Kodaikanal Observatory.

BULLETIN No. XXXVIII.

A PRELIMINARY NOTE ON THE DISPLACEMENT TO THE VIOLET OF SOME LINES IN THE SOLAR SPECTRUM,

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THE majority of the metallic lines in the solar spectrum are shifted to the red when compared with their positions in the electric arc. There are, however, many exceptions In the tables at the end of this paper I give the results of some comparisons of arc spectra (chiefly iron) with the spectrum of the centre of the sun's disc for the study of these exceptions

I. IRON LINES

1. Sun and Arc Comparisons.

The iron spectrum was produced by the arc between iron terminals in air at 580 mm. pressure (the normal pressure at the altitude of the Observatory) with a direct current from a battery at 110 volts. The current strength was usually between 6 and 8 amperes, and the length of the arc was varied in different experiments. The polarity of the terminals was reversed at the middle of the exposure in order to equalise the intensity of the arc lines above and below the solar spectrum. The same arrangement as was previously used [1] for simultaneous exposure on the sun and arc was employed but the duration of exposure on the arc was varied in different regions in order to produce lines easily measurable. The spectrograph has been previously described [2]

It was at once noticed that nearly all lines which are unsharp in the arc at ordinary pressures gave negative values for the sun—arc displacement, *i e.*, were relatively shifted towards the violet in the sun (*e.g.*, λ 3948·246, Table VIII), but that several lines apparently sharp (*e g.*, λ 4233·772, Table VIII) were also shifted to the violet. On considering, however, the behaviour of these lines under pressure, it was found that the lines shifted to the violet, including those apparently sharp, were those which widen unsymmetrically towards the red with increased pressure, and which therefore are really unsymmetrical at atmospheric pressure, but not obviously so. The number of lines shifted to the violet was apparently greater on photographs taken using an extremely short arc (about 2 mms. in length), as was done in some regions between λ 4924 and λ 5317 in order to obtain the enhanced lines as strong as possible. These plates were therefore considered first, and the lines sorted out according to the Mount Wilson classification of the iron lines [3]. The Mount Wilson workers have divided the iron lines into groups *a, b, c, sub-d, d*, or *e* according to their pressure shifts, and also into classes 1, 2, 3, 4, 5, or 6, lines of classes 1, 2, 3, and 4 remain symmetrical under pressure, class 5 widen unsymmetrically towards the red and class 6 unsymmetrically towards the violet. When the sun—short arc displacements (Table VIII) are grouped according to the character of the arc lines, as in Table I below, it is seen that whilst symmetrical lines (groups *a* and *b*) have normal displacements to the red in the sun, unsymmetrical lines (groups *c*5, *d, sub-d*, and *e*) behave abnormally; lines widened unsymmetrically in the arc towards the red are displaced to the violet of the arc line, and the line 5133, much widened towards the violet, is greatly displaced to the red [4]. The lines in group *c* which have not been classified are, judged from their negative displacements, probably widened unsymmetrically towards the red.

[1] Evershed and Royds, Roy. Astr. Soc., M N ,73, 554, 1913. [2] Evershed, Kodaikanal Observatory Bulletin No XXXVI

[3] { Gale and Adams, Astrophysical Journal, 35, 10, 1912.
St. John and Miss Ware, Astrophysical Journal, 36, 14, 1912 and 39, 5, 1913.

[4] The line 5424 measured by Evershed and by Fabry and Buisson to have a displacement in the sun of + ·030 Å is also widened to the violet.

Table I.—Sun—Short Arc Displacements.

A.—*Symmetrical Lines.*

λ	Group	Sun—Short Arc in Å/1000
4376·107	*a* 3	+ 6
4427·482	*a* 3	+ 0
4994·316	*a*	+ 5
5028·308	*a*	+ 3
5151·020	*a*	+ 7
5195·113	*a*	− 1
5216·437	*a*	+ 1
5242·658	*a*	+ 5
4337·216	*b* 3	+ 9
4352·908	*b* 3	+ 3
4383·720	*b* 1	+ 9
4404·927	*b* 1	+ 5
Mean displacement ...		+ ·0043 Å

B.—Lines unsymmetrically widened towards the red.

λ	Group	Sun—Short Arc in Å/1000
4210·494	*c* 5	0
4890·948	*c* 5	− 2
4919·174	*c* 5	− 12
4957·480	*c* 5	− 6
4966·270	*c* 5	− 8
4233·772	*d* 5	− 13
4982·682	*d* 5	− 18
5192·523	*sub-d*	− 11
5208·776	*sub-d*	− 3
5215·353	*sub-d*	− 14
5263·486	*sub-d*	− 4
5273·339	*sub-d*	− 12
5281·971	*sub-d*	− 9
5302·480	*sub-d*	− 8
Mean displacement		− ·0086 Å

C.—Lines unsymmetrically widened towards the violet.

λ	Group	Sun—Short Arc in Å/1000
4191·843 *	*e*	0
5133·870	*e*	+ 35

D.—Lines of group c unclassified

λ	Group	Sun—Short Arc in Å/1000
4938·097	*c*	− 10
66·270	*c*	− 11
85·432	*c*	− 8
85·730	*c*	− 6
5005·896	*c*	− 8
06·306	*c*	− 7
15·123	*c*	− 3
22·414	*c*	− 6
5139·427	*c*	− 11
39·644	*c*	− 11
91·629	*c*	− 14
5217·552	*c*	− 8
Mean displacement ...		− ·0086 Å

* The 4191·8 line is not nearly so unsymmetrical as the 5133 line.

