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The Displacement of the Cyanogen Bands in the Solar Spectrum.

In Kodaikanal Observatory 'Bulletin,' No. 39, some measures were given of the displacement *sun* − *arc* of the more conspicuous bands and lines of the cyanogen group near λ 3883. These give a mean result from eight plates of approximately +0·005 Å at the centre of the disc, and, by inference from measures of limb-centre plates, +0·008 Å at the limb.

The displacement of these bands in the Sun is of particular interest, because they are not subject to appreciable pressure-shifts or to "pole effects" in the arc, and we are free to assign the whole of the effect either to motion in the line of sight or to the gravitational effect resulting from Einstein's theory of relativity. I do not consider anomalous dispersion to be an effective agent in displacing any solar lines.

If we suppose that the limb-shift of +0·008 Å is due to motion we are faced with the intolerable idea that the Earth is controlling the motion, *i. e.*, driving away the cyanogen gas at all points on the Sun's limb with a velocity of about 0·62 km./sec. Assuming on the other hand that Einstein's theory of relativity is true, we should expect to find, after eliminating other causes of shift, a displacement to red equivalent to a radial velocity of 0·634 km./sec., or, within the limits of error of the measures, the same value which we obtained above for the displacement at the limb.

Unfortunately, the matter cannot be settled offhand by this result because of the inherent difficulty of measurement of the triplets forming the bands, especially at the Sun's limb, and of the probability of lines due to other elements being mixed up with the bands. These might cause an apparent shift towards red or towards violet according as the interfering line happened to overlap the red or violet edge of the cyanogen band. In the short series of twelve lines and bands which we measured at

Kodaikanal there may have been a preponderance of these spurious shifts towards red, or finally the measures may have been subject to some systematic error, especially in the case of the partially resolved triplets.

Recently Dr. St. John, of the Mount Wilson Observatory, has attempted to solve the problem by extending the measures so as to include 43 single lines in which there can be no ambiguity in the measurement, as in the wide bands or partially resolved triplets near the head of the series. Separating these into two groups, one including 25 lines of intensities ranging from 00 to 1, and the other including 18 lines of intensities 2 to 4, St. John finds at the centre of the disc a great variety of shifts, mostly with the plus sign and ranging from +0·006 Å to −0·003 Å. For the fainter lines the mean shift is only +0·0006 Å, but for the stronger lines it is +0·0024 Å. This is his result for the direct method of comparison with simultaneous exposures on Sun and carbon arc. Using indirect methods he gets still smaller values, and his final conclusion is that the average shift of all the lines measured is zero.

Coming now to *limb—arc* shifts, which have a more direct bearing on the Einstein effect because of the elimination of possible motion of the gas in the direction of the Sun's radius, St. John has measured a total of 35 of the same series of faint and strong lines which were used for the centre—arc measures. From these he gets 23 plus, 8 minus, and 4 zero shifts. Again, the stronger lines give the larger shifts, the mean of the 18 strong lines being +0·0037 Å, whilst the mean for the 17 faint lines is zero, and for the entire series +0·0018 Å only. The conclusion from the whole investigation is: "That within the limits of error there is no evidence in these observations of a displacement to longer wave-length, either at the centre or at the limb of the Sun, of the order of 0·008 Å, as required by the principle of relativity."

Dr. St. John has also measured at the centre of the disc the triplet bands near the first head at λ 3883, and compared his results with those obtained at Kodaikanal, with the result that while the signs of the shifts agree with our measures, the plus shifts appear to have been systematically over-estimated at Kodaikanal. The mean shift for eleven lines or bands is +0·0015 Å according to the Mt. Wilson results and +0·005 Å according to Kodaikanal.

While agreeing with St. John in considering that his results are entirely unfavourable to the principle of relativity, I do not think that they should be taken as finally disposing of the question as to whether or not there is any shift of the cyanogen bands at the Sun's centre or at the limb—a question apart from relativity which is of great interest and importance.

With regard to the shift at the centre of the disc, St. John does not tell us how many plates were measured or the dates of their exposures. It is a common experience in sun-arc measures that individual plates will give abnormal values, and little reliance can be placed on results secured in a single day, since it appears probable that variable radial currents in the Sun disturb these measures to some extent. The Kodaikanal results referred to are the means from plates taken on eight different dates. The inclusion by St. John of a large number of very faint lines is also, I think, open to question. He states that the probable occurrence of blends is least for the narrowest lines (hence these are given highest weights), but the broader lines and bands, although more likely to be blends, are less likely to be displaced by the blending line than the narrow lines. For instance, the cyanogen band at 3880·5 in the Sun has the same relative width as in the arc when compared with the remaining triplet bands, yet it is apparently blended with some foreign line within its triplet structure, but this blend does not alter the mean wave-length. On the other hand, the narrow line at 3876·448, forming the third member of a triplet, is in my judgment too strong in the Sun to be assigned to cyanogen only, and this line is probably displaced by the blend, for it has a zero or possibly a minus shift, whilst the two other members of this triplet yield an average plus shift at the centre of the disc. This is a line to which St. John gives high weight. He also gives high weight to the fine narrow lines because of the greater precision of measurement. It is true that the stronger of these narrow lines are easier to measure by the ordinary method than the wider lines, but we have found that, owing to their faintness, most of the weak lines measured by St. John are very difficult and unsatisfactory lines to measure, especially in the limb spectra, and in several cases there is uncertainty whether they really represent cyanogen in the Sun, *e. g.*, the line 3842·980, which is relatively much too strong for the Sun; and there are several others, including the line 3876·448, which in my judgment are stronger in the Sun than they should be if due to cyanogen only. The lines 3868·542 and 3868·702 are of equal intensity in the arc, but the former is obviously the stronger of the two in the Sun, and is therefore contaminated. Among the stronger lines I consider that 3846·1 and 3853·6 should be omitted from St. John's tables because their intensities are too great in the Sun, also the line 3866·1 because it is diffused towards violet in the Sun.

