A NEW METHOD OF USING A SPECTROGRAPH FOR SOLAR ROTATION WORK.

J. Evershed, F.R.S.

In his valuable paper entitled "Spectroscopic Observations of the Sun's Rotation made at the Royal Observatory, Edinburgh, 1914–31," * Mr. Storey calls attention to the "large differences in the rotation value which occur from plate to plate and often on the same plate." As I have had similar experiences in measuring rotation spectra, it seems desirable to attack the problem once again with improved arrangements for obtaining the photographs and a more accurate method of measuring them. Also the present time of minimum solar activity affords a favourable opportunity for obtaining consistent values of the rotation uninfluenced by sunspot or other disturbances. It is evidently important to discover whether the apparent variations are real or due to instrumental causes.

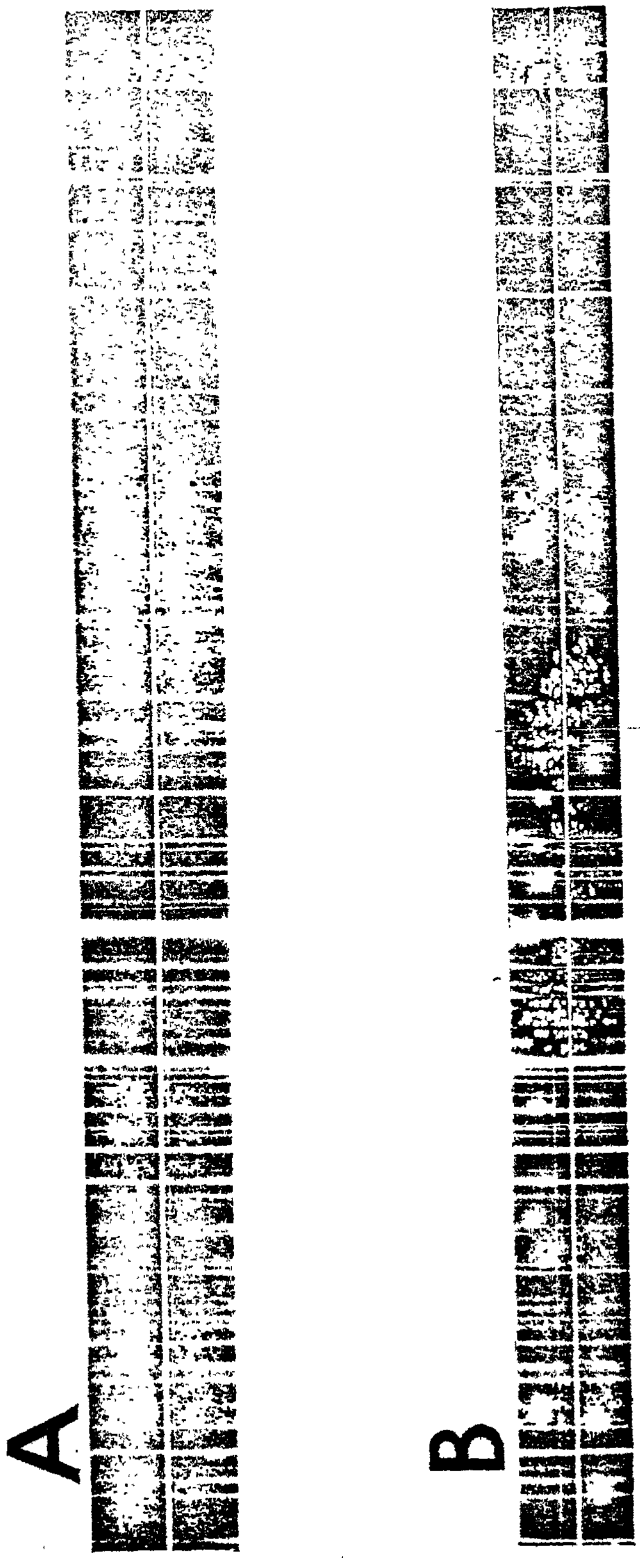
I give here a description of the apparatus I am now using, and the methods of measuring the spectra.

The spectrograph at Ewhurst is fed by a cœlostat which reflects the Sun southward. A second mirror sends the light downwards through a 6-inch object-glass of 20 feet 9 inches focal length. A third mirror in the underground room reflects the light horizontally northward to a focus on the spectrograph slit. By this arrangement the east and west points on the Sun's image lie on a horizontal diameter, and remain so at all times.

The beam of sunlight coming from the object-glass is divided into two parts about 3 feet from the focus, where two right-angle prisms are placed, reflecting the light from the east and west limbs upwards to a single plane mirror: this reflects it to the slit of the spectrograph. The two images, east limb and west limb, are here in focus and may be moved relatively until they coincide or overlap slightly. This is done by means of a fine screw adjustment applied to each of the two reflecting prisms moving one image horizontally through a solar diameter and adjusting the other image vertically.

The object is to photograph the two limbs simultaneously; but it is necessary to cut out one-half of each to avoid overlapping of the two spectra. Also on account of the considerable angle between the two beams of light (the angle subtended at the slit by the two patches of light falling on the reflecting prisms) neither beam will illuminate the collimator lens, and they fall on each side of the collimator tube. To correct this and at the same time to cut out one-half of each limb, a thin plano-convex cylindrical lens (a spectacle lens is used) is cut in half, forming essentially two similar wedges of varying angle. Each half is placed over half the length of the slit, and they are carefully adjusted laterally, as shown in the diagram A. By this arrangement the light of half of the east limb image and half of the west

* *M.N.*, 92, 7[illegible]. 1932.

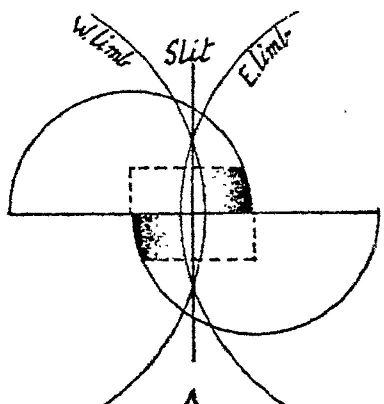


Solar Rotation Plate. Latitude 10°·8. D region (red to left).

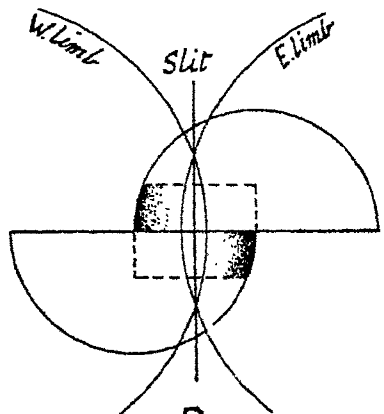
Evershed, New Method of Using a Spectrograph for Solar Rotation Work.

image is made to fall centrally on the collimator lens. The other halves of the limb images are by the same action thrown entirely away from the collimator, and are completely suppressed by the velvet lining of the tube. In this way the spectra of the two limbs appear in contact, and the displacements of the spectrum lines at the junction of the images represent twice the Sun's rotation velocity at the latitude of the east and west points, which may vary between the equator and latitude 26°.

In the diagram B a similar device is shown, but with the half lenses arranged to interchange the east and west limbs and so give the displacements between the upper and lower spectra in the opposite direction. The purpose of this is to facilitate the measurement of the spectra, as will appear later. In the diagrams the portion of each half lens that is effective as a



A



B

wedge is shown by the broken lines, the shaded part representing the thinner part of the cylindrical surface.

This method of obtaining east and west spectra simultaneously supersedes that in which small reflecting prisms are arranged at the two limbs, reflecting the light to similar prisms placed over the slit at the centre of the Sun's image, a method which is difficult to arrange satisfactorily except for very large solar images. The equal illumination of the collimator, or prism face, by the two limbs is of course essential, and is much more easily secured with the variable wedges than with the small reflecting prisms. The half lenses are cemented to a metal plate which can be easily attached to or detached from the slit mounting. The cement used * takes a day or two to harden if no heat is applied, and this property makes it easy to slide each half to the correct position, determined beforehand approximately, so that the light from each limb falls centrally on the collimator. With the slit at its working width 0·02 mm. the first diffraction band is much wider than the effective aperture of the prisms; consequently any slight error in the adjustment of the wedges has no effect on the spectra.

In solar rotation work it is best to avoid taking the light from points very

* This has the trade name "Firmas."

near to the limb, owing to the relative increase in the admixture of scattered light from the sky as the limb is approached: it is necessary, therefore, to know the exact distance within the limb from which the light is taken in order to determine the correction to be applied. This is not easily ascertained when small prisms are used, but in the new method the distance between the cusps in the overlapping images affords an accurate measure of the position of the slit within the limbs at the east and west points.

In order to measure the spectra with the greatest possible accuracy, and to avoid systematic errors, the positive on negative method is adopted.* By this scheme the intervals measured are doubled, and so are equivalent to four times the rotational velocity. Also, with practice, greater precision can be achieved in setting the positive image of a line on the negative image than is possible in placing a fine thread centrally on a line. This applies especially to broad lines such as those of sodium and magnesium.

In measuring two contiguous spectra by the positive on negative method it is necessary to obtain *reversed* positives of the spectra, and as satisfactory copies cannot easily be obtained by direct contact through the glass a simple method is to photograph a pair of negatives, one with the cylindrical lenses arranged as in diagram A, and the other with another pair of half lenses arranged as in B. Ordinary contact copies are then taken of the two negatives, and in the measuring micrometer the positive of A is superposed on the negative of B without reversing the spectra end for end. This enables displacements to be measured to the best advantage by this method, and eliminates a troublesome systematic error which may arise if the spectrum lines are not exactly normal to the spectrum, a condition that requires very careful adjustment of the slit mounting. This error applies equally to the ordinary method of measuring when the thread is not quite parallel to the lines.

In order to reduce the accidental errors of measurement, the positive image B may be superposed on the negative A, and the mean of the two sets of measures taken.

In cases where, owing to cloudy conditions, only one east and west spectrum has been obtained, this is measured by taking a reversed positive in a special 8-foot camera in which the negative is placed film outwards, and an image formed in the conjugate focus of a lens placed exactly midway between film and plate. In this case it is necessary to ascertain that the lines are at right angles to the spectrum. This is tested by placing a reseau ruled in squares over the negative.

A considerable number of spectra near D and near *b* has been secured by this method, using the high-dispersion liquid prism spectrograph, and the measures of these give very promising results.

A sample photograph of the D region is given in Plate 7 showing the opposite displacements in the images A and B. Incidentally these spectra, representing latitude 10°·8, show how small is the interval to be measured—about the width of the narrower lines—and we attempt to measure this to an accuracy of about one part in two hundred.

* *Kodaikanal Observatory Bulletin*, 3, 17, 1913.

It is hoped to obtain a good series of these spectra during the period of minimum solar activity, and to communicate the results of the measures to the Society in a subsequent paper.

Ewhurst :
1932 *December* 27.