THE SECOND HINODE SCIENCE MEETING
ASP Conference Series, Vol. 415, ©*2009*
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An Erupting Filament and Associated CME Observed by *Hinode*, *STEREO* and *SOHO*

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Abstract. A multi-spacecraft campaign was set up in May 2007 to observe the off-limb corona with *Hinode*, *STEREO* and *SOHO* instruments (*Hinode* HOP 7). During this campaign, a filament eruption and a coronal mass ejection (CME) occurred on May 9 from NOAA 10953 at the West limb. The filament eruption starts around 13:40 UT and results in a CME at 4°SW latitude. Remarkably, the event was observed by *STEREO* (EUVI and COR1) and by the *Hinode*/EIS and *SOHO*/UVCS spectrometers. We present results from all these instruments. High-cadence data from Stereo/EUVI A and B in the He II λ304 line were used to study the 3-D expansion of the filament. A slow rising phase, during which the filament moved southward, was followed by an impulsive phase during which the filament appeared to change direction and then contribute to the westward-expanding CME as seen in *STEREO*/COR 1. *Hinode*/EIS was scanning with the 2" slit the region where the filament erupted. The EIS spectra show remarkable non-thermal broadening in lines emitted at different temperatures at the location of the filament eruption. The CME was also observed by the *SOHO*/UVCS instrument: the spectrograph slit was centered at 1.7 solar radii, at a latitude of 5°SW and recorded a sudden increase in the O VI $\lambda\lambda 1032-1037$ and Si XII λ520 spectral line intensities. We discuss the overall morphology of this interesting eruptive event, and provide a preliminary assessment of its temperature and density structure.

1. Introduction

Between May 7–10, 2007 a *Hinode–TRACE–SOHO* campaign (*Hinode* HOP 7) was running, aimed at measuring electron temperatures, densities, and ele-

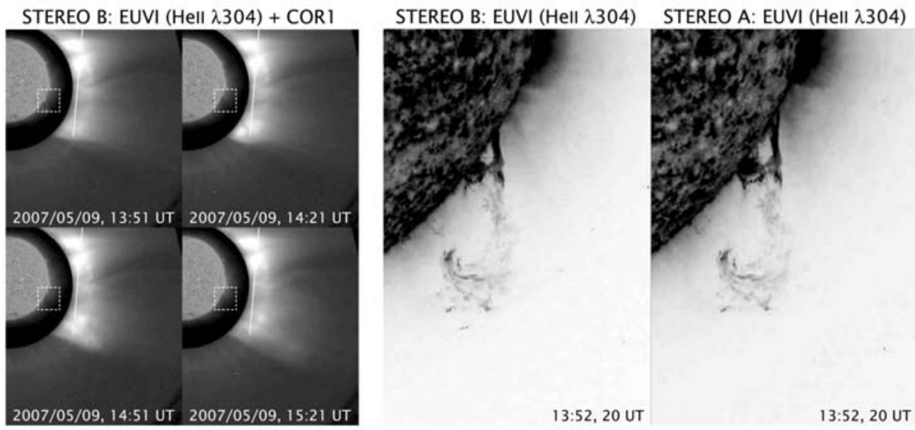

Figure 1. Left: the May 9, 2007 eruption as seen by the EUVI (He II λ304 line) and COR1 (H-α λ6565 line) telescopes aboard the *STEREO* B spacecraft; the dashed box marks the FOV covered by the EIS raster, while the solid line shows the position of the UVCS slit FOV centered at 1.7 $R_\odot$, at a latitude of 5°SW. Right: a comparison between two EUVI He II λ304 images of the erupting prominence acquired at the same time (13:52 UT) from the *STEREO* A and B spacecrafts. These two images have been used to derive information on the 3-D structure of the filament (see text).

mental abundances in the low corona at different altitudes and latitudes above the Active Region (AR) NOAA 10953, that was crossing the West solar limb in these days (see also Del Zanna et al. 2008, in this volume for more detailed information). This campaign involved in particular the *Hinode* EUV Imaging Spectrometer (EIS; see Culhane et al. 2007) and the *SOHO* Ultraviolet Coronagraph Spectrometer (UVCS; see Kohl et al. 1995).

