—	00		0000	
5086-79	—	0000	5086-84	1	
5087-24	Ti	0	5087-22	3	Widened towards violet.
5087-60	Y?	1		00	
5088-02	*	0000 N	5087-99	00	
5088-72	Ni	0		1	
5089-13	Ni	0		00	
5089-39	—	OOONd?	5089-41	00	Sharp line on band.
			5089-74	000	
5090-00	—	0000	5690-02	00	Broad lines.
5090-57	—	0000	5090-53	00	
6091-48	—	0000	5091-49	0	
6091-90	—	0000	5091-88	00	
5092*06		000	5092-07	0	
5092-28		0000	5092-33	00	
5092-48		00	5092-60	00	
			5092-77	01	
6092-98	—	000	5092-99	000	
5093-62	—	0000	5093-76	0	Diffuse.
6093*86		0000 N			

TABLE I.—*cont.*

X Howland.	Origin.	Intensity iii sun.	K Measured.	Intensity in spot.	Eemarks.
5094-59	Ni	1		0	
5094-79	—	0000	5094-78	00	
6094-20	—	000 M'	5094-22	0	
5095-12	—	00	5095-05	0	
5095-35	—	00 d?	5095-38	00	
5095-51	—	00	5095-56	00	
5096-03	—	000	5095-95		
5096-22	—	0000		1	Strong band unresolved.
5096-36	—	000			
5096-66	—	0000	5096-53		
6098-30	—	00N	5098-37	00	
5099-50	Ni	1		1	Widened.
5100-11	Ni	2		1	
5100-41	—	0000	5100-43	0	Striated band. Not resolved.
5100-83	—	00	5100-81	0	Perhaps four lines.
5101-03	—	000	5101-07	00	
510M1	—	000		?	
5101-25	—	000	5101-24	00	Band with maxima at these poaifciona.
5101-44	—	0000	5101-49	00	
5101-65	—	000	5]01-64	00	
5101-79	—	0000	5101-85	(«0	
5101-99	—	00001	5102-11	000	
5102-18	—	0000;			
5102-41	—	0000	5102-40	0	
5102-84	—	0000	5102-82	00	
510314	Ni	1		000 ?	Obliterated ? (Not affected May 11).
5103-30	—	0000	5103-39	000	
5103-57	—	000	5103-55	000	
5103*91	—	0000	5103 92	00	
5104-20	Fe	(!	5104-21	0	
5104-61	—	0		0	
5105-07	—	000	5105-05	00	
5106-41	—	0000	5106*40	00	
5106-57	—	0000	5106-58	00	
5106-77	—	000	5106-75	00	
5107*05	-	0000	5107-04	00	
5107-36	-	000	5108-43	00	Broad ine*
5107-56	—	00			
5108-81		0000	5108-83	0	Poorly defraedtlines.
5109-29	I	oood?	5109-23	0	
5110-94	Or	00	5110-91	0000	
Mn-H	—	0000	5111-10	0000	
5111-43	—	0000	6 111-44	00	Group of 4 or 5 close linos Tinresolyed except
5112-05	—	000	5112-01	00	for narrow spaoe in middle.
			5112-32	00	
5112-82	—	O0O0N	5112-83	1	
5113-30	Or	00	5113-30	1	
6113'62	Ti	0		1	
5113-92	—	0000	5113-84	OO	
5114-20	—	OOONd ?	5114-21	1	
6114-68	—	OOONd ?	5114-73	1	
			5115-22	0000	
5115-57	Ni	2		i	
5115-96	Fe	0	5115-97	GOU	
5116-22	—	0000	5H6-20	00	

TABLE I.—*cont.*

A.Rowland.	Origin.	Intensity in sttn.	A Measured.	Intensity in spot.	Eemarks.
5116-36	—	0000	5J16-35	00	
5116'Hl	—	OdOO	5116-65	1	
5116-94	—	000	5116-97	1	
5117-33	—	0001)	5117-27	00	
5118-35	—	00001			
5118-53	—	0000 J	5L18"47	1	Y;ery wide diffused lines.
5118-99	—	OOONd?	5118-99	1	
5119-56	—	000	5119-53	0	
511994	—	0000	5.1.19-91	f0	
5120*28	—	0000	5120-28	00	
5120-59		0		2	
5121'06	—	0000	5121-08	00	
5121-20	—	0000	5121-21	00	
5121-40	—	0000	5121-41	00	
5121-83	Fe	2	5121-81	1	
5122-30	Or	0001	5122-37		
6122-48	—	0000 J		1	
5122-97	Oo.	000	5122-97	1	
5123-39	Y	0	5123-34	000	
512H-64	Or	000	5123-63	0	
5124-22	—	000	5121-24	0	Fe line at 5123-90 is unaffected.
5124-56	—	000	5124-58	00	
5124-78	—	00	5124-77	00	
5125-65	—	0000	5125-67	0	Btriated band ending with 5126-38.
5126-37	Fe, Oo	2	5126-38	1	
5126-86	—	000	5126-86	00	
5127-04	—	000	5127-13	0	
5127-19		0000 J			
5127-53	Fe, Ti	3	5127-53	4	
6127-86	—	00	5127-86	00	
6128-25		0001	5128*31	00	
5128-38		0000 J			
5128-66		000	5128-72	0	Width 0-25 A.
5129-84	Ti?	3		2	p. Ti. Diffuse.
5129-55	Ni	2		2	
5128*81	Fe	1		0000	
5129-99	—	0000	5130-00	0	Strong band unreRolyed.
5130-54	Ni	00			
5130-76		000	5130-83	0	
6131-10	—	0000	5131-18	00	Clear space between 5130-8 and 5131*2
5181-64	Fe	2		?	Widened.
5131-94	Ni	1	5131-99	1	
5132*34	—	0000	5132-34	0	
5132-67	—	000	5132-71	00	Obliterated.
6132-84	—	00			
5133-12	—	000	5133-07	0	
5133-36	—	000	5133-41	0	
			5184-41		Barely separated.
5134-51	—	0000	5134-54	1	
5134-85	—	0000	5134-82	1	
5185-35		0000	15135-34	1	
6135-88		000	i 5135-89	0	
5136-27	Fe	00	5136-24	1	
5136-44	—	000	i 5136-44	0	
5186-63	—	0000	5136-67	0	

TABLE I.—*cord.*

X Rowland.	Ojtigin.	Intensity in sun.	X Measured.	Intensity in spot.	Remarks.
5138-13	—	0000	5138-16	000	
5138-52	—	0000	5188-54	0	
5138-69	—	0000	5138-78	00	
5188-89	—	000	5138-92	0	
5139-64	Fe	4		4	Strong shading on red side of Fo line extends
5139-82	Or	00	5140-01	0	to 5140. Probably duo to Cr line.
5140-34	I	00001	5140-42	1	
5140-55		0000 J			
5140-99	—	00		—	Obliterated
			5141-03	00	
5141-50	—	000H	5141-46	0	
5141-92	Fe	3		4	
514*46	—	0000	5142-54	(I?	Scarcely separated from Fo lino at 5142*69,
5143-76	I	0001	5143-83	1	
5143-90		00 j			
5144-20		0000	5144-22	1	
5144-88	Or, C	00	SI 44-88	1	
5145-27	Fe	1		2?	Much widened. N'ob intensified,.
5145-64	Ti	0		1	
5145-91	—	0000 N	5145-98	0	
S146-29	c,-	00	5146-38	0	Probably a line between these.
5146-66	Ni	3		3	
5146-9?	Co	000d?1			
5147-27	—	000 J	5147-12	00	
5147-65	Ti	0	5147-67	3	
5147-99	0,~	000	5147-96	0	
5148-22	Fe	2		1	
5148-41	Fe	3	5148-43	3	Displaced to red compared with solar lino*
5148*85	—	000	5148-88	0	Limits of broad line or band.
5149-01	—	000	5149-10	0	
5149-68	—	0000 N	5149-68	1	
5149-96	—	000	5149-97	1	
5150-36	—	00	5150-40	2	
5151*02	Fe	4		4	Widened.
5151-34	—	0000N"	5051-36	00	
505J-63	—	0000K"	5051-63	000	
5152-09	Fe	3		3	Widened.
5152-3d	Ti	0		2	
5152-70	—	0000	5152-80	0	
5153-18	-C?	000	5153-13	0	
§153-41	Fe	1	5153-42	000	
5153-58	—	001		1	Faint band.
5153-69	—	00 j			
5153-85	—	000	5153-88	0	
5154-91	—	0000		?	Strong band.
5155-03	—	0000	5155-17	0	
^155-94	Ni	2	5155-89	3	
5156-58	—	000	5156 47?	0	Broad nebulous lines.
5156-82	O,-	dON	5156 84	1	
5157-16	—	0000	5157-17	I	
5157-78	—,C	000	5157-77	1	
5158-15	—	00	5158-16	000	
			5158-46	0	
5158-70	C	0001			
5158-83	C	0000 J	5158-79	1	

TABLE I.—*cont.*

λ Rowland.	Origin.	Intensity in sun.	Measured.	Intensity in spot.	Remarks.
5159-23	Fo	2		1	Fe line widened.
5159-45	—	0000	5169*44	00	Clear space at 5159-71.
5159-95	—	0000	5159 94	1	
5160*42	C,~-	00N	5160*35	2	
5101-19	0,~	000	5161 18	00	Unresolved. Faint band.
5161*91	C,—	000	5162'04	00	
5162*69	C	0000	5162-69	0	
6162-90	—	0000	5162-83	1	Strong band, unresolved.
5163*33	—	0000	5163-34	1	Clear space like bright line at 5163*57. DoeB not coincide with bright sptoco in photo-sphere spectrum.
5163-59	0,—	000		—	Obliterated.
5163-70	C,—	000	5163-80	2	
5164-72	Fo	1		0	
5165*08	O,~	000	5165'02	00	
			5165 39	00	
5165*59	Fe	2		2?	Very much widened.
5160-18	—	0000	5166-09	0	
5167*89	—	00	5167 97	0	
6168*36	—	OOONd ?	5168*34	1	
5169-07	Fe	3		3	
5169'22	Fo	4		3 ?	p. Fe.
5169-66	—	0000	5169*64	00	
5170*27	—	0000	5170-25	00	
5170*77	—	000	5170 77	1	
6170*94	Fe	0		—	Obliterated.
5171*19	—	0000	5171*18	i	
6173*92		2	5173*93	3	Broad, probably two lines.
			5174-71	000	
5175*10	—	000	5175*12	0	
5175*57	—	000	5175-55	0	
5175*92	B,	OOONd ?	5175*96	0	
5176*31	—	000	5176-31	•	Clear space like bright line at 5176-57.
5176-74	Ni	1	5176-75	00	
5176-95	Y	000	5176-98	1	Clear space like bright line at 5177*23.
5177-41	Fe	0	5177*48	1	
5177-78	—	0000	5177*80	00	Fine line barely distinguished from shading.
5177-98	—	0000	5178*00	00	
			5178*29	00	Clear space herts.
5178-64	—	000	5178-68	1	Perhaps unaffected.
5178-97	—	00	5178-99	0?'	
5179*29	—	000	5179-24	1	Clear space like bright line at 517S*4o.
			5179*57	000	Very faint group of poorly defined lines.
5179-70		0000	5179*70	000	
6179*96		000	5179-88	000	
5180*57	—	000	5180-79	0	
6181-04	—	0000	6181-12	000	
5181*33	—	000	5181-35	o	
5181-72	—	0000N	5181-71	0	

TABLE *I.-^cont*

X Rowland.	Origin.	Intensity in sun.	X Measured.	Intensity in spot.	Remarks.
5182-12	—	0000	5182-15	00	
5182-52	—	0000	5182-40	0	
5185-20	—	0000	5185-18	1	
			5185-90	0	
5186-07	Ti	2		0	p. Ti.
5186-50	Fe	000N	5186-57	1	
6186-72	—	000			
			5187-27	0000	Broad line.
5187-62	—	000	5187-71	1	
5188-08	Fe			0?	
5188-23	—	0000	5188-23	0	
5188-86	Ti	2		1?	p. Ti. General appearance indicates dooreaae of Ti line and increase of Oa line.
5189-02	Oa	3		4	
5189-74	—	000	5189-79	00	
			5190-33	0	
			5190-73	0	
5191-24	—	000	5191-26	0	
5192-16	Or	00	5192-16	0	
519314	Ti	2	5193-14	4	
5193-67	Or	000	5193-62	00	
5194-03	—	0000	5194-09	0	Not separated.
5194-22	Ti	000	5194-24	00	
5195-11	Fe	4	5195-10	5	
5196-23	Fe	1	5196-o-n 5196-34	1	Widened to thesa limits.
5196-61	Or	0			
5196-74	Mn	00		2	
5197-33	Ni, Mn	00	5197-36	00	Perhaps weakened.[1]
5197-54	—	000ON	5197-58	1	
5197-74	—	A		0	p. Ee (Fowler)*
5198-11	—	0		00	
5198-51	—	0000	5198-52	0	
5198-89	Fe	3	5198-88	5	Widened.
5199-77	—	000	5199-79		
5200-36	Or	oo		0	
5200-59	V	0	5200*64	1	Displaoed to red compared with solar line.
5200-99	—	O00ON	5200-99	0	
5201-26	Ti	000	5201-26	1	
5201-77	—	OOOON	5201-80	0	
5202-44	Fe	2	5202-50	7	Widened.
5202-52	Fe	4			
5202 95	—	0000	5'202-94	00	
5203-12	—	0000	5208-17	00	
5203-66	—	000	5203-63	0	
5204-68	Or	5		10	
5204-77	Fe	3	—	000	
5205-90	Y	0	5205-31	000?	This line is merged in continuous absorption.
5206-71	—	000	5206-73	00	
5207-26	—	0000	5207-26	00	
			5207-45 ?	00	
5207-79	—	000N	5207-77	00	
5208-04	—	0000	5208-01	00	
5208-601	Or	5		5	
5208-78	Fe	2		1?	