In my opinion the highest weights should be given, and, in fact, measurements should be confined, to the stronger lines and bands which in the Sun have the same widths and relative intensities as in the carbon arc, excluding all those which appear in any way different in Sun and arc. Working on these lines, I have made a selection of 30 lines and bands between 3819 and 3882, which I think should give fairly reliable mean results, especially when measured by the very much more satisfactory method of superposing the bright-line images of the arc spectrum on the dark images of the solar spectrum. In this way the double shift is measured, and the bands and triplets present no difficulty or

2 G 2

systematic error—in fact, they are easier to measure than the fine lines. By this method one takes a pair of similar negatives, A and B, each having a central strip of the Sun with the carbon arc contiguous on both sides, or, preferably, with a small intervening space. Negative A is then superposed on negative B, film to film, in the positive on negative micrometer, and the spectra are displaced laterally so that the arc lines of A are superposed on the solar lines of B and the arc lines of B on the solar lines of A. As the spectra are not reversed, end for end, no confusion results, and the arc triplets fit into the solar triplets very satisfactorily. Measuring in this way, I have this year confirmed my former measures at the centre of the disc, but I get a smaller mean value for the whole series of lines and bands. The means are approximately +0·004 Å at the centre of the disc and +0·006 Å at the polar limbs. These are provisional values only, pending the completion of a long series of measures, and it is to be noted that there are still great irregularities in the amount of the shift for different lines. A series of high-dispersion spectra has been secured, extending over some weeks in March and April 1918 during a spell of exceptionally clear sky, but only a preliminary set of measures has been accomplished up to the present. Meanwhile, Mr. R. J. Pocock, Director of the Nizamiah Observatory, who is spending three months' privilege leave at Kodaikanal, has kindly made an independent set of measures, both at the limb and at the centre of the disc, by the ordinary method. His results are of great interest, for they reveal not only marked differences on different dates, but also a systematic difference between the north and south polar limbs. At the north limb and in the neighbourhood of the equator the mean limb-arc shift appears to differ but little from his centre-arc results, and is approximately +0·004 Å; whilst at the south pole all the plates agree in yielding a much larger shift, the mean being +0·0081 Å, or just equal to the Einstein shift. There can be no instrumental cause for this difference, as the north and south limbs were photographed under precisely similar conditions, the exposure on arc and Sun being simultaneous in each case, and the spectrograph amply protected against temperature change. It is to be regretted that Dr. St. John does not tell us whether his results are derived from the mean of both polar limbs or whether only one pole was photographed.

If we compare with St. John's values our mean results for individual lines, using all the plates measured by myself or Mr. Pocock, we do not find any very serious discrepancies excepting in the case of the triplet bands near the first head at 3883, where our results give larger values than those of St. John, and, for the plates so far measured, confirm my previous results, as before mentioned. The main point on which we differ is in the selection of lines to be measured, and to which high weight should be given. From the general results of our new measures at

Kodaikanal, I feel fairly convinced that the cyanogen bands share in the general displacement of the solar lines towards red, both at the centre of the disc and at the limb. But it appears that the shift at the limb is perhaps on the average not much more than half of the predicted gravitational effect, whilst for the iron lines it is in many cases twice as great at the limb as is required on the relativity hypothesis. If we exclude relativity, we are "up against" the Earth effect, and, even if we assign the shifts to a combination of relativity and motion, we cannot by that means escape the Earth effect, for the motion component would still be in the direction of the Earth.

One very simple explanation of the otherwise puzzling limb-shifts is so obvious that it appears to have been overlooked hitherto. If the great majority of the Fraunhofer lines are in reality slightly unsymmetrical and shaded off towards red, the "centre of gravity" of a line will tend to shift towards red the longer the path of the photospheric light through the absorbing layer. Although the metallic lines in the Sun appear to be perfectly symmetrical and equally well defined on both sides, the behaviour of the arc-lines of iron at three-fourths atmospheric pressure, which have been studied here by the positive-on-negative method, shows that a very large proportion of the Fe lines are very slightly shaded towards red; and this suggests that there may be a residual effect of this kind also in the solar lines.

But in whatever way we may eventually interpret the limb-arc shifts, we seem able even now to state, with St. John, that our results are distinctly unfavourable to relativity.

Kodaikanal,
1918, June 4.

J. Evershed.

The Sun-spots of November 1916.

Only a moderate amount of activity was displayed by the sun-spots of November, the largest group being No. 7871, which appeared at the East limb on November 3, a few degrees in advance of the place of Group 7857, seen in the previous rotation. It was, however, almost certainly a new formation, as on November 3 it consisted merely of some very small faint markings, and developed rapidly later to form a fine stream. The chief characteristic of the sun-spots of the month was the appearance of numerous very small, faint, short-lived markings that never developed into fully-formed groups. The mean daily spotted area for the month was 635 millionths of the Sun's visible hemisphere.

Notes on the Principal Spot-Groups.

Group 7869.—Near the place of Group 7849, but a new formation. A few very small faint spots at first, which