POSITION PAPER:

INVERSION OF CHROMOSPHERIC LINE PROFILES

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Because of the large amount of high resolution data which becomes available now from solar observations, fast codes are urgently needed in order to interpret disturbed line profiles. I will present briefly two kinds of algorithms usable in the case of chromospheric lines.

I. Inversion of CaII line profiles (non linear)

We use a theoretical 1D. model atmosphere, such as the VAL C'. We disturb it by some fluctuations of temperature and radial velocity (It can be shown that line disturbances due to pressure fluctuations are much smaller than disturbances due to temperature, at least in the case of amplitudes related by an adiabatic assumption). We expand the disturbances linearly versus height, by using 4 coefficients : fluctuations of temperature $\Delta T/T$ and temperature gradient $\nabla (\Delta T/T)$, velocity $V$ and velocity gradient $\nabla V$. The electronic density is calculated again by assuming that the hydrogen NLTE departures are undisturbed. The new statistical equilibrium of CaII leads to theoretical disturbed profiles. The fluctuations of any parameters $P_n$ defining these profiles can be connected with $\Delta T/T$, $\nabla (\Delta T/T)$, $V$ and $\nabla V$ by a second degree relationship.

Now, if we turn to observed profiles, we can compute for each of them a set of parameters $P_n$. By solving the relationship where temperature and velocity fluctuations are now unknown values (least square code), we can derive the corresponding atmosphere disturbances.

Of course, the efficiency of the method depends upon the choice of $P_n$. In order to disentangle temperature and velocity, it is valuable to use the coefficients of a Fourier expansion, on the condition that high order overtones are avoided, especially because of phase ambiguities for large velocities. So it is necessary to reach accurate profiles by a fast convergence of the Fourier expansion. This is achieved by using "double profiles", including observed profiles (range $-\lambda + \lambda$) and reversed ones (range $+\lambda$, $3\lambda$). Details can be found in Mein N. et al. ("Chromospheric diagnostics and modelling", Sacramento Peak 1985).
The scheme can be described in the following way:

\[ \text{VAL C'} + \text{disturbances} \]
\[ \Delta T/T, \nabla(\Delta T/T), \nabla, \nabla \nabla \]

Theoretical disturbed profile \[ \xrightarrow{\text{least squares}} \]

2d degree relationship \[ \xrightarrow{\text{Fourier coefficient fluctuations}} \]

of "double profile" \[ \xrightarrow{\text{observed profile}} \]

II. Inversion of \text{H}_\alpha\text{ profiles}

\text{H}_\alpha\text{ is less sensitive than the CaII lines with respect to the local temperature in the chromosphere. Many years ago, Beckers suggested that a "cloud model" could be used to interpret the spectra of peculiar \text{H}_\alpha\text{ structures. More recently, this model was investigated extensively by Grossman - Doerth and Von Uexküll. It is generally assumed that the source function and the radial velocity are constant throughout the "cloud". Although the first assumption seems reasonable, at least in the case of optically thin structures, the second one may be unrealistic, especially for fast ejecta where velocity shears can be present.}

So, we characterize the opacity of the cloud by a function of the wavelength \[ \tau(\lambda) \] which is no more a gaussian - type function. The observed profile \[ I(\lambda) \] is
related to the "chromospheric background profile" $I_0$ and to the source function $S$ by the equation

$$\frac{I(\lambda) - I_0(\lambda)}{I_0(\lambda)} = \left[1 - S/I_0(\lambda)\right] \times \exp(-\tau(\lambda)) - 1$$

Since we do not make any assumption about the velocity distribution, we cannot derive $S$ from the observation in a simple way. However, in the case of absorbing structures, that is in the case when $I(\lambda) < I_0(\lambda)$ whatever is $\lambda$, we know that

$$0 < S < I_{\text{min}}$$

where $I_{\text{min}}$ is the minimum value of the profile $I(\lambda)$.

An absorbing feature, associated with a type III radio burst, was observed with the MSDP of the Meudon Solar tower on May 10, 1980.

We have computed $\tau(\lambda)$ in several points along this structure. The figure (1) shows the results for a source function $S$ given arbitrarily inside the useful range ($S = I_{\text{min}} \times 0.5$).

![Graph showing absorption features](image)

**Figure 1.**

We also computed an average cloud velocity defined by

$$v_c = \frac{c/\lambda H_\alpha}{\int \tau(\lambda) \times \left( \lambda H_\alpha - \lambda \right) d\lambda}{\int \tau(\lambda) d\lambda}$$
The figure (2) presents $V_C$ as a function of the curvilinear abscissa, derived from $\tau (\lambda)$, in the cases $S = 0.5 \times I_{\text{min}}$ (thick line), $S = 0.1 \times I_{\text{min}}$ and $S = 0.9 \times I_{\text{min}}$ (thin lines). The radial velocity derived directly from line dopplershifts is also plotted (broken line). We see that $V_C$ depends very little on $S$ inside the range $0.1 \, I_{\text{min}} - 0.9 \, I_{\text{min}}$.

This enables us to take advantage of observed time series for dynamical modelling. The figure (3) shows two velocity curves corresponding to times $t_1$ and $t_2$ ($t_2 - t_1 = 2 \text{mn}$).
Very fast changes are present and cannot be accounted by a steady flow. We must probably assume transient motions along moving magnetic lines (see also the Poster entitled "Mass motions in Hα absorbing structures of the solar chromosphere", Mein et al.).

Question by R. Hammer:

Did you apply your general scheme for deriving the 3D flow structure to actual observations — and what kind of MHD constraints did you use?

Answer:

In the peculiar case of post-flare ejections at the solar limb, we have fitted a moving geometry to the observed dopplershifts (Mein P, Mein N, SP 80, 161). The time sequence was observed far enough from the acceleration phase, so that pressure effects can be neglected. We have assumed a free-fall along a dipole-type magnetic field, increasing with time.