. TABLE *I.—coni.*

A Rowland.	Origin.	Intensity in sun.	A Measured.	Intensity in spot.	Eemarks.
			5209-32	00	
5209-78	—	0000	5209-77	0	Gaps in the shading at 5209-5 and 5210-73
5210-06	—	000	5210-02	0	
5210-56	Ti	3	5210-57	5	Widened slightly both sides.
			5210-86	on	
5211·11	—	0000	5211-12	uu 00	
5211-37	—	000	5211-41	000	
5211-70	Fe	00		000	
5212-40 *		000N	5212-41	0	
5212-86	—	OOONd?		000?	Protoably unaffected.
5214-29	Or	00	5214-30	00	
5215-74	—	000		—	Obliterated.
5219-87	Ti	0	5219-87	4	
5220-36	Ni	0		00	
5222-85	Ti, Of	00		1	
5223-79	—	000	5223-80	1	
5224-47	Ti	0		2	
5225-10 }	Or	01 }			
5225-20 }	Or,Ti,3?e	00 }		3	
5225-70	Fe	2	5225-70	3	
5226-71	Ti	2		1	p.Ti.
5227-04	iFe, Or	3		4	
5230-38	Co, Or	00		0	
			5233-95	00	
5234-26	—	0000	5234-27	00	
5254*79	—	2	5234-80	00	p. Fe (Fowler).
5235'35	Oo	000	5235-35	00	
5237-49	Or?	1		0	Very wide and diffused especially on red side.. p*. Or. (Fowler).
5238-74	Ti	000N	5238-72	2	
5239-14	Or	00		0	
5239-99	—	1		0	Shaded on red side.
5240-64	—	000	5240-69	00	Displaced to red compared with liae ®n phofco* sphere.
5241-04	—	000	5241-05	00	
5241-62	—	0000	5241-65	00	
5243-63	—	0000	5243-63	0	Very diffuse and broad.
5246-73	—	0000	5246-72	00	Plate of May 11th, 1907 begins here.
5247-74	Or	2	524775	4	Widened.
5249-28	Fe	00		00	Much widened.
5250-39	Fe	2		3	Widened.
5251-09	—	0000 N	5251-10	00	
			5251-66	0	
5252'15	Fe	0		0?	The two lines are not separated.
5252-28	Ti	000		0 ?	
			5252-74	00	
5253-20	—	00		000?	Muoh widened and weakened.
5255-12 }	Fe	3 }		5	Mnoh widened.
5255-29 }	Or	0 }			
5255-83 }	—	0001		0	Nebulous-line.
5255-91 }	—	000 j			
5257-10	Sr?	00			Obliterated.
5260-14	—	000		00	
5260-56	Oa	0		1	
5264'98	—	0		ûû	
5268-52	Ni	0		UU	
5275-15	—	0		000	

TABLE I.—*cont.*

Rowland.	Origin.	Intensity in sun.	Measured.	Intensity in spot.	Remarks.
5282-58	Ti	00		0	Plate of June 20th, 1907 ends here.
5284-60	Fe, Ti	00		0	
5284-28	Ti	1		0	
5284-79	—	00		000	
5285-82	—	000	5285-87	00	Broad lines.
			5286-27	000	
			5286-71	000	
			5287-09	0000	Very narrow.
5287-74	—	000N	5287-82	000	Broad band; two lines ?
5287-96	—	000	5288-16		
5288-97	—	000	5289-00	0000	
5289-45	—	0001	5289-50	00	
5289-68	—	000			
5292-76	Fe	0		00	
5294-13	Fe	0		00?	
5295-96	AWT?	00		1	
5296-87	Or	3		4	
5297-56	Or	2		2?	Thickened on violet side.
5298-46	Or	4		5	
5300-15	—	00		0	Haze extending on violet side.
5300-93	Or	2		3	
5303-59	—	000	5303-60	000	Not separated, invisible on photosphere.
5303-74	—	000	5303-70	000	
5304-02	—	00		—	Obliterated.
5304-36	Or	0		1	
5306-04	—	0		000?	
5308-60	—	0		00?	A diffuse shade takes the place of this line and extends 0·22 Å. on red side.
5309-63	—	0000	5309-50	0000	Invisible on photosphere.
			5310-01	00	
5310-66		000	5310-66	0	A broad band including the solar line 5310-87.
5310-87		0		0	
5311-10		000	5311-13	0	
5313-25		000	5313-38		
5313-42		00N			
5316-79	Fe	4		3	p. Fe.
5316-96	—	2		1	
			5317-45	000	
5317-72	—	OONd?	5317-72	000	Band. Line on violet side perhaps unaffected.
5318-21	—	0000	5318-04	000	
5318-96	Or, Fe	0		?	This line is very ill-defined in spot and seems widened.
5325-74	—	2		1	
5329-33	Or	3		4	Or line 5329·98 is widened, not intensified.
5331-64	Oo	00d	6331-64	0	
			5332-30	000	
5333-95	—	000	5333-94	0	
5334-40	—	000	5334-30	00	
5335-05	Oo?	1		0	p. Or (Hale).
5335-15	—	0000	5335-43		
5335-55	—	0000		00	Band unresolved.
5335-77	—	0000	5335-64		
			5335-92	000	
5336-36	—	000	5336-23	0	Broad line.
5336-48	—	0000	5336-50	0000	

TABLE I.—*cont.*

X Howland.	Origin.	Intensity in sun.	A.Measured.	Intensity in spot.	Llemat'ks.
5336-66	–	00001	5386-70	000	
5336-79	—	0000 J			
5336-97	Ti	4		3	p. Ti.
			5337-35	00l>	
			5337-63	000	
5338-52	—	00N	5338-49	0	
5339-40	—	0001	5339-52	00	
5339-61	—				
5342-89	Oo	00 J		0	
5343-15	—	0000	5343-14	0	
					Olear space, very narrow, at fiS43'2U.
			5344-37	00	Broad line.
5344-94	Or	00	5344-94	€0	ftluoh widened, 0*24 Å in width.
5345-99	Or	5		5?	Widened.
5346-27	–	001	5346-36	000	
5346-52	—	000 J			
6348-51	Or	4		4?	Widened.
5351-26	Ti	00		?	
			5355-55	0000	Poovly defined.
5356-27	—	000	5356-25	00	
			5356-65	00	111-dofined and broad.
5357-38	—	00	5357-34	000	
			5357-91	000	
5359*39	Co	0		0000	Obliterated P There is a dark irregular shade which may mask the lino.
5360-33	—	000ON	5360-33	000	
5362-37			5362-43	000	
5363-06	—	3		2	p, Fo (Fowler).
			5363-70	000	
			5364-21	000	
			5365-84	0000	
5366-83	—	000	5366-83	?	
5369-13	—	0000	5369-20	00	
5374-61	—	000	5374-69	0000	Broad, ill-defined lines.
5375-37	—	000	5375-39	0000	
5376-07	—	000 j	5376-22	00	Not visible on. photosphei'e.
5376-32	—	000 j			
5376-66	—	000	5376-69	00	Do.
5377-03	Fe	0		000?	Reduction of intensity uncertain Ill-defined group interferes.
5377-80	Mn	2N		2	
5377-99	—	000			
5378-12	—	0000	5378-10		
5381-22	—	2		1	p. Ti.
5384-27	—	0000"	5384-36	000	
5384*40	—	0000 J			
5384-83	—	000	5384-81	000	Hazy on violet Bide.
5385-33	—	000	5385-35	0000	
5386-53	Fe	?		0	
5387-16	Fe, 0	0		?	
5387-77	Or	00	5387-78	000	
5388-55	—	00	5388-51	00	A band including fche solar line 5388*55 which is unaffected.
5388-71	—	000	5388-77	00	
5389-37	—	000	5389-33	t	
5390-20	—	000	5390-20	0	

TABLE I.—*cont.*

X Rowland,	Origin.	Intensity in snn.	A Measured.	Intensity in spot.	Uemarka.
5390-73	—	0		00	
5392-53	HI	00		000	Clear spaoo aii r>3{&'78.
5393-38	Fe	5		5	
5393-58	—	000	5393-57	000	
			5394-09	000	Plato of May 12fch, 1907 bpgitiH here.
5394-84	Mn	1			
5394-91		1		5	Widoned.
			5396-76	0000	
5396-78	Ni	OOON			
5396-94	—	000	5396-80	1	Probably 2 lines.
5397-82	Fe	1		0	
5400-71	Fe	3		2	
5401-47	—	0	5401-53	0	Loss refrangible than 6401*47 which mucfc be weakened in spot.
5401-90	—	OOONd ?	5401-94	000	
5402-15	—	0000	5402-18	?	
5402-27	—	00			A nebulous band including tho iiolar Haea.
5402-80	—	0000	5402-44	no	
5402-98	—	0			Obliterated.
			5403-06	?	
5403-67	—	0000	5403-61	00	Plate of May 11th, 1907 ends here.
5405-55	—	1		00	
5405-99	Fe			0	
5407-59	Mn	6		7	
5407-69		01		2	
5409-13	—	0	5409-12	00	
5409-34	Fe			1	
5410-00	Or	0000		5	
5411-43	M	2		00	
5411-76	—	4	5411-72	0000	
5412-21	—	1	5412-14	00	
5412-39	—	0000	5412-44	000	Poorly defined lines.
5412-78	—	0000	5412-57	00	
5413-00	Mn	000		0	
5413-30	A?	000		—	Obliterated.
5413-89	Mn	00		0	
5414-28	—	OON		—	Obliterated.
5416-28	—	OON	5416-31	000	
5419-14	A?	00			
5419-31	A?	0000	5419-22		
5419-42	A?	0000		0	Band with these limits.
5419-63	—	0000	5419-57		
5420-51	Mn	00.0		2	
5420-61	Mn	0000			
5421-61	—	0	5421·52	00 ?	Intensity difficult to estimate from proximity of solar line 5421-88.
542316	—	0			
5425-46	—	000	5423-14	000	
		0000		.0	Widened and reduced in intensity,
5426-47	—	1	5426-15	0000	
6429^35	—	00	5426-46	2	Widened.
5429-91	Fe	00		0	
5432-75	Mn	6d? 1Nd ?		7	Muoh widened.
5435-79	—	0000	5435-74	2	
				0000	

TABLE *I.—conl*

X Rowland,	Origin.	Intensity in sun.	λ Measured.	Intensity in spot.	Remarks.
				2	Widened on red side.
5436-80	Fe	1	5437-99	000	Broad.
5438-00	—	0000	5438-49	0	Hazy on violet side.
5438-51	—	000	5438-93	00	Band strongest at 8439-00.
5438-92	—	0000	5439-69	00	
5439-68	—	0000	5439-95	000	
5439-91	A	000			
5440-71	—	00001	5440-77	000	
5440-86	—	000 j	5442-13	000	
5442-16	—	0000			
5442-50	A	00001	5442-57	00	Probably includes solar line at 5442-63.
5442-63	Cr	00 J	5442-92	000	
5442-92	—	0000 N	5443-85	000	Poorly defined lines.
5443-83	—	000	5444-36	00	
5444-30	—			7	
5447-13	Fe	0000	5448-17	000	
5448-14	—	6d?	5449-06	00	
5449-14	—	0000		?	Ill-defined band ending in narrow line at 5449-76.
5449-37	—	000	5449-76	000	
			5451-02	?	Perhaps unaffeoted.
5451-01	Sr	000	5451-47	00	Ill-denned band.
				0000	
5453-44	—	00	5453-88	0	
5453-86	—	000	5454-54	0000	
5454-57	—	0000			
5455-67	Fe	2		5	
5455-83	Fe	4			
5457-64	} Mn	000 }		00	
5457-70		000 }	5457-92	0000	
			5460-19	0000	
5460-27		0000 N	5460-72	2	Wave-length confirmed by measures on. plate- .of June 21st.
5460-72	—	00			
				0 ?	Much, -widened.
5461-76	—	0		0	Widened and reduced in intensity.
5462-70	Ni	1		3 ?	Slightly -widened·
5463-49	Fe	3	5465-92	000	Poorly defined.
			5466-61	3 ?	Widened.
5466-61	Fe	3	5467-23	2 ?	Perhaps displaced to red·
5467 20	Fe	1			
5467-61	—	000	} 5467-68	000	Broad line.
5467-77	—	0000	5468-01	0000	
5467-99	—	000		0	
5468-32	—	00	5468V 60	0	
5468-60	—	000 Nd?	5468-83	000	
5468-84	—	000	5469-00	000	
5469-00	—	0000		00	Widened.
5470-30	—	00			
5470-80	} Mn	0	}	2	Widened;
5470-88		0		2	
5471-41	Ti	000	5471·98	000	
				1	Widened,
5472-92	Fe	1		0000	
5473-37	—	00			
5473-59	—	000	} 5473·66	000	
5473-76	—	000		0	
5474-44	Ti ?	00			

TABLE I.—*cont.*

Rowland.	Origin.	Intensity in sun.	λ Measured.	Intensity in spot.	Remarks.
5474-67	—	000			
5474-96	—	0000 N	5474-73	0000	Poorly defined lines,
			5475-09	000	
5475-64	—	000 N	5475-64	000	
5475-94	—	0000 N	5475-89	000	
5477-90	Ti	00		X	
5478-67	Fe	0		000	p. Or.
5480-72	Or	00N		00	Solar line appears to be of intensity 000,
5481-65	Fe, Ti	1		2	
5482-08	—	00		2	
5483-31	Fe	1		0	
5483-57	Or	1d ?		2	
5484-24	—	000	5484-32	000	
5484-52	—	0000	5484-49	000	
•5484-85	—	000	5484-86	00	
5485-02	—	0000	5485-08	0000	
•5485-76	—	000	5485-76	00	
5486-32			5486-41	0000	
5486-97	—	000	5487-02	000	
5487-35	Fe	1		0	
5488-37	—	00 Md?		0	
5489-19	—	00		—	Obliterated.
5490-3?	Ti	0		2	
5490-91	—	0		—	Obliterated ?
5491-04	—	000	5491·03	1	
5493-45	—	00		—	Obliterated.
			5495-64	0	
5496-12	—	00u0	5496-07	00	
5496-78	—	00	5496-78	0000	
•5497-74	Fe	5		7	Widened.
			5500-27	000	
5500-81	—	0000	5500-83	000	
5501-68	Fe	5		6	Widened slightly.
5502-30	—	0		00	
5503-29	Fe	1		0	
5504-12	Ti	0	5504-11	1	
5505-10	—	0000	5505-10	000	
5505-75	—	0000 N	5505-74	000	
5506-10	Mn	1		1 ?	Widened. Not intensified.
5507-00	Fe	5		6	
5508-84	Or	0		—	p. Or. Obliterated.
5509-06	—	0000	5509-04		
5509-32	—	0000	5509-32	000	
			5509-60		
			5509-83	0000	
5510-23	Ni	1		0	
5511-17	—	0000	5511-17	0000	
5511-38	—	0000	5511-38	000	
5511-64	—	000	5511-59	000	
5511-87	Fe	0000	5511·91	00	2 lines ?
5512-01	—	00	5512·08		
5512-47	Fe	1		0	
5512-74	Ti	2		3	
5514-56	Ti	2		2	Intensity 2 in sun seems too great for [illegible] lines.
5514-75	Ti	2		3	

