SOLAR WAVE-LENGTH DISPLACEMENTS OBSERVED AT THE JAPAN ECLIPSE OF 1936 JUNE 19.

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The spectrum from the limb of the Sun cannot be obtained free from admixture of general sunlight except when, in the course of a total or partial eclipse, light from all parts of the Sun other than the extreme limb is cut off by the Moon. Evershed has found * that in observations made in full sunlight the weak iron lines have a smaller limb shift than the strong lines, and considers that eclipse spectra might show complete equality among all intensity groups. For the purpose of testing this point the Government of India sent me on deputation to join the expedition of the Joint Permanent Eclipse Committee to Japan to observe the wave-lengths of sunlight during the eclipse of 1936 June 19 with the large grating spectrograph of the Kodaikanal Observatory.

The spectrograph consisted of a Rowland plane grating with a collimator of 7 feet focus, and a camera lens of $13\frac{1}{2}$ feet focus with its axis at about 60° to the axis of collimation. The dispersion amounted to 0·73 A. per mm. in the third order blue region. The image of the Sun, 28 mm. in diameter, was projected on the slit by an 8-inch object-glass of $9\frac{1}{2}$ feet focus. It was originally intended to use an image rotator to turn the Sun's image so that the limb at the points of contact before and after totality would be parallel to the slit, but the rotator was found to introduce considerable astigmatism. The rotator was therefore discarded, and observations were made along a solar diameter from the E. point to the W., with the result that the slit was not parallel to the limb at the points of contact: the slit was vertical and the E. and W. line made an angle of 41° to the horizontal.

The iron arc standards were obtained from a Pfund arc operating at 5 amperes. The arc was photographed simultaneously with the Sun by using two small right-angled prisms in front of the slit to reflect the arc light above and below the Sun's spectrum. These prisms could be independently adjusted so that the beams of light from the arc fell centrally on the collimating lens. This adjustment was verified immediately before the eclipse, and found correct immediately afterwards. At the centre of the Sun's disc the requisite exposure was 5 seconds for the solar spectrum and 20 seconds for the arc.

The guiding of the Sun's image was controlled by watching the image on a prepared slit screen on which had been inscribed circles fitting the Sun's image for different positions along the E.–W. line.

Although the effect sought after was not expected to affect wave-lengths except near the limb of the Sun, a programme of observations was prepared before the eclipse for photographing the Sun's spectrum as close as possible to the Moon's limb at various positions between the centre of the Sun's

* J. Evershed, *M.N.*, **91**, 260, 1931.

disc and the limb. It was originally intended to compare the eclipse plates with plates taken before or after the eclipse for each position on the Sun where a photograph had been obtained at the eclipse, but the weather conditions did not permit this to be done.

During the partial phase before totality the programme was carried through almost completely and with clear sky in most cases, but two exposures in the programme could not be made on account of thick cloud. Just at the commencement of totality (which was expected at $6^h 21^m 58^s$) the Sun became completely covered by clouds, which remained until the partial phase after totality was so far advanced that the first photograph after totality was at 0·80 radii from the centre. Thereafter the sky was clear, and the prepared programme was departed from in order to obtain as many photographs as possible.

The definition in the eclipse spectra is very good in all photographs, except in the last two taken at the centre of the Sun's disc in which all the arc lines are not sharp for some unknown reason. In all, six plates were exposed, there being space for five exposures on each. Particulars of the exposures and of the measures of the displacements are given below in Table I. Since the scattering effect which is sought after may be expected to depend on the intensity of solar lines, it will suffice here to group the lines according to their intensity. Eleven *Fe* lines measurable on most plates were divided into three intensity groups as below.

Group I	Group II	Group III
Mean intensity 5·2	Mean intensity 3·0	Mean intensity 11·0
4375·946 (6)	4430·624 (3)	4383·559 (15)
4427·319 (5)	4443·205 (3)	4404·763 (10)
4442·351 (6)	4454·390 (3)	4415·135 (8)
4464·662 (4)		
4466·564 (5)		

The lines of Groups I and II are usually easy to measure, but the lines of Group III are most easily measured when the Sun's spectrum is over-exposed.

Considering first the displacements of the lines of Group I, we see the results in Table I where the third column contains the actual displacements in units of 0·0001 A., after correcting for the Earth's motion by DeLury's tables.* The results from plates A5 to D5 have been used to determine the solar rotation which has to be allowed for before arriving at the true solar displacement. The solar rotation was determined by combining the displacements at nearly equal distances from the limb, assuming that the component of rotational velocity in the direction of the Earth was equal to the limb velocity multiplied by the cosine of the angle γ in DeLury's notation. Limb velocities were thus obtained for slightly different latitudes, all near the equator. The mean value for the equatorial solar rotation comes out to be 2·02 km./sec., and this has been used to correct the whole series for the solar rotation, the corrected values being given in the fourth

* DeLury, *Publ. Dom. Obs. Ottawa*, **6**, parts 7, 8 and 9.

column of the table. These are the residual solar displacements for Group I. For Groups II and III the residual shifts are given in the fifth and sixth columns.

