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Dynamical properties of quiescent prominence in He D3 5876 Å line emission

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Abstract. We have observed a quiescent prominence with the Coudé spectrograph of Udaipur Solar Observatory during May 24-25, 1995. Analysis of two dimensional spectroscopic data was carried out in order to obtain the line shifts and line widths of He D3 5876 Å emission line. These quantities are used to study the dynamical properties of the observed prominence. The line-of-sight velocity distribution over the prominence follows a Gaussian distribution with a half width of $\pm$ 4.2 km s^{-1}. However the line width over the prominence does not show a well defined distribution as does the line shift. Most of the line profiles have the half-width at half-maximum (HWHM) ranging from 180 mÅ to 280 mÅ. Assuming a typical prominence temperature of 8000K, we find turbulence velocity of around 4 km s^{-1} within the prominence. In this paper we present detailed results of the observations, and discuss their implications for the structure and dynamics of the prominence.

Key words : solar prominence, HeI D3

1. Introduction

It is observed that the prominence eruption is generally related to the changes in the underlying photospheric magnetic fields, and the occurrence of flares in the neighbourhood. However, the dynamical processes associated with stability and eruption of the solar prominences are not well understood. For instance, in several cases it has been observed that only the uppermost portion, and not the whole, of the prominence is erupted. It is therefore important to study the dynamical properties of the prominences of various type using selected emission lines. With this aim, we have initiated the observation of prominences in He I D3 line at Udaipur Solar Observatory. In this paper, we present the initial results of quiescent prominence observation.

The HeI D3 line at 5876 Å is very useful for studying the kinematic properties of solar chromosphere. Because the He I lines have excitation potential of about 20 ev, they are not easily excited. It is now known that while other chromospheric lines come from the spicules, D3 comes from a low thin layer far below the spicule tops. These lines are originated at a height of about 1000 to 2500 km above the photosphere due to the excitation of He lines by coronal UV radiation (Hirayama, 1971). Prominences observed at high spatial resolution show characteristic He - to - H emission line ratios which are related to the mean kinetic temperatures, non-thermal line broadening and the fine-structuring (Stellmacher and Wiehr, 1994). It has been found that highly structured prominences have a temperature T ≥ 8000 K and less structured ones T ~ 6000 K. The simultaneous observations of He I D3 and H_α show that whereas Balmer excitation is almost uniformly distributed thoughout the prominence, the He excitation is enhanced in structured prominences of low Balmer brightness or outer part of unstructured bright prominences, where exciting and ionizing EUV radiation can freely penetrate. In these regions helium ionization may exceed that of hydrogen