TABLE *I.—cont.*

X 'Rowland.	Origin,	Intensity in sun.	\ Measured.	Intensity in spot.	Remarks,
.0516*16	—	0000	5516-13	0000	
5515-32	—	0000	5515-32	0000	
5515-70	—	0000	5515-75	0	Broad lines.
5510-25	—	0000 N	5516-21	000	
6610*61	—	0001	5516-61	000	
6616*71	—	000J			
5518-58	—	0000	5518-60	000	Very broad.
6619*00	—	0000	5518-96	000	
			5519-49	0000	
5511)*B0	Fe	0		000	
5620*73	—	00 N	5520*70	0	
6622*66	Fe	2		2	Unaffected ?
662*2*88	—	0000	5522-93	00	
5523*IB	—	0000	5523-18	000	Band.
5528-47			5523-44		
66'23'tt0	—	0000	5523-94		
5524-08	—	0000		000	Band.
6621-tJl	—	00	5524-19		
5524-48	—	000	5524-51	00	
6626-01	—	000	5524-96	000	
6626*57	—	0000		000 ?	Probably a line on violet side of Fe line at 5525-77.
5520*07	—	000 N	5526-01	00	
55*27-03	Sc	3		2	p. So. (Fowler).
5527-62	—	00001	5527*72	000	
•6627*80	—	000 dj			
5628'08	—	0000	5528-12	0000	
5628-30	—	000	5528*35	0000	
5529*12	—	00		0	
5529*38	Fe	00		0	
6631*00	Ti	**00 N**		0	
5631-01	—	0000	5531-91	000	
5532*20	—	00		—	Obliterated.
5582-35	—	000	5532-26	00	Band.
6532*67	—	000 N	5532-54		
5533-00	—	0		000	
5533-25	—	000	5533-26	00	
5533-79	—	000	5533-81	000	
6535-06	Fe	2		1,	p. Fe (Fowler).
5537-93	Mrs,	00	5537-95	0	
6638-03	Mn	00	5538'06	0	
6538-74	Fe	1		1	"Widened. 0*17 A in width.
5539*51		0		—	Obliterated.
5640'66	—	000N"	5-540-68	000	
6541*11	—	000	5541-15	000	
5541-50	—	0000	5541-50	000	
			5542-19	000	
5542*55	—	0000	5542-55	000	
5542*97	—	0000	5542-98	000	
5544*83	Y	000	5544-81	000	
6644*98	—	0000	5545-03	000	
5545-49	—	0000	5545-82	000	
6646-16		000	5546-17	000	On violet side of solar line at 554«*25.
5646-73	Fe	2		3	
6647-22	Fe,V	1		2	

TABLE *I.—eont.*

Bowland.	Origin.	Intensity in sun.	A Measured.	Intensity in spot.	Rpmarks.
5547-52	—	0000 isra?	5547-53	00	
5548-16	—	0000	5548-20	000	
5548-54	—	0000	5548-59 {	0	
			5549-18 }	00	Ill-definod band.
5549-88	—	00	5549-83	0	
5550-87	—	0000	5550-91	0	
			5551-36	000	
5554-16	—	0000			
5554-46	—	0000 N	5554-31	0000	
5555-95	—	0000	5555-93	0	Diffused on violot Hide.
5556-42	—	0000 N	5556-44	0	
5556-69	—	0000	5556-71	000	
5556-93	—	0000 N	5556-94	00	
5557-29	—	000	5557-32	00	
5557-71	—	000	5557-70	000	
5558-14	—	0			
5558-21	Fe	0		1	
5558-39	—	0000	5558-34		Shading to horo.
			5558-93	00	
			5559-39	00	
5559-87	—	00	5559-85 {		
5560-11	—	000	5560-05 }	CO	Ill-dofinod band.
5560-43	Fe	2	5560-43	1	
5560-65	—	0000 \			
5560-91	—	0000 J	5560-78	000	Probably two linos.
5561-23	—	0000	5561-15	0000	
5561-46	—	00	5561-46	000	
5561-70	—	0000 N	5561-72	00	
5562-34	—	000	5562-24	00	
			5565-07	000	
5565-70	Ti	00	5565-75	1	
5566-63	—	0000	5566-64	000	
5566-9£	—	000	5566-94		
5567-04	—	0001			
5567-2]	—	000 J	5567-16	00	
5570-62	—	000 \			
5570-83	—	000 j	5570-71	000	
			5571-26	000	
5571-71	—	0000	5571-76	0000	
5588-99	Ca	6		8	
5596-40	—	000	5596-43	000	
	—		5598-01	000	
	—	000	5605-20	00	
5620-72	Fe	0		ftft	
5624'77	Fe,Y	4		uvj	
6625-10	—	000	5625-10	8	
5625-54	Ni	0		n	
				00	
			5626-27	0	
5627-86	Y	00		A	
5628-87	Cr	00		u	
5636-93	Fe	0		8	
5640-54	—	0		00	
5641-21	—	1		0000	
5643-30	Ni	0		0	
5645·83	Si	1		000	
				00	

TABLE I.—*cont.*

\ Kowland.	Oi'igin.	Intensity in. snn.	A Measured.	Intensity in spot,	Remarks.
5646-32	—	000 N	5646-35	0	
5647-46	Ti	00		0	
5648-80	Ti	00		0	Widened.
5657-67	—	000		0	
5659-82	Fe	0		000	
5664-80	—	000		00	
5665-78	Si	1		00	
5668-59	V	000		0	
5669-26	—	1		0	
5671-07	y	0		2	
5672-05	So	0		1	
5680-15	*-	000		0	
5682-43	Ni	2		I	Plate of June 21st, 1907 begins here.
5682-87	Na	5		6	
5684-71	Si	3		I	
5687-06	—,	000		2	
5688-44	Na	6		7	
5689-69	Ti	0		2	
5690-65	Si	3		1	S seems too great intensity in sun.
5694-96	Or	'b		1	
5698-75	V	1		3	
5700-40	—	00	5700-41	2	
5701-32	Si	IN		000	Broad line.
5702-54	Or	0		1	
5702-88	Ti	000		1	
5703-80	V	1		3	
5704-96	A?	0		000	
5707-20	Y	0	}	9	
5707-27	Fe	1	J	X	
5708-62	Si	3		1	
			5708-78	0	
5712-10	Fe	3		5	Ti 5712-07 and Fe 5712*09 according to. HassoJborg:
5713-00	Or	0		1	
5714-12	—	000	57.1411	1	
5714-38	Fe	0		00	
5716-67	Ti	00	5716-68	1	
5717-52	—	0000	5717-50	00	
5718-51	- ,, A?	000 N	5718-50	000	
5720-04	—	00	5719-99	000	
5720-67	Ti, A	0	5720-67	0	This line is much weaker on photosphere tlaari' ^Rowland's estimate, the atmospheric component being probably absent.
5721-12	—	0	5712-10	00	
5723-89	_	000	5723-87	000	
5724-31	—	000	5724-30	000	
5727-27	TiY	2N		4	
5727-87	_	00	5727-88	2	
5731-44	__	00	5731-48	3	
5731-98	Fe	4		2	
5732-52	—	0		—	Obliterated.
5734^26	A?	000	5734-28	00	
5735-92	—	00	5735-89	00	
5737-29	—	0	5737-28	3	

TABLE I.—*cont.*

λ Rowland.	Origin.	Intensity in sun.	λ Measured.	Intensity in spot.	Remarks.
5739-70	—	0	5739-67	1	
5740-20	—	0	5740-21	0	
5742-07	Fe	2		1	
5743-18	—	0		00	
5743-65	—	00	5743-64	2	
5747-89	—	1		0	
5748-58	Ni	2?		2	Slightly widened. Intensity 1 on Highs' map.
5752-25	Fe	4		2	
5753-86	-Or	1 N		000	
5754-88	Ni	5		6	Widenod slightly.
5762-48	Ti	000 N }		2	Width. 0·17 1.
5762-64	Fe	1 }			
5766-55	Ti	0		1	
5771-82	—	00	5771·82	00	Perhaps unaffected,
5772-36	Si	3		00	
					Plate of May 12th, 1907 ends herp.
5772-63	—	000 }	5772-71	00	
5772-80	A	000 }			
			5773-48	000	
5774-25	Ti, A	0		1	
5775-30	Fe	4		3	
5776-96	A	000 N	5776-89	0	
5778-68	Fe	1		1	Widened on blue side. Clear space at 5778-80 appears Jiko a narrow bright lino bordering the, Fo line.
5781-40	Or	0		1	
5783-29	Or	2		2	Much widenod.
5784-08	Or	3		4	Widened.
5784-88	Fe	1		—	Obliterated.
5785-19	Or	2		2	Widened,
5785-95	Or	1		2?	Intensity difficult to estimate.
5786-19	Ti, Or	0 N }	5786-24	1	
5786-37	—	000 }			
5787-24	Or	00 }			
5787-49	—	000 }	5787-30	0	
5788-14	Or	4		5	
5793-29	—	3		0	
5794-14	Fe	2		0	
			5798-00	0	Does not coincide with 5798*08.
5798-08	—	3		—	Obliterated. ?
5804-48	Ti	0	5804-49	2	
5804-68	Fe	0		—	Obliterated.
5805-44	Ni	4		2	
5823-91	—	00	5823-92	0	
5828-10	—	0		X	
5831-82	Ni	1		00	
5847-22	Ni	1		0	
5853-38	—	0		1	
5857-98	Ni	3		00?	Intensity difficult to estimate.
5859-81	Fe	5		4	
5862-58	Fe	6		4	Widened.
5866-68	Ti	0		0	Plate of June 22nd, 1907 begins hore.
5867-79	Ca	0		2	Plate of June 21st, 1907 ends here.
5880-49	—	00	5880-48	3	
5890-19	Na	30		40-?	

TABLE I.—*cont.*

λ Rowland.	Origin.	Intensity in sun.	λ Measured.	Intensity in spot.	Remarks.
5896·16	Na	20		30 ?	
5897·05	A (wv)	2		3 ?	Intensity in spot doubtful.
5899·52	Ti	1	5899·52	3	
5903·56	—	00	5903·54	2	
5905·90	Fe	4		2	
5918·77	Ti	0	5918·74	3	
5922·33	Ti	0		3	
5925·22	A (wv)	2		0	Widened.
5938·04	—	000	5938·03	4	
5941·85	A (wv)	2 }	5941·96	5	Obviously on red side of pair.
5941·99	Ti	00 }			
5944·95	A (wv)	1	5944·95	3	
5948·77	Si	6		2	
5953·39	Ti	1		3	
5955·17	A (wv)	1		000	
5956·92	Fe	4		6	
5966·08	Ti, A ?	2		4	
5977·01	Fe	4		2	
5978·77	Ti	1		3	
5984·81	—	0000	5984·81	1	Both these lines seem wiAm<d and weak-
5985·04	Fe	6		4	ened,
5987·29	Fe	5		4	
5988·79	A (wv)	0	5988·78	1	
5991·60	—	2		0	
5996·96	Ni	1		—	Obliterated.
5999·92	Ti, A(wv)	0		2	
6002·97	—	0000 N	6002·91	1	
6005·77	Fe	1		0 ?	
6007·54	Ni	1		0	
6039·95	V	0	6039·95	3	Plate of June 22nd, 1907 teatis,
6042·32	Fe	3		1	

or by wltoiiag. have be- entered. Probably many more, especially of the stronger liiu», ore "li^tly ^cted- lates were examined under a Hilger microscope to ^A\™J^L\te intensitie, of the spot lenses for giving a wide field with rather a low power. [illegible] the method advocated by Fowler was adopted, advantage being taken of the numerous lines in the photosphere spectrum which were within the field of view. Assuming Rowland's intensities for these (except in one or two instances), it was possible to form a fairly good estimate of the amount of increase or decrease in the intensities of the spot lines. All the lines in the spot band which could not, wit,U certuinty, be ^**£ ection with lines in the photosphere spectrum a with refereoce, to the nearest well were measure l, and then positic and defined known lines. These lines form a very large proportion of the delude the complicated or bands identified by Fowler with the 8peotru,n of magnesium h case of the well-defined lines measured, the deduced wave-lengths are probably correct within 0·02 Å; hazy lines.

and bands with ill-defined limits cannot be assigned accurate wave-lengths and separate measures made by the same observer will give results differing by as much as 0·10 Å.

In Table I. the first three columns are from Rowland's Preliminary Table, and give the wave-lengths, origins, and normal intensities of all the affected lines, which could be identified, either by inspection, or, in the case of the fainter lines, by the accordance of position with the measured lines in the spot spectra. The fourth and fifth columns give the measured wave-lengths and estimated intensities in the spot spectra; a line connecting two or more wave-lengths in the fourth column, indicates a shading extending between. Many of the lines to which Rowland assigns intensities of less than 00 were invisible on the negatives outside the spot band, and in cases where the positions of measured lines do not agree within 0'05 i with Rowland's lines the identifications must be considered extremely doubtful.

Over 90 per cent, of the total number of affected lines coincide more or less closely with lines measured by Rowland, but 88 lines in a total of 1,043 appear to be unrepresented. In the following list (Table II.) I give the unidentified spot lines separately: they are without exception weak lines, the larger proportion being of intensity 00 or less, whilst none of them exceed intensity 0. A considerable number of the more conspicuous of these lines are almost certainly present in the solar spectrum although not apparently noticed by Rowland. A careful examination of Higgs' map, or of a specially good negative of the spectrum, reveals the presence of very faint lines coinciding in position with at least 12 of the more conspicuous lines in the above list.

The identification of a very large proportion of spot lines with, lines in the normal spectrum is in harmony with the results obtained by Hale and Adams from a discussion of spectra obtained on Mount Wilson in 1905.* The obvious conclusion to be drawn from this result is that the spot spectrum differs from the normal solar spectrum solely in the relative intensities of the lines, the small number of very faint spot lines apparently absent in the Fraunhofer spectrum cannot be considered as proving any essential difference in the spectra* except as regards relative intensity, and the same materials which produce absorption in the spot must be universally distributed over the solar surface.

Messrs. Hale and Adams, in their discussion, give a table showing the spot intensities estimated on ten different plates (presumably referring to one and the same spot, although this is not stated). These refer to 345 lines in the region

* Astrophysical Journal, XXIII., 24.

TABLE IT.

Unidentified Lines in Spot Spectmm.

