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Determination of the physical properties of an erupting prominence from SOHO/LASCO and UVCS observations

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Summary. — We studied the physical conditions of an erupting prominence observed in the core of a coronal mass ejection, using combination of SOHO/LASCO-C2 visible-light images and SOHO/UVCS ultraviolet data. Measured intensities and profiles of the neutral-hydrogen Lyman-α and Lyman-β lines and the 977 Å C III line were used together with the visible-light brightness to derive the geometrical and physical parameters of the prominence, such as the line-of-sight apparent thickness, electron column density, kinetic temperature, and microturbolent velocity. These parameters were used to constrain a non-LTE (*i.e.*, out of local thermodynamic equilibrium) radiative-transfer model of the prominence that provides the effective thickness, electron density, and flow velocity, in a sample of points selected along the prominence. The prominence can be described as a hot structure with low electron density and very low gas pressure compared to typical quiescent prominences. Intensities of the hydrogen lines were also used for a detailed determination of the plasma line-of-sight filling factor, in the two prominence points where simultaneous and cospatial LASCO-C2 and UVCS observations were available.

1. – Introduction

Erupting prominences are often observed in visible light and ultraviolet (UV) as bright structures in the core of coronal mass ejections (CMEs). The expanding plasma is responsible for a significant emission in UV lines such as the H I Lyman-α line (1216 Å), as revealed by spectral observations from the Ultraviolet Coronagraph Spectrometer (UVCS) on board SOHO [1]. Because of the high-density and low-temperature conditions that are typical of prominences [2], the plasma embedded in erupting prominences may not be optically thin even if they are observed in the corona. Therefore, interpretation of the UV spectra emitted by these structures requires a detailed analysis including the

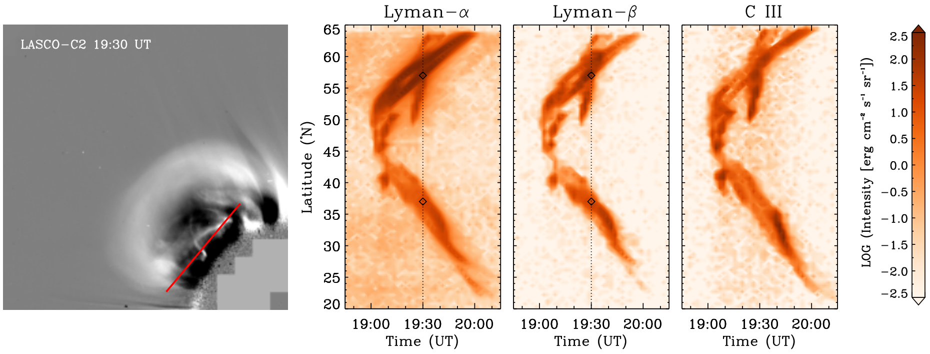

Fig. 1. – *Left:* LASCO-C2 base-difference image, acquired at 19:30 UT, showing the analyzed CME. The red line is the UVCS slit. *Right:* Integrated intensities of the Lyman-α, Lyman-β, and C III lines, plotted as functions of time and latitude along the UVCS slit. The diamonds in the panels of the Lyman lines mark the position of points P1 (57°N) and P2 (37°N) described in the text.

solution of the radiative transfer problem out of the local thermodynamic equilibrium (non-LTE) [3]. In this paper, we summarize the main results concerning the physical properties of an erupting prominence observed in the core of a CME, derived in our previous works [4-6].

2. – Observations, data analysis, and results

We studied a CME event occurred on August 2, 2000 [4] and observed by the LASCO-C2 coronagraph (see Fig. 1). LASCO total-brightness images were used to measure the electron column density in the prominence and to estimate the apparent thickness of the structure along the line of sight (LOS), $D \simeq 56000$ km. UVCS recorded the spectral profiles of the Lyman-α, Lyman-β, and C III lines, when the prominence crossed its field of view, a 40 arcmin wide slit centered at a latitude of 40°NE and at a heliocentric distance of 2.3 $R_\odot$. In particular, in two points (designed as P1 and P2) simultaneous and cospatial UVCS and LASCO data were available (see Fig. 1).