On May 9, 2007 a prominence eruption occurred: the ejected plasma crossed, during its propagation, both the EIS and UVCS fields of view (FOV; see Fig. 1.) and resulted finally in a slow Coronal Mass Ejection (CME). Unfortunately, at this time the source AR was located $\sim 14°$ behind the West solar limb, so there is no information on its pre-eruptive evolution. The present study focuses on the physical parameters of the erupting plasma as derived from EIS and UVCS spectra. The eruption has been also observed by the two *Solar Terrestrial Relations Observatory* (*STEREO*; see Kaiser et al. 2008) A and B SECCHI EUV Imagers (EUVI; see Wuelser et al. 2004): these data have been used to derive information on the 3-D structure of the erupting prominence. After illustrating the May 9, 2007 event (§ 2), we describe the first results we derived from EUVI, EIS and UVCS data (§ 3); conclusions are summarized in § 4.

2. The May 9, 2007 Filament Eruption

Between April 25 and May 8, 2007 the $\beta\gamma\delta$ AR NOAA 10953, located at a latitude of 11°S, crosses the disk dragged by solar rotation. Images acquired in the He II λ304 line by the two EUVI telescopes show that, even if no major flares occur, the coronal loops above the AR are highly unstable. Chromospheric

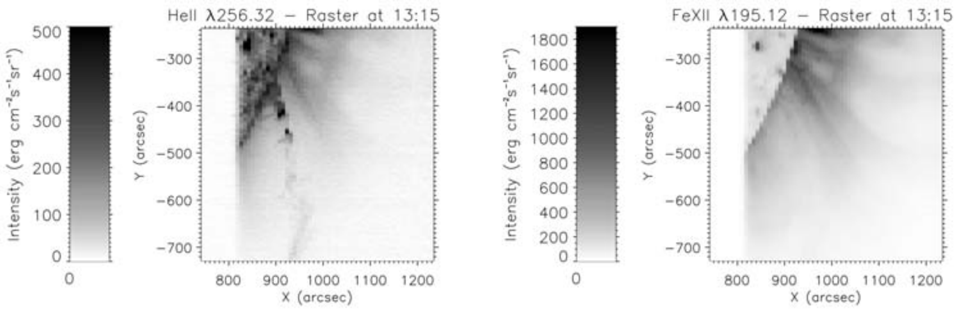

Figure 2. The erupting filament material and the surrounding corona as seen by EIS in the He II λ256.32 (left) and Fe XII λ195.12 (right) spectral line intensities.

material is continuously ejected from the AR in a sequence of small homologous eruptions that were unable to result in a CME.

On May 9, 2007, when the AR 10953 is already behind the solar limb, one of these eruptions results in a CME: snapshots of this event are shown in Fig. 1. The high cadence ($\sim$ 37s) images acquired on that day by the EUVI instruments in the HeII λ304 line (see Fig. 1) show a tongue of plasma, anchored at an approximate latitude of 24°S, that starts to expand southward around 13:40 UT. Over the following minutes the prominence progressively accelerates and changes its direction of propagation resulting in a slow ($v_{CME} \sim 310$ km s^{-1}), decelerating ($a_{CME} \sim -7.4$ m s^{-2}) CME (see the LASCO CME catalog, http://cdaw.gsfc.nasa.gov/CME_list/) that propagates around a latitude of 26°S (Fig. 1, panels a–d). The eruption crossed both the EIS and the UVCS FOV and was observed also by EUVI in the He II λ304 line.