Wave-length.	Intonaify.	Eemarks.	Hale and *Ai&m®,* λ	Hale and *Ai&m®,* Intensity.
4895·61	0	Visible on Higgs' map.		
4896·60	0	Shading on red side of Fe line at 4896'62.		
4B»7-11»	U			
4898·29 } 4898·59 }	0			
4915·11	0	Visiblo on Higgs' map.		
4929·08	00			
4929·40	00			
4929·79	00			
4930-82	0	Visible on Higgs' map.		
4U3HW	00			
4034« HI	0			
4935·21	0			
4958 08	00			
4U60*Kt	000			
n»«l'7-l	00			
	0			
«»«9*57	0			
4975·04	0	Vory faint on Higgs' map. Extends some distauoo over dišo in photographs but is exceedingly faint.		
4975·90	0	Visible on Higgs' map.		
4980·68	00			
5013-20	000			
5029*10	0			
60,10-57	00		H and A begims	
5031·65	0		5035-10	00
filKUJ-05	00	Visible on Higgs[1] map.	5043·00	0
5U-i3-0-J	0	Clearly visible in Higgs[1] map. Extends over diso on one side for 5 or 6 spot diameters. (In ono plate only.)		
5043·28	0000			
5040-11	0000			
5016-73	000			
5055-27	00			
5055-50	00			
5063·01	00			
5063·22	0			
5068·18	000			
5077-10	00		5092·76	0
5085-74	0		fIIS-9*	00
5002-77	0			
5112-32	00		5188*60	00
6115-22	0000			
5158-46	0			
617-J-71	000	Perhaps = 5178-36 (0000) in Rowland.		
5178*29	00	Perhaps = 5179-69 (0000) in KowlancL		
5170-57	000		5190·35	00-0
5185-90	0	Visible on Higgs' map.	5190·78	00-0
6190-83	0	Visible on Higgs' map.		
5190-78	0	Visible on Higgs' map ?		
5207-45	00		H and A ends at 5212	
5209-82	00	Visible on Higgs' map		
5210·86	00			
5233·95	00			
5237·61	000			

TABLE *II.—cont.*

Wave-length.	Intensity.	Remarks,	Hale and. Adams.	
			\	Intensity.
5251-66	0	A group of lines from 5251*0 to 5251-8 in Higg-fi' map.;		
5252-74	00	Shading in Higgs' map.		
5286-27,	000			
5286-711	000			
5287-0^	0000			
5310-01!	00			
5317-45	000			
5332-3(5	000			
5335-92	000			
5336-23;	**0**	Perhaps == 5336'36 (000) in Rowland.		
5337-35!	000			
5337-63	000			
*344'37	00			
5355-55	0000			
5356-65	00			
5357-91	000			
5363-70	000			
5364-21	000	Perhaps = 5364-36 (000) in Rowland.		
5366-84	0000			
5394 09	000			
5426-15;	0000			
5451-47:	000			
5457-92	0000			
6460-19'	0000	Perhaps = 5460-27 (0000 N) in Rowland.		
5471-98	000			
5475-09,	000			
5495-64'	0			
5500-27.	000			
5519-49,	0000			
5542-19	000			
5549-18	00			
5565-071	000	Perhaps = 55G5'19 (0000) in Rowland.		
5571-26	000			
5598-01	000			
5626-27	0	Visible) on Higgs' map.		
5773-48	000			

between 5009 and 5854. In addition they give a table including 127 "band" lines, measured in the region 5032—5212. A careful comparison of both these tables with our results shows a very satisfactory general agreement in the estimates of intensity, as well as a close accordance in the measurements.

Amongst numerous faint lines there are about 36 lines of spot intensity 0 or over in our table, and intensified at least one grade, which are not given by Hale and Adams, nor do they record 55 weakened lines of Fe and Ni noted in our table.* On the other hand their lists include 25 intensified lines which are not recorded by us. Of these the following seven lines seem to me to be wrongly identified by Hale and Adams with Fraunhofer lines.

* In Messrs. Hale and Adams discussion no attempt "was made to giro an exhaustive list of affected lines.

Wavu-lengfcli Hale and A.dams	Origin.	Intensity.		Eemarks.
		Sun.	Spofc.	
5080-95	—	000	0	Probably the same as 5086-8 i, intensity 1, in, our list.
5401-47	—	0	1	Probably 5401-53, intensity 0, -which is certainly not coinci-dent with the line at 5401.-47.
5400-02	—	000"	0	Probably 5409'12, intensity 00 which is on the red side of the solar line 5409-02.
5646-04	—	00	1	Probably 5646'35, intensity 0 iu. our list.
5698-56	Fe}Or.	1	2	Perhaps SBOS^S, intensity 3 in our list. The Fe, Cr. line is unaffected in oar plates.
f>776^JG	A.	000	0-1	Probably 5776"89, intensity O in. our list.
5853-54	—	000	0	Probably SSSS^S, intensity 1 in. oar list.

Of the remaining 18 lines not given in our table, 10 seem to be unaffected on our plates, while 8 appear to be slightly intensified, but not sufficiently so to be recorded by us.

X have gone somewhat into detail in the above comparisons solely with a view of ascertaining whether any real differences occur in the spectra photographed by Hale and Adams in 1905 and in our plates obtained in 1907; and, notwithstanding the apparent discordances above noted, I am of opinion that the spectra are in reality identical in every detail. The considerable number of lines recorded by us and not by Hale and Adams may easily be accounted for by the fact that their list does not profess to include every affected line, whilst the very small number of lines recorded by Hale and Adams and not by us are not of a striking character, and their omission by us might be due to personal differences which must always occur in estimates of relative intensity. The general accordance of the vast majority of the Hues is indeed very striking, strongly suggesting a constancy in the spot spectrum equal to that of the Fraunhofer spectrum itself.

A close comparison was also made with a catalogue of about 350 widened lines observed here in the years 1904-1905 (Kodaikánal Observatory Bulletin No. IV.) Of the lines in this list observed on more than 4 occasions (167 in number) during about 250 days of observation, all occur as strongly intensified lines in table I. with the possible exception of the following:—

Line observed.	Origin.	Jto. of times seen.	Remarks.
5001-16	Ti	39	N"ot affected in photographs.
5150-74	C	6	Perhaps = 5150-36.
5366-62	—	13	Probably = 5366"85.
5493-71	—	17	Not affected in photographs.
5460-57	—	202	Probably 5460-72 in photographs,
5903*75	—	5	Probably 5903*54 in photographs.

The last two have almost certainly been identified wrongly with the solar lines which are faint and not easy to distinguish, whereas the measures of these lines (which have been repeated) leave no doubt as to the true wave-length. No certain, evidence of change can therefore be deduced from this comparison.

(b) The Weakened Lines.

The behaviour of the "Spark" lines in spots was first studied by Fowler, who showed that in general these lines are weakened.* A large number of weakened lines are shown in our photographs, and in Table I. 185 are recorded. I will not discuss these in detail, as Mr. Nagaraja has already made a careful study of all the weakened lines observed by him.† It is necessary to say, however, that in the detailed examination of the negatives under the micrometer microscope a good many more weakened lines were detected than were noted by Mr. Nagaraja, who discovered all his lines with an ordinary lens from contact prints of the spectra. A small number of the less important lines noted by him were not found by me. On the whole, *my* independent estimates of weakening are in excellent agreement with his, and no revision of the conclusions he drew from them seem necessary. With regard to the weakening of the enhanced lines, however, the case appears to be even stronger than he put it, since there is no instance of a spark line clearly visible in the photosphere spectrum which is not weakened in the spot; there are however a few compound lines containing a spark line in which no weakening is recorded, such as the line at 5154*24 Ti, Oo. and 5276*17—24 Fe, Cr. The well-known spark lines of iron 4924-1, 5018-6, 5169-2, 5316-8, so prominent in the flash spectrum, and in metallic eruptions, are all weakened in our spectra. The Ti spark line 5188*86 mentioned by Mr. Nagaraja as an exception, is noted in my table as probably weakened, but the amount of reduction in this case is impossible to estimate, owing to the close companion line of Oa at 5189*02. The two lines are barely resolved on our plates but the general appearance of the pair under the microscope indicates a decrease in the more refrangible component, and an increase in the less refrangible component, the total intensity being unchanged, and this lias since been confirmed on plates of higher dispersion which give a clear separation of the pair.

(c) Magnesium Hydride Lines in the /Spot Spectrum.

In Table III. I give in the first column a list of wave-lengths in the magnesium hydride spectrum, kindly furnished by Professor Fowler, to whom I am indebted for permission to publish them here. For comparison, I give in columns 2 and 4 the wave-lengths of the coinciding lines in the spot spectrum, and in the

* Monthly Notices E.A.S. LXVI. 361. † Asfcropbysioal Journal XXVI., 143.

solar spectrum; the former taken from table I. and the latter from *R,,aUn*** FreMmmary Table,*

In the magnesium hydride spectrum there occur several close pairs of lines which would almost certainly appear in our spectra as single broad lines; treating those a* single lines tie total number of lines measured by Fowler in this region is HO, and these occur in the spot spectrum as follows :—

tfiffcy linos coincide more or less closely with lines of unknown origin in tho spot spectrum.

Twenty-four lines coincide with, or fall very near to, solar lines of Fe_5 Ti Cr, Mg_o otc, and would therefore be indistinguishable in the spot spectrum.

Hix lines arc not found in our list of spot lines.

Tho 50 coinciding lines may be further sub-divided as follows :—

In SO the differences of wave-length do not exceed 0-02Å.

In 13 tho differences lie between 0*02Å and 0-05Å.

lu 7 the differences lie between 0*04Å and 0'09Å.

Homo of tho larger differences may easily be accounted for by the difficulty in measuring linos in the spot spectrum which fall near the edge of a band or shading. Also it should be Btatod that Fowler's measures were based primarily on Fabry and Buissori standards and were reduced to Rowland's system by a mean difference, so that t'hft appreciable errors in .Rowland will affect the comparison.

Tho six MgH lines absent from our list are the following:—5175-37, 618V91, 5185*00, 5185-58, 5199*01, 5209*07. On re-examining the negatives of the spot Hpectrum ib is found that the first, second, and last of these lines are probably present, but confused with neighbouring lines; the third is present but was overlooked in the measures, whilst no trace can be seen of the lines 5185-00 or 5199*01 although both of these lines are given in Rowland's table as very weak solar lines.

On tho whole the agreement in the two spectra is such as to fully justify Professor Kowlor'n claim that these lines in the spot spectrum are due to the prosoiKJo of magnesium hydride.

Turning now to the solar lines in Rowland's table it will be seen that no less than 40 of the coinciding spot lines, *i.e.,* 80 per cent, are represented in the normal solar spectrum by very faint lines, the intensities ranging from 00 to 0000. The agreement with the magnesium hydride lines is slightly better than that of the spot lines, since in 68 per cent, of the solar lines the differences do not exceed 0'02A.

The general statement on page 28 as to the coincidence of spot lines with lines in the normal solar spectrum, is borne out also in the particular case of the magnesium hydride lines, and a similar conclusion must be drawn, namely that this compound is not confined to spots but must be universally disputed over the sun's surface.

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TABLE III.

λ MgH. (Fowler).	λ Spot (Evershed).	Differences F—E.	Rowland. λ Sun.	Rowland. Origin.	Rowland. Intensity in sun.	Intensity in spot.	Remarks. (Referring to spot spectrum.)
5175·09	5175·12	−0·03	5175·10		000	0	
5175·37			5175·42		000		
5175·56	5175·55	+0·01	5175·58		000	0	
5175·91 } 5175·98	5175·96	−0·02	5175·92		000 Nd?	0	
5176·30	5176·31	−0·01	5176·31		000	0	
5176·97	5176·98	−0·01	5176·95	V	000	1	Clear space like a bright line at 5176·57.
5177·48	5177·48	0·00	5177·41	Fe	0	1	Clear space like a bright line at 5177·23.
5177·76	5177·80	−0·04	5177·78		0000	00	
5178·00	5178·00	0·00	5177·98		0000	00	
5178·22 } 5178·36	5178·29	0·00				00	
5178·65	5178·68	−0·03	5178·64		000	1	Clear space between 5178·29 and 5178·68.
5178·92	5178·99	−0·07	5178·97		00	0	
5179·21	5179·24	−0·03	5179·29		000	1	
5179·58	5179·57	+0·01				000	Clear space at 5179·45.
5179·72	5179·70	+0·02	5179·69		0000	000	
5179·94	5179·88	+0·06	5179·96		000	000	
5180·16			5180·23	Fe	1	1 ?	Fe line interferes.
5180·54	5180·58	−0·04	5180·57		000	0	
5180·76	5180·79	−0·03	5180·75		000	0	
5181·06	5181·12	−0·06	5181·04		0000	000	
5181·36 }	5181·35	+0·04	5181·33 }		000 }		
5181·43 }			5181·50 }		00 }	0	
5181·69	5181·71	−0·02	5181·72		0000 a?	0	
5181·91							
5182·15	5182·15	0·00	5182·12		0000	00	
5182·46 } 5182·53	5182·49	0·00	5182·52		0000	0	
5182·95			5182·91		000		} Shading of bl probably obscures lines in spot spectrum.
5183·36							
5184·32			5184·36		000		
5184·48			5184·45	Fe	2		
5185·00			5185·00		0000		
5185·20	5185·18	+0·02	5185·2?		0000	1	
5185·58							
5185·91	5185·90	+0·01				0	
			5186·07	Ti	2	0	
5186·59	5186·57	+0·02	5186·50		000 N	1	
5187·26	5187·27	−0·01				0000	
5187·73	5187·71	+0·02				1	
			5188·08	Fe	1	0?	
5188·23	5188·23	−0·07	5188·23		0000	0	
5190·40	5190·33	+0·07				0	
5190·74	5190·73	+0·01				0	
5191·24	5191·25	−0·02	5191·24		000	0	

TABLE III.—*cont.*

λ JMgJI (Fowler).	λ Spot (Evershed).	Differences F--E.	Rowland. λ Sun.	Origin.	Jnfensitiy in Bun,	Intensity in spot.	Remarks. (Eeferring to spot spectrum.)
5192-77			5192-79		000		
5193-55	519rf-62	— 0-07	5193-67	Cr	000	00	Spot line probably compounded of Cr and JMgH.
5194-04	5194-09	— 0-05	5194-03		0000	0	
	5194-24		5194-22	Ti	000	00	
5195-21	5195-10		5195-11	ire	4	5	
5196-13	5196-02	+ 0-11				0	Pa line intensity 1 at 519G-23.
5196-37	5196-34	+ 0-03	5196-43		0000 N		
5196-63			5196-61	Cr	01	oj	
			5196-74	Mn	00		
5197-57	A197-33		5197-54		0000 N	1	
5198-51	5198-52	— 0-01	5198-51		0000	0	
5198-71	5198-88		5198-89	Fe	3	5	Widened,
5199-01			5199-03		0000		
5199-77	5199-78	— o-oi	5199-77		000	1	
5200-68	5200-64	+ 0-04	5200-59	V	0	1	
5200-98 „	5200-99	— o-oi	5200-99		0000 N	0	
5201-19 *	5201-26	— 0-07	5201-2H	Ti	000	1	
5201-82'	5201-80	— 0-02	5201-77		0000 N	1	
5202-64	5202-50		5202-4-4	Fe	2	7	Widened.
			5202-52				
5202-92	5202-94	— 0-02	5202-95		0000	00	
5203-16	5203-17	— o-oi	5203-12		0000	00	
5203-67	5203-63	+ 0-04	5203-66		000	0	
5204-40			5204-41		0000		
5204-66			5204-68	Or	5	1	
5204-91			5204-77	Fe	3	10	
5205-33	5205-31	•f 0-02				000	
5205-94			5205-90	Y	0	000	The Y line is merged in continuous absorption.
5206-16			5206-22	Cr, Ti	5		
5206-44			5206-37		00	0 r	
5206-79	5206-73	+ 0-06	5206-73		000	00	
5207^27	521)7-26	+ 0-01	5207"J6		0000	00	
5207-44	5207-45	— 0-01				00	
5207-76	5207-77	— o-oi	£207-79		000 N	00	
5208-04	5208-01	+ 0-03	5208-0!		0000	00	
5208-38-1			5208-28		000		
5208-49			5208-60	Cr	5	5	
5208-86			5208-78	*Ve*	2	1?	
5209-07							
5209-281	5209-32	— 0-01				00	
5209-35							
5209-75	5209-77	— 0-02	520978		0000	0	
5209-94	5201-02	— 0-08	5209-95		000	0	
5210-41	5210-57	·	5210-56	Ti	3	5	Widened on bobh sides.
5210-58							
5210-89	5210-36	+ 0-03				00	
6211-11	5211-12	— o-oi	5211-11		0000	uo	

(d) Telluric lines in the 8pot Spectrum.