The relative shifts of these different groups are very striking. They cannot be easily explained as shifts due to a difference of pressure between the sun and arc for on this assumption the deduced solar pressure has the impossible value of about one atmosphere *below vacuum*. moreover we shall see later that a relative displacement of these groups can be produced by different conditions of the arc at the same pressure In fact, the abnormal shifts seem to depend solely on the unsymmetrical character of the lines. Nevertheless they are not wholly due to errors of setting on an unsymmetrical line. It is true that in the case of a line widened unsymmetrically towards the red, for example, the tendency would be to set too far on the red side of the true maximum and the solar line would appear to be displaced too much towards the violet, but there are many lines displaced to the violet in which the error of setting must be extremely small, for they are very narrow. There are also many lines particularly of other elements than iron, *e g.*, the sodium pair λλ 6161, 6151 and the calcium triplet λλ 6162, 6122, 6102, all on the same plate, where a glance at the photographs shows that the shift is real It is possible also that the lines unsymmetrical in the arc are unsymmetrical in the sun as well, but there is at present no evidence of such being the case. The error introduced through setting on the centre of a solar line really unsymmetrical would, however, have the effect of making the true shifts still more abnormal, and therefore need not now be considered.

The above results were obtained in comparing the sun with a short arc. Most of my photographs using a long arc were taken in the ultraviolet and blue regions and there are not many lines belonging to the unsymmetrical classes, but the following are measurable in both sun and arc —

TABLE II —SUN—LONG ARC DISPLACEMENTS

Lines unsymmetrically widened towards the Red.

λ	Group.	Sun—Long arc in Å/1000
4227 606 ...	*d* 5	— 5
33 772 ...	*d* 5	− 6
36 112 ...	*d* 5	+ 3
50 287 ...	*c* 5	+ 7

Mr. Evershed[1], using a long arc, has many lines of groups *d* 5, *sub-d* and *c* in his list; 12 are shifted to the violet in the sun and 21 to the red. It is clear that with the long arc displacements to the violet are less frequent than when the sun and short arc are compared. None of the lines known to be symmetrical are shifted to the violet of the long arc according to the measures either of Fabry and Buisson[2], Evershed[1] or myself.

There are in addition to the lines already discussed many iron lines which have not been classified according to their character and pressure displacement. Many such lines are unsharp in the arc at atmospheric pressure and when the sun is compared with the short arc none of these lines are displaced to the red. With the long arc, however, 10 are displaced to the violet and 10 to the red, 4 being undisplaced. It is not possible to say from the photographs at atmospheric pressure alone whether these unsharp lines are unsymmetrical or not.

2. COMPARISON OF THE LONG ARC AND SHORT ARC.

The fact of negative values for the sun—arc displacement being more frequent with the short arc than with the long suggested the possibility of certain classes of lines being displaced in the short arc. I made some comparisons of the sun and an arc 2 mms. long, and of the sun and an arc 7 mms. long, keeping the current as nearly as possible the same, thus obtaining indirectly the displacement between the short and long arcs. Also, three photographs were taken directly confronting the central portions of the long and short arcs on the same plate. The results are given in Table VIII at the end It is hoped to make a more complete investigation shortly, but there is a clear indication of the different behaviour of unsymmetrical lines. Those lines unsymmetrically widened towards the red are shifted in the short arc to the red, those widened towards the violet are shifted to the violet, whilst symmetrical lines have smaller displacements as a rule, if they are really displaced at all.[3] The average displacements, short arc—long arc, for the different groups are given in the following table. —

[1] Evershed, Kodaikanal Observatory Bulletin, No XXXVI. [2] Fabry and Buisson, Astrophysical Journal, 31, 109, 1910.

[3] [Note added May 5th —Photographs recently obtained of other unsymmetrical lines not only confirm these conclusions but also, by having the lines equally wide in both the long and short arcs, show that the shifts are not due to errors of setting on the maxima of unsymmetrical lines].

TABLE III.—SHORT ARC—LONG ARC DISPLACEMENTS.

	Symmetrical Lines			Lines unsymmetrical towards the red			Lines unsymmetrical towards the violet
Group	*a*	*b*	*c* 4	*c* 5 and *c*	*sub-d*	*d*	*e*
Average Displacement in Å	+ ·0007	— ·0001	+ ·004	+ ·0076	+ ·0067	+ ·0135	— ·0085
Number of Lines	10	7	1	5	3	2	2
Means	+ ·0006 Å			+ ·0085 Å			— ·0085 Å

The following are some of largest displacements measured as yet :—

TABLE IV.—LARGE VALUES FOR SHORT ARC—LONG ARC DISPLACEMENT

λ		Short arc—Long arc in Å/1000
4157·948	... .	+ 11
4158·959	... .	+ 6
4233·772	... ...	+ 7
5133·870	... ...	— 15
5162·449	... ...	+ 20

