The Wave-length of Hε and the Displacements of the Hydrogen Lines in the Sun. By J. Evershed, F.R.S.

Prominence spectra in the H and K region occasionally show a strong image of *Hε*, about 1·6 A. on the less refrangible side of the calcium line H. In measuring over 500 plates for determining the rotation shift and the Einstein effect for the calcium lines, the interval separating H and *Hε* has been measured in all spectra in which the hydrogen line was well enough defined for accurate bisection. The calcium line is always very much stronger than *Hε*, but the relative intensities are far from constant. The lines differ also when there is considerable distortion of H due to motion, for the hydrogen line seems to be less affected. For this reason, only plates showing no appreciable motion are used for these measures.

Only a very small proportion of the total number of plates measured for H and K gives good images of $H\epsilon$, and up to the present 34 plates have been measured. As the prominences are now diminishing in number and intensity, it seems desirable to record the results obtained without waiting for a larger number of measures.

The mean value of the interval H $-$ $H\epsilon$ from 34 plates is 1·607 A. The average deviation from the mean is 0·005 A., and the probable error $\pm$ 0·0008 A. The terrestrial wave-length of H in air and at normal pressure is 3968·471, according to my recent measures.* This is based on the secondary and tertiary standards of the iron arc published in the *Trans. I.A.U.*, 1, 1922. To reduce this to zero pressure I use the consistent values of the pressure shift obtained by Humphreys at 42, 69, and 101 atmospheres,† which give a mean shift per atmosphere of + 0·0020 A. for H. This line at zero pressure therefore reduces to 3968·469, and hence the wave-length of $H\epsilon$ observed in air, but produced at zero pressure, is 3970·076 $\pm$ 0·0008, in close agreement with the value determined by Curtis,‡ which is 3970·075 $\pm$ 0·0016 A. But this value is based on Burns's measures of standard iron lines, which differ very slightly in wave-length from the secondary and tertiary standards quoted above, and, assuming that Curtis used six of the Fe lines nearest to $H\epsilon$, a correction of $-$ 0·001 is necessary, which would make his value smaller than mine by 0·002 A. It is to be noted also that my value assumes that the interval H $-$ $H\epsilon$ is the same in the prominences as in terrestrial sources, that is to say, there is no differential shift in the Sun for the two lines. The close agreement indicated shows that this is approximately true, and that $H\epsilon$ is shifted towards the red in the prominences by an amount of the same order as the shift of the calcium line, which I have already determined as + 0·015 A.

At the centre of the Sun, according to the authors of the Revision of Rowland's Preliminary Table, $H\epsilon$ has the wave-length 3970·078, implying a shift in this position of only + 0·002 A. The absorption line is normally very ill-defined and faint, and cannot be measured with accuracy. I have estimated the position from spectra of sunspots when near the centre of the Sun, where the line occasionally appears with increased absorption, or in eruptions as a bright line, and the centre of the absorption or emission appears to me to lie midway between the Cr line 3969·762 and the Fe line 3970·401, which implies the wave-length 3970·081, and a shift of + 0·005 A.

It is now possible from my value of $H\epsilon$ to estimate the wave-lengths and shifts of two of the other less refrangible hydrogen lines by the aid of Balmer's unmodified formula

$$\lambda = \frac{s^2}{a(s^2 - 4)}$$

and the tables of Meggers and Peters of the dispersion of air.§ Computing a, the wave-number of the limit of the Balmer series *in vacuo*,

* *Monthly Notices R.A.S.*, **90**, 189, 1929.
† *Astrophysical Journal*, **26**, 21, 1907.
‡ *Proceedings of the Royal Society*, A, **90**, 613, 1914.
§ *Astrophysical Journal*, **50**, 61, 1919.

I obtain the values of $H\delta$ and $H\gamma$ (reduced to air) given in the table below, in which the shifts of all the hydrogen lines from ϵ to α are compared with the Einstein effect. Curtis's results show that Balmer's formula is only an approximation to the truth, and it fails if extended to $H\beta$ and $H\alpha$. It will, however, give the values of $H\delta$ and $H\gamma$ to practically the same limits of accuracy as that of the measured line.

To obtain the shifts of β and α, I take Curtis's uncorrected values, because for these lines he appears to have used secondary standards which differ only very slightly from the standards published by the *I.A.U.* in 1922.*

Approximate Shifts of the Hydrogen Lines at the Centre of the Sun.

	λ Vacuum.	λ Sun.	Sun − vacuum.	Einstein effect.
$H\epsilon$	3970·076±·0008	·078	+·002	+·008
$H\delta$	4101·739 } computed	·750	+·011	+·009
$H\gamma$	4340·469 } computed	·477	+·008	+·009
$H\beta$	4861·326±·0010	·344	+·018	+·010
$H\alpha$	6562·793±·0017	·816	+·023	+·014

The solar wave-lengths are from the Revision of Rowland's Table, which is based on the standards of 1922. The probable errors are not known, and it is doubtful if the values can be trusted to be accurate in the last decimal. The lines are wide and ill-defined, and the difficulties of accurate bisection are increased in the case of $H\delta$ by closely adjacent lines. Perhaps the line $H\gamma$ is the most reliable: it gives a shift nearly in agreement with the Einstein effect. Notwithstanding the errors affecting this table, there can be little doubt that the relative shift increases with wave-length: in the case of $H\epsilon$ it is less than the theoretical, and in the case of $H\alpha$ very much greater. This can readily be explained if we postulate a descending motion of about 0·4 km./sec. in the higher levels of the chromosphere, decreasing to zero at an intermediate level, and changing to a slight ascending motion at the level of $H\epsilon$. For the different lines of hydrogen represent different levels in the chromosphere, $H\alpha$ the highest, $H\gamma$ intermediate, and $H\epsilon$ a low level.

St. John has found that absorption lines originating at a level of 520 km. above the photosphere show displacements in agreement with general relativity. Below this level upward currents exist, and above it his results also indicate a downward movement.†

* It is unfortunate that Curtis does not quote the wave-lengths of the standard lines actually used in his measures, except that in the case of $H\alpha$ he gives in a footnote four wave-lengths of secondary Fe standards used for this line. Of these one is obviously erroneous, owing probably to a misplaced figure: the other three have values on an average 0·003 A. smaller than Burns or the 1922 standards. If a correction is made in this sense, the shift of $H\alpha$ in the Sun is reduced to + 0·020 A.

† *Astrophysical Journal*, 67, 195, 1928.