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Helical Structure in an Eruptive Prominence Related to a CME (SUMER, CDS, LASCO)

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Abstract. SOHO (SUMER/CDS) observed an eruptive prominence on May 1, 1996, associated with a CME observed by LASCO. We investigate the physical conditions of this prominence in order to quantify velocity, temperature, and density. SUMER spectra in Si IV and O IV lines are used to obtain Doppler-shift images of the prominence. The prominence shows large-scale red and blueshifted regions, revealing a large helical structure with a global twist. In addition, fine structure analysis shows multiple components in the line profile, suggesting integration of many threads along the line-of-sight with a large dispersion of velocities ($\pm$ 50 km s^{-1}).

1. SUMER Observations

One of the main objectives of SOHO is to study the dynamics of prominences and the prominence-corona interface. By analyzing the spectra of O IV and Si IV lines observed with SUMER and the spectra of 15 lines with CDS, Doppler shifts, temperatures, and electron densities were derived in different structures of the prominence (Wiik et al. 1997).

1.1. Calibrated Intensity

Wilhelm et al. (1997) give the calibration curve of SUMER Detector A and discuss a procedure to calibrate the SUMER spectra. Mean Si IV 1393.76Å profiles averaged along the slit are shown in Figure 1. Profiles from both the prominence and the disk are shown. The count rate in the prominence is low. As a result, the profiles of lines emitted in the prominence are rather noisy. The ratio between the emission in the prominence and that of the disk was

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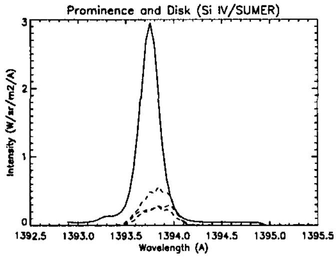

Figure 1. Calibrated mean profiles in the prominence (solid and dashed lines) and over the disk (dot-dashed line) close to the prominence.

low, 10% in the dense bubble and 5 to 8% in the rest of the prominence. The Si IV 1393.76Å emission reached 0.5 W/sr/m^2/Å in the dense bubble while the maximum 1401.51Å O IV line emission was only 0.07 W/sr/m^2/Å. The ratio between these two lines (around 2.5) is too low for us to use them to accurately determine electron density (Cheng et al. 1982). The ratio between the O IV 1401.51 and 1399.75Å lines is more useful and was used to derive electron density in different structures of the prominence (Wiik et al. 1997).

1.2. Dopplershifts

To determine quantitative values of Doppler shifts we have calibrated the lines in wavelength (Wiik et al. 1997). We use two methods to compute the velocity field: 1) fitting all points with a single Gaussian, and 2) fitting specific points in the helical structure with multiple Gaussians (using the procedure "xcfit" developed by S. Haughan). The maps displayed in Figure 2 were obtained with the single-Gaussian fits. Parallel to the axis of the loop, we see redshift on one side and blueshift on the other. We interpret this as helical motions around the axis of the loop, although it is difficult to determine how many coils there are. O IV 1399.74Å and Si IV 1393.76Å profiles yield similar results when fitted with multiple Gaussians. Here we show results from fitting the Si IV profiles. Figure 3 shows examples of profiles in the helical loop. Table 1 gives the characteristics in three different locations. The locations are indicated in Figure 2a.

We see that in addition to the global motion along the loop there are also individual pixels with blue- and redshifts. These structures appear consistently in the different lines observed. We interpret them as individual twisted threads and suggest that the global motion is, in fact, the combined motions of the individual threads.