Now St. John and Miss Ware[1] found different wavelengths for the lines in one arc photograph compared with four others taken under apparently the same conditions. Moreover the displacement between this photograph and the rest varied according to the class of line. They give the following means for three groups of lines :—

Group	.	*b*	*d*	*e*
Average displacement	.. .	—·0006 Å	+ ·012 Å	— ·007 Å
Number of lines	.. ..	5	4	5

These displacements are exactly similar to the displacements I have found in the short arc, and since the arc spectrum appeared stronger in the displaced photograph than in the rest it seems likely that the arc was in this case shorter, or possibly had a greater current density. St. John and Miss Ware state that pressure variations within the arc are not of sufficient magnitude to account for the shifts measured. They also state that the displacement occurs in the region of the arc near the negative pole, where the lines are strongest and most widened. In my photographs any dissimilarity between the two poles is lost owing to the practice of reversing the polarity in the middle of the exposure, and I have therefore not been able to test this latter conclusion.[2]

It is noteworthy that of the seven lines for which Mr. Evershed did not get consistent values for the sun—arc displacement when more than one photograph was available, all except two are unsymmetrical lines. The different values are therefore probably due to different lengths of the arc. Also the discrepancies between Evershed's values and those of Fabry and Buisson[1] can now be explained. Their values agree extremely well for all symmetrical lines, whilst for all the lines widened unsymmetrically towards the red in the arc Fabry and Buisson find the solar lines to be much more shifted to the violet relative to their arc. This is shown clearly by the following averages for the symmetrical and the unsymmetrical lines in Evershed's Table II :—

Lines symmetrical in the arc (Groups *a*, *b*, *c*4). *Sun—Arc displacement.*		Lines unsymmetrically widened towards the red in the arc (Groups *c*5, *sub-d*, *d*). *Sun—Arc displacement.*	
Evershed.	Fabry and Buisson.	Evershed.	Fabry and Buisson.
+ ·0082 Å	+ ·0088 Å	— ·0001 Å	— ·0089 Å

[1] Evershed, Kodaikanal Observatory Bulletin, No. XXXVI.

[2] [Note added May 5th :—I have now been able to confirm this statement of St. John and Miss Ware.]

According to my results, MM. Fabry and Buisson's larger shift to the violet of the unsymmetrical can be explained if they have had a shorter arc than Mr. Evershed, or, it may be, had a greater density of material in the arc

3. A NEW CAUSE OF THE DISPLACEMENT OF LINES.

There is now therefore a considerable amount of evidence of the displacements of certain classes of iron lines due to some other cause than pressure or motion in the line of sight. The most obvious cause which suggests itself is change of density since this is the principal change which occurs in varying the length of the arc. The density hypothesis is strongly supported by a phenomenon observed by Duffield[1] the significance of which has not been sufficiently appreciated, namely, that in all the reversed lines which were unsymmetrically widened towards the red under pressure, the emission line was displaced to the red of the absorption line. The emission line is due to the inner portions of the arc where the density is high and the line broad, and the absorption line is due to the outer portions where the density is low and the line narrow. This is in agreement with the displacement between the short arc and the long, for the lines unsymmetrically widened towards the red are shifted to the red by shortening the arc, which corresponds to increasing the density. King[2] has tried the effect on wavelength of varying the density of the iron vapour in the furnace with negative results, but unfortunately all the lines tested belong to group *a*, which I also find to have very small displacements

Since the unsymmetrical lines are displaced in the short arc in the opposite direction to their displacement in the sun when both are compared with the long arc, it follows that the condition of the vapour, whether it is density or not, in the long arc more nearly approaches that in the reversing layer than the condition in the short arc But still the long arc falls short of the conditions in the reversing layer of the sun, since many unsymmetrical lines are still abnormally displaced. For this reason and especially because it is desirable to have the density of the vapour under control, it is intended to try the furnace spectrum for comparison with the sun.

The existence of a density effect on wavelength may modify some of the conclusions which have been drawn from the displacement between solar and terrestrial sources. For instance, if the pressure in the reversing layer is deduced by comparing the displacements of the lines most shifted to the red by pressure with those least shifted, we must now bear in mind that the former consist chiefly of lines which are displaced by density whilst the latter are not. The relative displacement of the former to the violet would lead to the conclusion that the pressure in the sun is less than atmospheric, but it now appears that it is due, to some extent at least, to the different conditions in the sun and arc, probably difference of density. For the present, therefore, we are compelled to confine our attention to the symmetrical lines since, so far as we know, they are affected least, if at all, by the peculiar conditions in the arc. Firstly we can compare the shifts of the lines of groups *a*, *b*, *c*2 and *c*4, all symmetrical, in the same spectral region, and secondly, since there happen to be lines of group *a*, both in the ultraviolet and in the yellow-green regions, we can compare the shifts in these two regions knowing the law according to which the pressure shift varies with wavelength. Making use also of Evershed's values I obtain the following average sun—long arc displacements for each group of iron lines.

TABLE V.

