SPECTRAL ANALYSIS OF A QUIESCENT FILAMENT

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Abstract. We have determined principal plasma parameters in a filament by applying the appropriate cloud model to several observed spectral lines. Then we compared them to prominence models from the recent numerical NLTE modelling of Gouttebroze et al. (1993) (referred to as GHV). Some preliminary results of such an attempt are described and related problems are briefly discussed.

Key words: Sun – Filament Spectra – Cloud Model – NLTE Models

1. Observations and Cloud Model

Using the VTT Echelle Spectrograph of the Sacramento Peak Observatory we have obtained high resolution spectrograms of a filament located at E24, S13 on April 6, 1991 at 16:51 UT. Spectral lines H\textalpha{} and H\beta{}, as well as the Ca\textsc{ii} H and \&\ 8498 Å lines were detected photographically with dispersion of 5 – 16 mm/Å. The spectra were digitized by the AMD-1000 microdensitometer of the Sternberg Astronomical Institute. Calibration of the line profiles has been done using a procedure based on the PC VISTA software. The observed spectral line profiles were smoothed and the occurring blends were excluded. Both wings of the obtained symmetrical line profiles were subsequently folded to get the resulting half-profiles for each line (see dotted and dashed profiles in Fig. 1).

To derive basic plasma parameters, the standard Beckers’ cloud model has been applied (see Mein and Mein, 1988). Four parameters (\(\Delta\lambda_D\), \(v_{LS}\), \(\tau_0\) and \(S\)) define the cloud model. \(\Delta\lambda_D\) is the Doppler width (involving the temperature \(T\) and turbulent velocity \(v_t\)), line-of-sight velocity \(v_{LS}\) is considered to be zero, and \(\tau_0\) and \(S\) are the line-center optical thickness of the cloud and the line source function, respectively. Formal solution of the transfer equation along the optical path \(\tau(\lambda)\) reads

\[
I(\lambda) = I_0 e^{-\tau(\lambda)} + \int_0^{\tau(\lambda)} S(t) e^{-t} dt,
\]  

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where \( I(\lambda) \) is the intensity of the emergent radiation and \( I_0(\lambda) \) is the intensity of the background mean quiet-Sun radiation. Assuming \( S \) to be a constant, eq. (1) leads to a more simple form

\[
I(\lambda) = I_0 e^{-\tau(\lambda)} + S(1 - e^{-\tau(\lambda)})
\]

with

\[
\tau(\lambda) = \tau_0 e^{-\left(\frac{\lambda_A}{\lambda_D}\right)^2}.
\]

Optimization of the cloud model parameters was performed by the method of trials and errors.

**Figure 1.** The observed data (dots), smoothed (dashed) and the evaluated cloud model profiles (full lines) for the H\( \alpha \), H\( \beta \), CaII H and CaII 8498 Å lines.
2. Results and Discussion

The evaluated line profiles were compared to the observed ones. Both can be seen in Fig. 1. The poorest correspondence between the observed profile and the evaluated one was found in the Hα line, see the left upper pannel. This result can be explained by the fact that our assumption about a constant source function $S$ is not valid for this line as its optical thickness $\tau_0 \gg 1$ (see GHV models).

For the observed filament the best fitted parameters are as follows:

Temperature $T$: 9,000 K  
Turbulent velocity $v_t$: 5 - 10 km/s  
Optical thickness $\tau_0$: 2 - 36, depending on the particular line  
Source function $S$: 0.04 - 0.15 % of the local continuum intensity, depending on the particular line.

Note that this $\tau_0$ is the optical thickness along the line of sight. From the position of the filament on the disk we have estimated its inclination and then evaluated $\tau_0$ normal to the prominence slab (to be comparable to GHV data).

The optimum plasma parameters values were then compared to theoretical predictions based on GHV prominence models. As starting values for the comparison to the GHV models we chose: temperature $T = 8,000 - 10,000$ K, turbulent velocity $v_t$ was derived from CaII H and CaII 8498 Å lines as 5 km/s, the same as in GHV. We estimated the effective geometrical thickness from the Hα slit-jaw pictures of the filament as $\Delta z \leq 2,000$km. A typical range of the gas pressure for such a prominence was taken to be 0.05 - 0.5. After a careful comparison we found that no relevant GHV prominence model fits well our parameters derived from the cloud model, particularly the optical thickness $\tau_0$, the source function $S$ and the ratio of line-center intensities Hα/Hβ.

We consider three plausible reasons of the discordance between the evaluated cloud model parameters and those of GHV. The first effect cloud be the amount of scattered light that plays an important role when the filament is rather dark and narrow which was our case. As the second effect we consider the unknown value of the filling factor. If the filament or prominence is highly structured, the filling factor is becoming very important and subsequently the ratio between the Hα and Hβ central line intensities decreases (see GHV). Finally, the unknown background intensity $I_0(\lambda)$ can also have an effect on our results and the “differential cloud model” (Mein and Mein, 1988) would be more relevant to our case.

References