A considerable number of lines in the less refrangible region of the spot spectrum appear to coincide in position with lines in the normal solar spectrum to which llowland assigns telluric origins, and a still larger number have been recorded visually at this observatory as widened in spots.*

As a large proportion of these lines are due to water vapour, it is of importance to make a critical study of them, with a view to determining whether the evidence is sufficient to warrant the conclusion that water vapour really exists in spots.

In a recent paper read before the Dublin meeting of the British Association, Cortie calls attention to these telluric lines, and from his own observations of spot spectra, he concludes that water vapour probably does exist in spots in the form of superheated steam. This conclusion receives support from the fact that traces of water vapour seem to be essential for the production of the magnesium hydride spectrum which is so prominent in spots.f

In our spectra the telluric water vapour lines are all relatively feeble, that is, their intensities compared with true solar lines all fall below those given in Rowland's Preliminary Table. This is doubtless due to the dryness of the air and its low pressure at 7,700 feet above sea level, also to the considerable altitude of the sun at the time the plates were exposed. It is, however, a condition most favourable for determining whether the lines are really affected in spots, since if so the change of intensities in passing from photosphere to spot should be much more marked than in the case of photographs taken under moist atmospheric conditions and showing the telluric lines very strongly.

In Table IV. T give a list of all the telluric lines occurring in Table I. as well as of all those which have been observed visually in sunspots at this observatory during the past five years. These are simply transcribed from the catalogues published in the Kodaikánal Observatory Bulletins referred to above.

There are twenty lines in the above table recorded as widened in spots, which appear to coincide with lines attributed to water vapour. Some of these lines are also shown as intensified in the photographed spot spectrum. But the lines at *x X* 5879-95, 5922-74 and 5944*53 have probably been wrongly identified in the visual observations, as intensified lines are found on the photographs at 5880-48, 5922-33, and '5944-95. Also the three double lines at 5903-56-75, 5918-64-77 and 5941-85-99 each containing a solar and a telluric component have certainly been wrongly identified with water vapour; the measures indicating without any doubt that it is the solar component of each line which is intensified in the spot.

Omitting the first line in Table IT., which is doubtfully attributed to water vapour, and the line at 5999-92 to which Rowland assigns a Ti component, there

* "Kodaikanal Observatory Bulletins, "Nos. IV., Vill. and XI.

t According to B. E. Brooks the presence of water yapour is not an essential condition for the production of the MgH. spectrum. (Astropliysical Journal XXIX. 187.)

TABLE IV.

Telluric Lines in Spot Spectrum.

λ Photographed.	λ Observed.	Rowland's Origin.	Rowland's Intensity in sun.	Photographic intensity in spot.	Number of times observed.	Mean widening.	Remarks.
5295-96	5295-9(5	A wv ?	00	1	5	4	
5419-14		A?	0000				C A band in spot spectrum coincides with these solar lines.
54 19 Ml		A?	0000	0			
5419-42		A?	0000				
54.19*91		A	000	000 ?		.	Probably intensified in spot.
	5689-81	A?	0		4	5	Probably the *Ti* line at 5689*69 which is intensified in photographs.
5704-96		A?	0	000			
	5717*72	A	00		1	8	Probably 5717*50 which is intensified in photographs.
5718-60		— A ?	000	000?			
5719 90	5719-80	,	00	000	2	5	Weakened in photographs.
5720 67	6720-67	A	00	0	5	8	
	5724* II	Ti, A			2	4	Perhaps 5724-31 on photo* graphs.
		A					
6734-26		A?	000	00			
	5741-09	A?	000		3	6	
5772*63			000	00			f Measured position of line in spot is 5772*71.
5772-80		A	000				
5774-25	5774-25	Ti, A	0	1	4	7	
6776-90	5776-96	A—	OOON	0	1	8	
	5879-95	A wv	1		1	6	Probably 5880-48 which is intensified in photograph.
					1	6	
	6892-61	A wv	3				Intensity in spot doubtful.
5897-05		A wv	2	3?			
	5900-26	A wv	4		5	6	
5903-56		..	00	2			
	5903-75	A wv	1		6	6	Wrongly identified in visual observations. = 5908'5t5 on photographs.
					5	6	Wrongly identified, = 5918-77 on photographs.
	6918-64	A wv	4				
		Ti	0	3			
6918-77					2	4	
	5922-74	A wv	2				Perhaps the 25 Hne at 5922-33 which is intensified on photographs.
					4	6	
	5923*87	A wv	1				
					1	8	
	5924-04	A wv	2				Widened in spot.
		A wv	2	0			
5925-22					5	6	Wrongly identified in visual observations. It is the *Ti* component which w intensified in spots.
5941-85	5941-85	A wv	2				
§941-99		Ti	00	5			
					1	6	
	5942-79	A wv	3		1	7	Probably mistaken, for next line.
	5944-53	A wv	1				
				3	1	6	
5944-95	5944-95	A wv	1				Almost obliterated in spot.
5955-17		A wv	1	000	9	6	
5966-06	5966-06	Ti,A?	2	4	2	5	
5988-79	5988-79	A wv	0	1	1	5	
	5989-51	A wv	0		1	2	
	5992-22	A wv	0		1	6	
	5999-44	A wv	00	2	2	6	
5999"-92	5999-92	iTi, A wv	0		1	7	
	6004-10	A wv	000		1	6	
	6009-58	A wv	000				

remain twelve lines observed visually to be widened in spots which appear to coincide with undoubted water vapour lines. But of these only two are confirmed by the photographs, viz., the lines at 5944*95 and 5988*79; and a careful inspection of several excellent plates of this region taken recently, has failed to show any of the others intensified in the spot spectrum. Since most of these lines were only seen on one occasion, we must conclude that the apparent widening was in all probability an illusion.

The certain evidence for the presence of water vapour in spots rests therefore on two lines only, and these are lines that are not especially prominent in the water vapour spectrum.

It should be mentioned that several water vapour lines appear to be slightly weakened in the photographs. In again going over the plate of June 22, 1907, the following intensities were found:—

	Intensity Rowland,	Intensity in photosphere.	Intensity in spot.
5893-73	1	00	000?
5909-21	3	0	00
5922-74	2	0	000
5925-22	2	0	00
5947-06	1	000	0000?
5955-17	1	0	00
5966-88	1	0	00

An examination of several recent plates shows that the weakening of these lines is not seen on plates which show the telluric lines strongly; and in the best plates obtained the weakening is less than is indicated above, and indeed entirely absent in the first and fourth line of the list. It is difficult to account for this weakening except on the supposition of a compound origin for the lines.

In summarising the whole of the evidence we may take the region between 5850 and 6000 which contains the great majority of the telluric lines due to water vapour.

But water vapour lines of Rowland's intensity 0 and under are practically all invisible on our plates either in the photosphere or spot spectrum; we are limited therefore to lines of intensity 1 and upwards of which there are 70, and these behave in the spot spectrum as follows :—

Thirteen lines of Rowland's intensity 1 are not found on either spot or photosphere spectrum.

Forty-five lines are unaffected in the spot spectrum.

Three lines are probably unaffected but the intensities cannot be correctly estimated owing to the presence of companion lines strongly intensified in the spot.

Seven lines are probably slightly weakened in the spot spectrum.

Two lines are certainly strengthened.

The very large proportion of unaffected lines including as it does the strongest lines in the whole series of water vapour lines is clearly against the supposition that water vapour is present in spots. The two strengthened lines we must consider to be due to other substances present in the sun, the lines being accidentally associated in position with water vapour lines.*

Regarding the other telluric lines not attributed to water vapour, six are compound lines, three containing a Ti component, whilst seven are marked in Rowland's table A?, implying uncertainty as to their telluric origin. One line, 5717-72, is probably wrongly identified in the visual observations, and of the remaining two at X A, 5439*91 and 5719-99, the former is slightly strengthened and the latter slightly weakened in our photographs.

On the whole it must be admitted that the evidence for the strengthening of telluric lines of whatever origin in spot spectra is practically negligible.

(e) *The apparent bright lines, or interruptions in the continuous absolution of the spot spectrum.*

The continuous nature of the general absorption in spot spectra has been questioned by some observers owing to the presence of several well-marked bri'ght spaces in the spot band in which the intensity appears to be equal to that in the photospheric spectrum.

Numerous bright spaces are shown in our photographs ; good examples are at XX 5163-6, 5176-6, 5177-2, 5178-4, 5179*3 and 5343*3. Conspicuous broader spaces occur also at 5144-6 and 5150*8. Owing to the much longer exposure given to the spot spectrum than to that of the surrounding photosphere the density of silver deposit in these spaces appears greater than in the photospheric spectrum on either side. This would be caused by a bridge of photospheric intensity extending across the spot spectrum and interrupting the continuous absorption.

To determine whether this effect is real or is due to an illusion caused by the presence of absorption lines in the spot spectrum contiguous to the apparent bright spaces, photographic comparisons were made of the intensity of light actually transmitted by the film at different points in the spot spectrum, and similar points in the photospheric spectrum. To effect this, arrangements were devised as follows : two very small holes were drilled in a brass plate at a distance apart equal to the distance separating the spot band and the centre of the strip of photosphere spectrum on one side. The holes were approximately 0*04 mm. in

* In some recent high dispersion plates of the D region taken in a dry atmosphere and with a high sun faint lines are shown at the positions of both.the above mentioned water vapour lines, although, all other water vapour linos excepting some of those of intensity 4 and over in. Eowland's table, are entirely wanting. It is almost certain therefore that these two outstanding lines are in reality of solar origin, the coincidence in position with Water vapour lines being aooidental.

'diameter, •which is slightly less than the width of the bright space at 5163'6. The original, negative of *ih.e* spectrum was moimted in a sliding frame actuated by a screw, and the plate with the holes placed in a fixed position immediately over it and almost in contact with the film. The sliding frame carrying the negative could be thus moved by the screw in the direction of the spectrum, so that any desired wave length could be brought under the two holes.

The plate was adjusted so that the line joining the holes was parallel to the spectrum lines, one hole being over the centre of the spot band, and the other over the same wave length in the photospheric spectrum. The whole was mounted in a 'window of the dark room, light from the sky falling on the back of the negative and thence through the two minute apertures. Photographs were then taken of the-oat of focus images of the holes formed by a photographically corrected lens. Perfectly uniform circular disks differing slightly in blackness were thus obtained. Repeated trials were made at different points in the spectrum, al ways however with the result that the ratio of the intensities of the two contiguous disks was the same, so far as it could be judged by eye, for all portions of the continuous spectrum where there were no absorption lines ; and it was the same at 5163*6 as at any other portion of the continuous spectrum, the silver deposit at this point being iri. fact *less* dense in the spot than in the photosphere, notwithstanding the strong illusion to the contrary. Since possible inequalities in the amount of light admitted by each aperture would affect the latter result (it would not affect the equality of the ratios found at different points) the position of the holes was reversed with respect to the spot and photospheric spectrum but without appreciably altering the relative intensities.

In Plate 3, A, B, and 0 are *positive* reproductions of some of the images obtained, that is to say, the darker images represent the clearer portions in the original negative. The two pairs of images under each letter represent exposures made with the holes in reversed positions.

It will be seen that in both A and B the upper images are the darker, allowing that the spot band (which was slightly underexposed) was move transparent in the negative at the wave lengths indicated than the photospheric spectrum. But had the apparent bright line at 5163"6 been of photospheric intensity, or anything approaching it, the relative intensities would have been reversed in A, the lower images being very much darker than the upper. Since however the contrast between the upper and lower images in A and B is about the same, or even perhaps a little greater in A than B we can only conclude that the spot band at 5163'6 must be quite as dark as, if not a trifle darker than the continuous spectrum at 5,164*5.

The value of the ratio of intensities in the upper and lower images depends on the relative exposures originally given to the spot and photosphere, and on the darkness of the spot, and would have no value if determined. The important fact is the equality of the ratios or contrasts in A and B, since it proves that no interruption occurs in the continuous absorption of the spot at 5163*6, which is just as dark here as elsewhere. As the other bright spaces in the spectrum are all of the same character as that at 5163'6 we must conclude that there is no evidence whatever of any discontinuity in the general absorption of the spot spectrum.*

The images in plate 3, under tbe letter C are of interest as indicating a slight change in the relative intensities when the holes are placed over a strong dark line such as $b_{IJ(}$. Here the intensities appear almost equal, the upper images being still slightly the darker, although in the reproductions the right hand pair do not show this. The diminution of contrast means that the spot would appear less dark if viewed in monochromatic bj, light than it appears in general light.

But another explanation is possible, namely, that owing to insufficient exposure the radiation of b_4 did not impress the original negative at all, either in the spot or in the photosphere, consequently both regions remain quite transparent and yield images of equal density. Further experiments are needed to settle this point.

SECTION III.

Pressure in Sunspots.

The method of estimating pressure in the reversing layer by the relative displacements of the lines in the solar spectrum which are most and least affected by pressure f may be employed in determining relative pressures in different regions of the sun's disk. Such estimates will be free from the effects of accidental and systematic errors inherent in wave-length determinations, and will depend for their accuracy on measures of relative displacements of lines in contiguous portions of the sun's surface, and on the accuracy of determinations of pressure shift.

The estimation of pressure differences which may occur in passing from the umbra of a sunspot to the surrounding photosphere is of especial value if only as affording a means of testing the validity of certain spot theories which would seem to demand large * pressure effects. An attack on this problem was accordingly undertaken recently at this observatory.

Taking advantage of the very'clear skies combined with excellent definition prevalent here in the early months of the year, spectrograph II. was employed in January 1909 in photographing a series of spot spectra with the highest attainable

* It has since been noticed that the illusion of a bright space in the continuous absorption is at once dispelled by covering up the whole spectrum on. either side of the space 'with a straight edged soreen, the edge heing placed parallel to the spectrum lines and close up to the edge of the apparent space.

f Kodaikánal Observatory Bulletin No. 18.

dispersion, and selecting those regions of the spectrum which contain the Hues most affected by pressure.

A reference to the tables published by Humphreys and by Dufhekl will show that most of these lines occur in three rather limited regions as follows ;—

Region 4180-430U contains 12 iron lines with a shift exceeding 0'2 A for 42 atmospheres, and 9 iron lines with a shift not greater than 0-09 A.

Region 4700-49*20* contains 4 iron lines with a shift of about 0*4 A for 42 atmospheres and 4 iron lines with a shift not exceeding OOS A. This region also includes a manganese line with a shift of 0'27 A.

