“An erupting filament and associated CME observed by Hinode, STEREO, and SOHO”

A. Bemporad\textsuperscript{1}, G. DelZanna\textsuperscript{2}, V. Andretta\textsuperscript{3},
M. Magri\textsuperscript{3}, G. Poletto\textsuperscript{4}, Y.-K. Ko\textsuperscript{5}

\textsuperscript{1}INAF-Osservatorio Astronomico di Torino (IT), \textsuperscript{2}Mullard Space Science Laboratory, London (UK), \textsuperscript{3}INAF-Osservatorio Astronomico di Capodimonte, Napoli (IT)
\textsuperscript{4}INAF-Osservatorio Astrofisico di Arcetri, Firenze (IT),
\textsuperscript{5}Naval Research Laboratory, Washington DC (USA)
Outline

• The May 7 – 10, 2007 campaign

• The May 9, 2007 CME:
  - Stereo/EUVI observations: filament structure and expansion
  - Hinode/EIS observations: non thermal line broadening
  - SOHO/UVCS observations: CME plasma parameters

• Conclusions
The Hinode HOP 7 campaign: 7 – 10 May 2007

- HINODE/EIS: off-limb observations over AR 10953
- STEREO/Secchi: high cadence observations
- SOHO/UVCS, CDS: quadrature campaign with Ulysses

EIS (FeXII λ195.12 line)
LASCO CME catalog:
- PA: 244° (26°SW)
- $v_{\text{lin}} \sim 310$ km/s
- $a \sim -7.4$ m/s²

Possible CME source:
- AR 10953 (11°S, 91°W on 08/05/2007)
- H-\(\alpha\) filament
The eruption as seen by STEREO/EUVI

- EUVI HeII λ304 shows a filament expanding southward and turning westward.
- The separation angle between the two Stereo spacecrafts was ~7.2°. High spatial resolution (~1.5”/pixel) → triangulation study can be performed.
- Identification of same features in both images → 3D structure, 3D expansion.
Results: Filament structure

• 3D reconstruction made from 100 pairs of points selected along the filament
• The erupting filament is **hook-shaped**, mostly **2-dimensional**
Results: Filament expansion

$a_r = (180 \pm 80) \text{ m/s}^2$

$\alpha_t = (8 \pm 2) \times 10^{-7} \text{ rad/s}^2$

$\sim (600 \pm 150) \text{ m/s}^2$

$\alpha_{\text{LASCO}} = -7.4 \text{ m/s}^2$
The eruption as seen by HINODE/EIS

EIS raster: start 13:15, end 14:18 ➡️ CME start ~ 13:40
latitudes ~ 15°–40°S ➡️ CME lat ~ 20°–45°S

CME observed by EIS?

<table>
<thead>
<tr>
<th>ion</th>
<th>$\lambda$ (Å)</th>
<th>$\log T_{\text{max}}$</th>
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<tbody>
<tr>
<td>HeII</td>
<td>256.32</td>
<td>4.9</td>
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<tr>
<td>FeVIII</td>
<td>185.21</td>
<td>5.8</td>
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<tr>
<td>FeX</td>
<td>257.26</td>
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<td>6.0</td>
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<tr>
<td>FeXI</td>
<td>180.40</td>
<td>6.1</td>
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<td>FeXI</td>
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<td>SiX</td>
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<td>FeXIV</td>
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<tr>
<td>FeXV</td>
<td>284.16</td>
<td>6.4</td>
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Rasters with the 2" slit, separated by 8", 61 exps/raster, 60 s/exp, ~1 h/raster
Plasma emission at different temperatures

The cool filament material disappears above $\log T \sim 5.6$ ($\sim 4 \cdot 10^5$ K)
The detection of non-thermal velocities
Non-thermal velocity evolution

In the following rasters the $v_{nth}$ are located at the CME latitudes, fading with time.
The detection of non-thermal velocities

Which interpretation?