	Mean wavelength, λ 4400.			Mean wavelength, λ 3800.		Mean wavelength, λ 5250.
	Group *a*	Group *b*.	Groups *c*2 and *c*4.	Group *a*.	Group *b*.	Group *a*.
Pressure shift at 9 atmospheres	+ ·0158 Å.	+ ·023 Å.	+ ·0547 Å.	+ 0105 Å.	+ 0164 Å.	+ 029 Å
Mean sun—long arc displacement.	+ ·0072 Å.	+ 0090 Å.	+ ·0060 Å.	+ ·0076 Å.	+ ·0075 Å.	+ ·0088 Å.
Mean intensity ...	4	7	6·5	13	13	5
Number of lines ...	4	15	6	14	13	19

[1] Duffield. Phil. Trans. Roy. Soc A., 208, 111, 1908. [2] King. Astrophysical Journal, 35, 183, 191 .

It is seen that the displacements of groups *a*, *b* and *c*, at mean λ 4400 are practically equal if we allow for the lower level (as judged by the smaller intensity) of group *a*; similarly in the region λ 3800 groups *a* and *b* have sensibly equal displacements. This equality of displacement of lines differently shifted by pressure indicates that the pressure in the reversing layer is about the same as that of the air at the Observatory *i.e.*, about three-quarters of an atmosphere. It is difficult to compare the relative shifts of lines of group *a* in the region λ 3800 with those in the region λ 5250 since the effective levels of the lines in the two regions are very different. In order to compare lines of the same effective level we should require, according to St. John's investigations, lines of about intensity 3 at λ 3800 to compare with those of intensity 5 at λ 5250. Such lines are not available, but considering that the motion displacement decreases as the intensity diminishes[1], and that the pressure displacement increases as the square or the cube of the wave-length, the relative shifts of group *a* in the two regions may not be inconsistent with the first conclusion that the pressure in the sun is about the same as that of the air at the altitude of the observatory.

Mr. Evershed has already demonstrated[1] that the displacement at the centre of the sun is chiefly due to a velocity of descent decreasing with depth, and this conclusion is not seriously affected by the abnormal behaviour of unsymmetrical lines, for they are fairly evenly distributed in intensity if we except the largest intensities of which there are no unsymmetrical lines. If we exclude lines known to be unsymmetrical or unsharp in arc, the average displacement at the centre of the sun of lines grouped according to their intensities are given in the following table which shows clearly the smaller displacement of fainter lines corresponding to lower depths in the sun :—

TABLE VI.—*Sun—Long arc displacements of symmetrical and sharp lines.*

Intensities	2, 3 and 4	5, 6 and 7	8, 9, and 10	over 10
Mean sun—long arc displacement.	+ ·0030 A.	+ ·0033 A.	+ ·0062 A.	0122 A.
Number of lines	36	25	19	14

Moreover, the existence of the motion displacement can be demonstrated by the displacement of the cyanogen lines, which are not shifted by either pressure or density.[2]

II. LINES OF OTHER ELEMENTS THAN IRON.

Using a carbon arc into which a small quantity of salt or metal had been introduced, the displacements in the sun of lines of a few other elements have been measured and are given in Table IX at the end. The lines chosen were generally series lines, partly because their pressure shifts are mostly known and partly because each line in a pair or triplet might be expected to behave similarly. The photographs were mostly taken using a very long arc, since only with a long arc could the very diffuse arc lines be made measureable at all.

The sodium pair λλ 5682, 5688 and the calcium triplet λλ 4092, 4095, 4098, both very diffuse, are enormously displaced in the sun relative to the arc; the displacement may partly be due to errors of setting on the much widened lines but there is undoubtedly a large real shift. In the cases of the sodium pair λλ 6154, 6160, the calcium triplets λλ 4578, 4581, 4586, and 6102, 6122, 6162, and the magnesium line λ 4703, the reality of the large displacement is obvious on the photographs.

Many of the lines in Table IX have a high effective level in the sun but their displacements are not in as good agreement as they should be were they due to motion in the line of sight alone. Only the strontium pair 4077, 4215 have displacements of the order to be expected from the velocity indicated by the high level iron lines. The displacement and the height to which each line extends in the chromosphere according to Mitchell[3] are given in Table VII below :—

[1] Evershed, Kodaikanal Observatory Bulletin No. XXXVI.

[2] The displacement of the cyanogen lines will be given in a later Bulletin.

[3] Mitchell, Astrophysical Journal, 38, 407, 1913.

TABLE VII.

λ	Element.	Height in chromosphere in kms.	Sun—Arc in Å/1000.
4077·885	Sr.	6,000	+14
4215·703	Sr.	6,000	+15
4226·904	Ca.	5,000	− 2
3944·160	Al.	2,000	+ 2
3961·674	Al.	1,500	+ 2
5167·497	Mg.	750	−10
72·856	Mg.	1,000	− 7
83·791	Mg.	1,200	− 9
5890·186	Na.	1,000	+ 8
96·155	Na.	1,000	+ 7
4554·211	Ba.	1,200	− 5
4934·24	Ba.	750	−12

From the enormous shifts of many of the lines in Table IX it is clear that some cause of displacement of these lines, other than pressure or motion in the line of sight, is at work. Whether this cause is difference of density between the arc and sun or not we have no information, but the narrowness of the solar lines is an indication of low density in the sun. It is perhaps significant that the wavelengths of the calcium triplet λλ 4092, 4095, 4098 in the sun approach more nearly those of the arc in vacuo as determined by Crew and McCauley[1] than of the arc in air. Whether the large change of wavelength of these lines passing from the arc in vacuo to the arc in air is purely a pressure effect appears to me doubtful; it seems probable that here also some cause such as differences of density of material is active in producing displacements. In the following Table I give the wavelengths in the sun according to Rowland and those of the arc in vacuo according to Crew and McCauley reduced to Rowland's scale.

