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

A. Bemporad[1], G. DelZanna[2], V. Andretta[3],
M. Magri[3], G. Poletto[4], Y.-K. Ko[5]

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

ASI – Italian Space Agency

INAF – Italian National Astrophysics Institute

OATo – Torino Astronomical Observatory

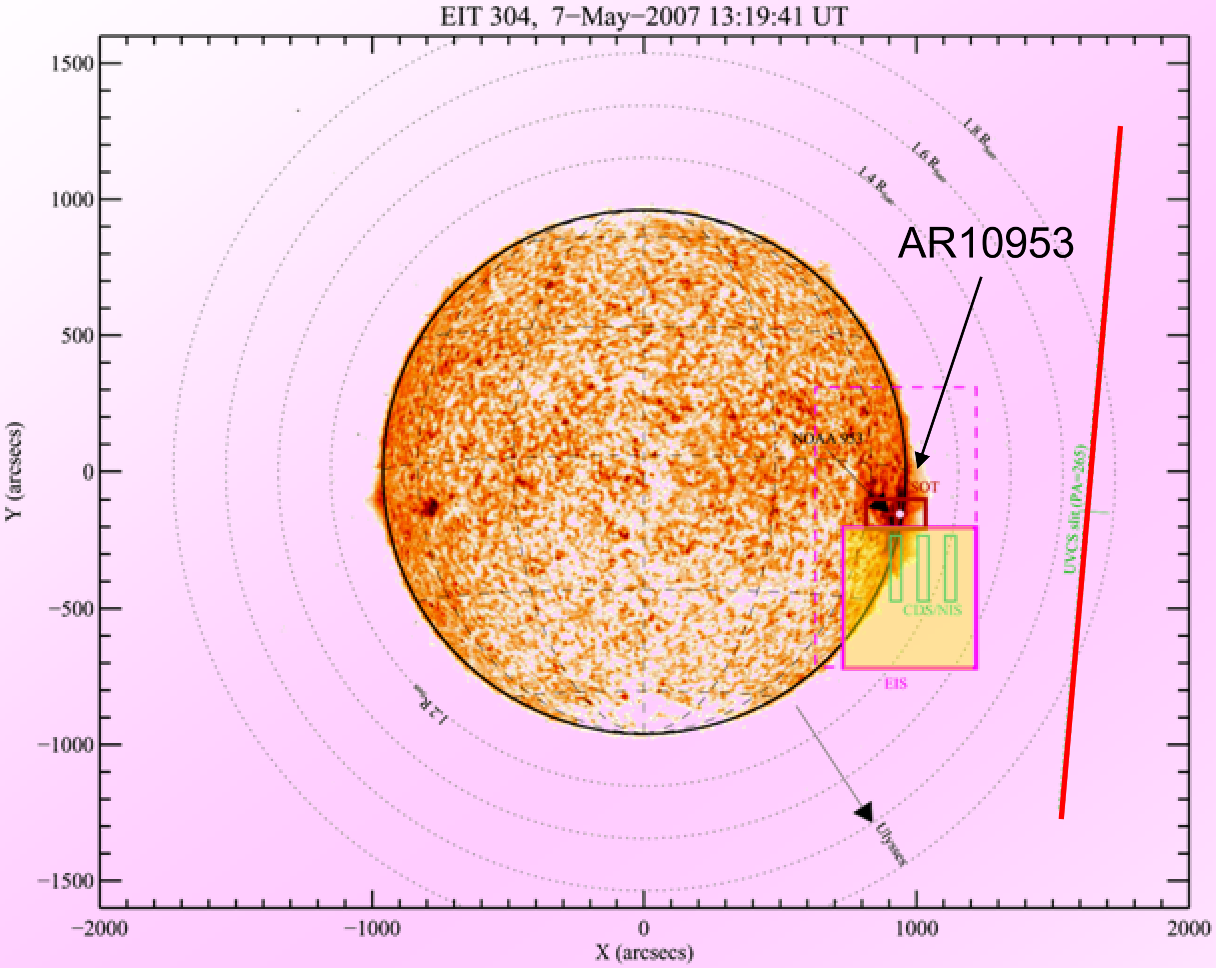
Outline

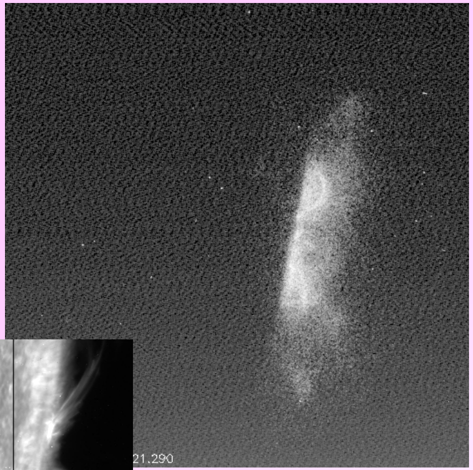
- The May 7 – 10, 2007 campaign
- The May 9, 2007 CME:

  - **Stereo/EUVI** observations: filament structure and expansion
  - **Hinode/EIS** observations: non thermal line broadening
  - **SOHO/UVCS** observations: CME plasma parameters

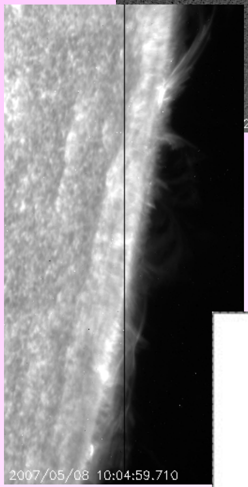
- Conclusions

The Hinode HOP 7 campaign: 7 – 10 May 2007

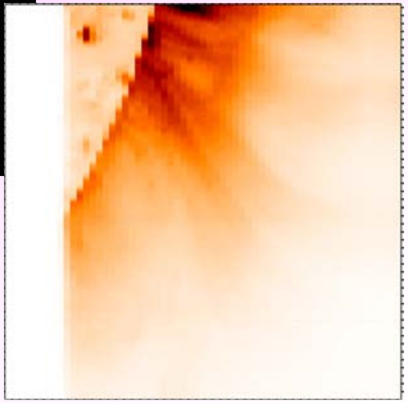




XRT
(“Al thick” filter)

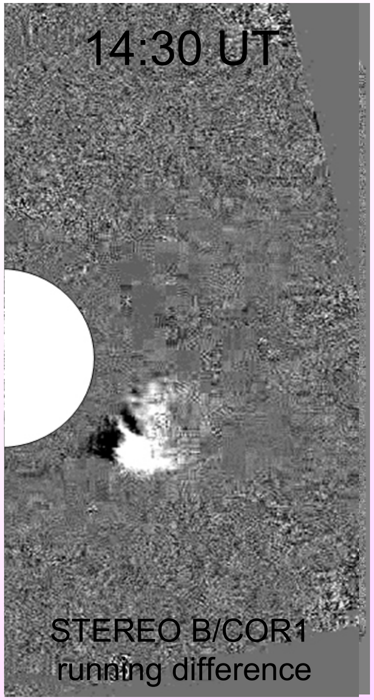


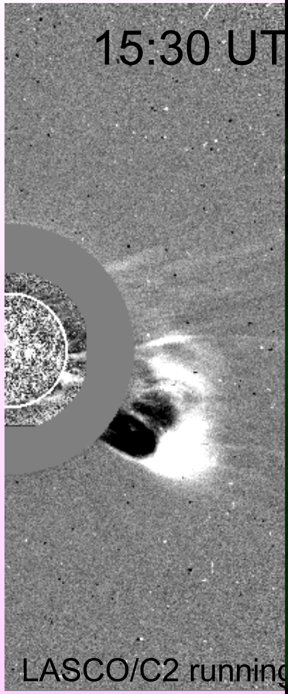
SOT
(CaII H line)