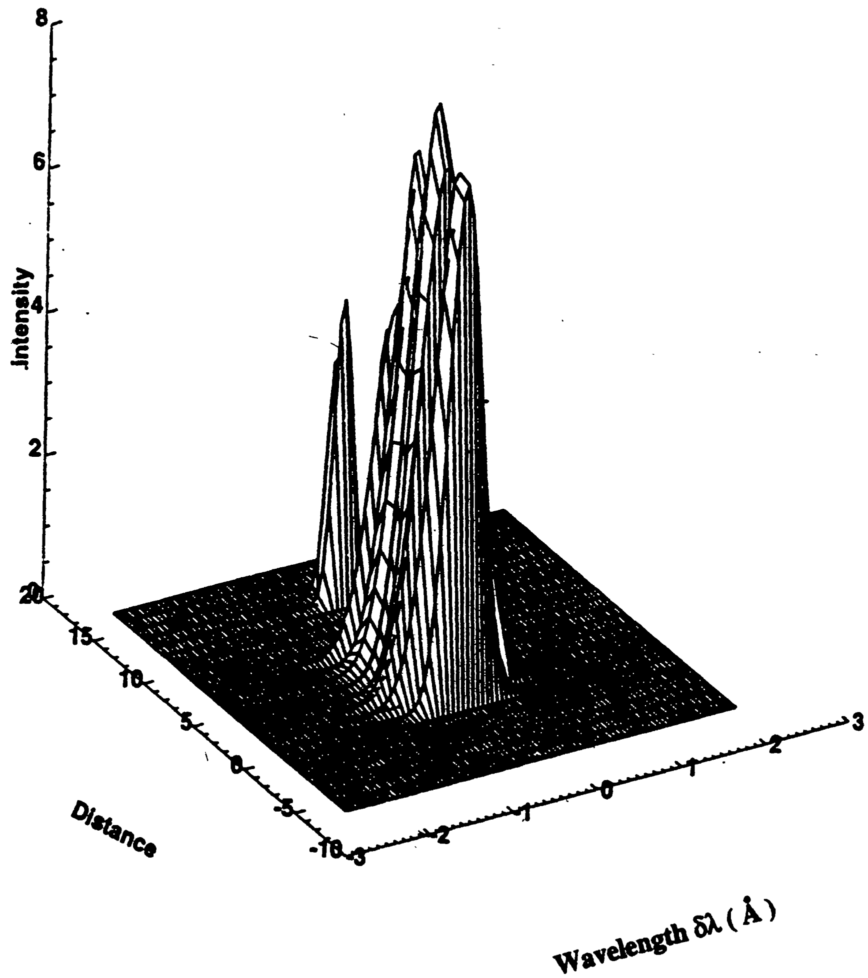

Figure 1. Three dimensional plot of the corrected D3 spectrum. The units on the intensity axis is arbitrary, distance axis is × 10^4 km and wavelength axis is Å. The zero value in distance axis corresponds to the photospheric height and the positive values are prominence distances above the solar limb.

(Stellmacher and Wiehr, 1995). These studies have indicated that the He D3 emission basically originates from the upper chromosphere, where the coronal UV emission can easily penetrate. As the upper layers of the prominences participate in the pre-flare processes, their study using D3 emission may reveal the pre-flare conditions in these objects.

2. Observations and analysis

The observations were made by using the Coudé spectrograph of Udaipur Solar Observatory. A 15 cm aperture, f/15 Carl Zeiss Coudé telescope is used as light feed for the spectrograph. With suitably positioning the imaging lens, the effective telescope beam is slowed down to ~ f/40. The spectrograph is operated in Littrow configuration with a 100 mm aperture f/15 lens. A square diffraction grating of 102 mm size having 600 lines mm^{-1} with blaze angle of 22° 02' is used in second order to record the D3 spectrum. With reflective slit of 0.1 mm width, the spectrograph has the linear dispersion of ~ 6 Å, which yields a resolution of about 0.05 Å $pixel^{-1}$. The reflected slit-jaw image is recorded in a separate camera in order to identify the position of observation over the area-of-interest.

After flat-fielding correction, it was found that considerable amount of scattered light was present over the spectrum, which varied along the dispersion axis. It is expected that the spectral line would follow a Gaussian profile in the quiescent prominence due to the random mass motion in the prominence material. Therefore, each CCD row was fitted with a Gaussian function. In order to remove the scattered light, we used a non-linear least-squares fit to a function f(λ) with six parameters, where f(λ) is a linear combination of a Gaussian and a quadratic function as expressed below :

$$f(\lambda)=A_0 \exp(-\frac{z^2}{2})+A_1+A_2x+A_3x^2 \quad (1)$$

where,

$$z=(\lambda-\lambda_0)/\delta\lambda,$$

In Eq. 1, λ_0 and $\delta\lambda$ are the central wavelength, and the line width, respectively. Furthermore, A_0 is the amplitude of the Gaussian profile. A_1, A_2 and A_3 are the constant, linear and quadratic terms, used for removing the observed background noise from the images. Figure 1 shows three dimensional plot of a corrected spectrum. As may be clearly noticed, considerable detail in the structure is seen along the slit, implying the nonhomogeneity of the prominence as observed in the D3 wavelength.

