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ON ESTIMATION OF THE OPTICAL THICKNESS OF SOLAR PROMINENCES

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Abstract. A method for rough estimation of the optical thickness of solar prominences in Hα line is presented. The method is based on the fitting of observed profiles with the synthetic ones computed by using the model of an isobaric 1-D slab with constant source function under the assumption of complete redistribution. The method was applied on 52 prominences observed with the Ondřejov HSFA2 spectrograph from April 2007 to March 2008.

1. INTRODUCTION

Prominences are relatively cool and bright structures emerged in upper parts of solar chromosphere and in corona. They are visible in emission lines above the solar surface. Models presume that the magnetic field is responsible for the existence of all prominences. They are formed of a low-temperature plasma, similar to that of the chromosphere and due to this, they mostly radiate in optical spectral lines. Density of prominences is much higher than the density of the surrounding corona and their radiation mainly comes from the scattering of photospheric and chromospheric radiation in the plasma. The influence of the physical parameters such as temperature and density on the radiation at some frequency ν can be represented by the optical thickness at that frequency τ_ν. Correlation between the physical properties of a prominence and the emitted radiation has been studied both theoretically, by modeling prominences in different ways (e.g. Gouttebroze et al. 1993, Heinzel et al. 1994), and by using observations in different domains (Heinzel et al. 2007).

The evaluation of opacity in observed emission lines of solar prominences is important for the investigation of their physical properties. Due to many practical difficulties encountered in deriving reliable values of optical thickness in emission lines, here we propose a method for a rough estimation of the line-center optical thickness τ_0 of prominences in Hα emission line. The method presented here is aimed at obtaining a value of τ_0 from non-calibrated profiles (i.e. without flat-fielding, subtracting the scattered light, etc.).

2. METHOD

The analysis was performed under the following assumptions:
- prominence is treated as an isobaric 1-D slab,
- the source function is taken to be constant along the z axis,
- complete redistribution is assumed.

Then the specific intensity of the radiation at wavelength λ in an emission line (Hα in this case) can be represented by the following expression:

$$I_\lambda = S(1 - e^{-\tau_0 \cdot e^{-\frac{(\lambda-\lambda_{max})^2}{\Delta\lambda_D^2}}}) \ , \tag{1}$$

where S is the source function which depends on the prominence's total optical thickness. The profile parameters, λ_{max} (the wavelength of the maximum intensity of the line profile) and $\Delta\lambda_D$ (Doppler width), can be easily found for each line profile using the maximum value and the width at half maximum of the emission line profile. The method is based on the fitting of the observed profile with the function given by Eq. (1).

A problem of fitting occurs when the function contains two unknown parameters. As one unknown parameter, the source function, depends on the other one (the optical thickness), we suggested the following iterative procedure to be used:

1. To start the procedure, we assumed $\tau_0 = 1$ as an initial value which is a reasonable assumption if we know that the optical thickness of prominences, derived by other methods, rarely exceeds 2.

2. With the given τ_0 and for $\lambda = \lambda_{max}$, Eq. (1) becomes $I_{max} = S(1 - e^{-\tau_0})$, enabling the value of the source function to be derived.

3. Using so obtained value of the source function in Eq. (1), we fit the observed profile by choosing τ_0 from an interval around the initial value.

4. The steps 1-3 are repeated until the convergence is achieved by narrowing down the interval for τ_0 in each iteration step.

3. RESULTS

In the beginning, the program was tested on a few already calibrated profiles. One of these fits is given in Fig. 1 (left). It is evident that the computed profile only slightly differs from the observed one. Since our principal goal was to get a rough and fast estimation, we performed no statistical analysis to evaluate the correlation, although the expansion of the code for such an option is planned for the future work. A fit of one of the non-calibrated profiles is also shown in Fig. 1 (right). The quality of the fit in this case is almost as satisfying as that of the calibrated ones.

In order to evaluate the method we compared the results for τ_0 obtained from calibrated and the non-calibrated profiles. For one particular prominence the results are shown in Table 1.