Region 4590-4760.—Nickel provides in this region 7 lines with a shift of from 0*27 to 0-46 A for 42 atmospheres but the comparison lines of small shift have to be selected from other elements such as Ti, Fe, and Or.

It is unfortunate that the total number of lines with large shifts is not groat. It is however sufficient to give a fairly accurate estimate of pressure in sunspots, making of course the assumption that the gases in the sun behave like those in the arc, also that the shift is a linear function of pressure for pressures less than one atmosphere.

We have not yet obtained plates covering the whole of these regions, but some preliminary results from measures of our best available plates are of sufficient interest to be here given. The grating was used with its surface nearly normal to the collimator, the diffracted ray making an angle of 60° to 66° with the normal to the grating; with a camera lens of 210 cm. focal length a sufficient linear dispersion was thus obtained, the scale of the photographs ranging from 1 mm. = l i to 1 mm. = *OSi* Å. Excellent definition was obtained in the third and fourth orders and exposures in the H£ region of the fourth order did not need to be greater than 4 minutes to bring out details in the umbra! spectrum. In some instances the neutral tinted glass[1] screen described in Section I. was used to reduce the intensity of the photosphere spectrum to approximate equality with that of the spot.

Care was taken in selecting plates for measurement to choose only spectra of large spots obtained under the best atmospheric conditions. The superposition of photospheric light in the umbral spectrum of small spots is liable to occur from unsteadiness of the image during exposure, and a white sky has the same effect on all spot spectra, tending to obliterate the finer details of the spectrum and to bring displaced lines back to their normal positions.

All the spectra measured show the characteristic spot lines strongly contrasted with the lines in the photosphere, a good test of the absence of superposed light. Many of the spectra show strong Doppler shifts, which do not however seriously interfere with the measurement of pressure shifts. It was in fact in this series of plates, taken originally for the purpose of estimating pressure in spots, that the systematic nature of the Doppler shifts was first noticed, leading to the discovery of radial motion in the absorbing gases in spots {*see* K.O. Bulletin JNo, 15).

The investigation of the cause of the Doppler shifts has delayed the work on pressuro and only U spectra have been measured up to the present time ; these however appoar to give fairly consistent results and indicate, first, that minute pressure effects aro traceable in sunspots, and secondly, that the region of absorption in spots is at a *lowor* pressure than that over the photosphere immediately outside.

Iu measuring the plates a single thread was used parallel to the spectrum lines and normal to the direction of movement of the micrometer screw. A blackened metal screen having a slit about 1 mm. wide was placed over the negative* limiting the field of view to a narrow strip of spectrum, this screen was attached to the micrometer table without touching the negative and was capable of movement parallel to the spectrum lines through 5*8 mm. Before beginning a series of measures the negative was adjusted so that when the sliding screen was central, the umbral spectrum was alone visible, while with the screen pushed to either end of its traverse the photosphere spectrum only was seen. In making a sob of measures of a single line, five bisections were made in the photosphere spectrum above the spot as seen in the microscope ; the screen was then moved to the contra and five bisections were made in the spot spectrum. Next five bisections WOPO made in the photosphere below the spot and finally, with the screen placed in the centre a second time, five more bisections in the spot concluded the series. In this way ten settings were obtained of the lines both in the spot and in the photosphere. The measures being entirely differential errors of the screw do not enter into the result, the displacement of each line being determined independently.

By the method of using the grating all the observed displacements are subject to a correction for curvature of the lines, which, however, it isunnecessary to apply because we are here dealing only with relative displacement'.

In Table V. I give as examples the residuals or displacements obtained in four different spots, of the lines most and least affected by pressure, and the pressure shifts of the lines at 42 atmospheres taken from Humphrey's tables. In the summary, Table VI., are given the mean relative shifts of the most affected lines with respect to the least affected, and the deduced relative pressure in each spot.

It is to be observed that while large variations occur in the residuals tor different lines there is a marked preponderance of values with the minus sign among the most affected lines and of plus signs among the least affected lines, so that the mean values' indicate a relative shift of the most affected lines towards the violet in each case. The individual variations are probably due to accident^ errors of setting and to photographic irregularities, the former must necessarily be yery setting and p , T g , i p i.:i.;^,H ^aai+ wi+.li Kinr.ft a difference ot one unit, or llrge'compa-d'with'the entities dealt with, since a *f* ^ ^ ^ on 0-001 I, in the position of a line corresponds approximately with 0 001 mm. the plates, which is near the limit of visibility in the microscope.

In measuring minute displacements such as these which, are almost at the limit of perception, great care has to be taken to guard against unconscious bias. I believe this has been almost completely avoided by the methods adopted, but as a further test of the reality of the small pressure effect found the plates have been remeasured independently by Mr. S. Sitarama Aiyar (First Assistant at this Observatory) who h.ad no knowledge as to which were the lines most or least affected by pressure. His results show also a relative shift of the most affected lines to the violet in most cases.

TABLE Y.

Lines most affected bg Pressure.

Rowland's λ⊙	Rowland's Origin.	Pressure shift at 42 Atmospheres.	Residuals, Spot—Photosphere. Thousandths of angstroms. Spot No. 6591.	Spot No. 6592.	Spot No, 6602.	Spot No. 6604.
4592 71	Ni	0-320	0	— 2	— 8	0
4600*54	Ni	0-464	0	— 7	— 2	— 3
4605-17	Ni	0-280	0	+ 1	— 2	— 1
4648-84	!Ni	0-270	— 5	— 8	— q	— 2
468640	Ni	0-325	+ 3	- 3	+ 6	— 2
4714-60	Ni	0-274	— 4	+ 3	[illegible]	[illegible]
4756-71	Ni	0-297	— 2	- 2	....	....
4783-61	Mn	0-290	....	+ 2	....	—
		Means	—0-0011	—0-0019	-0-0007	—0-0008

Lines least affected by Pressure.

Rowland's X.0	Rowland's Origin.	Pressure shift at 42 Atmospheres.	Residuals, Spot—Photosphere. Thousandths of angstroms. Spot No. 6591.	Spot No. 6592.	Spot No. 6602.	Spot No. 6604.
4580-23	Cr	0-040	....	+ 1	....	....
4600 93	Cr	0-085	4- 4	— 1	— 3	— 3
4603-13	!Fe	0 093	+ ^	- 4	— 2	+ 6
4613-54	Or-La	0-050	— 4	....	....	+ 5
4616-31	Or	0-053	+ 2	+ 6	+ 2	+ 7
4626-36	Or	0-056	+ 5	+ 2	— .1	+ 7
4646-35	Cr	0-065	....	— 8	+ 2	-r— 1
4647-62	Pe	0-070	....	— 5	— 4	+ 3
4652-34	Or	0-058	+ 1	+ 2	+ 4	+ 1
4662-15	!Fe	0*067	— 1	+ 2	— 8	—. 1
4682-09	Ti	0-077	+ [illegible]	— 2	+ 4	— 3
4710-47	'Fa	O-o6O	+ 4	+ 6	+ 4	+ 3
4758-31	Ti	0-067	— 3	— 3	....	....
4759-46	Ti	0-092	0	— 2	....	....
4787-00	Pe	0-066	....	0	....	....
		Means	+ 0-0012	—0*0003	+ 0*0003	+0-0022

TABLE VI.

Summary,

—	Spot Ho. 6591.	Spot No. 6592.	Spot No. 6602.	Spot. No. 6604.
Mean relative shift in angstroms of most affected lines for each, atu ospbere above normal pressure.	+ 0-0060	•f 0-0059	+ 0-0060	+ 0-0061
Mean relative sliiffc in angstroms of most affected lines in spots.	— 0-0023	— 0-0016	— o-ooio	— 0-0030
Deduced relative pressure in atmospheres for each spot, compared with surrounding region.	— 0-38	— 0-27	- 0-17	— 0-49

Another possible source of error is the tendency to obtain a spurious displacement between lines of different character when spectra are measured in one direction only. This error will certainly not appreciably affect the mean result, firstly, because some of the spectra were measured with the red end to the right and others with, the red end to the left, and secondly, because among tie lines used of large pressure-shift only two differ in character from, those of small shift. These are the Fe lines at 4236'11 and 4260-64 which are broad and shaded lines.

It should be mentioned that in the region of spectrum near H/2 no lines of small shift are given by Humphreys nearer than 4841*07. This is unfortunate because three lines of iron occur with a very large pressure shift and suitable in every way for measurement. In two plates of this region which have been measured I have been compelled to adopt the somewhat doubtful expedient of using five Ti lines of unknown shift, assuming for these a mean shift equal to the mean of all the Ti iine3 measured by Humphreys between 4000 and 5000. Since no Ti lines measuvod by Mm have large shifts it would seem tolerably safe to assume that the lines I have selected are no exception, or at any rafe have a mean shift which is much smaller than that of the three iron lines.

These two determinations are those of January 20th, given in table VII. and they ought, strictly, to be given less weight than the others which depend only on lines of known pressure shift.

It may be objected that it is not permissible to use Ti lines whether- of known or unknown pressure shift, for comparison with Fe or Ni, since they probably originate at a higher level under different conditions of pressure. In reply it may be said that since the pressure in the higher regions must be lower than in the region of Fe and Ni absorption, the absolute displacements of Ti lines towards the red will be lesa in proportion to the difference of pressure, and this will have the effect of slightly lessening the relative shift of the Fe and Ni lines towards the-violet. In other words the pressure effects found perhaps need to bo *inm-ased* by a small amount.

The fact that in the solar spectrum the Ti lines generally are not appreciably displaced towards the violet compared with the iron lines, indicates that the pressure *gradient* in the chromosphere must be very much less stoop than might have been anticipated from the relative heights of the two absorbing regions, and the force of gravity in those regions. Were there a difference of prosfmro of *a* few atmospheres between the mean level of Ti absorption and that of *Fe,* it could not fail to be revealed in comparing the wave lengths of certain iron lines with those of Ti. Yet this difference of level according to observations made at eclipses must amount to at least *1"* or 450 miles.

In the estimates of pressure made with the nickel lines the comparison linos of small shift used are those of Cr and Fe in addition to Ti. These wore chosen because no Ni lines of small shift are given by Humphreys in this region. *A* taliough it would have been preferable to have used nickel lines had there boon any available I believe that no serious error is introduced in employing Cr and Fo lines, *mwo* tho pressure gradient in the reversing layer does not appear to bo largo, nor is thoro evidence of any great difference of level between the elements Cr and Po on the one hand and Ni on the other.

The examples which I have given to illustrate the method are typical of olevon determinations of pressure which we have made. The results arc brought together in table VII. in which the relative pressures expressed in atmospheres aro given in the last two columns.

TABLK VII.

Relative pressures in Stinspots compared with the surrounding region.

Date.	Greenwich number of spofc.	Most affected lines used.	Origin.	Kegion o£ spectrum.	PruHBtm* in Atmosphores. Ever shed.	Silunmiau
1908, Dec. 6 ..	6677	3	Pe	4233—4315	— 0-64	+ 0-06
Do. 7 ..	6577	3	Pe	4233—4316	~ 0-23	+ 0-01
Do. 7 ..	6577	5	Ni, Mn, Pe	4756—4920	+ 0-15	-j- 0-04
1909, Janj. 5 ..	fi.591	7	Ni	4690—4756	— 0-38	4- o-oi
Do. 7 ..	6592	8	Ni, Mn	4590—4787	- 0-27	- 0*78
Do. 7 ..	6592	6	Ni, Mn, Pe	4680—4872	— 0-16	— 0-75
Do. 18	6602	6	Ni	4590—4715	- 0-17	0-00
Do. 18 ..	6602	3	Ni	4590—4630	— ()'O6	— 0*82
Do. 18 ..	6604	6	Ni	4590—4715	— 0-49	-• 0'6Q
Do. 20 ..	6602	3	Pe	4840—4925	- 0-71	— 0-07
Do. 20 ..	6604	3	Pe	4840—4925	- 1-00	- 0-41
				Weighted mean.	- 0-82	- 0-35
				J'ro.bable error.	db 0-06	=b 0'08

Although the accordance of the determinations made by me and by Mr. Sitarama is not so good for each spectrum examined as might have been anticipated, they are in agreement in showing the pressure in spots to be perceptibly lower than that in the surrounding region. If the results are weighted according to the number of most affected lines used in a determination, the means and probable errors given at the foot of the columns are obtained.

If it is assumed that spots do not differ greatly among themselves, we must conclude that the pressure is about one-third of an. atmosphere below that of the surrounding photosphere, distant 40" from the centre of the spot.

It has been shown already from a comparison of Kayser's wave-length measures in the spectum of the iron arc and Rowland's solar wave-lengths, that the pressure in the general reversing layer itself is probably below one atmosphere, therefore if these measurements are to be trusted we are forced to conclude that the absolute pressure in spots must be extremely low; or, tnat th« pressure in the region surrounding a. spot is above the average for the whole disk,

Residual displacements due to motion.— Supplementary to the determinations of pressure I have made a few estimates of the motion of the umbral gases perpendicular to the solar surface. The method of estimating pressure by the relative displacements of different sets of lines can be applied to discriminate between pressure effects and motion in the line of sight. Thus by assuming a pressure difference of $^1/_3$ atmosphere for the spots measured compared with the surrounding region and applying the appropriate corrections for this pressure to the mean displacements of each set of lines, a residual shift is obtained which, is made up of curvature, and a general shift of all the lines which we may assume to be due to motion in the line of sight.

The curvature corrections are readily calculated with the aid of the formula.

$$\text{Radius oi curvature} = \frac{\sim}{\text{Sin. } a + \text{Sin } P}$$

F being the focal length of the camera leas, *a* and *ft* the angles of incidence and diffraction at the grating respectively.*

I have applied these corrections to the measurements and obtain in all but one determination' a residual displacement towards the red. The results are set out in Table VIII. The corresponding velocities perpendicular to the sun's surface are given in the last column, the minus sign here indicating a motion of descent of the umbral gases.

The. measures in all cases refer to the central region of the spot umbrae and it does not seem likely that they can be affected by the radial motion effect (*see* section IV.). This would displace the lines in some cases quite appreciably if the spectrograph slit did not bisect the spot centrally through the umbra. But

* G. T. Walker, K.O. Bulletin No. 1C,

TABLE VIII.

