DIAGNOSTIC CONSTRAINTS ON PROMINENCE PARAMETERS FROM SOHO AND GROUND BASED OBSERVATIONS

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The cold material of prominences is observed by CDS as an absorption in coronal lines which have wavelengths shorter than the hydrogen Lyman continuum edge. The coronal emission in these UV lines is partly absorbed by the resonance continua of hydrogen and helium. Some of the authors have already used this kind of observation to derive the hydrogen column density and the optical thickness of the prominence. We apply the same method for a quiescent prominence observed on June 5, 1997 by SOHO/CDS, SOHO/SUMER and ground-based telescopes. \textsc{Hα} observations are available from the multichannel spectrograph in Ondřejov; calibrated \textsc{Hα} profiles have been reconstructed. We interpret these combined data in terms of recent NLTE prominence modelling (see Schmieder et al. 1999).

(T $>$ 10\textsuperscript{5}K) are due to H and He continuum absorption of the coronal lines and develop a new technique to measure the column density of neutral hydrogen in a prominence.

During a coordinated campaign between SOHO and ground-based observatories a prominence was observed in multi-wavelengths. We will focus our study on data of CDS, \textsc{Hα} spectra obtained in Ondřejov, and Lyman series observed with SUMER. We will show that the NLTE modelling of \textsc{Hα} and Lyman lines gives consistent results with the CDS approach.

2. Observations

Prominences are cool plasma embedded in the hot surrounding corona. The formation and the structure of these objects are still unknown and are topics of controversy. In order to understand the main ingredient involved in supporting prominences against gravity we need to measure the finest structures in prominence at different temperatures. It is established that prominences have multi-thread structures (Wiik et al. 1999). With recent space-borne instruments we are able to observe prominences at multiple wavelengths, both in emission and in absorption (Engvold et al. 1999, Kucera et al. 1998). The co-alignment of the various temperature structures is important but limited by the spatial resolution of the instruments. The radiative transfer modelling is an approach which can be very sensitive to the physical conditions of the plasma surrounding prominences (Schmieder et al. 1999). We compare this approach with a new technique based on a hot line absorption model: Kucera et al. (1998) show that the dark features observed in hot coronal lines by CDS.

Data were taken on June 5 1997 by SOHO/CDS and SOHO/SUMER instruments, and the prominence was as well observed in Ondřejov in \textsc{Hα} line.

Figure 1 gives the co-alignment between all these data. The absorption region observed in Mg X with CDS fits well the \textsc{Hα} shape of the prominence. The bottom left part of the Figure 1 shows an image of the slit jaw camera with the slit of the spectrograph which scans the prominence. Twenty five spectra were obtained every second. We reduced the spectra corresponding to the points nearly crossed by the SUMER slit and calibrated the data (Fig. 2).

Figure 4 shows the prominence at different wavelengths observed with CDS, and a fit to all the data. The black dot in the white line shows where the fit was done. This is along the location of the SUMER slit.

The Lyman series was observed by SUMER (Fig. 3).
Figure 1. Co-alignment of various observations of the June 5 1997 prominence in Mg X (CDS), and Hα (Ondřejov) with vertical bar representing the SUMER slit.
Figure 2. Example of Hα profile observed by the Ondřejv spectrograph (intensity unit in $\% \times 2.84E+06$ erg/(ster*Angst*cm²*s))

Figure 3. Lyman line profiles in the 5 June 1997 prominence as observed by SUMER. Solid lines represent profiles at pixel position 60 (averaged over ±4 pixels around slit center) and dashed ones correspond to an average over the prominence along the slit (90 pixels). Due to calibration uncertainties, the error can reach 30%.
Figure 4: June 5 1997 prominence observed with CDS and the intensity cut plots
3. Absorption Model

The absorption model is described in Kucera et al. (1998). Let us overview the main aspects of the method.

For high temperature we assume that all optically thin line emission comes from the corona surrounding the prominence. The prominence does not emit in the coronal lines but rather absorbs by H and/or He continuum absorption.

The prominence absorption is computed by using:
the cross-section $\sigma_i(\lambda)$
the column-density $\xi_i = \int n_i dh$
the optical depth $\tau(\lambda) = \sum_i \xi_i \sigma_i(\lambda)$, where $i$ is the species index.