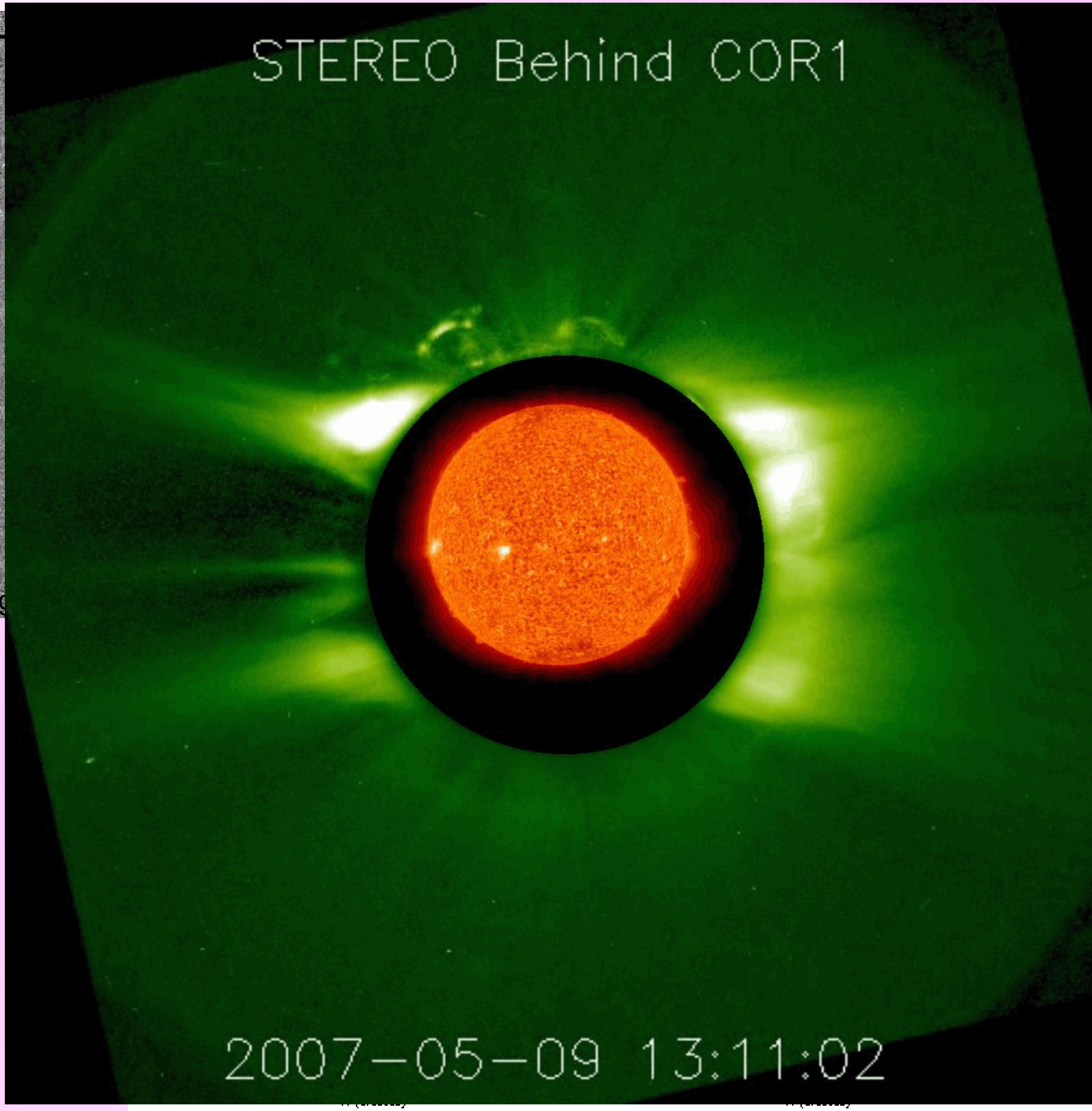


EIS (FeXII λ195.12 line)

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







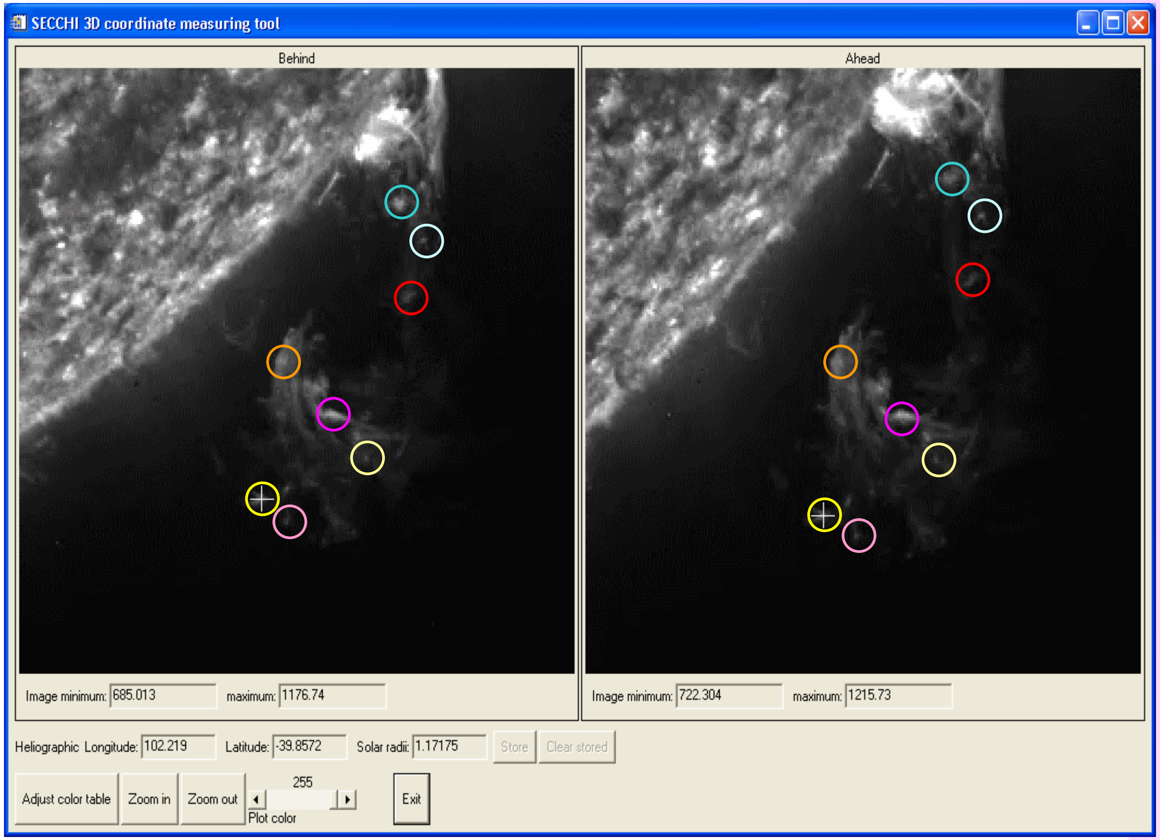
LASCO CME catalog:

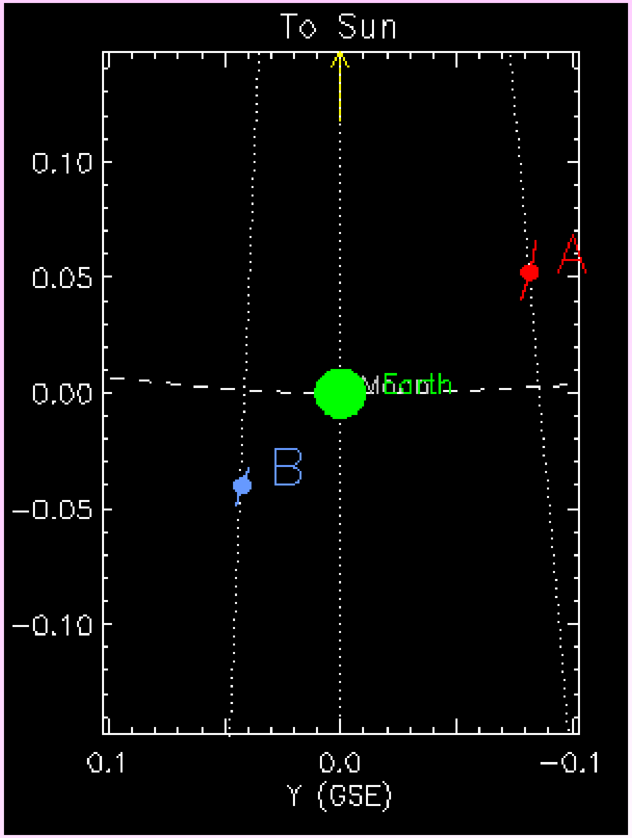
- PA: 244° (26°SW)
- v_{lin} ~ 310 km/s
- a ~ -7.4 m/s^2

Possible CME source:

- AR 10953 (11°S, 91°W on 08/05/2007)
- H-α filament

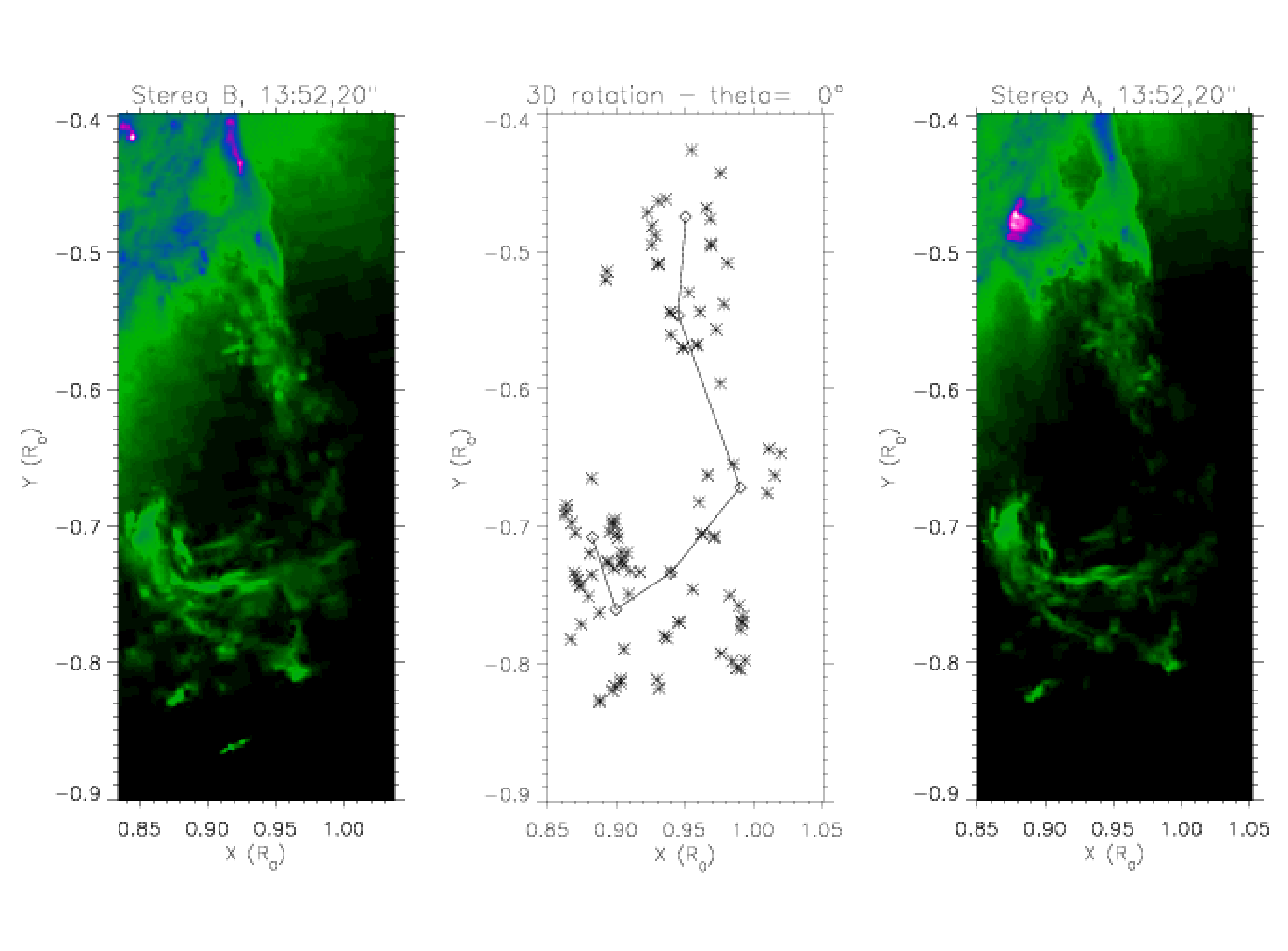
The eruption as seen by STEREO/EUVI





- 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**.