We selected a sample of points along the prominence to perform a non-LTE radiative-transfer modeling using the MALI technique [3]. The total intensities of the three spectral lines have been calculated assuming as input parameters of the model the observed quantities derived from LASCO and UVCS data (prominence height, kinetic temperature, and microturbulent velocity) and a grid of values for the electron density, effective thickness, and flow velocity. Since the prominence plasma can be highly fragmented along LOS because of its rapid expansion, a geometrical filling factor $f < 1$ has been considered so that the prominence effective thickness $D_{\rm eff} = D \cdot f$ can be lower than the measured apparent thickness. The best agreement between computed and observed intensities constrained the physical properties of the prominence plasma in 30 points where the emergent Lyman-α line is optically thin [5]. Optically-thick points require a more complex analysis, therefore they were not considered. The prominence turned out to be hotter ($T \simeq 10^5$ K) and more rarified ($p \simeq 10^{-3}$ dyn cm^{-2}; see Fig. 2) than typical quiescent prominences [2], with electron densities of the order of $\sim 10^8$ cm^{-3}. The resulting effective thicknesses are consistent with filling factors ranging from few percents up to ~ 1.

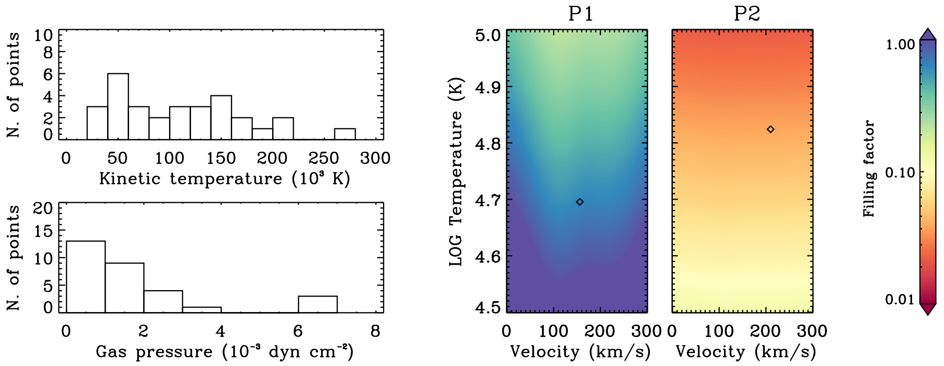

Fig. 2. – *Left:* Kinetic temperature (top panel) and gas pressure (bottom panel) distributions for the sample of 30 optically-thin points selected along the prominence. *Right:* 2D maps of the filling factor obtained as a function of flow velocity and kinetic temperature for point P1 (left panel) and P2 (right panel). The diamonds mark the locations in the (v, T) plane corresponding to the non-LTE-model results for points P1 and P2 (giving $f = 0.7$ and $f = 0.07$, respectively).

The measured intensities of the Lyman-α and Lyman-β lines have been used together to estimate independently the prominence LOS filling factor, with the technique suggested by [7]. The filling factor has been derived as a function of kinetic temperature and flow velocity in the two points P1 and P2 through the evaluation of the resonantly-scattered and collisional components of the Lyman lines using the electron column density derived from LASCO images and taking into account the Doppler-dimming effect. The resulting filling factors (see Fig. 2) are consistent with the model values in both points, but the agreement depends strongly on the assumed kinetic temperatures [6].

3. – Conclusions

Our works have shown that combination of visible-light and UV observations with full non-LTE radiative-transfer modeling can provide detailed information on the physical properties of erupting prominences embedded in the core of CMEs. Techniques similar to those developed in our works will be applied to future UV and visible-light observations from the Metis coronagraph [8] on board the Solar Orbiter.

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