3. Discussions and conclusion

Figure 2(a) shows an example of the corrected line profile in which the circles are the data points and solid line is the Gaussian fit. The distribution of line shifts obtained from this analysis is given in Figure 2(b). As may be noticed, the distribution follows a Gaussian, implying random motion of the prominence plasma. The distribution of the observed line-width is given in Figure 2(c) and the relative intensity as a function of distance from the solar limb is shown in Figure 2(d). The line-of-sight velocity distribution over the prominence follows a Gaussian distribution with a half-width of ± 4.2 km s^{-1}. However the line width over the prominence does not show a well-defined distribution as does the line shift. Most of the line profiles have the half-width at half-maximum (HWHM) ranging from 180 mÅ to 280 m Å. Assuming a typical prominence temperature of 8000K, we find turbulence velocity of around 4 km s^{-1} within the prominence. The turbulence velocities obtained from both the

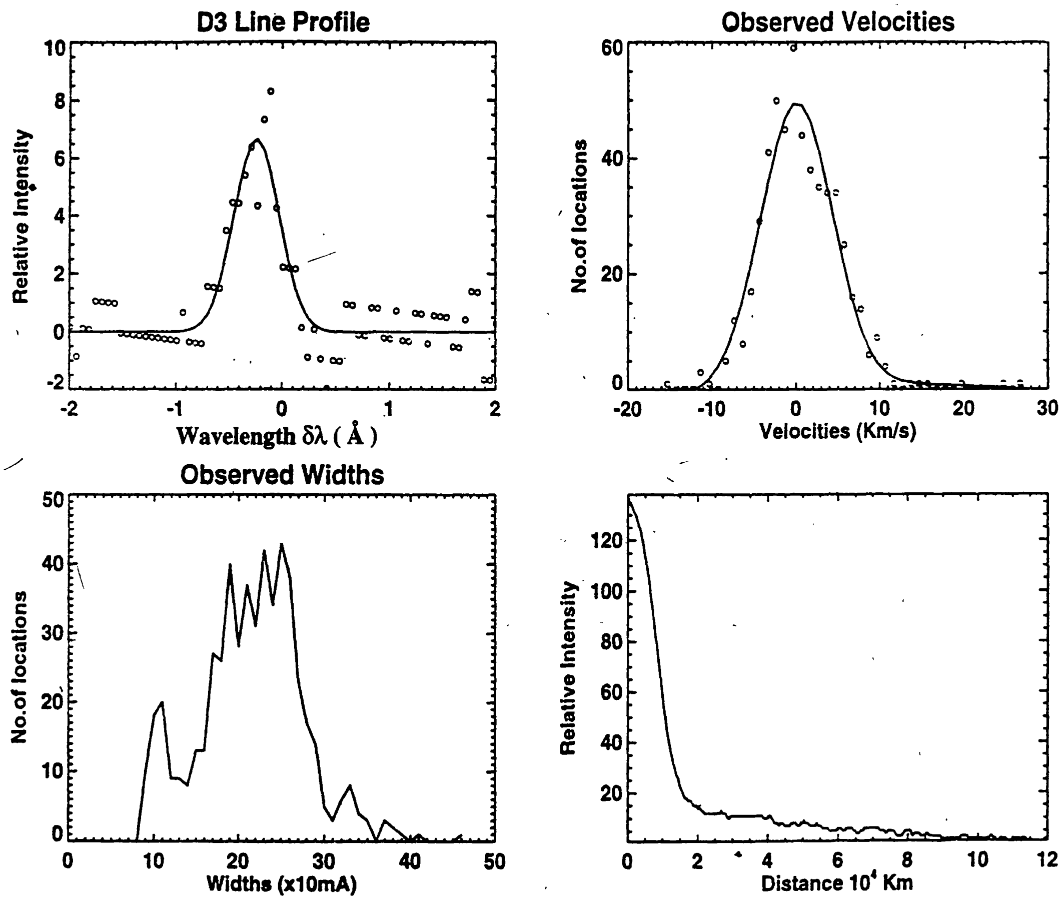

Figure 2. (a) An example of corrected D3 line Profile, the circles are data points and the solid line is Gaussian fit, (b) Distribution of the line-of-sight velocities derived from the line shift measurements, (c) Distribution of observed line-width measurements, (d) Intensity profile along the prominence.

line-of-sight velocity distribution and the individual line profiles show that the turbulence is uniformly distributed over the entire prominence, at least at those regions where the coronal UV penetrates.

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