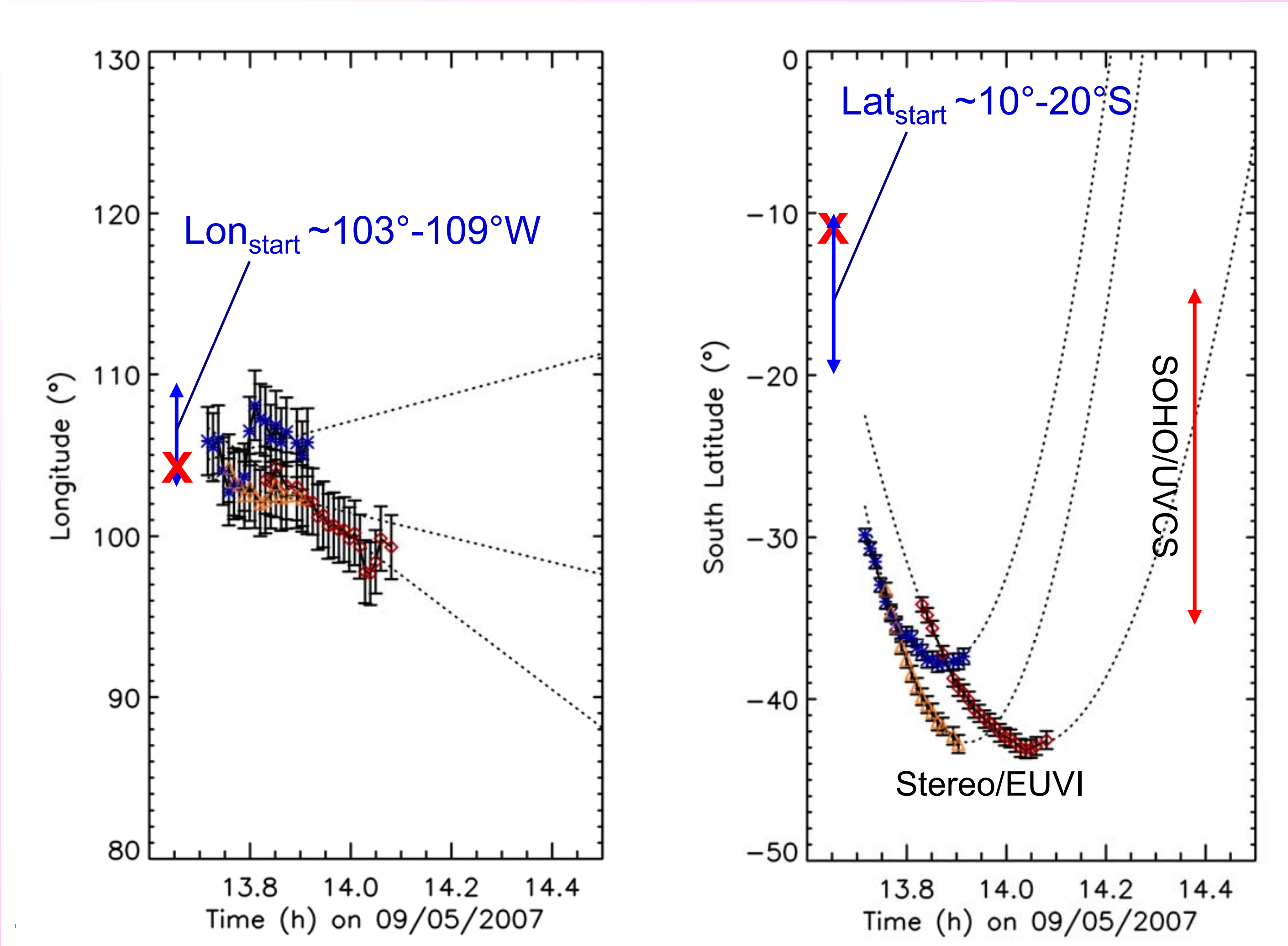
Results: Filament structure



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

X AR10953
(11°S,104°W)

