ELECTRON DENSITIES IN SOLAR PROMINENCES

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Abstract. Observations of a quiescent prominence made with the MSDP spectrograph at the Pic du Midi Observatory provided H\textsubscript{\textalpha} line profiles in each pixel of a 2D field of view. Comparing the absolute observed intensities with values derived from NLTE computations, we estimated the range of electron densities \( N_e \approx 1 - 5 \times 10^{10} \text{cm}^{-3} \), source functions \( S/I_c \approx 0.07 - 0.12 \), and optical thickness \( \tau \approx 0.3 - 8.0 \) within the observed prominence. Two dimensional maps of the electron densities are presented assuming two limiting values of the geometrical thickness along the line-of-sight. It is shown that if we consider geometrical thickness variations within a factor of about four, the electron density will be determined to within a factor of two, just by measuring the H\textsubscript{\textalpha} line intensity.

Key words: Sun – Prominences – Electron Densities

1. Introduction

In order to understand various processes involved in the formation and support of quiescent prominences, we have to determine how the plasma parameters are distributed throughout the prominence body. In this paper we concentrate on the determination of electron densities, using Subtractive Double Pass (MSDP) spectrograph at Pic du Midi. These observations and the data reduction are described in detail by Wiik \textit{et al.} (1992). In the next section we discuss a new approach for diagnosing the electron densities by comparing the observed H\textsubscript{\textalpha} intensities with theoretically predicted variations of the line-center intensity versus \( N_e \).

2. Variations of H\textsubscript{\textalpha} Emission with the Electron Density

A NLTE radiative transfer code based on the probabilistic approach to H\textsubscript{\textalpha} line formation (for the method see Wiik \textit{et al.}, 1992) was used to plot the variations of the

IAU Colloq. 144 "Solar Coronal Structures", V. Rušin, P. Heinzel, & J.-C. Vial (eds.), 381–383

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H_α central intensity versus the electron density. In Fig. 1b we show the results for the prominence geometrical thickness \( D \) in the range 750 – 3,000 km and for the height typical for our MSDP observations. We use here \( T = 7,500 \) K as a typical value since the results are not critically sensitive to the temperature (Fig. 1a). The vertical bars indicate, for some limiting models, the differences between our present approximate calculations and those made with the NLTE code of Heinzel which treats all transitions in detail (see Heinzel et al., 1987). Both approaches refer to a five-level hydrogen model atom with continuum.

It follows from Fig. 1 that by measuring the H_α line-center intensity, we can directly estimate \( N_e \), provided that we know \( D \) (\( D \) is the effective geometrical thickness). Although this thickness is difficult to determine, the estimate of the electron density is rather good: from Fig. 1b we see that for given H_α intensity, \( N_e \) varies only within a factor of about two if \( D \) is unknown to within a factor of four (750 – 3,000 km). Quite recently, this behaviour was explained by Heizel et al. (1994) (see also this issue), who have used 140 detailed NLTE models computed previously by Gouttebroze et al. (1993). For a reasonable range of H_α intensities they found the relationship \( E(\text{H}_\alpha) \propto D \times N_e^2 \), where \( E \) is the integrated H_α intensity.

Comparing the observed maximum (line-center) intensities (Fig. 2a) with the results from Fig. 1b, we were able to construct 2D electron density maps. In Fig. 2b,c we plot the electron density contours for the upper part of the prominence (see the box inside the Fig. 2a). This was done for two limiting values of \( D \), just to demonstrate possible variations of the electron density inside the prominence body. We conclude that the range of \( N_e \) is \( 1 - 5 \times 10^{10} \) cm\(^{-3}\).
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Figure 2. (a) MSDP intensity map of the prominence observed at Pic du Midi on June 11, 1988. (b) and (c) Electron density contour maps with $D = 750 \text{ km}$ and $3,000 \text{ km}$, respectively. The unit of density is $\text{cm}^{-3}$ and the difference in electron density between two contours is equal to $1.0 \times 10^{10} \text{ cm}^{-3}$.

3. Conclusions

By using the results of approximate NLTE computations, we have examined the different types of profiles observed at the top of the prominence. For structures with temperature 7,500 K, having an effective thickness in the interval $750 \text{ km} < D < 3,000 \text{ km}$ and having the optical thickness between 0.3 and 8.0, we derived electron densities ranging from $10^{10} \text{ cm}^{-3}$ to $5 \times 10^{10} \text{ cm}^{-3}$. Assuming a constant effective thickness within the prominence, the electron density decreases towards the edges. However, if smaller effective thickness is accepted at the edges, the electron density may increase at the boundary between the prominence and the corona.

References