Wavelength in sun.	Wavelength in arc in vacuo.
4092·821	·80
95·094	·09
98·689	·70

SUMMARY.

1. The iron lines which are unsymmetrically widened to the red in the arc (Mt. Wilson groups *c*5, *d*5 and *sub-d*5) are displaced to the violet in the sun relative to a short iron arc, and those unsymmetrically widened to the violet (Mt. Wilson group *e*) are displaced to the red. Symmetrical lines give normal displacements to the red. The relative displacements are too large to be explained as pressure effects.

2. When the sun is compared with a long arc there is still the same tendency.

3. There are many clear cases which show that the displacement is not wholly due to errors of setting on the maximum of an unsymmetrical line. The same phenomenon is also to be seen in other experimenters' results.

4. A new cause of changing the wavelength of certain classes of iron lines, other than pressure or motion in the line of sight, has been found. The unsymmetrical iron lines are displaced in the short arc compared with the long arc. Those widened towards the red are displaced to the red in the short arc and those widened towards the violet to the violet, whilst symmetrical lines have mostly small displacements. The results of St. John and Miss Ware and a comparison of Evershed's and Fabry and Buisson's sun—arc displacements also indicate the peculiar behaviour of unsymmetrical lines.

5. Differences in the density of vapour may be the cause of the displacement between the different kinds of arc, but the matter requires investigation.

6. The longer the iron arc the more nearly do the conditions approach those in the reversing layer of the sun. On the density hypothesis, the density of the iron vapour in the sun is lower than in a long arc between iron poles in air at atmospheric pressure.

[1] Crew and McCauley, Astrophysical Journal, 39, 29, 1914.

7. The unsymmetrical iron lines are therefore, owing to their behaviour in the arc, unsuitable for estimating the pressure in the reversing layer. Using symmetrical lines only, the deduced pressure in the sun is about equal to that of the air at the altitude of the Observatory, *i.e.*, about three-quarters of an atmosphere.

8. The displacements of the symmetrical iron lines to the red in the sun are due to descending motion on the sun as discovered by Evershed.

9. Lines of other elements than iron also have sun—arc displacements which cannot be explained as due to pressure or to motion in the line of sight.

I have much pleasure in acknowledging my indebtedness to Messrs. G. Nagaraja Ayyar and A. A. Narayana Ayyar, B A., for the careful and painstaking manner in which they have measured the photographs for this Bulletin.

Explanation of Table VIII.

Table VIII contains all the iron lines on the displacements of which the conclusions arrived at in this Bulletin are based. The photographs were taken with the same spectrographic arrangements as those used by Mr Evershed, but the values here given are, apart from this fact, independent of those in Bulletin XXXVI.

The wavelengths and intensities in columns 1 and 2 are taken from Rowland's tables; a letter *n* in the second column denotes that the line appears unsharp in the arc at atmospheric pressure. The third column gives the Mount Wilson classification of the iron lines. The remaining columns contain the measured displacements, sun—long arc, sun—short arc and short arc—long arc, respectively, and the number of photographs measured.

TABLE VIII.

λ	Intensity.	Group.	Number of plates.	Sun-long arc in Å/1000.	Number of plates.	Sun-short arc in Å/1000.	Number of plates.	Short arc—long arc in Å/1000	λ
3650·178	5*n*	...	2	+ 6	...	.	..	..	3650·178
80·069	9	*a*1	2	+ 10	...	.	...	.	80 069
97·567	5*n*	...	2	− 16	.	..	.	...	97·567
3701·234	8*n*	..	2	+ 5	..	..	...	...	3701·234
05·708	9	*a*1	2	0		..	...	...	05·708
07·186	5*n*	...	2	− 1	..		.		07 186
09·389	8	*b*1	2	− 2	.	...	...		09·389
16·591	7	...	2	− 5	...	.		...	16·591
20·084	40	*a*1	2	+ 10	.	...	...	...	20 084
24 526	6	..	2	+ 3	.	...	.	..	24·526
27·244	3	.	2	− 2	.	..	.	..	27 244
35 014	40	*b*1	2	+ 9		...	..	..	35·014
37 281	30	*a*1	2	+ 1	...	..	...	.	37·281
48·408	10	*a*1	2	+ 2	...	...	...	..	48 408
49 631	20	*b*1	2	+ 2	..	...	.	.	49·631
60·196	5	.	2	− 1	..	.			60 196
60 679	4	.	2	0	...	...	.		60·679
63·945	10	*b*1	2	+ 7	.	...	.	..	63·945
67·341	8	*b*1	2	+ 3	.	...	...	...	67·341
3815 987	15	*b*1	2	+ 18	...	.		...	3815·987
26·027	20	*b*1	2	+ 6				..	26 027
27·980	8	*b*1	2	+ 6		...	.	...	27 980
43·404	4	.	2	+ 4	...	...	.	..	43·404
46·943	5	..	2	+ 2	...		...	..	46·943
50 118	10	..	2	− 2		...	...	...	50 118
50·962	4	...	2	+ 3	...	..	...	.	50 962
52 714	4	...	2	− 1	...			..	52·714
56·524	8	...	2	+ 7	...		...	..	56 524
59 355	3	..	2	+ 11				..	59 355
60·055	20	..	2	+ 11	...	.	...	..	60·055
85·657	4	..	4	+ 5	.		.	..	85·657
86·434	15	*a*1	4	+ 4	...	..	...	.	86·434
87·196	7	*b*1	4	+ 8			.	...	87·196
90 980	3*n*	.	4	+ 6	...	.	.	...	90·980
92·069	4	.	2	+ 3	.	...		..	92 069
94·057	2	...	2	− 1	.	...	...	..	94·057
97 596	2	..	2	+ 4	.	...	...	...	97·596
3906·628	10	*a*1	2	+ 4	...	...	...	...	3906 628
08·077	5		2	+ 2	...	...	..	...	08·077
13·775	4	..	2	+ 1	...	...	...	..	13 775
16 879	5	..	2	0	...	...		..	16 879
20 410	10	*a*1	2	+ 11	...	.	.	...	20 410
23 054	12*d* ?	*a*1	2	+ 5	...	...	..	...	23 054