*Displacements due to vertical motion in umbrae**

Date.	Greenwich. Fo. of epot.	Total number of lines used.	Distance of spot from centre of disk in degrees.	Displacements in Angstroms.		Velocity in km seo. (mean of E and 8).	
				Evershed.	Sitarama.	Radial to Karth.	Uadial to Sun.
1908, Dec. 6 ..	6577	8	30-0	— 0-0004	-f 0-0037	— 0-12	— 0-14
Do, 7 ..	6577	8	19-6	- 0-0017	-f- 0 00.16	+ 0-01	-j- 0-01
Do. 7 ..	6577	10	19-6	+ 0-0075	+ 0-0061	— 0-42	— 0
1909, Jany. 5 ..	6591	18	30-0	+ 0-0059	+ 0-0075	— 0'43	[illegible]
Do. 7 •.	6592	22	34-1	-f- 0-0051	H- 0-0070	— 0-39	[illegible]
Do. 7 ..	6592	12	34-1	+ 0-0080	+ 0-0057	-0-43	[illegible]
Do. 18 ..	6602	16	25-4	-f- 0-0059	+ 0-0033	-0-30	— 0
Do. 18 ..	6602	8	25-4	+ *0-0022*	+ 0-0007	— 0-10	- 0-.-4
Do. 18 ..	6604	17	55-1	+ 0-0068	+ 0-0056	— 0-40	-0-ix
Do. 20 ..	6602	9	1-8	+ 0-0u67	+ 0-0059	-0-39	~ 0-70
Do. 20 ..	660i	8	30-0	+ 0-0093	+ 0-0071	— 0-51	— 0-39
					"Weighted Mean		— 0-42
					Probable error		d=0'04

It would he a matter of pure chance whether the displacement was towards the red or towards the violet.*

It is to he noted that if no corrections for curvature had been applied the mean displacement to the red would nearly vanish. The data for these corrections were very carefully determined, and a table was prepared giving the radii for all regions of the spectrum, and the corrections to be applied when measuring the lines at definite distances from the centre of a spot spectrum. The corrections were also verified by measuring the curvature with a very wide spectrum.

The results appear to indicate different velocities for different spots. Thus, spot JNo. 6602 appears to give a consistently small value and spot JNo. 6604 a high value, whilst spot JSTo. 6577 gives very different velocities on different plates. I believe these differences are purely accidental and due in part to errors of measurement and in part to imperfect guiding of the spot upon the speetrograph slit, thereby introducing a component of the horizontal motion.

The remarkable constancy of the horizontal motion in the penumbrae (see page 50) affords some ground for postulating a constant vertical motion in the umbrae, and this is my justification for giving at the foot of the last column a mean value weighted according to the number of lines used, and a probable error derived from the accordance of the eleven determinations.

* A displacement towards the red indicating a descending movement of calcium vapour over spots wus shown in a few meaacres of the blight lines H_4 and K_s by Adams in 1905. Astropbysical Journal XXI1L, 6*0.

SECTION IV.

Radial movement in Sunspots.

• Hio plates taken for the investigation of pressure in sunspots although yielding an almost negative result as to pressure have led to a discovery of conwcierablo importance as regards motion in spots, for it has been found 'that in ail spots examined the penumbral region is the seat of a force directed radially outward from the umbra, in all directions, parallel to the solar surface. This force, $ on the materials of the reversing layer, gives rise to an accelerating Juout of tho gases outward from each spot centre. The motion may amount to er 2 km. per second at the outer limits of the penumbra, but is apparently not continued outside the penumbra.

Tho whole of tho evidence obtained up to the end of January 1909 is given in Kodaiktinal Observatory Bulletin No. 15. It is sufficient here to state that evpry auofc appearing since that date up to the time of writing (June 1909) has shown the name phenomenon, which must be fundamental in character. The motion of matter in this penumbras manifests itself by a very obvious displacement of practically all fcho absorption lines in the spectrum when the spot is not less than *U*> dogrocs distant from the centre of the sun's disc, and is bisected by the slit of tho Hpectroscopo in a direction passing through the centre of the disc. Under theses conditions th^ lines crossing the spot band appear quite straight but inclined more or loss to the direction of the undisplaced lines of the photosphere. The inclination is always towards the violet on the side of the spot nearest the centre of tho disc, and towards the red on the side nearest the limb.

In Plate 3 an attempt is made to show the opposite inclination of the lines crossing an eastern and a western spot, when the slit lies approximately in the same dirnction and points towards the centre of the disc. Unfortunately in the illustration tlio letters B and *W* have been transposed, the upper end of the spectrum lines representing the western end of the slit in each spectrum. The centre of the sun's disc must be supposed to lie above the upper spectrum and below the lower. Negative enlargements were used as they show the lines in the penumbra more clearly than positives, but the inclination of the lines is not nearly ao obvious as in the original negatives, notwithstanding the smaller scale of the latter. The broad line to thb right is the hydrogen line /?, and the violet end of the spectrum is to the left hand. It will be seen that the inclination is towards the violet on the side nearest the centre of the disc in each spot. This has been found to be an invariable rule; whatever position the spot occupies on the disc, the motion is always towards the observer on the side-nearest the centre.

No appreciable inclination of the linns has so far been obtained with the slit placed at right angles to the direction of the centre of the disc and lying centrally across the umbra. If, on the other hand, it should lie to one side across the penumbra tlie lines are always found to be curved, convex towards the violet if the slit is on the side nearest the centre of the disc and convex towards the red on the limb side.

Spots situated within 10 degrees of the centre of the disc show no displacements, whatever the direction of the slit may be. Outside this limit the displacements increase in amount with distance from the centre. Quite near the limb, however, they are difficult to observe; the penumbras being often hidden by banked up faculse, and always very much foreshortened in the direction of the centre of the disc. Atmospheric tremors therefore greatly reduce the apparent displacements by superposing photospheric light on the spectrum of the penumbrse.

In the case of complex spot groups, with patches of penumbra scattered irregularly in the neighbourhood, complicated zig-zag bendings of the lines occur from which it is not always easy to trace out the corresponding movements taking place in the disturbod area. But every large spot centre seems to originate an outward horizontal movement, mid the velocity at the outer limits of the penumbrse appears to be remarkably constant for spots of approximately tho same size.

The hypothesis of an outward radial movement parallel to the sun's surface, and acclerating towards the outer limits of the penumbra, seems to account quite satisfactorily for all the observed phases of the displacement phenomena as has already been shown in the bulletin referred to above. More recent investigations at this observatory have shown that the movement is in all probability confined to the reversing layer, and it may oven differ materially in different levels in that layer. But the gases of the higher chromosphere do not share in the movement, calcium appears in fact to be imbued with a contrary tendency. In almost all. the photographs hitherto taken of the 1:1 and K region of the spot spectrum, the central absorption lines of H and K are found to be slightly inclined in a direction opposite to that of all the other absorption lines. That is, the displacement is towards the red on the side of the spot nearest the centre of the disc, and towards the violet on the side towards the limb; indicating therefore an indraft of calcium vapour at high levels. There are indications also that the line Ho- behaves in the same way as H and K, but the other hydrogen lines are of too ill. dennned a character to show any such effect.

It must be admitted that the hypothesis of radial motion appears to conflict with the recent discovery by Prof. Hale of the Zeeman effect in the spot spectrum; this seems to require a vortex or circular motion of the gases in a sunspot to account for the magnetic field shown to exist there. But according to Hale's latest work it would appear probable that the magnetic field must be produced very low down in the spot,* perhaps beneath the photospheric level. Further it may be said that while the line displacements show no evidence of circular motion,

* Astrophysioal Journal, XXVIII., p. 329.

a slow rotation of the umbral gases is not precluded. If iis exists however the velocity of the rotating gases must be of a different order of magnitude from that of the radial motion and must be insufficient to reveal itself by a Doppler shift of the spectrum lines •with, the dispersion employed.*

The indraft of the higher gases of the chromosphere, particularly calcium vapour, shown by the opposite bending of the central absorption lines of H and K would seem to be in agreement with Prof. Hale's observation of the inward movement of a dark flocculus towards the centre of a spot,† and to show that this inward tendency may be general in spots.

SECTION" V.

General conclusions and Summary.

Messrs. Hale, Adams, and Gale in an important paper on the cause of the characteristic phenomena in sunspot spectra, ‡ have shown that the differences of intensity in the lines of the principal elements concerned in spot absorption compared with, the intensities in the photosphere, are clue to temperature difference, the spot intensities corresponding with a lower temperature. These observers found that the characteristic intensification of a large number of lines in the spot spectrum, and the reduction of others, compared with the normal solar spectrum, corresponded in a remarkable way with the differences in the spectra produced in the electric arc when the current strength was changed from 30 to 2 amperes. This result was further confirmed and extended by observations of spectra obtained with an electric furnace, where temperature effects alone could influence the radiating elements.

With, regard to the lines which are enhanced in the spark, the reduction of intensity in passing from the spark to the strong arc, and from the strong arc to the weak arc or the outer flame of the arc, points to temperature alone being a sufficient cause of the phenomenon of enhanced lines ; and this is confirmed in a more convincing way by the still greater reduction of relative intensity in the furnace.

* Since the above was written some spoofcra have been -measured -which afford distinct evidence of a alow rotation, amounting to about 0'25 km. per second at the outer edges of the penumbra, hut decreasing towards the umbra, where the line displacements become too small for detection.

It appears probable, therefore, that the gases in sunspots are not moving outwards in straight lines, but in curved spirals. The direotion of rotation observed in a soixthern spot was clockwise, and in a northern spot it was reversed" These directions agree with the movements indicated by the spiral stream lines shown in Hale's Ha photograph of 1908, Sept. 9, assuming that the hydrogen in. the higher chromosphere flows inward towards the spot centre, as seems certainly to he the case with calcium vapour,

† Astrophyeical Journal, XXIIL, 108. ‡ Loc. cit. XXIV., 185.

In my discussion of the spectra obtained at the eclipse of May 28, 1900, I postulated a vertical circulation in the solar gases which appeared to offer a reasonable explanation of the differences between the relative intensities of the bright lines of certain elements in the flash spectrum, and the dark lines of the same elements in the tfraunhofer spectrum.* According to this, the flash spectrum, in which the spark lines are so prominent, represents the emission of the hot ascending o-ases, whilst the character of the Fraunhofer spectrum is largely determined by the absorption of the cooler descending materials. It appears that this hypothesis may be extended so as to form a new point of view from which to regard the phenomena of sunspots. The constancy of the spot spectrum, and the universal distribution of the spot absorbing materials over the whole surface of the sun, suggest that this spectrum is in reality the fundamental spectrum of the cooler slowly subsiding gases. On this view, a sunspot is not to be regarded as a localized, collection of cool gases, but rather as a portion' of the true solar atmosphere, undisturbed by jets of hotter gases, which, ascending partially above the general absorbing layer, give rise to the photospheric granules, and above these to the high temperature gases giving the spark lines. The darkness of spots, so far as is due to general absorption, may be caused by the same conditions which give rise to the general absorption at the limb.

In a more recent paper by Hale and Adams " On a Photographic Comparison of the Spectra of the limb and centre of the Sun," f two facts strike one as significant of the relation between limb and spot absorption. First as regards general absorption: these observers find a ratio of exposure times between limb and centre of 8-10 to 1 in the violet, and 4-5 to 1 at the red end of the spectrum. These results are so closely the same as in the case of sunspots, that were it possible to cut out a small portion of the photosphere at the sun's centre and replace) it by a similar piece from the limb, the result would be a sunspot of ordinary blackness, having the same relation of general absorption to wave-length. The second significant fact relates to the selective absorption at the limb. According to Hale and Adams the lines of the elements Mn, Fe, 0a, and to a less extent Ti, are affected in the same direction as in spots, although to a lesser degree. One may fairly draw the inference, therefore, that the materials giving both the general and the selective ahsorption at the limb are identical with, and in the same condition as, those producing absorption in spots. The absence of photospheric granules in spots, and their partial obscuration beneath a greater thickness of absorbing material at the limb, producing analogous effects.

^ A spot then, according to this view, is a region where the photosphere does not exist, or has been thrust aside, revealing the solar atmosphere as it would appear were there no ascending jets of relatively hot gases. It is certain that a spot can

* Phil. Trans. A-201, 457.

+ Asteophydoal Journal, XXV., 300.

no longer be regarded as a mass of cool gases settling down upon the photosphere- which is obscured by fclie general absorption of its materials, and one is tempted to speculate as to whether the outward radial force which has been shown to exist in spots may not be the agent whereby this breach in the photosphere is made.

This outward radial movement of the permmbral gases seems to show •conclusively that spots are not cyclones in the solar atmosphere analogous to terrestrial atmospheric disturbances, us has been so often assumed, although cyclonic movements may possibly take place in the higher regions of the chromosphere, as appears to be indicated in some of Hale's Ha- photographs.

It must be admitted that the discovery of this radial movement, while destructive of current theories, cannot be said to bring enlightenment as to the cause of sunspots. It is,indeed very difficult to form any conception as to the origin of this movement, yet no other interpretation of the observed line displacements seems .possible.

It should be realized that the whole mass of the reversing layer in the penumbra of spots appears to be in motion outwards, and this motion is continued unabated throughout the life of the spot. There must consequently be a continual supply of fresh material flowing into the umbra. The only possible source of supply would seem to be from the interior regions beneath the photospheric level,, yet the evidence given in this memoir although meagre is decidedly against any ascending movement of the umbral gases. On the other hand, photographs of the H and K region of the spectrum, as already stated, indicate that there is an. indraught from the higher chromosphere above the spot, but there is no evidence that any elements other than calcium and perhaps hydrogen are thus drawn in.

The accelerating movement is perhaps the most remarkable feature of the phenomenon and suggests ionized matter moving under an electric force. It is curious to note that in the umbrae where the Zeeman effect is greatest, the movement is least, and at the outer limits of the penumbrte where the Zeeman broadening of the spectrum lines becomes inappreciable the radial movement reaches its greatest amount. The Doppler shift of the lines ceases at this point quite suddenly, so that the Zeeman effect, the radial motion, and the absorption phenomena in spots appear to be exactly coterminous. The sudden apparent stoppage of the motion at the penumbral limits may be explained, as suggested to me by Prof. 0. Miehie Smith, by the passing out of sight of the penumbral gases as they penetrate into and beneath the banked up faculse surrounding the spot.

The relatively low pressure found in spots may really indicate high pressure' in the surrounding region> a condition which would naturally follow from the continuous radial bombardment and heaping up of the gases surrounding the spot. However, those who still desire to believe that spots are analogous to low pressure cyclonic storms in the terrestrial atmosphere may claim that the effects found are a direct confirmation of their views.

I will now briefly summarize the main results of the foregoing researches.—•

(1) The spot spectrum appears to be a* constant in character as the tfraunhofer spectrum. It appears to toe the same for nil spots and thero is no evidence of change with time.

(2) The spot spectrum consists mainly of intensified .Fraunliofer lines. In other words the vast majority of the sp..t lines and magnesium hydride flutings are faintly shown over the entire solar surface. Telluric lines are not affected in spots,

(3) The high temperature, or spark, lines in the solar spectrum are all weakened in spots. But a small proportion only of the weakened lines in the npofc spectrum are known to be spark lines.

(4) The general absorption in spots is strictly continuous and similar In character to the absorption at the limb.