Results: Filament expansion

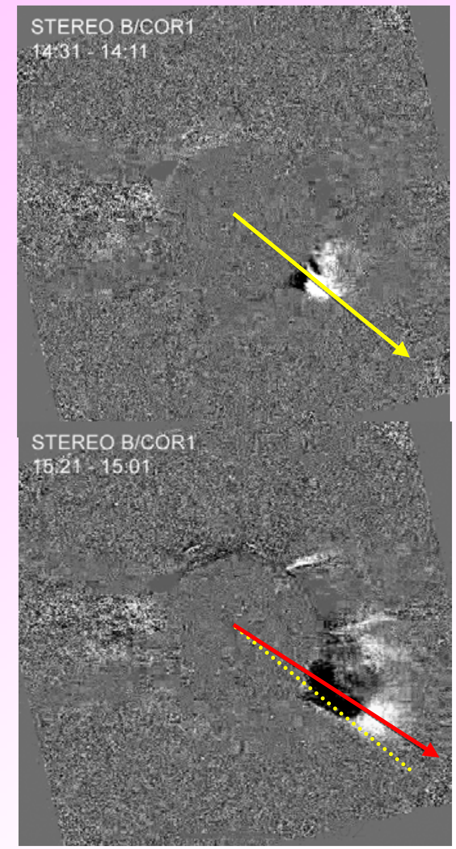


a_r = (180±80) m/s^2

a_t = (8±2)·10^{-7} rad/s^2

~ (600±150) m/s^2

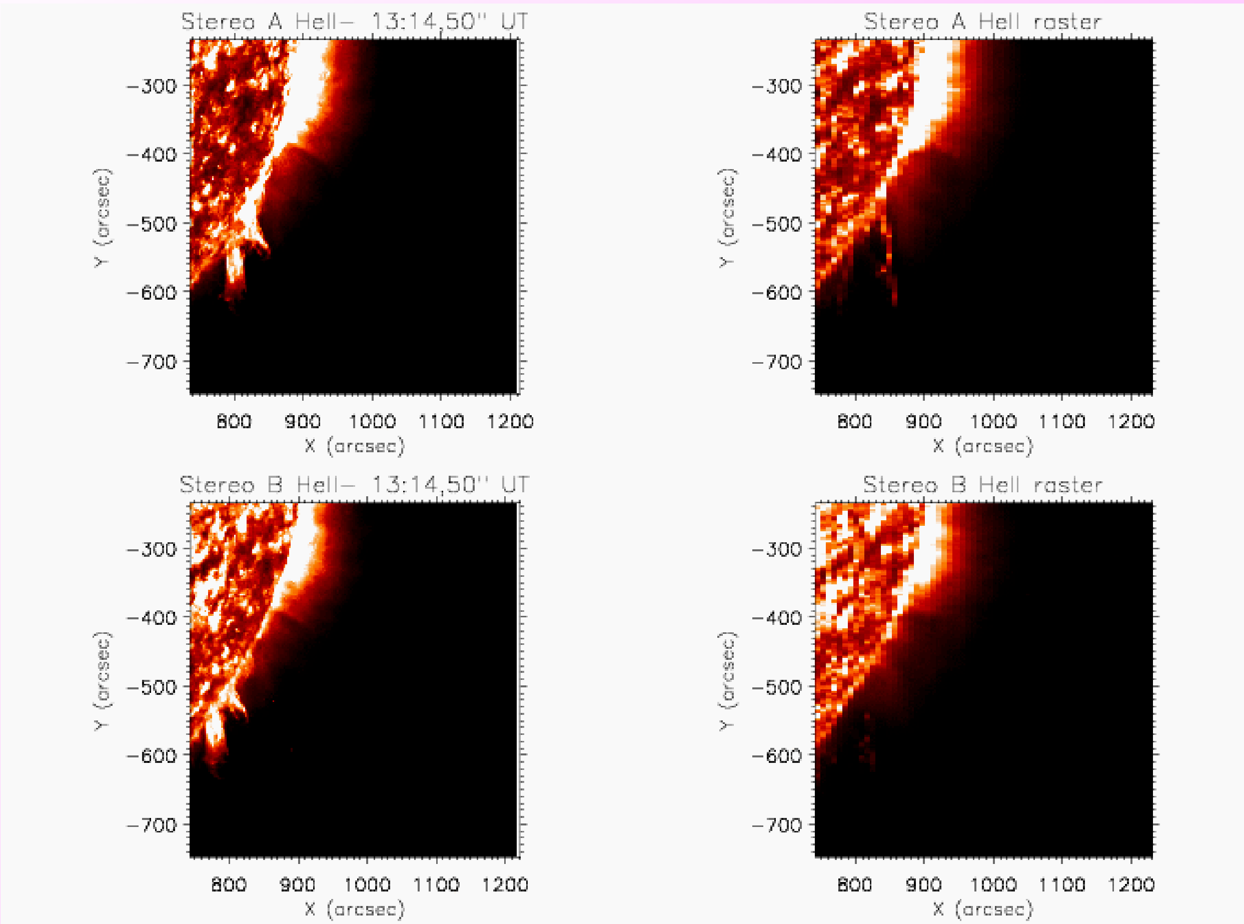
a_{rLASCO} = -7.4 m/s^2



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

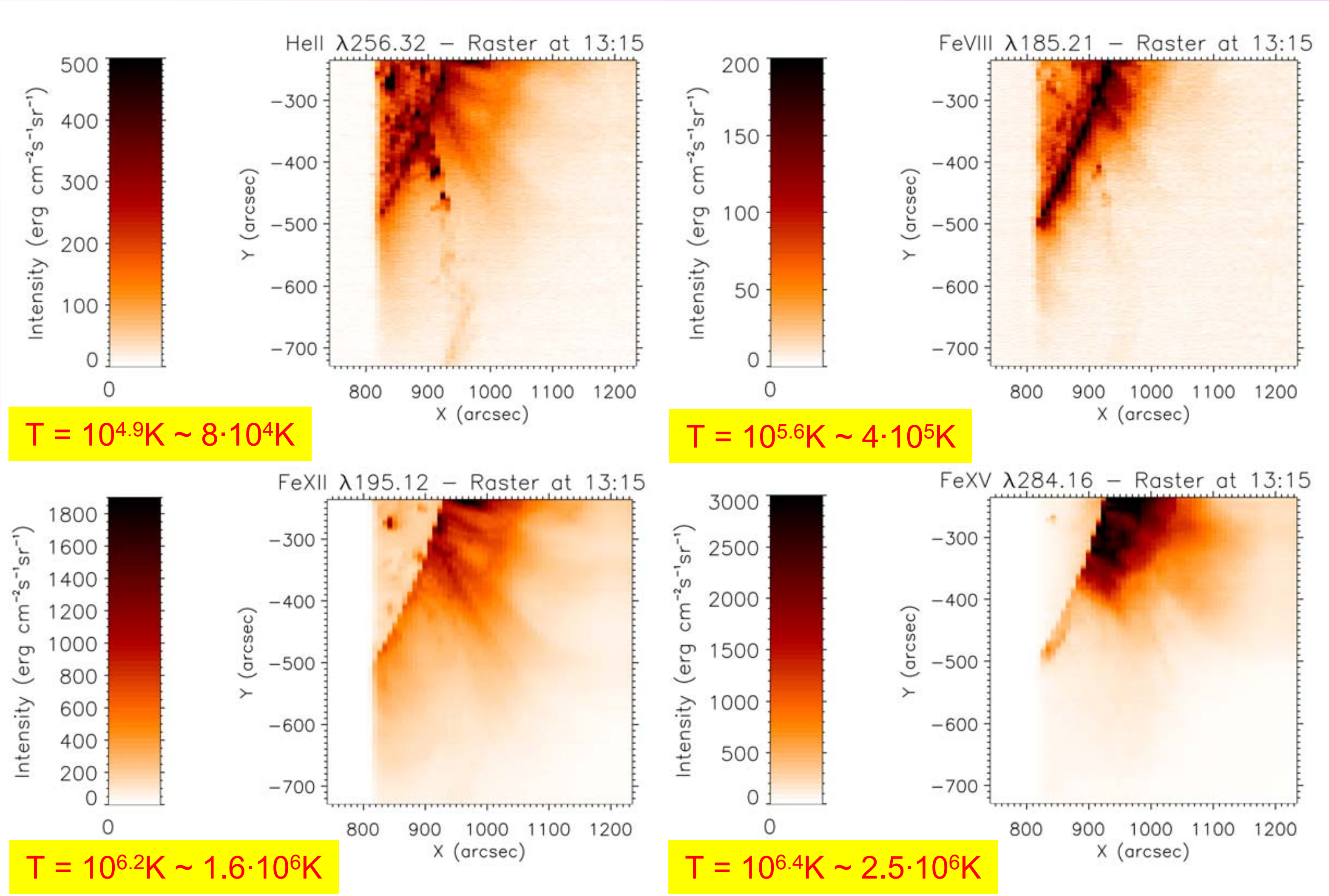
➡ **CME observed by EIS?**



Rasters with the **2" slit**, separated by **8"**, 61 exps/raster, 60 s/exp, ~1 h/raster