TABLE VIII—*cont.*

λ	Intensity	Group.	Number of plates.	Sun-long arc in Å/1000	Number of plates	Sun-short arc in Å/1000	Number of plates.	Short arc—long arc in Å/1000	λ
3925·790	5		2	+ 3	.			..	3925 790
28 075	8	a1	2	+ 11			.		28 075
30·450	8	a1	2	+ 5		.			30 450
32·785	1n	.	2	+ 5	.		.		32 785
37·479	3		2	0	.	.	...		27 479
48 246	5n		2	— 11	.		.		48 246
50·102	5		2	+ 4		.			50 102
56·819	6	b4	2	+ 3		.	..	...	56 819
63 252	3n		2	— 6	..	.		.	63 252
66 212	3		2	+ 2	.	.			66 212
66·778	3n		2	+ 10		.	.	.	66 778
4022 018	5	.	1	— 2	..				4022 018
24·881	4n		1	— 4	..		.	.	24·881
40 792	3		2	+ 1			...	.	40 792
45·975	30	b1	3	+ 9		+ 9[1]	1	0	45·975
62·599	5		2	+ 4	..				62 599
63 759	20	b1	3	+ 7	...	+ 8[1]	1	— 1	63 759
66·742	2		1	— 1		..	1	0	66 742
67·139	5		2	+ 10			1	+ 1	67·139
67·429	3	...	2	+ 3	..	.	1	+ 1	67·429
68 14	.			..	.	...	1	0	68 14
70·930	4n	...	1	0	.	..	1	— 1	70 930
71 908	15	b1	4	+ 10		+ 11[1]	1	— 1	71 908
73 921	4n		1	0	..		1	+ 4	73 921
74 947	3	..	1	+ 3	..		1	+ 1	74·947
76·792	4n		1	0			1	+ 4	76 792
79·996	3	..	2	+ 1		.			79 996
84 647	5n		1	+ 3	...	..	1	+ 3	84 647
85 161	4	...	2	+ 4	.		1	0	85·161
85·467	1		..	.	..	.	1	— 1	85 467
96·129	3	...	1	+ 2		.	1	— 1	96 129
98·335	5n	.	1	— 1	...		1	0	98·335
4100 901	4	...	2	+ 5	...	...	1	0	4100 901
11 606	4	.	2	+ 4		...	.	.	14 606
18 708	5	...	3	+ 5	.	...	...	...	18 708
22 673	3		2	+ 1	..	..	..	.	22 673
27 767	4	...	2	+ 2			...	.	27 767
32·235	10	b1	3	+ 13			..	..	32 235
33 062	4	..	1	+ 9	..		...	..	33 062
34 840	5	b4	3	+ 2			..	.	34 840
44·038	15	b1	3	+ 11	.	..	...	..	44 038
54 667	4		1	+ 7	1	+ 6	.	+ 1[1]	54 667
54·976	4	5[2]	1	— 2	1	— 3	.	+ 1[1]	54 976
56 970	3	..	1	+ 4	1	+ 7	.	— 3[1]	56 970
57 948	5	..	1	— 10	1	— 21	...	+ 11[1]	57 948
58 959	5	..	1	— 14	1	— 20	.	+ 6[1]	58 959
74 095	3	...	.	..	1	+ 2	...	...	74·095
75 806	5	.	4	2	1	+ 3		— 1[1]	75 806
81 919	5	.	3	+ 6	..		..	.	81 919
87 204	6n	5[2]	6	+ 1	.	..	.		87 204
87·913	6	...	5	+ 8	...	..	...	..	87 943
91 595	6n	5[2]	6	+ 2	...		...		91 595
91 843	3n	e	1	— 2	1	0		— 2[1]	91 843
95 192	5	...	1	— 3	1	— 6		+ 3[1]	95 492
96 372	4	...	1	— 7	1	— 11	...	+ 4[1]	96 272
4200 148	2	.	...		1	+ 4	.		4200 148
02 198	8	b1	6	+ 10	...	..	...		02 198
10 491	4	c5	1	+ 3	1	0	...	+ 3[1]	10 494
13 812	3		1	— 2	1	+ 2		..	13 812
16 351	3d ?	b3	3	+ 3	.	..	...	...	16 351
22·382	5n	5[2]	4	— 2	1	— 6	1	+ 4[1]	22 382
25 619	3	..	1	+ 1	..	...	...	..	25·619
26 581	2	...	1	— 9	1	— 10	1	+ 1[1]	26 584
27 606	4	d5	1	— 5	..		...	...	27 606
29 677	2	..	..	.	1	+ 3	...	...	29 677
29 926	3	..		..	1	— 2	...	.	29 926
33 772	6	d5	4	— 6	1	— 13	1	+ 7[1]	33 772
36·112	8	d5	1	+ 3	...	..	.	..	36 112
38·970	5n	...	4	— 15	1	— 24	1	+ 7[1]	38 970
50·287	8	c5	2	+ 7	...	..		.	50 287
58 477	2	...	1	+ 9	..		..	.	58 477
67 122	3	...	1	+ 6	...	...	..		67·122
71 325	6	5[2]	2	+ 5	...	..			71 325
71 934	15	b1	5	+ 17	..	...	..	...	71 934
82·565	5	b1	2	+ 10	.	...	.	...	82 565
90·542	1	...	1	+ 4	...	...	...	..	90 542
4315 262	4	b3	2	+ 14	...	...	...	...	4315 262