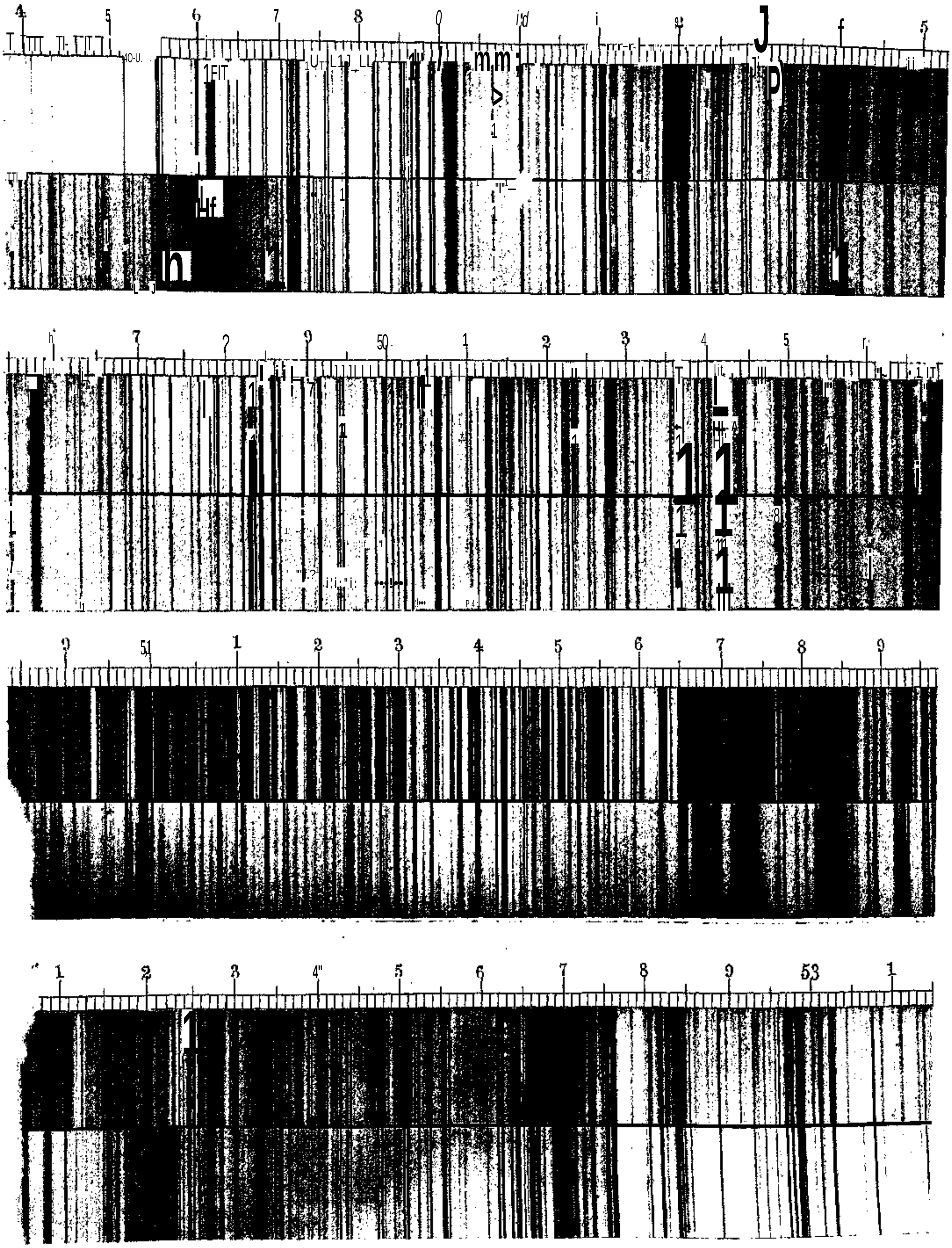
(5) Measures of the relative displacements in spots of linos which are numb and least affected by pressure indicate that small pressure effects are traceablo in spots, the pressure being usually less in the umbra than in the reversing layer jover the surrounding photosphere.

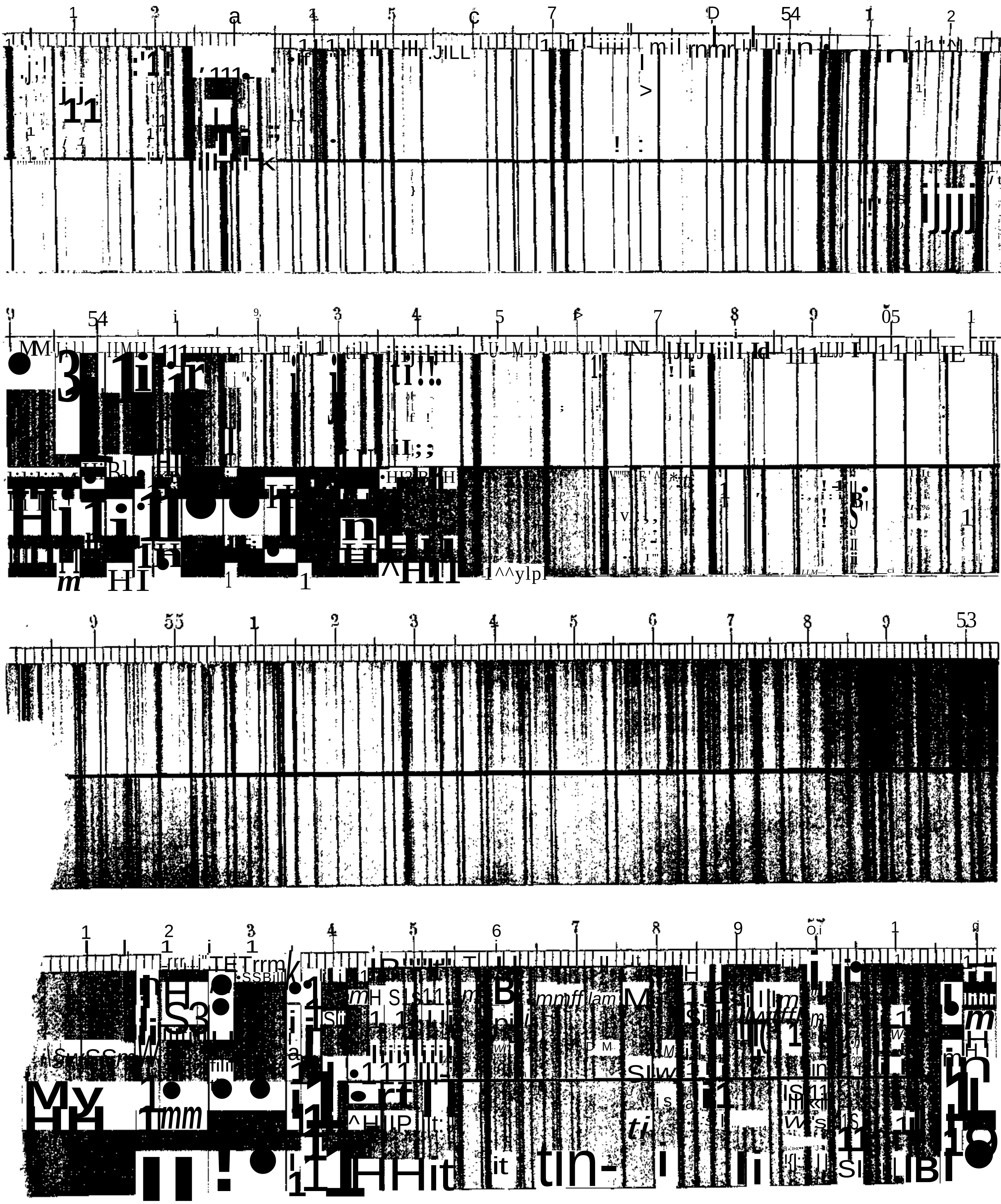
(6) The umbral and penumbral gases are in motion radially outwards from the spot centre and parallel to the solar surface. The motion acceleiut.ort outwardly, and velocities of 2 km. per second have been measured ut fcho outer limits of the penumbra.

(7) The gases of the higher chromosphere (hydrogen and calcium) do not stare in this motion but, on the contrary, show • a tendency to move inwards with a diminishing velocity towards the spot centre.

(8) The movement of the umbral gases perpendicular to the sun's 'surface (excluding hydrogen and calcium) is in all cases small in comparison with the horizontal radial motion. In five spots investigated a descending movement of order of 0-4 km. per second was measured.

^ • In concluding this memoir I wish to express my obligations fco .Prof. 0, Miohio Smith for his assistance in these researches, and for many valuable suggestions aad criticisms offered during the course of the work. Also I have to thank the members of the observatory staff for their willing co-operation.





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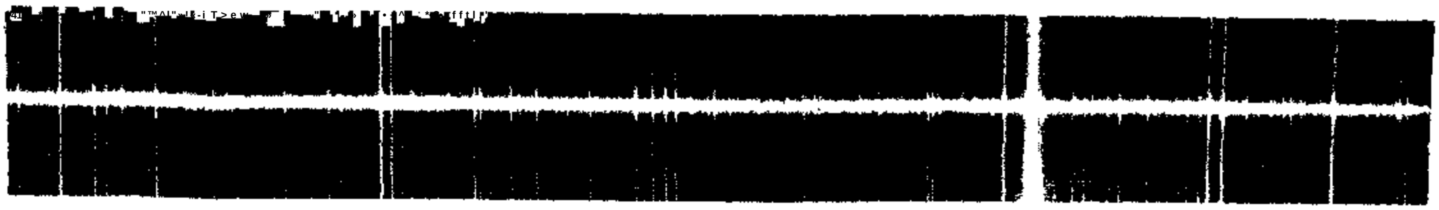


W

Eastern Spot 1909, January 31 Longitude 25°E Latitude i7°S

Position Angle of West end of Spectrograph Slit 305^0

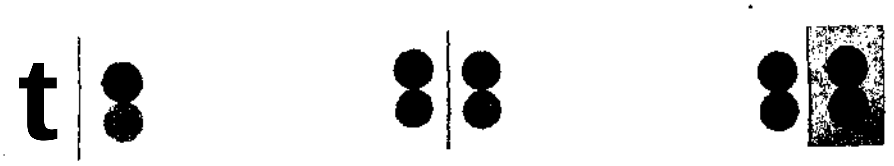
E

W

Western Spot 1909, February 4 Longitude 4i°W Latitude 7°N

Position Angle of West end of Spectrograph Slit 275^0

A B C



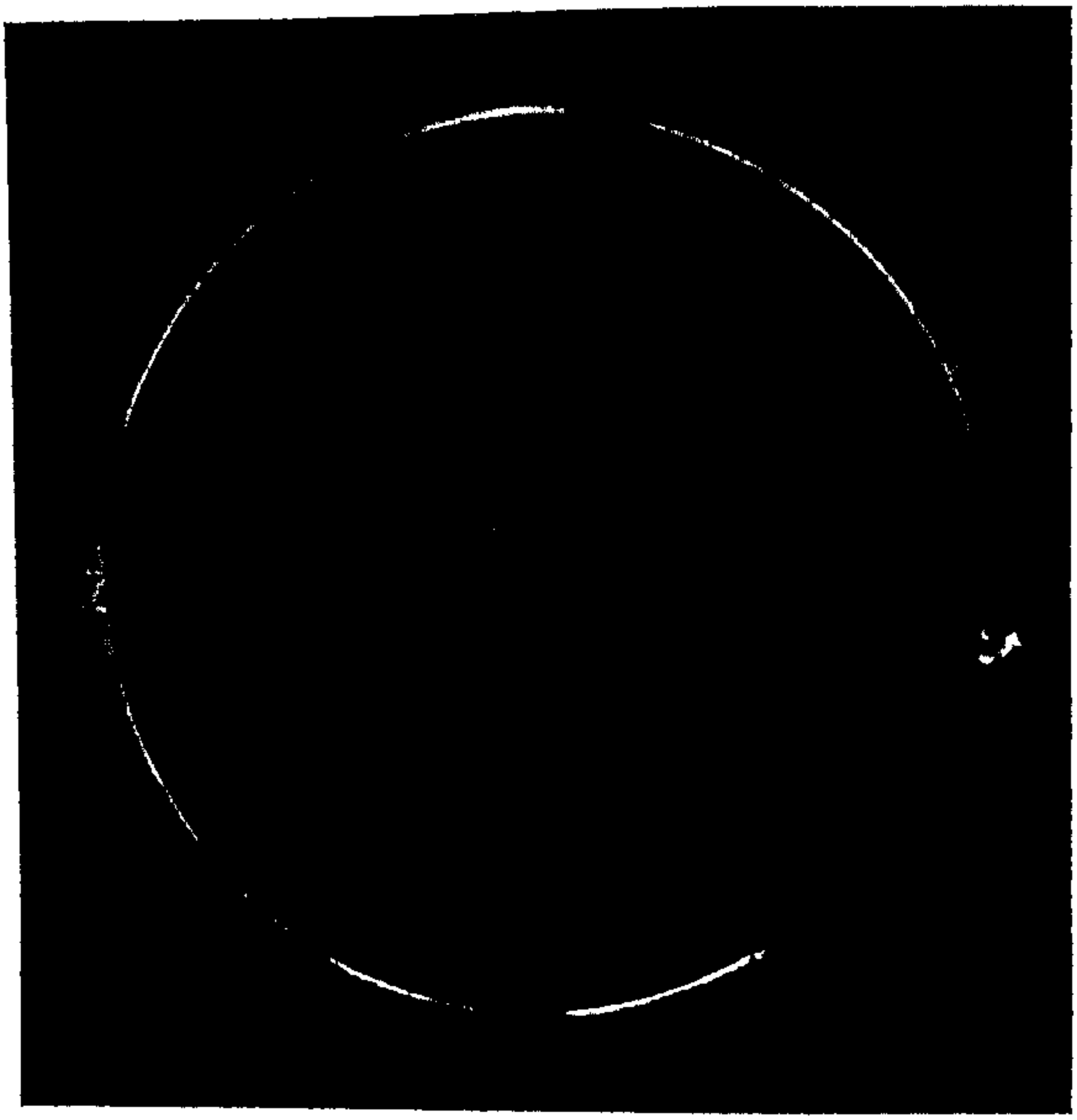
5163-6 5164·5 5^7-5 (b^{lv})

Relative intensities in different Parts of the Spot band compared wtih the neighbouring Photosphere-Spot above. Photosphere below

A	In an apparent bright space at	X $5^{16}3''^{6}$
B	In the continuous spectrum at	X $5^{16}4$*5
C	In the dark line $b^{'v}$	X 5167*5

Plate I.

WEST



EAST

THE SUN'S LIMB PHOTOGRAPHED AT KODAIKANAL IN K LIGHT,

April 28, 1910. 9^h-19^m-

On the East, at 2° North, is an eruptive prominence which was rising rapidly and also showing evidence of movements in the line of sight in both directions. It was situated over a sunspot.

On the West, at 7° to 23° South, is a very long-lived prominence at its last apparition. It had already been photographed five times on the limb, its first appearance being on February 6, and it was also photographed when crossing the disc during its three successive transits in February, March, and April. See plate VIII figs. 1 and 2 for previous apparitions on west and east limbs, and plate XI for disc apparitions as a calcium absorption marking.

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