THE CALIBRATION OF STELLAR SPECTRA USED IN MEASUREMENTS OF THE GENERALIZED COMPTON SHIFT

M. Missana

Astronomical Observatory of Brera, Milano-Merate

ABSTRACT. In the study of the changes induced by the Compton effect and Thomson scattering on the shape of spectral lines in light traversing a chromosphere or a planetary nebula it is necessary to have accurate wavelength measurements, central intensities and half widths (FWHM) of the lines. In the comparison of FWHM measures belonging to different spectra it is useful to have the intensities of the continuum at the wavelengths of the lines. The studied spectra should have a dispersion higher than 10 Å/mm and a spectral range larger than 700 Å. A short recommendation is also given about the comparison spectrum and the calibration plate.

1. THEORETICAL RESULTS

The numerical values of the generalized Compton effect in stellar spectra are determined from the equation:

$$\lambda_s - \lambda_l = \Delta(U,\lambda_l) + \beta\lambda_l ; \qquad (1)$$

where λ_s and λ_l are the stellar and laboratory wavelengths of the spectral line, $\beta = V/c$ is the mean radial velocity of the stellar atmosphere observed from the Earth, divided by the light velocity c and $\Delta(U,\lambda)$ is the generalized Compton shift. Δ depends on the profile of the spectral line (here defined by means of the width U), on the wavelength λ and on the temperature and thickness of the scattering layer. The function $\Delta(U,\lambda)$ can be obtained from the solution of the radiative-transfer equation (Chandrasekhar 1960, Missana 1977) and depends on the scattering cross-section of the photons with the bound and free electrons and with the atomic nucleus; it depends also on the Delbrück scattering cross-section (Schweber 1966). The rigorous computation of the $\Delta(U,\lambda)$ function is still an unresolved problem. However an approximate solution has been found for wavelengths in the visible spectral range far from a resonance of the scattering atoms for free or bound electrons with a cross-section

D. S. Hayes et al. (eds.), Calibration of Fundamental Stellar Quantities, 595–597.

https://doi.org/10.1017/S0074180900079560 Published online by Cambridge University Press

independent of wavelength, as in the Thomson cross-section.

In that simpler case, for lines having a Gaussian shaped profile before the scattering, one obtains $\Delta(U,\lambda) = \Delta(U)$, where U is the full half width of the line (FWHM) or the normalized width of the line, which is defined as the equivalent width W divided by central intensity I of the line, (U=W/I). $\Delta(U)$ is a crescent function of U which becomes nearly constant for $U>U_o$; the value U_o depends on the optical thickness of the scattering layer. This theoretical result is in fair accord with the measurements of the solar spectrum (Missana 1982). Hence in the study of the stellar spectra by means of equation (1) it is necessary to know the U values of the lines in addition to the usual data.

2. THE MEASUREMENTS

The practical measurement of U is quite sensitive to the adopted definition of the continuum; so in the comparison of values of U measured in different spectra it is useful to know the intensity of the continuum at the wavelength of the line.

In the computation of the generalized Compton effect by means of equation (1) the spectral lines, free of apparent blends, are ordered in an increasing sequence with respect to U; then they are divided in n classes with at least 9 spectral lines in each class, if the wavelengths are distributed in a spectral interval of at least 700 Å; all the lines with the same U have to be in the same class, of course. Then we assume that the Δ-function is constant in each class and the n+1 unknowns Δ and β are computed by means of the method of least squares, together with the standard deviation S of the residuals of the equation (1). It is useful to notice that a few measures, with large errors, change the results of equation (1) in a quite remarkable way, as underlined by Trumpler et al. (1953); hence a careful examination of S and an accurate sampling of the spectral lines is recommended.

From the results of the article by Missana et al. (1975) it follows that Δ is smaller than 0.05 Å except in the case of the stars surrounded by a thick layer of interstellar matter or embedded in a planetary nebula etc. Then the division of the spectral lines into 2 or 3 classes of the width U is sufficient. Please note that some formulae of the quoted article contain typographical errors. From the study of some spectra from the Haute-Provence Observatory the writer has deduced that dispersion of 9 Å/mm for the stellar spectra and a spread of the wavelengths in an interval of 800 Å is sufficient for a reliable computation of the Δ and β values. These spectra have been measured with a Gaertner comparator and the wavelengths of the comparison spectra have been taken from Crosswhite (1958). The normalized widths have been obtained at the Nice Observatory with a quite large error mainly depending on the definition of the continuum.

3. CONCLUSIONS

About sixty years ago the first study of the Compton effect was published; now at last it is possible to measure that effect also in stellar spectra. For a reliable computation of the generalized Compton shift it is necessary to have at least 25 spectral lines in a spectral interval of at least 700 Å; for each line one must know the wavelength with an error smaller than about 0.02 Å, the central intensity and the equivalent width or the half width FWHM. It is also useful to know the intensity of the continuum at the wavelength of each line.

When the photographic spectrophotometry is used one should have 2 calibration plates at different exposure times and, in my opinion, a lamp with a known intensity distribution should be used. The use of a hollow cathode lamp for the comparison spectrum and of an impersonal oscilloscope comparator for the measurements are recommended. Less accurate measurements are needed for spectra of light passing through a thick layer of interstellar matter or that are observed in a wider interval of wavelength.

REFERENCES

Chandrasekhar, S. 1960, Radiative Transfer, (Dover Publications Inc., New York), p.328.

Crosswhite, H. M. 1958, The Spectrum of Iron I, (The Johns Hopkins University, Baltimore).

Missana M. and Piana, A. 1975, Astrophys. Space Sci., **37**,263.

Missana, M. 1977, Astrophys. Space Sci., **50**, 409.

Missana, M. 1982, Astrophys. Space Sci., **85**, 137.

Schweber, S. 1966, Relativistic Quantum Field Theory, (Harper & Row, New York), p.705.

Trumpler, R. J. and Weaver, H. F. 1953, Statistical Astronomy, (Dover Publications Inc., New York), p.183.

https://doi.org/10.1017/S0074180900079560 Published online by Cambridge University Press