The Ultra-Violet Region in Sun-spot Spectra.

By John Evershed.

It is well known that the more conspicuous of the lines which are intensified or otherwise affected in the spectra of sun-spots are found in the less refrangible region of the spectrum, those in the red being by far the most easily seen, whilst in the ultra-violet the lines of the same elements, although far more numerous in this region, seem to be totally unaffected.

A considerable number of photographs of sun-spot spectra, taken in the ordinary way, in the region more refrangible than G, have from time to time been examined in detail by the writer, but, excepting always the hydrogen lines and H and K, these have always shown an entire absence of details which could be certainly distinguished from the adjacent photosphere spectrum.

Recently, however, with improved apparatus and exceptionally favourable atmospheric conditions, a series of spectra have been obtained at this observatory showing a considerable number of affected lines in the region λ 3990–4350.

Owing to the intrinsic darkness of the spot band in the ultra-violet, a very long exposure is necessary, in photographing the umbral spectrum, to give a density equal to that of the spectrum of the surrounding photosphere. Thus I have found for the region near K the umbra requires from ten to twelve times the exposure needed for the photosphere, and it is obvious that in long exposures the diffuse light from the sky will impress the plate more or less, superposing the general solar spectrum on the true spot spectrum. It is questionable, however, whether this admixture of skylight is sufficient to explain the apparent poverty of detail in the ultra-violet, as compared with the red and yellow regions of the spot spectrum.

The photographs were taken in the fourth order of a Rowland plane grating, having 14,438 lines to the inch and a ruled surface of 3 inches. The collimator used is a visually corrected lens of $2\frac{1}{2}$ inches aperture and 36 inches focus. The camera lens is a plano-convex of 4-in. aperture and 7-ft. focus for H. The slit is provided with a sliding shutter, having a $<$-shaped aperture, which enables its length to be varied within wide limits during an exposure. In photographing a spot spectrum, the slit is reduced to a length equal to about two-thirds or less of the diameter of the umbral image. A long exposure is then given, after which the slit is lengthened, and the exposure continued for a short interval to impress the adjacent photosphere spectrum.

The spectrograph was erected in the spectroheliograph room, using as image lens the 12-in. photo-visual lens usually employed for the spectroheliograph. The exposures given on spot and photosphere were as follows :—

Plate exposed 1907 June 20. λ 3900–4140.

No.	Umbra.	Photosphere and Umbra.	Total Exposure.
1	120 seconds	15 seconds	135 seconds
2	180 ,,	25 ,,	205 ,,
3	205 ,,	20 ,,	225 ,,

Plate exposed, 1907 July 16. λ 4090–4350.

1	20 seconds	7 seconds	27 seconds
2	30 ,,	5 ,,	35 ,,
3	40 ,,	5 ,,	45 ,,

The first set of three exposures represents the spectrum of the large southern spot, which passed the central meridian on June 21. The second series represents the same spot after a rotation of the Sun. The latter was not obtained under nearly as favourable conditions as the former, and probably many more affected lines will be added to the list in subsequent photographs.

The two plates were examined and measured quite independently; and in the region where they overlap, the agreement in the estimates of intensity was remarkably good, although, as was to be expected, fewer affected lines were noted on the July plate.

In the following table I give only those lines in the spot spectrum which can be quite certainly distinguished from the photosphere spectrum by an increase or decrease of intensity, or by the absence of a line in the one spectrum which is present in the other. Since a considerable number of the lines visible in the umbral spectrum could not be traced on the photosphere spectrum, the positions of these were measured with a micrometer with respect to neighbouring known lines, from which the wave-lengths were deduced. The measured wave-lengths are given in the first two columns to two places of decimals only, to distinguish them from those lines which could be identified with solar lines by inspection: to these Rowland's values of the wave-lengths are given. The third and fourth columns give the estimated intensities in photosphere and umbra respectively, the former being from Rowland's table. In estimating intensities the spot line is compared with one or more of the neighbouring solar lines having the same apparent intensity, and the intensities of these comparison lines are taken from Rowland's table after comparison with Higgs' map.