[1] These values are obtained from the other two columns by subtraction.

[2] According to Fabry and Buisson.

TABLE VIII—*cont*

λ	Intensity.	Group	Number of plates.	Sun-long arc in Å/1000	Number of plates	Sun-short arc in Å/1000	Number of plates.	Short arc—long arc in Å/1000	λ
4321·961	2	...	1	+ 7		.	.	.	4321 961
25 939	8	b1	5	+ 12		..			25·939
26·923	2	..	1	+ 4				..	26 923
28 080	2	...	1	+ 7	.			..	28 080
37·216	5	b3	2	+ 8	..	+ 9[1]	1	− 1	37 216
52 908	4	b3	2	+ 4		+ 3[1]	1	+ 1	52 908
68 071	2	..	.		.		1	+ 2	68 071
76 107	6	a3	1	+ 7	..	+ 6[1]	1	+ 1	76·107
83 720	15	b1	2	+ 8	.	+ 9[1]	1	− 1	83 720
88 571	3n	..	1	− 7	.	.	1	+ 4	88 571
4401 456	2	.	1	− 4			.		4401 456
04 927	10	b1	2	+ 7		+ 5[1]	1	+ 2	04 927
15 293	8	b1	2	+ 6	.	...			15 293
27 482	5	a3	2	+ 3		0[1]	1	+ 3	27 482
30 785	3n	c4	1	+ 1		.	1	+ 4	30 785
33 390	3n	...	1	+ 4	.		1	+ 4	33 390
35 321	2n		1	+ 5	..		1	+ 1	35 321
42·510	6	c4	2	+ 8	..	..			42 510
43 365	3	b3	1	+ 3	.				43 365
54·552	3	b3	1	+ 5	..				54 552
61 818	4	a3	2	+ 7	.		..	.	61 818
4525·314	5n	..			1	− 8			4525 314
28·798	8	.	...	.	1	+ 8			28·798
31 327	5			.	1	+ 6		...	31 327
48 024	3		...		1	− 4			48 024
92·840	4			...	1	+ 4	..	..	92 840
4603 126	[illegible]	.			1	+ 2		.	4603 126
4890 948	6	c5	.		2	− 2	...	.	4890 948
4919·174	...	c5		...	2	− 12		...	4919 174
24 107	p Fe 5		.	..	1	− 10	.	.	24 107
38·997	4	c	..	.		− 10		...	38 997
57 480		c5			.	− 6		...	57·480
66 270	4	c5				− 8	...	..	66·270
82 682	4n	d	.	..	2	− 18	..	...	82 682
83·433	3n	...		...	1	− 14	..	..	83 433
84·028	3n			.	2	+ 2	.	...	84·028
85 432	3	c	..		2	− 8	.	.	85 432
85·730	3	c			2	− 6		.	85 730
94·316	3	a	...		2	+ 5	..		94 316
5002·044	5		..		2	− 7	...	..	5002 044
05·896	4	c		.	2	− 8	...	.	05 896
06 306	5	c	.		2	− 7	..		06 306
15·123	3n	c	...	..	2	− 3	.		15 123
18·629	p Fe 4			...	2	+ 16		..	18 629
22 414	3	c			2	− 6	.	.	22 414
28 308	2	a	.		2	+ 3	...	..	28 308
5133 870	4n	e	..	.	1	+ 35	2	− 15	5133 870
39 427	4	c	.	.	1	− 11	2	+ 9	39·427
39 614	4	c		.	1	− 11	2	+ 9	39 614
43·111	3	.		..	1	+ 5	2	0	43 111
51 020	4	a	.	.	1	+ 7	2	0	51 020
62 449	5n	d	..	...	1	[3] large −	1	+ 20	62 449
69 069	3	.	...	.	1	+ 2	1	− 1	69·069
69 220	p Fe 4	...	..		1	+ 18		..	69 220
91·629	4	c	...	...	1	− 14	2	+ 9	91 629
92·523	5	ub -a	..		1	− 11	2	+ 10	92 523
95·113	3	a	.	..	1	− 1	2	0	95·113
5208 776	2n	sub-d	..	.	1	− 3	2	+ 4	5208 776
15 353	3n	sub-d	..	..	1	− 14	2	+ 6	15 353
16 437	3	c	.	.	1	+ 1	2	0	16 437
17 552	3n	a	...	..	1	− 8	2	+ 8	17 552
42·658	2	a	.	..	1	+ 5	..	...	42 658
50 817	2		..	..	1	+ 3			50 817
63 486	4n	sub d	..		1	− 4		.	63 486
73·339	3n	sub-d	..	.	1	− 12		.	73 339
81 971	5	sub-d 5[2]	...	..	1	− 9	...	...	81 971
83·802	6	sub-d[1]	...	..	1	− 8	..		83 802
5302·480	5	sub-d 5[2]	.		1	− 9	.	..	5302 480
07·541	3			.	1	+ 3	..	..	07 541
16·790	p Fe 4		.	.	1	− 1	.		16·790
5123·899	3	a	.		.		1	+ 1	5123·899
5127·533	3	a	..	..		..	1	+ 2	5127·533
5162 087	3	a	..	.	..	.	1	− 1	5152 087
5167·678	5	a	..	.	..	.	1	+ 1	5167 678
5171 778	6	.	..	...	..	..	1	0	5171 778
5202 516	4	a	..	...		...	1	0	5202·516

