ON THE DETECTION OF SMALL DOPPLER SHIFTS IN THE SPECTRUM OF THE REVERSING LAYER.

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The positive on negative method of measuring small shifts in spectrum lines, first described in 1913 in *Kodaikanal Bulletin*, No. 32, has been applied recently to some of Dr. Hale's original spectra upon which he based his discovery of a general magnetic field in the Sun. In these spectra the Zeemann effect is much too small to show the separation of lines into doublets or triplets, such as are seen in the much stronger fields in sunspots. The lines are very slightly widened, and by means of polarizing apparatus placed in front of the slit of the spectrograph the red and violet components of the Zeemann doublets are cut out alternately in the contiguous narrow strips into which the spectrum is divided. This has the effect of shifting the centre of the line slightly towards red in a strip and slightly towards violet in the adjoining strip, the whole length of a spectrum line representing a section of the Sun's image in varying latitudes along the central meridian.

The method I adopted in measuring these plates was to take an ordinary contact positive and place it film to film over the negative in the micrometer, without reversing the plates end for end. Each line in the negative was therefore covered by the corresponding line in the positive. Then, by shifting the positive laterally by one 2-mm. interval, the positive images having red shifts were superposed on the negative images having violet shifts, and *vice versa.* In this way, bringing the positive and negative images in each strip in succession into exact coincidence by moving the negative with the micrometer screw, the positive being fixed in position above it, the difference of readings gave twice the actual shift between successive strips.

The method seems to be superior in three ways to other methods of measuring such spectra. First, the interval measured is twice the actual shift; secondly, the adjustment for coincidence can be made with greater accuracy than in other methods; and thirdly, the width of a line has little effect on the accuracy of adjustment. This last is of value in measuring plates having a great linear dispersion, in which even the narrowest solar lines have very appreciable widths. The grating plates of the magnetic field have a dispersion of 5 mm. to the angstrom unit, and shifts of the order of ·001 A. can be measured with certainty, since this change of wave-length is represented by a movement of the micrometer screw of ·01 mm.

The general result of the few plates measured was very satisfactory. The right order of shift was obtained and the right sign in the two hemispheres of the Sun, but, as in all spectrum measurements, anomalies were met with in most of the plates, and especially in low latitudes where the Zeemann effect would be smaller. These might be due to local magnetic fields, or to the disturbing effects of small Doppler shifts. The plates were obtained at a time of minimum sunspots, when disturbances giving motions in the line of sight might be expected to be small, or even non-existent.

In view of these results I have now made a special effort to discover whether such small Doppler shifts do occur at the present time of minimum solar activity. I had already found irregular movements extending over large areas in the immediate neighbourhood of sunspots, and these are very easily detected by the positive on negative method. In this case it is necessary to obtain a positive by photographing the negative through the glass in a camera. The negative is placed film outwards, and the camera lens arranged exactly midway between the film and the plate. This gives a positive image the same size as the negative, and is equivalent to copying through the glass instead of film to film. If this positive is placed film to film on the negative, but reversed end for end, the positive image of a line may be superposed on the negative image of the same line, and the condition is fulfilled whereby any point along the negative image coincides with the same point on the positive image. If there is a change of wave-length at this point, the displacement will be in opposite directions in the two images. This has the effect of making small shifts plainly visible, and if the positive is made on a slow plate of good contrast and density the line will appear dark, but no longer straight, in fact near to sunspots the finer lines often show marked displacements to red and violet alternately, taking a sinuous course.

I have adopted this procedure to detect and measure small Doppler effects which may occur at the present time of minimum activity. High-dispersion spectra of sections of the Sun's disc have been obtained with four transmissions through the liquid prism spectrograph. These have a linear dispersion equal to 1·8 mm. to the angstrom at $H\beta$, increasing to 2·8 mm. at $H\gamma$. The slit is 20 mm. long, and covers one-third of the diameter of the Sun's image. Exposures of from 30 seconds to 4 minutes are required, and are made only under good conditions of seeing: with bad seeing, small localized disturbances are more or less reduced or entirely obliterated. A new slit curved to a radius of 11 inches had to be made in order that the spectrum lines should be perfectly straight. Otherwise the coincidence of positive and negative images when reversed could not be made along the whole length of a line.

Up to the present, 24 plates have been secured of sections of the disc between the centre and the limb, and in all of these small shifts and sinuosities are seen in the narrower lines—that is to say, lines of Rowland's intensities 2, 3 and 4. The displacements of course vary from plate to plate, showing that they are not due to irregularities in the slit of the spectrograph. In any one plate they occur at the same points in all the lines examined: they cannot therefore be ascribed to accidental irregularities in the silver deposit. Ten plates have been taken also with the slit crossing the centre of the disc, and in eight of these the shifts appear to be entirely absent. On two, however, very small irregularities are shown either at the centre or near to it.

The measured shifts in the region between $H\beta$ and $H\gamma$ range from ·002 to ·005 A., the majority of those easily visible ranging between ·003 and ·004 A. Shifts smaller than ·002 A. were not estimated.

It is evident from these preliminary results that measures of the Zeemann effect in the general magnetic field, which involve shifts of the order of ·001 A. only, may be largely affected by what may be considered accidental shifts of considerably greater magnitude. The effects of these disturbances are, however, minimised by the very long exposure time needed in photographing the high-dispersion grating spectra, whereby the inevitable movements of the Sun's image on the slit will tend to obliterate any localised Doppler effects without influencing the general Zeemann effect. Also as the positive image in measuring these plates is not copied through the glass or reversed on the negative, but is displaced laterally by an amount corresponding with the change of sign of the Zeemann shifts, the local Doppler shifts will tend to be reduced in amount, whilst the Zeemann shift is always multiplied by two in the measures.

Assuming the shifts I have observed to be Doppler effects, the fact that they appear mostly at a distance from the centre of the disc, and rarely at the centre, would indicate that the movements causing them are mainly parallel to the solar surface. In this they resemble the radial motion in sunspots, in which vertical motion is rarely detectable. The motion outwards from the umbra being horizontal, the component in the line of sight vanishes when the spot is near the centre of the disc.

The actual motion indicated by the measures cannot be computed exactly. The mean value of the component in the line of sight from 36 measures is ·21 km sec., which becomes ·36 km./sec. if multiplied by the cosecant of the mean angular distance from the centre, but this assumes the motion to be in the direction of the centre of the disc. The actual motion would in general be greater: it is in any case rather surprisingly large.

Experience so far indicates that these movements are extremely local. They cannot therefore be considered as winds in the solar atmosphere extending over appreciable areas: more probably they may be thought of as incipient sunspot disturbances. They are apparently confined to the lower reversing layer, and are therefore not easily detected near the Sun's limb where the lines represent higher levels.

It is hoped to determine the latitudes in which shifts are most frequent, and possibly to correlate them with the beginning of the new sunspot cycle.