TABLE I

*Sun minus Arc Displacements at Eclipse, expressed in A./*10000

Plate	Time U.T.	Distance from Centre in Radii	Sun – Arc corrected for Earth's Motion: Group I	Residual Shifts		
				Group I	Group II	Group III
	h m					
A1	5 45	o	+ 124	+ 124	+ 103	+ 160
A2	5 46	o	+ 113	+ 113	+ 81	+ 83
A3	5 56½	·28 E.	+ 21	+ 104	+ 85	+ 148d †
A4	5 57	·28 E.	+ 15	+ 98	+ 91	+ 68
A5	6 04	·57 E.	− 12	+ 151	+ 135	+ 98
B1	6 06	·57 E.	− 47	+ 116	+ 78	+ 126
B2	6 11	·76 E.	− 46	+ 178	+ 139	+ 220
B3	6 12½	·76 E.	− 106	+ 118	+ 53	+ 135
C1	6 18½	·90 E.	− 129	+ 137	+ 88	+ 84d †
C2	6 19	·95 E.	− 106	+ 175	+ 157	+ 170
C3	6 20	·97 E.	− 140	+ 145	+ 130	+ 103
C4	6 20½	·98 E.	− 129	+ 160	+ 89	+ 70d †
C5	6 21½	·99 E.	n.m.*	...	...	...
D1	6 35½	·80 W.	+ 385	+ 149	+ 132	+ 155
D2	6 36	·66 W.	+ 342	+ 147	+ 102	+ 131
D3	6 37	·61 W.	+ 318	+ 138	+ 98	+ 105d †
D4	6 38	·57 W.	+ 305	+ 141	+ 106	+ 89
D5	6 39	·57 W.	+ 287	+ 123	+ 85	+ 140
E1	6 40½	·47 W.	+ 222	+ 82	+ 49	+ 69
E2	6 42½	·47 W.	+ 217	+ 78	+ 46	+ 44d †
E3	6 43½	·43 W.	+ 194	+ 67	+ 19	+ 33
E4	6 45½	·38 W.	+ 186	+ 73	+ 43	+ 48
E5	6 46½	·33 W.	+ 181	+ 83	+ 43	+ 75d †
F1	6 48½	·28 W.	+ 158	+ 75	+ 47	+ 82
F2	6 49½	·24 W.	+ 135	+ 64	+ 5	+ 37d †
F3	6 50½	·24 W.	+ 164	+ 93	+ 78	+ 85

* n.m. = not measurable owing to faintness.
† d = difficult to measure.

The values of the limb shift from limb spectra free from the effects of light scattered from the whole Sun have been averaged from the plates C1 to C4. The values for the centre of the Sun's disc have been averaged from plates A1 to A4 and E1 to F3 ; whether some allowance is made for the change in the displacement (relative to the centre of the disc) for the different distances from the centre at which these plates were obtained, or not, only makes a difference of a few units.

The values for the displacements without an eclipse are taken from

those of Evershed and Royds,* and from new determinations from photographs taken at Kodaikanal in January 1937.   The means have been taken for comparison with the eclipse spectra.   The results are given below in Table II.

TABLE II

Sun minus Arc Displacements

	Centre of Disc		Limb	
	Without Eclipse	Eclipse	Without Eclipse	Eclipse
Group I	0·0084 A.	0·0088 A.	0·0148 A.	0·0151 A.
Group II	0·0050	0·0058	0·0122	0·0116
Group III	0·0100	0·0078	0·0122	0·0121

Conclusion.—We see in Table II the summary of displacements at the centre of the Sun's disc and near the limb both with and without eclipse. Both at the centre and at the limb there is no significant difference in the eclipse spectra from those taken in full sunlight.   The differential shift between different intensity groups is maintained in eclipse spectra, showing that the effect of scattering in full sunlight does not appreciably affect the wave-lengths of lines as weak as intensity 3 up to points 0·98 radii from the centre of the Sun.   Hence the results show that the differences observed in full sunlight in the limb shifts of different intensity groups are not due to scattering of general sunlight into the limb spectrum, but must be taken to be real, and consequently that the relativity theory, or any other theory requiring a general displacement of solar wave-lengths, is not adequate to furnish a complete explanation of solar displacements.

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* Evershed and Royds, *Kodaikanal Observatory Bulletin*, No. 39, 1914.

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