VARIATION OF THE GENERALIZED COMPTON RED SHIFT IN THE SUN

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ABSTRACT. The most accurate measurements of red shifts in the solar spectrum, made in different epochs by different astronomers, show a systematic difference, in the average 2 mA° (0.2 pm) , that seems quite independent on the wavelengths. Such a result can be explained, at least from a qualitative point of view, by the Compton effect. Indeed a variation of the normalized width U of the spectral lines causes a consequent variation of the Compton red shift: increasing U of the 50% , also the red shift increases of about 0.1 pm . Besides that a variation of the average depth h for the formation of the spectral lines in the reversing layer, may cause, in some model atmospheres a change of the red shift: an increase of about 90 Km for h may induce an increase of about 0.4 pm in the Compton red shift.

1. THEORETICAL RESULTS

The wavelengths of the spectral lines of a star may show, in some region of the visible spectrum, variations in different epochs which are independent on the wavelength. Such a result cannot be easily explained by a difference of radial velocity but instead can be easily explained by a change of magnetic field, temperature and pressure in the low chromosphere. They indeed may cause a variation of the normalized width U of the spectral lines and a consequent variation of the Compton redshift as shown in previous articles. Besides that they may cause, in some model atmospheres, a change of the number of scattering atoms crossed by the observed photons and hence of the Compton red shift. We now shortly illustrate how to compute these two kinds of red shift by a theory of radiative transfer. First of all we remember that the normalized width U of a spectral line is a parameter that says if the profile is narrow or broad and it is used to determine the dependence of the Compton red shift of the line on its shape. That dependence is calculated with a quantum theory of radiative transfer, which includes of course the Compton effect, but it results to be mainly of geometrical kind. A simple definition of the normalized width is $U = W / I_t$, with W equivalent

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width of the line and I_t central intensity. However one could also take the half width FWHM and so on. If the intensity $I(\lambda)$ of the line, with λ wavelength, has a Gauss shaped profile:

$$I(\lambda) = I_t \exp\left[-(\lambda - \lambda_o)^2/(2\,D^2)\right] \quad ,$$

it follows that $U \simeq \sqrt{2\pi}\,D$ and FWHM $= \sqrt{8\ \ln 2}\,D$. Then we define an optical thickness τ of the layer of scattering atoms crossed by the observed photons: $\tau = \sqrt{3}/2\ \sigma \int N(h)\,dh = 5.8\ 10^{-29} \int N(h)\,dh$,

where σ is the total Thomson cross-section, $N(h)$ is the number of scattering centres per cubic metre at the position h and the integration is extended along the straigth line from the source to the observer. That being stated we assume that the normalized width of a line has changed. Then this produces a little variation of the wavelength of the line that can be computed, for $\tau \leqslant 0.7$, by means of "table 1" of the article Missana et al. 1976, where we have the red shift of the wavelength at the top of the line, with respect to the laboratory wavelength , as a function of the observed width U of the line and of the thickness τ of the scattering layer. For instance assuming a variation of U from $\sim$ 8 pm to $\sim$12 pm and an optical thickness of the solar chromosphere $\tau \cong 0.3$ (Missana 1982), it follows that the red shift of the line, due to the scattering, increases from 0.31 to 0.42 pm , etc . For thicker scattering layers, $\tau > 0.7$, it can be used the "table 1" of the article Missana 1977, where the Compton red shift is given as a function of τ and of the width $W_o = U/\sqrt{\pi}$ before the diffusion. For instance assuming an optical thickness $\tau = 1$ and a variation of U from $50\sqrt{\pi}$ to $100\sqrt{\pi}$ pm it follows that the red shift of the line increases from 3.76 to 3.84 pm . We consider now the consequences of a change of optical thickness of the scattering layer which could be due to a variation of the reversing layer, at least for the lines of the atoms giving a smaller contribution to the thickness τ , but of course it could be also due to an incoming cloud of interstellar matter. First of all this different deep of formation of the spectral lines may cause a variation of the width U , whose effects on the red shift are computed as before. The main consequence however, in the present scattering theory, is the change of red shift due to the change of the optical thickness τ , that can be deduced from the quoted tables. Consider for instance the reversing layer of the sun. If a spectral line is formed for instance at a heigth h = 178 Km in the reversing layer, as defined by Allen 1973, we have $\int N(h)\,dh = 10^{27.68}$ particles $m.^{-2}$ and then $\tau \cong 0.28$. But if the line is formed about at a heigth of 91 Km , hence below the former heigth towards the centre of the sun, we have $\int N(h)\,dh = 10^{27.97}$ part. $m.^{-2}$ and then $\tau' \cong 0.54$. From τ and τ' , by means of the quoted table, we obtain that the Compton red shift of the line having for instance a width U ≅ 12 pm , increases from ~0.38 to ~0.79 pm , and so on.

2. COMPARISON BETWEEN THEORY AND OBSERVATION

We pass now to see whether there is an observational support for this theoretical result. We notice that the most accurate measurements of red shift in the solar spectrum, given for different epochs by Adam 1958 and by Pierce et al. 1973, show an average difference of about 0.2 ± 0.3 pm for the red shifts of the 13 common lines of Fe with wavelengths: 5068.8, 5074.7, 5078.97, 5079.2, 5079.7, 5083.3, 5167.5, 5171.6, 5266.6, 5269.6, 5324.2, 5328.1 and 5328.5 . From the study of the lines of Adam article it seems that the difference of red shifts is independent on the wavelengths and hence it may be explained by a change of the reversing layer and the Compton effect, unless it is due to the fact that they used different sources for the laboratory wavelengths. Indeed the Adam measurements, giving the larger red shifts, were made in 1952-57 with the sun going to the epoch of maximum activity(1957.9) and the measurements of Pierce were made in 1967-73 , with the sun going to the epoch of minimum activity(1976.5) . Hence it is possible that the variation of solar activity causes a change of width of the spectral lines and of their depth of formation in the reversing layer with consequent change of red shift. On the other hand, we really observe that many lines change their width U with the heigth above the limb. Then it can be suggested that the observed variations of widths and wavelengths may be used, with a theory of radiative transfer, for a detailed study of the lower chromosphere.

In the spectra of the variable stars the considered effects seem to be more enhanced (Missana 1983) , at least for the O and B-type stars, even if there are not enough measurements of wavelengths and widths U for a conclusive study.

It may be also useful to remember that in the quoted dispersive theory the central intensity I_t of the narrow spectral lines, in unity of the continuum intensity I_c , changes with τ ; instead the equivalent width W is always conserved. Also the continuum intensity changes with τ according to the formula $I_c(\tau) = I_c(0)/(1+\tau)$, Missana 1977 . So we may conclude that the rigorous study of the dispersion of the electromagnetic radiation in the scattering layers gives useful results for the interpretation of the astrophysical spectra and it cooperates with the Doppler and Zeeman effects to changing the wavelengths of the spectral lines and with the absorption to the softening of the light intensity .

3. REFERENCES

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