WHAT WE HAVE LEARNED ABOUT PROMINENCES AND FILAMENTS FROM SOHO/SUMER AND CDS SPECTRAL OBSERVATIONS

P. Heinzel\textsuperscript{1}, B. Schmieder\textsuperscript{2}, and J.C. Vial\textsuperscript{3}

\textsuperscript{1}Ondrejov Observatory, Ondrejov, Czech Republic
\textsuperscript{2}Observatoire de Paris-Meudon, LESIA, France
\textsuperscript{3}IAS, Orsay, France

ABSTRACT

We summarize the results of our prominence and filament studies based on extensive spectral observations with SOHO/SUMER and CDS instruments. During the past decade we have gathered several sets of UV and EUV spectral data, containing various emission lines of different species. Our main objective was to better understand the formation of hydrogen Lyman lines and continuum (using the results of complex non-LTE transfer simulations), but we also have analysed also UV and EUV lines formed under transition-region and coronal conditions. Some highlights of our studies are: reproduction of Lyman-line profiles with partial redistribution, understanding the role of prominence-corona interface in the formation of Lyman-line cores, establishing the effect of the magnetic-field orientation on the shape of Lyman lines, discovery of EUV filament extensions (invisible in the H\textalpha line) and their explanation, reconstruction of a 3D topology of the filament using EUV coronal lines, temperature diagnostics based on measurements of the hydrogen Lyman continuum, proper explanation of a prominence darkening detected in coronal lines.

Key words: sun; filaments, prominences, EUV, radiative transfer.

1. INTRODUCTION

Hydrogen lines are the most prominent lines observed in solar prominences, namely the Balmer H\textalpha which serves as a standard for prominence imaging. The lines of the resonance Lyman series have been observed since the Skylab ATM experiment and by the LPSP UV-spectrograph onboard the OSO-8 satellite which provided calibrated line profiles of the first two members, L\alpha and L\beta (Vial 1982).

While the L\alpha line could be well reproduced using simple 1D non-LTE models with the standard partial frequency redistribution (PRD) using the approach of Gouttebroze et al. (1993) (GHV), L\beta was found to be much lower as compared to OSO-8 typical data. Discrepancies still exist and this was one of the objectives for the current SOHO/SUMER observations of Lyman lines. Another important objective was to study the structure of the base of PCTR. The Lyman lines are good indicators of the temperature and pressure structure of the lower PCTR, but detailed non-LTE modelling is necessary to infer the proper information.

Finally we observed that the Lyman profiles are different, reversed or non reversed according to the magnetic-field orientation, as predicted in Heinzel and Anzer (2001).

2. FILAMENTS

Filaments are clearly seen in Lyman lines (Figure 1). The primary objective here was to see how this complete set of all Lyman lines plus continuum compares with theoretical non-LTE model predictions. In Schmieder et al. (1998) we have analyzed the higher members observed by SUMER, in Heinzel et al. (2001a)
Figure 2. CDS observations of a filament channel on June 19, 1998.

Figure 3. Profiles of Lyman lines in the filament (solid lines) and in the EUV channel (dashed lines) on June 19, 1998.

Figure 4. Examples of Lyman lines series from L8 to L4 lines through a filament on June 19, 1998. The filament channel intensity is reduced.

Figure 5. Hα and EIT 304 Å images of a filament before its eruption (the arrow indicated the SUMER slit).

and Schmieder et al. (2003) we presented a new data set of observations which covers the whole Lyman series plus part of the Lyman continuum. After calibrating line profiles for lines Lβ to L11 we discuss their intensities with respect to computed ones.

We confirmed the existence of a transition region between the prominence and corona (PCTR). The PCTR plays a critical role in radiative transport in the Lyman lines.

Many papers have shown the importance of the absorption mechanism of the transition region and coronal lines with wavelength shorter than the Lyman head (912 Å) by the Lyman continua of H, He, He II (Heinzel et al. 2001a, Schmieder et al. 2003, 2004, Schwartz et al. 2004). This mechanism is not sufficient to explain the large channel observed in the vicinity of the filament (Figure 2). The volume blocking mechanism is also an important phenomenon. In the cavity around the filament, cool plasma does exist with a very low density and pressure compared with the values of the filament (Heinzel et al. 2003). This cool plasma blocks the coronal emission. The Lyman lines are reversed in the location of the Hα filament and not reversed in the channel (EUV filament) (Figure 3). The Lyman continuum is reduced in the EUV filament (Figure 4). Large width of EUV filaments compared to Hα ones is explained in terms of the Lyman-continuum and Hα opacities, respectively.

We denote some strong asymmetric profiles and even some profiles completely shifted. These are the signatures of high dynamical phenomena and need a careful study before giving values of the Doppler shifts, in order to completely understand if it is a bulk flow or complex motions of plasma at different temperatures (Gontikakis...
Figure 6. Lyman 4 spectra showing a high asymmetry indicating a flow larger than 100 km/s (slit in Fig.5)

Figure 7. Prominence and filament observed by TRACE in Lyman $\alpha$, the filament is a dark area, the prominence is in emission.

et al. 1997). In Schmieder et al. (2001), the asymmetry of the Lyman lines was related to the eruption of a filament (Figure 6). The flow can be estimated to 100 km/s (Figure 5).

3. PROMINENCES

Prominences are observed in Lyman $\alpha$ as a structures in emission (Figure 7).

The atlas of the spectrum of prominences has been published by Parenti et al 2004, 2005 (Figure 8).

Figure 8. Lyman spectrum observed with SUMER

Figure 9. SUMER spectrum of filament and prominence on March 23, 1999. Wavelength is along the x-axis and the pixel number from south to north is along the y-axis.

Figure 10. Lyman lines (1, 2, 3) observed in different prominences.

Figure 11. Lyman lines(4, 5, 6) observed in different prominences.
Prominences are observed in absorption in many different coronal lines (Kucera et al. 1998). Using CDS and SUMER data it has been explained by two mechanisms: the absorption by the Lyman continua of H, He, He II and by the volume blocking mechanisms (Heinzel et al. 2003).

In general the Lyman lines have more reversed profiles in filaments and less reversed profiles in prominences (Figure 9).

However, the SUMER data showed that the Lyman lines in prominences may have either reversed profiles or non reversed profiles (Figures 10, 11) (Heinzel et al. 2001b). This behaviour has been explained by using 2D non-LTE radiative transfer simulations (Heinzel and Anzer 2001, Heinzel et al. 2005). If the prominence fine structures are observed along the field lines, the profiles are unreversed, if they are observed across the field lines, the profiles are reversed.

4. CONCLUSIONS

The main conclusions are the following:

* We confirmed the existence of a transition region between the prominence and corona (PCTR).
* The PCTR plays a critical role in radiative transport in the Lyman lines.
* The orientation of a prominence with respect to the line of sight is important (uneversed profiles: observation along the magnetic field lines, reversed profiles: across the field lines).
* Large width of EUV filaments compared to Hα ones is explained in terms of the Lyman-continuum and Hα opacity, respectively.
* Opacity of the Lyman continuum is large compared to that of Hα. Their ratio could reach nearly two orders of magnitude (Schmieder et al. 2003).
* Cool material does exist in the EUV filament but is optically too thin to be visible in Hα images.

REFERENCES


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