On Some Measures of the Solar Rotation at Different Levels in the Chromosphere. By J. Evershed, F.R.S.

Photographs of solar spectra with iron-arc comparison were obtained in Kodaikanal in 1922 and 1923, using a prism spectrograph. This gives a dispersion in the H and K region of nearly 2 mm. per Ångstrom with excellent definition. With this instrument, and a 6-inch solar image, spectra were obtained at the centre of the disc, near the polar limbs, and near the equator east and west. These were primarily for the purpose of measuring the displacements sun – arc of the iron lines at the centre and at the limb; but the spectra of the equatorial limbs may be used also for determining the solar rotation.

A similar series was obtained for the D lines, using a potash salt in the arc, which gave narrow and very brilliant sodium lines. The grating spectrograph was used for this series.

The mean displacements of pairs of plates taken at nearly the same heliographic latitude east and west give values of the solar rotation. These are set out in Table I., Series 1 and 2, after slight corrections to reduce them to the equator and to sidereal velocity.

In Series 3 of Table I. the results are given of measures of some grating plates taken in the year 1918 of lines in the red region, near to and including the H_α line. These are solar spectra only, and were taken for the purpose of determining the rotation displacements with the greatest possible accuracy of measurement. The east and west spectra are photographed simultaneously on the same plate.

All of these series of spectra were measured by the positive-on-negative method. The probable errors are derived from the accordance of the plates in a series: the errors of measurement are much smaller.

In Table II. the various values are arranged according to the estimated heights of the absorbing gases above the photosphere; and to these I have added a value obtained from the H and K lines in sixty-one prominences photographed on the east and west limbs in the years 1908–1911. The measures were made at a mean height of 46″ above the photosphere and at mean latitude 31°. The reduction to the equator was made on the assumption of uniform angular motion. The third column of this table gives the mean deviations from plate to plate in km./sec. It is a common experience in spectrographic measures of the rotation that these deviations greatly exceed the errors of measurement, and they appear to be due to real changes of velocity. The fourth column gives the approximate values of the solar radius in the region of absorption (or emission in the case of prominences): these are expressed in seconds of arc to be added to the mean radius of the photosphere. The approximate amounts to be added are assumed to be one-half the height to which the gases ascend in the chromosphere, and are derived from measures of my eclipse plates of 1898 and 1900. The last column gives the daily angular motion, taking account of the increasing radius.

Two results of interest appear from these measures. First, the angular rotation speed increases markedly with the height of the absorbing region, as was found by Adams in his measures of the H_α line, and the line λ4227 of calcium.* Secondly, the deviations from plate to plate in a series tend to increase also with the height.

The measures of the D lines are slightly discordant in giving a lower value than that given by the strong lines in the ultra-violet; but owing to the great variation from plate to plate, and the small number of plates, the rotation value given has little weight. Comparing the strong and the weak lines in the same plates of the H and K region, the difference is striking, the strong lines giving a distinctly larger value than the weak lines, and also a larger deviation from plate to plate. The strongest lines of all, viz. H and K, could only be measured on two plates which happened to give measurable images of the calcium-arc lines: these give the highest angular speed of all, except the prominences. When we come to the prominence region, outside the chromosphere, the deviations from plate to plate are enormous, the mean exceeding 1 km./sec. The prominences selected for the measures are those of a more or less permanent type, which may be observed successively on the east and west limbs after intervals of fourteen days. They are not usually associated with rapid movements in the line of sight.

The value of the rotation period derived from the prominences is, of course, subject to considerable revision. If it gives a fair estimate of the rotation speed, it would appear that the shortest period of the sun's rotation, about twenty-one days, occurs entirely outside the limits of the chromosphere. This outer coronal region is apparently subject to violent conflicting movements, made evident by the erratic nature of the line-shifts, even when so-called "quiescent" types of

* *An Investigation of the Rotation Period of the Sun*, by W. S. Adams, published by the Carnegie Institute of Washington, 1911.

prominences are selected for the measures. It would seem that this turbulent motion extends downward through the chromosphere with diminishing amplitude, giving rise to the disconcerting variations in spectrographic measures of the rotation.

TABLE I.

Mean Sidereal Velocities at Sun's Equator deduced from Lines of Different Intensity and Different Spectral Regions.

	Km./sec.	
Series 1. H *and* K *Region.*—Twelve plates photographed between the dates 1922 Dec. 15 and 1923 Jan. 6, all within 5° of the Sun's equator—		
H and K lines	2·126	(2 plates only).
11 strong lines of Fe and Al, 3886 to 3969, mean intensity 9·2	1·950	±·024
8 weak lines of Fe, 3885 to 3977, mean intensity 4·3	1·931	±·015
Series 2. D_1 *and* D_2 *in Sun and Arc.*—Twelve plates photographed between 1922 Mar. 24 and 31, all within 5° of the equator	1·939	±·062
Series 3. H_α *Region.*—Nineteen plates photographed between 1918 Feb. 6 and Mar. 15, all within 12° of the equator—		
H_α line	2·067	±·028
5 Fe lines and 5 Ca lines, mean intensity 5·7	1·932	±·013

TABLE II.

Rotation Values at Varying Heights above Photosphere.

	Km./sec.	Mean Deviation.	Radius.	Angular Motion.
Weak lines in U.V.	1·931	·034	$962''+\frac{1}{2}''$	13°·6
Fe and Ca lines in Red	1·932	·060	$962+\frac{1}{2}$	13·6
Strong lines in U.V.	1·950	·073	962+1	13·8
D lines of Sodium	1·939	·155	962+2	13·7
$H\alpha$ (Hydrogen)	2·067	·128	962+6	14·7
H and K (Calcium)	2·126	..	962+7	15·0
Prominences	2·48	1·18	962+46	16·8