[1] These values are obtained from the other two columns by subtraction.

[2] According to Fabry and Buisson.

[3] 33 with the long arc according to Evershed.

[4] Symmetrical according to Fabry and Buisson

TABLE IX.

[The pressure shift is taken from Humphreys' tables. Those lines unsymmetrically widened to the red are marked ur.]

λ	Intensity.	Pressure shift in Å per atmosphere	Number of plates	Sun—arc in Å /1000.	λ	Intensity	Pressure shift in Å per atmosphere	Number of plates	Sun – arc in Å /1000
3949·039	Ca 1 ur	..	2	— 10	5682·869	Na 5 ur	·0532	1	–127
4095·094	Ca 4 ur	..	2	— 86	5688·436	Na 6 ur	·0575	1	–144
4098·689	Ca 4 ur	...	2	— 78	5890·186	Na 30	·0127	2	+ 8
4226·904	Ca 20	·0051	1	— 2	5896·155	Na 20	·0122	2	+ 7
4283·169	Ca 4	·0031	3	+ 6	6154·438	Na 2 ur	.	2	– 81
4302·692	Ca 4	·0031	3	+ 10	6160·956	Na 3 ur		2	– 79
4289·525	Ca 4	·0035	3	+ 10	4077·885	Sr 8	·0026	3	+ 14
4299·149	Ca 3	·0035	3	+ 6	4215·703	Sr 5 d?	·0034	4	+ 15
4425·608	Ca 4	·0084	3	+ 2	4607·510	Sr 1	·0053	3	+ 1
4435·129	Ca 5	·0081	3	+ 3	4554·211	Ba 8 d	·0036	2	– 5
4438·851	Ca 4	.	3	+ 2	4934·24	Ba 7 d	·0038	2	– 12
4456·784	Ca 2	·0079	3	+ 7	4703·177	Mg 10 ur	.	1	– 37
4527·101	Ca 3 ur	.	1	— 44	5167·497	Mg 15 ur	·0083	3	– 10*
4578·732	Ca 3 ur		2	— 25	5172·856	Mg 20 ur	·0078	3	– 7*
4581·575	Ca 4 ur	..	2	— 24	5183·791	Mg 30 ur	·0059	3	– 9*
4586·047	Ca 4 ur		2	— 30	4680·317	Zn 1	·0057	3	– 8
5262·419	Ca 3	.	1	0	4722·342	Zn 3	·0073	3	– 9
5264·415	Ca 3	...		+ 1	4810·724	Zn 3	·0065	2	– 14
5270·438	Ca 3	...	1	— 3	3944·160	Al 15	·0052	2	+ 3
5265·729	Ca 3		1	— 2	3961·674	Al 20	·0058	2	+ 2
5582·198	Ca 4	.	2	+ 2	4709·896	Mn 2	...	2	+ 3
5588·985	Ca 6	.	2	+ 2	4739·291	Mn 3	...	2	– 1
5590·343	Ca 3	..	2	+ 1	4754·225	Mn 7 ur		4	– 6
5594·691	Ca 4	·0072	2	+ 1	4783·613	Mn 6 ur	.	4	– 6
5601·505	Ca 3		2	+ 1	4823·697	Mn 5 ur		3	– 6
5698·711	Ca 4	.	2	+ 1	4761·718	Mn 3		3	– 2
6102·937	Ca 9	·0255	2	— 27	4762·567	Mn 5	.	3	– 2
6122·434	Ca 10	·0226	2	— 24	4766·050	Mn 3	..	3	0
6162·390	Ca 15	·0225	2	— 28	4766·621	Mn 4	...	3	– 3

* Calculated from limb displacements relative to centre of sun and to arc

THE OBSERVATORY, KODAIKANAL,
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T. ROYDS,
Assistant Director.

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