PROMINENCE PARAMETERS DERIVED FROM HYDROGEN LYMAN-α SPECTRAL PROFILES MEASURED BY SOHO/SUMER

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ABSTRACT

We present SOHO/SUMER observations of a solar prominence in the hydrogen Lyman-α line and compare the line profiles with synthetic ones obtained using our 2D prominence modelling. The observations contain the raster image of a solar prominence in Lyman-α and in Si III lines (observed on April 18, 2005). The raster consists of 76 \times 50 pixels and in each pixel we have the full profile of the two lines. In order to derive the prominence parameters we use our fine structure models of vertical threads in magnetohydrostatic (MHS) equilibrium (Heinzel & Anzer 2001 and Heinzel et al. (2005)). By varying of the input parameters (central temperature, boundary pressure, magnetic field, central column mass and turbulent velocity) we obtained synthetic Lyman-α profiles which are in good agreement with the observed ones. In this way we are able to determine thermodynamical parameters in the observed prominence.

2. OBSERVATIONS

The SUMER instrument (Wilhelm et al. 1995) on board SOHO is a stigmatic spectrograph equipped with two photon-counting detectors (A and B). Both detectors have 1024 spectral columns and 360 spatial rows. Since May 2004 the Detector A has been showing a deterioration of the electronics responsible of the readout in the y direction (y-ADC), affecting the spatial (along the slit) information, while the x-ADC is working correctly, leading to correct spectral information. During April 18, 2005 only the 58 rows at the bottom of the detector retained their full spatial resolution (≈ 1") and were used for the present study. The study consists of a scan of a 85" \times 50" area centred at coordinates X = 1001", Y = 200" inside a large prominence shown in the He II 304Å image (Fig. 1) from EIT at the day of the observation. The scan was obtained by stepping the telescope by 1.13" westward with the 0.3" \times 120" slit illuminating the bottom part of detector A. In such a way 76 spectra were acquired by exposing for 10 seconds. Two spectral windows ≈ 2Å wide (50 pixels, 43.8 mÅ/pix), centred on the Si III 1206.51 and on the H I Ly-α 1215.67, were selected to be finally telemetered to the ground. Observations started at 15:48:14 UTC and ended at 16:08:16 UTC. Due to the continuously changing detector conditions, special attention needs to be paid to the data reduction process. The flat-fields, in particular, have been obtained by averaging and median filtering large amounts of data acquired during this epoch.

The observational data consist of the raster of 76 pixels with the Lyman α and Si III line profiles in each spatial pixel. For the analysis of the Lyman α profiles, and for their comparison with the synthetic profiles obtained by modelling of a static prominence, we need profiles with symmetrical shape. Such profiles occur in the observational data in a small clustered locations (3 to 5 pixels...
close to each other) and they ensure us that there are no differential velocities in the observed areas. For the comparison of the observed data with our models we took out four small areas with symmetrical profiles clustered in nearby pixels. For each area (1, 5, 7, T - denotes a bright vertical thread) we did the average profile of nearby symmetrical profiles. In Fig. 2 we show the positions of these areas in the raster image.

3. MODELLING

Models of prominences we use here are presented by Heinzel & Anzer (2001) and Heinzel & Anzer (2005). They consist of two-dimensional vertically infinite threads in MHS equilibrium with empirically prescribed temperature structure. Two-dimensional prominence thread models provide us with different synthetic profiles when the orientation of the line-of-sight is along or across the magnetic field lines, respectively (Heinzel et al. 2005). The information about the orientation of the field lines with respect to the line-of-sight is an important constraint for analysis of the observed spectra. From the observations carried out by ground observatories one can see the shape of the filament before/after it is observed as a prominence on the limb. From the shape of the filament it is possible to estimate the orientation of the magnetic field in the prominence filament with certain accuracy. For our study we use the observations from the Meudon Spectroheliograph and from the Big Bear Solar Observatory (BBSO). The analysis of the ground-based observations from April 13 to April 18, 2005 shows that the following prominence is observed more-less along the field lines (Fig. 3).
Each model of the prominence is prescribed by a set of the input parameters. This set consists of a central (minimum) temperature $T_0$, column mass in the center of the thread $M_0$, horizontal field strength in the middle of the thread $B_0$, coronal pressure $p_0$, exponents $\gamma_1$ and $\gamma_2$ prescribing the temperature structure and a turbulent velocity given as a constant fraction of the sound speed. By varying of this set of the parameters we obtain the best fit of the synthetic Lyman $\alpha$ profiles to the observed ones for each area. The input parameters for these models are listed in the Tab. 1. Exponents $\gamma_1$ and $\gamma_2$ are equal to 5 and 30. The plots of the observed and the synthetic Lyman $\alpha$ line profiles are shown in Fig. 4. The full bold lines represent the synthetic profiles, the dashed lines are observed Lyman $\alpha$ profiles with plotted error bars.

4. DISCUSSION AND CONCLUSIONS

The observed profiles of the Lyman-$\alpha$ line shown in Fig. 4 could be very well reproduced in all four selected regions. Small discrepancies are still in the wings of the line, as the modelled profiles tend to be narrower than observed, while reproducing the width and depth of the central reversal. Thus the parameters derived in the Tab. 1 represent the best compromise obtained by fitting this complex line profiles. The good correspondence between the models and the observed profiles is the result of using rather sophisticated thread-like MHS models where the non-LTE radiative transfer is computed in 2D and using the partial redistribution in Lyman lines for analysis. Since we have met severe difficulties in fitting the higher Lyman lines by just 1D models, this novel approach seems to be promising. It also allows us to consider the effect of the line-of-sight orientation with respect to the magnetic field lines on the emergent line profiles which is rather critical for analysis.

From our results we find that $B$ is between 4 and 6 gauss near the limb and around 2 gauss higher up. However, this values are quite smaller than those recently measured by Merenda et al. (2005) in a polar crown (around 30 G). Values between 10 and 20 gauss are also measured by Casini et al. (2003). Further investigations, both theoretical and observational, seem necessary to solve this discrepancy.

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REFERENCES


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Figure 4. Lyman α profiles for each area on the raster (1, 5, 7, T). Full bold lines represent the synthetic profiles, the dashed lines are observed Lyman α profiles with plotted error bars.