1) Heating of the surrounding corona by:
   - adiabatic compression
   - magnetic reconnection

2) Outflows along field-lines opened by the CME (suggested by the line asymmetry? But why $v_{nth}$ changes for different ions?)

3) Plasma turbulence related to reconnections after the CME
The eruption as seen by SOHO/UVCS

<table>
<thead>
<tr>
<th>ion</th>
<th>$\lambda$ (Å)</th>
<th>$\log T_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HI Lyβ</td>
<td>1025.72</td>
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<tr>
<td>OVI</td>
<td>1031.91</td>
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<td>OVI</td>
<td>1037.62</td>
<td>5.5</td>
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<tr>
<td>SiXII</td>
<td>520.67</td>
<td>6.3</td>
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</table>

**UVCS slit**: centered at 5°S, 1.7 $R_{\odot}$
Spatial resol.: 56”
Time resol.: 120s

**UVCS coronal plasma diagnostic:**

- OVI $\lambda\lambda$ 1032-1037 intensities due to both collisional and radiative excitation;
- By assuming $v_{\text{out}} \sim 0$ the $I_{\text{rad}}$ and $I_{\text{col}}$ of both lines can be easily separated;
- $I_{\text{col}} \propto n_e^2 L$, $I_{\text{rad}} \propto n_e L \rightarrow I_{\text{col}} / I_{\text{rad}} \propto n_e$
- Given $n_e$ and by assuming O and Si abundances:

$$\frac{I_{\text{col}}(\text{OVI})}{I(\text{SiXII})} \propto \frac{A_O}{A_S} \frac{C_{\text{line1}}(T_e, n_e)}{C_{\text{line2}}(T_e, n_e)} = f(T_e)$$

$$n_e$$

$$T_e$$
Results: Coronal & CME plasma parameters

Pre-CME corona:
\( n_e \sim 7.0 \cdot 10^6 \text{ cm}^{-3}, \quad T_e \sim 2 \cdot 10^6 \text{K} \)

Post-CME corona:
\( n_e \sim 6.2 \cdot 10^6 \text{ cm}^{-3}, \quad T_e \sim 2 \cdot 10^6 \text{K} \)

Given the longitude vs time curve (STEREO) an estimate for the thickness of the CME emitting plasma can be derived → \( L_{CME} \sim 0.65 R_{\odot} \)

CME plasma: \( E_{M_{CME}} \sim 8 \cdot 10^{23} \text{cm}^{-5} = n_e^2 L_{CME} \rightarrow n_e(CME) \sim 4.2 \cdot 10^6 \text{ cm}^{-3} \)

By assuming a volume of \( (4\pi/3) \cdot 3R_\odot \times 0.65R_\odot \times 0.65R_\odot \rightarrow m_{CME} \sim 3.3 \cdot 10^{16} \text{ g} \)
Summary & Conclusions

During the HOP7 campaign a slow CME occurred on May 9, 2007;

**Stereo/EUVI HeII λ304 images**: erupting filament that expands initially southward and results in a CME expanding around 26°S → Filament material undergoes not only a radial acceleration, but also a much **stronger tangential acceleration**;

**3D reconstruction from Stereo A/B**: the filament has initially a **hook-shaped**, quasi 2D structure, with the hook base rooted on the Sun, close to the AR. The following **expansion is both latitudinal and longitudinal (i.e. superradial)**;

**EIS spectra**: first filament eruption detected by EIS reported so far! Spectral lines show strong **strong non-thermal velocities** (up to ~ 120 km/s) along the eruption path, decreasing with increasing ionization stages → coronal heating? “Fan-shaped” outflows? Plasma turbulence driven by reconnection?

**UVCS spectra**: info on the trajectory from Stereo are used to estimate the CME thickness along the LOS → the CME is **denser** than the surrounding corona by ~ 60% ; the CME mass is $m_{\text{CME}} \sim 3.3 \cdot 10^{16} \text{ g}$.