The method was applied on 52 prominences observed with the Ondřejov HSFA2 spectrograph from April 2007 to March 2008. It is possible to "map" the prominence

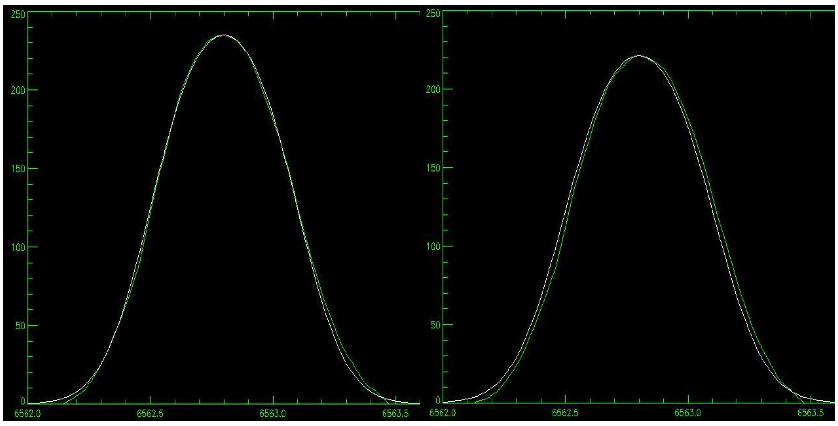

Figure 1: Fit of a calibrated (left) and non-calibrated profile (right). Estimated optical thickness is 1.31 (left) and 1.28 (right). Note: x axis is expressed in angstroms and y axis in arbitrary intensity units.

Table 1: The comparison between the estimated values of τ_0 for five, both calibrated and non-calibrated line profiles of a prominence observed on August 22, 2008.

Calibrated	1.17	1.26	1.29	1.13	1.26
Non-calibrated	1.23	1.37	1.26	1.30	1.15

with values of estimated optical thickness by taking spectra from different parts of the prominence. An example of one prominence processed in such a way is shown in Fig. 2, and the obtained results are given in Table 2.

The optical thickness estimated for all 52 prominences was in the range between 0.9 and 1.6. It rarely varies more than 0.4 for a particular prominence. We created a table of data for each prominence, which includes the estimation of the optical thickness as well as some comments on the effects that may have influenced the fit, such as:

- asymmetry and splitting of lines due to the prominence motion,
- self absorption,
- too low emission intensity,
- noise affecting lines, mainly in prominences near the surface.

The above mentioned effects may influence the fit significantly and they are not taken into account in the model we use. However, most of the profiles show no effects of this kind.

Table 2: Values of the estimated τ_0 for highlighted spots in Fig. 2.

Point No.	1.	2.	3.	4.	5.	6.	7.	8.
τ_0	1.27	1.34	1.24	1.20	1.33	1.37	1.23	1.27

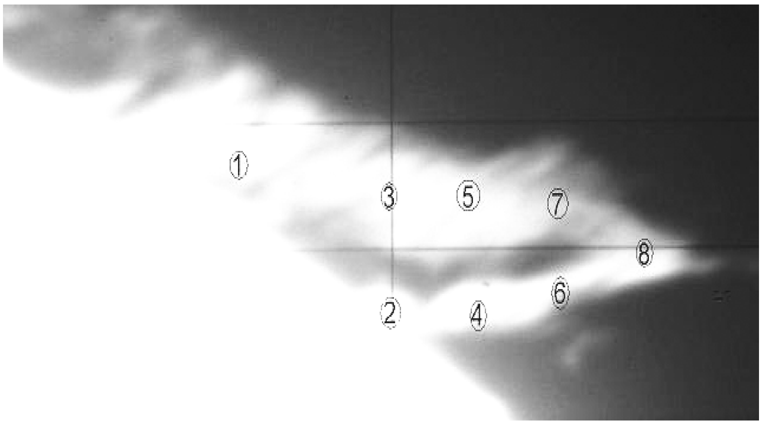

Figure 2: One of the analyzed prominences. Estimated optical thickness in 8 highlighted points is shown in Table 2.

4. CONCLUSION

If a rough and fast estimation of the optical thickness is needed, the described method seems promising. However, in order to test the method in a more rigorous way, it should be applied on a large grid of profiles generated by using a more complex prominence model.

The algorithm is simple and can be easily improved or adjusted. Also, the procedure can be expanded to be automatic if statistical analysis is required.

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References

Gouttebroze, P., Heinzel, P., Vial, J. C.: 1993, *Astron. Astrophys. Suppl. Series*, **99**, 513.
Heinzel, P., Gouttebroze, P., Vial, J. C.: 1994, *Astron. Astrophys.*, **292**, 656.
Heinzel, P. et al.: 2007, Active Galactic Nuclei, eds. R. D. Blandford, H. Netzer and L. Woltjer, Saas-Fee Advanced Course 20, Berlin: Springer – Verlag.