It is to be noted that, as in the visible region of the spectrum, titanium and vanadium figure largely among the strengthened lines, whilst of the seven affected iron lines six are weakened in the spot. The hydrogen lines γ and δ are notably weakened, both in width and intensity. Both are displaced relatively to the photosphere lines, but, curiously enough, in opposite directions, γ ·05 towards the red on the July plate, δ the same amount towards the violet on both plates.

List of Lines affected in Sun-spot Spectra in the region between Hζ and Hγ.

Plate Exposed June 20.	Plate Exposed July 16.	Intensity in Photosphere.	Intensity in Umbra.	Element.	Remarks.
λ	λ				
3911·316	...	0	3	Nd	
3914·87	...	0 n	1	Fe	The solar line is at 3194·880.
3930·022	...	2	3	Ti	
3933·825 K	...	...	...	Ca	Narrow bright line. Not displaced with respect to the chromosphere absorption line K3.
3960·422	...	4	3	Fe	
3964·663	...	3	<2	Fe	
3996·752	...	00	2	...	
3968·625 H	...	...	...	Ca	Narrow bright line. Not displaced with respect to the chromosphere absorption line H3.
4015·532	...	0	1	...	
4017·925	..	0	1	Ti	
4019·450	...	0	1	Co	
4023·834	...	2	4	Sc	
4047·93	...	...	2	...	Absent in photosphere.
4048·224	...	1 n	...	...	Absent in umbra.
4050·830	...	2	1	Fe	
4054·69	...	...	3	...	The solar line at 4054·591 is distinctly more refrangible and gives the umbral line a shading on the violet side.
4064·36	...	1	2	Ti	
4095·423	...	0	...	Mn	Absent in spot.
4095·633	4095·633	0	2	V	
4097·61	...	000	0	...	
4098·335	...	5	4	Fe	
4099·327	...	00	2	Ti	Probably the line at 4099·207, intensity 0, is included.
4101·921	...	2	1	Fe	
4101·85 Hδ	4101·85	40	10	H	Much reduced in intensity in umbra and displaced to violet ·05 A.U. in both spectra.
4102·31	4102·31	0	2	V	
4102·52	4102·55	...	0	...	Probably this is the yttrium line at 4102·541, intensity 0.
4102·71	...	...	00	...	
4105·318	4105·318	2	5	V	
4105·98.	4105·92	000	0	...	
...	4111·154	1	00	Mn?	Almost obliterated.

List of Lines affected in Sun-spot Spectra, etc.—continued.

Plate Exposed June 20.	Plate Exposed July 16.	Intensity in Photosphere.	Intensity in Umbra.	Element.	Remarks.
λ	λ				
4112·869	...	1	3	Ti	
4113·68	4113·69	000 n	1	...	Probably a double line.
4114·28	4114·18	00	2	...	
4117·113	...	0	...	...	Absent in umbra.
4117·63	4117·71	...	0	...	
4120·74	4120·74	...	1	...	Distinctly less refrangible than the solar line at 4120·775.
4123·664	...	1	5	Mn	The intensities of these two lines seem exactly reversed in the umbra.
4123·907	...	5	1	Fe	
4125·52	...	000	3	...	
4128·46	...	00	2	...	
4128·894	4128·894	2	...	...	Absent in umbra.
4129·10	...	...	2	...	Absent in photosphere.
4131·50	4131·507	0	1	Cr	
4133·60	...	...	0	...	Absent in photosphere.
4135·915	...	0	1	Zr	
4139·60	...	...	3	...	Probably a double line. Absent in photosphere.
Spectrum ends at 4140	4140·910	00	0	...	
	4146·78	0	2	...	
	4153·20	00	1	Cr	
	4159·805	0	1	Ti	
	4163·18	...	1	...	
	4252·468	0	>1	Co	
	4262·086	2	1	..	
	4262·142	...	...	...	
	4281·530	0	2	Ti	
	4299·803	2	3	Ti	
	4300·732	3	4	Ti	Rowland gives intensity 2, which seems too small.
	4340·31	0	1	Cr?	
	4340·68	20	10	H	The line is about ·60 wide in sun, and ·35 in spot, where it is displaced towards red, ·05 unit.
	4341·167	0	2	V	
	Spectrum ends at 4350				

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