3. Analysis of EUVI, EIS and UVCS Data

Thanks to the very high spatial resolution ($\sim$ 1.5"/pixel) of the EUVI telescopes it is possible to perform triangulation studies by identifying the same features (e.g. bright He II knots) in pair of frames acquired at the same time (Fig. 1) and to study the 3-D structure and expansion of the filament. It turns out that, at 13:52 UT, the filament is mostly a 2-D, "hook shaped" structure with an average thickness along the line of sight of $\sim 0.098\mathrm{R}_\odot$ and a length of $\sim 0.43\mathrm{R}_\odot$; there is no evidence for any 3-D flux rope shape. By identifying the same EUV features in successive frame pairs, it has been possible also to study the 3-D prominence expansion. Results show that over the following $\sim$ 20 minutes the filament expands in 3-D undergoing not only a strong radial acceleration $a_{CME} = (180 \pm 80)$m s^{-2}, but also a $\sim$ 3 times larger tangential acceleration, leading to the mentioned deflection and change in the direction of propagation.

The EIS raster acquired starting from 13:15 UT sampled the final part of the eruption, i.e. just a few minutes after the transit of the main part of the filament. The resulting EIS intensity maps (Fig. 2) show enhanced emission of the chromospheric erupting material only in the "cooler" spectral lines such as He II λ256.32 and Fe VIII λ185.21 (with maximum formation temperature of T$\sim 10^{4.9}$K and T$\sim 10^{5.6}$K, respectively), while no emission was detected in the "hotter" lines such as Fe XII λ195.12 and Fe XV λ284.16 (T$\sim 10^{6.2}$K and T$\sim 10^{6.4}$K, respectively), implying that, as expected, the prominence plasma is at most a temperature of $\sim 10^5$K. Interestingly, at the position of the ejected material, all the observed spectral lines show strong non-thermal line broadenings. In particular, once the instrumental and thermal broadenings are subtracted, it turns out that for instance the plasma emitting in the Fe XII λ195.12 line has non-thermal velocities up to $\sim$ 120 km s^{-1} (i.e. a kinetic temperature 3×10^7K, far in excess of the ion kinetic temperature). This effect seems to decrease for increasing iron ionization stages. Because the erupting material is not emitting in the Fe XII line, this non-thermal broadening has to be ascribed to the surrounding corona.

The UVCS data show, during the CME transit, a relatively faint ($\sim$ 20%) increase in the O VI $\lambda\lambda$1031.9–1037.6 doublet lines and a smaller increase also in the Si XII λ520.6 line; the O VI λ1031.9 intensity map shows that this increase is due to the transit of the CME front across the slit. This corresponds to an electron density increase by $\sim$ 60% with respect to the surrounding corona whose density is around 7×10^6 cm^{-3}. The h vs t curves extrapolated at the UVCS FOV altitude show a good agreement with the observed CME transit time.

4. Conclusions

We presented here results from a preliminary analysis of a unique data set which allowed us to study a prominence eruption observed from *STEREO*/EUVI, *Hinode*/EIS and *SOHO*/UVCS data. The information we derived from *STEREO* on the 3-D structure of the erupting filament led us to rule out the presence of a flux rope, even if this kind of structures is envisaged in many flare–CME models. The spectra acquired by EIS showed unexpected non-thermal velocities in the corona along the eruption path. These could be ascribed to magnetic reconnection occurring behind the eruption and closing the opened field lines, but also to plasma turbulence or other effects. To our knowledge, this is the first time that a similar study has been conducted on an erupting prominence; even if the data analysis and interpretation are still in progress, this initial study demonstrates the great potentiality of *STEREO* and *Hinode* for the study of solar eruptions.

References

Culhane, J.L. et al. 2007, Solar Phys., 179, 279
Del Zanna, G. et al. 2008, Proc. of the "2nd *Hinode* Science Meeting", this volume
Kaiser, M.L. et al. 2008, Space Sci. Rev., 136, 5
Kohl, J.L. et al. 1995, Solar Phys., 162, 313
Wuelser, J.-P. et al. 2004, Proceedings of the SPIE, 5171, 111