2. Discussion and Conclusion

The eruptive part of the prominence observed by SUMER consists of a bubble (plasmoid) of material at transition region temperatures with redshifts of up

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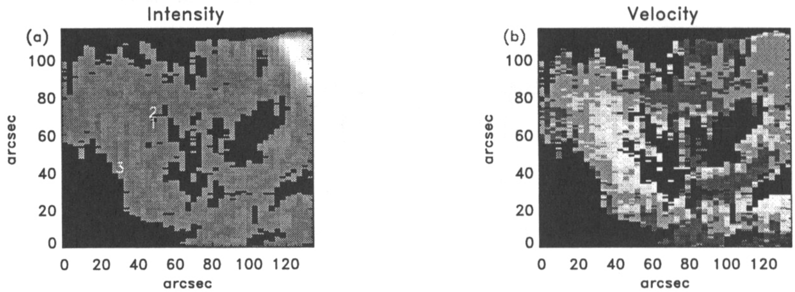

Figure 2. SUMER intensity (a) and velocity (b) (black/white for blue/redshifts) images of the prominence of May 1, 1996 (08:16-08:50 UT) showing the large helical structure of the prominence in Si IV at 1402.77Å. The limb is in the upper right corner. The locations of the spectra described in Table 1 are shown by the numbers 1, 2, and 3.

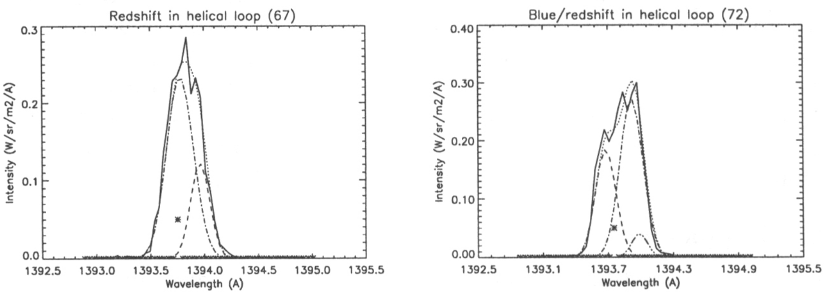

Figure 3. Examples of multi-structure profiles in the helical structure: observed profile in solid line, Gaussian components in dashed and dot-dashed lines, fitted profile in dotted line. The center of the line is indicated by an asterisk.

Table 1. Characteristics of profiles in the helical structure. Doppler shifts are in km s^{-1}. Blueshifted values are negative, redshifted ones positive.

Location	Moments	Gaussian 1	Gaussian 2	Gaussian 3
1. redshifted region	intensity	9.35	4.8	
	Doppler shift	4.9	50	
	line width	0.29	0.209	
2. blue/ redshifted region	intensity	7.4	10.8	1.6
	Doppler shift	-16.6	34.6	50.0
	line width	0.22	0.25	0.17
3. blueshifted region	intensity	19.6	0.5	
	Doppler shift	-10.9	18	
	line width	0.25	0.29	

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to 80 km s^{-1} and electron density of the order of $10^{10}\,cm^{-3}$. This could be the signature of a reconnection point between magnetic field lines due to an instability. Material might be ejected from such a point in the form of jets or surges (Shibata et al. 1992). This could destabilize all the structures above and produce the CME.

The whole prominence was very active. It developed both a large helical loop and several smaller loops consisting of twisted threads or multiple ropes. The profiles of the SUMER lines in these loops show a large dispersion of velocities ($\pm$ 50 km s^{-1}) and the ratio of the O IV lines indicates a large dispersion in electron density ($3\times10^{9}\,cm^{-3}$ to $3\times10^{11}\,cm^{-3}$). These variations are consistent with the idea that the prominence structure contains multiple threads.

The large helical structure of this prominence suggests that the event can be explained by an instability of the sort occurring in the model of van Ballegooijen and Martens (1989) for the formation and eruption of solar prominences based on canceling flux. In this model the magnetic flux is transferred from the arcade field, which supports the prominence, to a helical field. The magnetic field map (Kitt Peak) shows that the prominence lies in a corridor between two polarities. Based on the sign of the polarities and the sign of the velocities in the prominence we conclude that the helical loop is untwisted.

We observe transport of mass and no real heating of the prominence structure, indicating that the eruption is a purely dynamical phenomenon. The eruption looks like the ejection of a plasmoid, and the prominence loops are twisted.

The eruption of the prominence and the CME, spatially and temporally related, can be interpreted in terms of global destabilization of the magnetic field. The exact timing of the phenomena is difficult to estimate due to the low cadence of the SUMER and CDS observations so we have no evidence that one event triggered the other. However, it is clear that they are the result of the same magnetic instability.

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