We have the following definitions and equations:
The incident background radiation is $I_0(\lambda)$.
The foreground intensity $I_f$ emitted by the corona between the prominence and the observer. Then we obtain for observed intensity $I_{obs}(\lambda)$:

$$I_{obs}(\lambda) = I_0(\lambda) e^{-\tau(\lambda)} + I_f .$$

The intensity of the corona in the surrounding of the prominence is $I_0 = I_0 + I_f$

The absorption depth is:

$$d = 1 - \frac{I_{obs}}{I_0} = f \frac{I_f}{I_0} (1- e^{-\tau}) ,$$

With a geometry factor $G = f \frac{I_f}{I_0}$, the absorption depth defined by:

$$d = G (1- e^{-\tau})$$

We apply this method to CDS data, solving the equation numerically via $\chi^2$ minimization and calculating the hydrogen column density $\xi_H(\lambda)$ and the geometrical factor $G$.

The absorption was rather dark and it is difficult to find points where there are convergence. It means that the optical depth in the considered wavelengths is larger than 1.

Figure 5 shows just the data above 504 Å (the radiation absorbed only by hydrogen). There are only two points, and one of these has a very large error bar. The lower plot shows the $\chi^2$ space as a function of the log of the hydrogen column depth and the geometrical factor, G. The inner set of dark lines shows the 1-$\sigma$ contour. The outer pair is the 3-sigma contour. This figure represents our best determination of fit values - only lower limits to the column depth and G can be determined. Many curves did not converge at all.
If we assumed a value for the H/He ratio, we could use the He-absorbed radiation data and in that way reduce our $\chi^2$ contours.

4. Results from NLTE models

The data which constrain the NLTE modelling are the following: intensities of higher Lyman lines as shown in Fig. 3, Hα integrated intensities (from Ondřejov observations) of the order $2 \times 10^5$ erg/sec/cm$^2$/sr and the hydrogen column density as derived from the Lyman continuum absorption model. The computed profiles of higher Lyman lines are already presented in Schmieder et al. (1999), we will refer to the figures presented therein. The profiles obtained for $T=6000$ K (see Fig. 8a) are in reasonable agreement with SUMER data. For $T=8000$ K, Fig. 8b already indicated enhanced peaks and for $T=10000$ K the peaks are quite high. Therefore, we conclude that $T$ must lie somewhere between 6000 - 8000 K.

Taking the whole set of 1D-slab models of Gouttebroze, Heinzel and Vial (1993, GHV), one can see that the integrated Hα intensity mentioned above leads to $\tau_{912}$ of the order of $10^5$, which gives $\tau_{25}$ about 30. A similar result is obtained for a multi-thread model with $T=6000$ K, $p=0.2$ dyn cm$^{-2}$, $D=200$ km. One can roughly reproduce the observed $E$(Hα) with about 10 threads along the line-of-sight. At 625 A (i.e. the Mg X line), the prominence optical thickness in the hydrogen Lyman continuum amounts to about 33, more or less consistent with the abovementioned GHV 1D-slab models. This indicates that the Lyman continuum absorption is definitely saturated. Computed hydrogen column density is about $3.3 \times 10^{19}$ cm$^{-2}$ which is above the lower limit indicated by Kucera et al. (1998).

The only way to decrease $\tau_{912}$ is to increase the temperature (higher ionization), but this gives much stronger peaks in higher Lyman lines which we don't observe in the SUMER data. The fact that the absorption of Mg X coronal emission by the Lyman continuum is saturated is consistent with analysis discussed in Section 3.

5. Conclusion

This part of the prominence is relatively thick which makes the application of Kucera's et al. (1998) method difficult (due to saturation). Note that in order to have $\tau_{25}$ around unity, one needs about one order of magnitude fainter emission in the Hα line - this follows from the set of models of GHV.

Acknowledgements
The SUMER project is financially supported by DARA, CNES, NASA, and the ESA PRODEX programme (Swiss contribution). SUMER instrument is on board the space mission SOHO. SOHO is a joint project of ESA and NASA. We highly appreciate the help of the Orsay team during the MEDOC campaign and we wish to thank all those who contributed to the SOHO JOP 12. P.H. appreciates the support of CNRS and IAS. This project was also supported by grants K1-003-001 and A3003902 of the Academy of Sciences of the Czech Republic.

References:


