DISCUSSION OF THE SEMI-EMPIRICAL DETERMINATIONS OF THE OPTICAL DEPTH OF CHROMOSPHERE-CORONA TRANSITION C IV LINES

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From the emission ratio of two lines of a doublet (such as the C IV 154.8 and 155.1 nm lines) or from the center-to-limb variation of a single line, one can extract the effective optical depth of the responsible layers. However, these deductions depend heavily upon the implicit or explicit assumptions made in the derivation. Two methods were used to analyze C IV lines observed with the LASP spectrometer aboard the OSO-8 satellite (see Bruner *et al.*, 1977).

The correct expression of the measured intensity, at a given point on the profile, for one single line is :

$$I = \int_0^{\tau} S\, e^{-t} dt \qquad (1)$$

where τ is the optical depth of the emitting layer along the line-of-sight at any point of the spectral line profile. In a first approximation, the gradient of the physical quantities being steep and the depth τ being considered as corresponding to a narrow layer, one generally assumes S to be constant within the layer. Thus, the approximative form of Equation (1) may be written :

$$I = S\,(1 - e^{-\tau}). \qquad (2)$$

i) The *doublet method* essentially assumes that the two lines have the same source function. The ratio of the oscillator strengths of the two lines is $f_2/f_1 = 2$ in the case of the doublet C IV. Hence, τ_1 being the central optical depth for the weaker of the two lines (155.1), one may write :

$$\tau_1 = -\ln\,(2K - 1) \quad \text{and} \quad \tau_2 = 2\tau_1 \qquad (3)$$

where K denotes the quantity $I_2/2I_1$. I_2 and I_1 are the central intensity of lines 2 (λ154.8) and 1 (λ155.1).

An average value K = 0.875 was obtained for active areas (A), and 0.80 for the quiet areas (Q), which, respectively, correspond to τ_1 = 0.29 (A) and τ_1 = 0.51 (Q) for the fainter component of the doublet C IV. The error bar is estimated to be of the order of ΔK = 0.2 for the active areas and 0.35 for the quiet ones.

In this determination, we have combined results from all points of the solar disk. The two samples are indeed too small for a systematic differential study as a function of μ. The optical depths determined in this way shall hereafter be denoted by the single prime sign : $\bar{\tau}'$

ii) The center-to limb variation of a single line allows a determination of the optical depth, provided that the geometry is assumed to be essentially that of concentric spherical layers. The expression of the ratio of the line center intensities at two different locations on the solar disk is, thus, equal to :

$$I_o(\mu)/I_o(\mu=1) = (1 - e^{-\tau_0/\mu}) \;/\; (1 - e^{-\tau_0}) \qquad (4)$$

for $\mu \geq 0.2$, where the index o designates the quantities relative to the line center. Expression (4) does not depend upon the source function S, but (as for Equation (3)) S is assumed to be constant within the emitting layer ; the Doppler width is also assumed to be constant.

We obtained, for the 155.1 nm line, an optical depth at line center of 0.5 for active areas and 0.7 for quiet ones. The optical depths determined in this way shall hereafter be denoted by the double prime sign : τ''_o.

Some authors have also used the ratio of the integrated intensities, the integration being performed over the line profile such that :

$$I(\mu)/I\ (\mu=1) = \int_{-\infty}^{+\infty} (1-\exp(-\frac{\tau_0}{\mu} e^{-x^2})dx \;/\; \int_{-\infty}^{+\infty}(1-\exp(-\tau_o e^{-x^2})dx. \qquad (5)$$

According to Roussel-Dupré et al. (1979), who used this method, the ratio has the same form as Equation (4), where the indices o are suppressed ; then, τ (the "integrated depth") is equal to $k\tau_o$, and, according to the same authors, $k = \sqrt{\pi}$. Actually, this is slightly incorrect ; a complete determination shows that k is indeed a function of τ_o/μ and the values of k differ from the denominator to the numerator. The net effect of this on the use of the ratio of integrated intensity is, actually, that they obtained, for the 139.3 nm line of Si IV, a value of τ closer to τ_0 than to $\tau_o\sqrt{\pi}$. Although the use of Equation (5) presents no difficulty, we found it more convenient to use Equation (4) and the ratio of line center intensities.

iii) Both of the above determinations make use of certain hypotheses, and we will now assess their validity to our particular problems.

A given model corresponds to a certain value of the optical depth τ_o of the emitting layer in line 1 (155.1 nm), for instance. Simulated profiles of lines 1 and 2 can be computed and, then, τ_o' and τ_o'' may be determined from them. A comparison is thus possible and allows us to test the method of determination of τ_o' and τ_o''.

The computed profiles on various μ give, with method (i), K values which lead to different τ_o', the best one being obtained with profiles near the limb. If we take the average of K on the disk, the value obtained for τ_o' differs from τ_o (true optical depth) by about a factor of 2. Numerical experiments have shown that this discrepancy is associated with the fact that the ratio S_2/S_1 differs from unity, even if only by a few percentage points. The error made in the computation of τ_o' by assuming this ratio to be equal to unity is important when the optical depth is small, i. e., near the center of the disk, since the simulations are made assuming spherical symmetry.

Method (ii) yields a value of τ_o'' that differs from τ_o by as much as 30 % (using either Equation (4) or Equation (5)). Note that the simulated profiles were computed in a spherically symmetric atmosphere.

iv) Conclusion. If used for observed profiles, both methods (i) and (ii) give approximatively the same optical depths τ_o' and τ_o''; the discrepancy can be explained with the influence of the fine structure of the solar atmosphere, i.e. some departure from spherical symmetry. Indeed the method (ii) must give an higher value of the optical depth than the true one if the atmosphere is heterogenous. Let us remind that both methods can be applied only to optically thin lines.

References

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