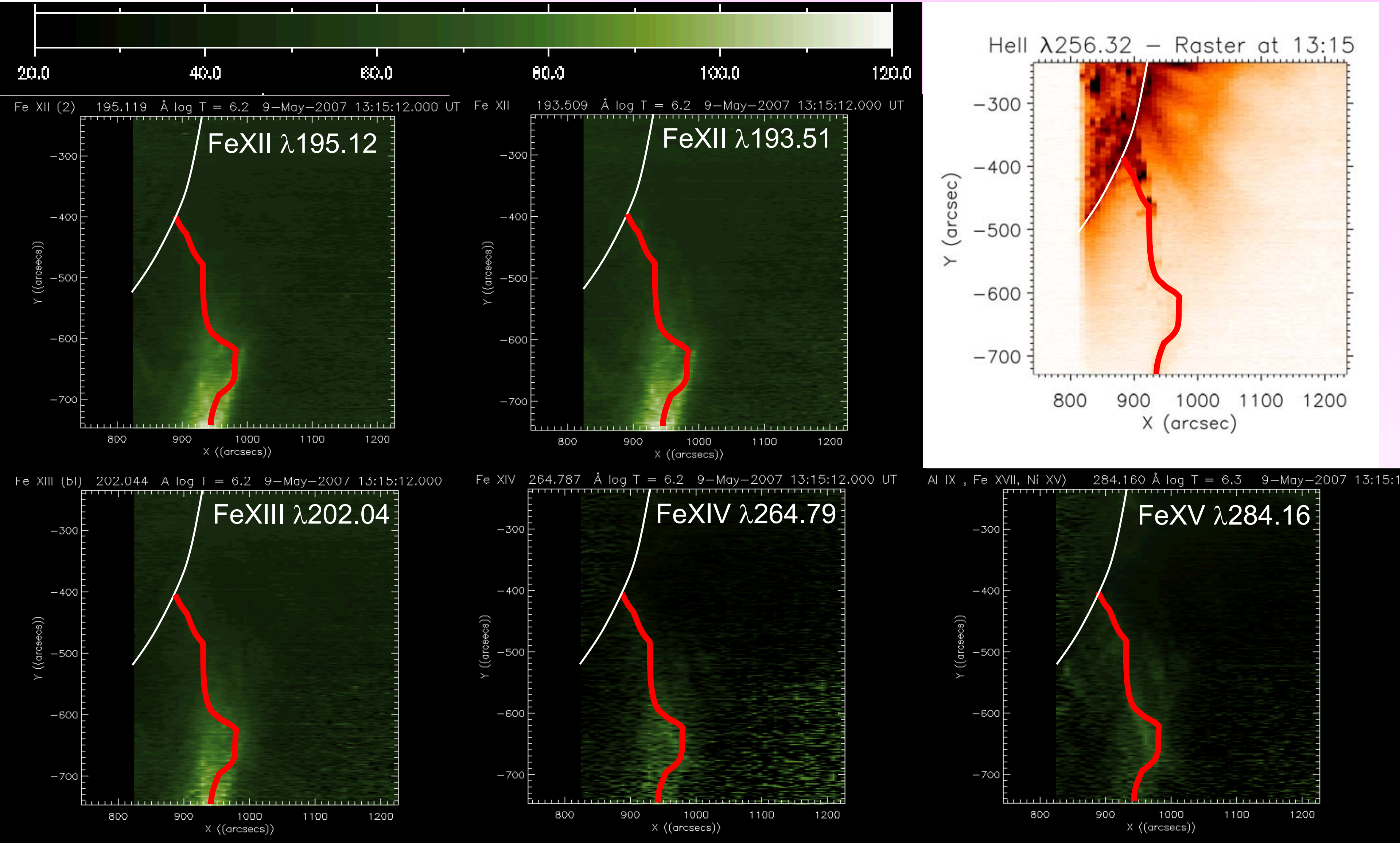
ion	λ (Å)	$\log T_{max}$
HeII	256.32	4.9
FeVIII	185.21	5.8
FeX	257.26	6.0
FeX	184.54	6.0
FeXI	180.40	6.1
FeXI	182.17	6.1
FeXI	188.23	6.1
SiX	258.37	6.2
SiX	261.04	6.2
FeXII	193.51	6.2
FeXII	195.12	6.2
FeXII	196.64	6.2
FeXIII	201.13	6.2
FeXIII	203.83	6.2
FeXIV	264.79	6.3
FeXIV	274.20	6.3
FeXV	284.16	6.4

Plasma emission at different temperatures

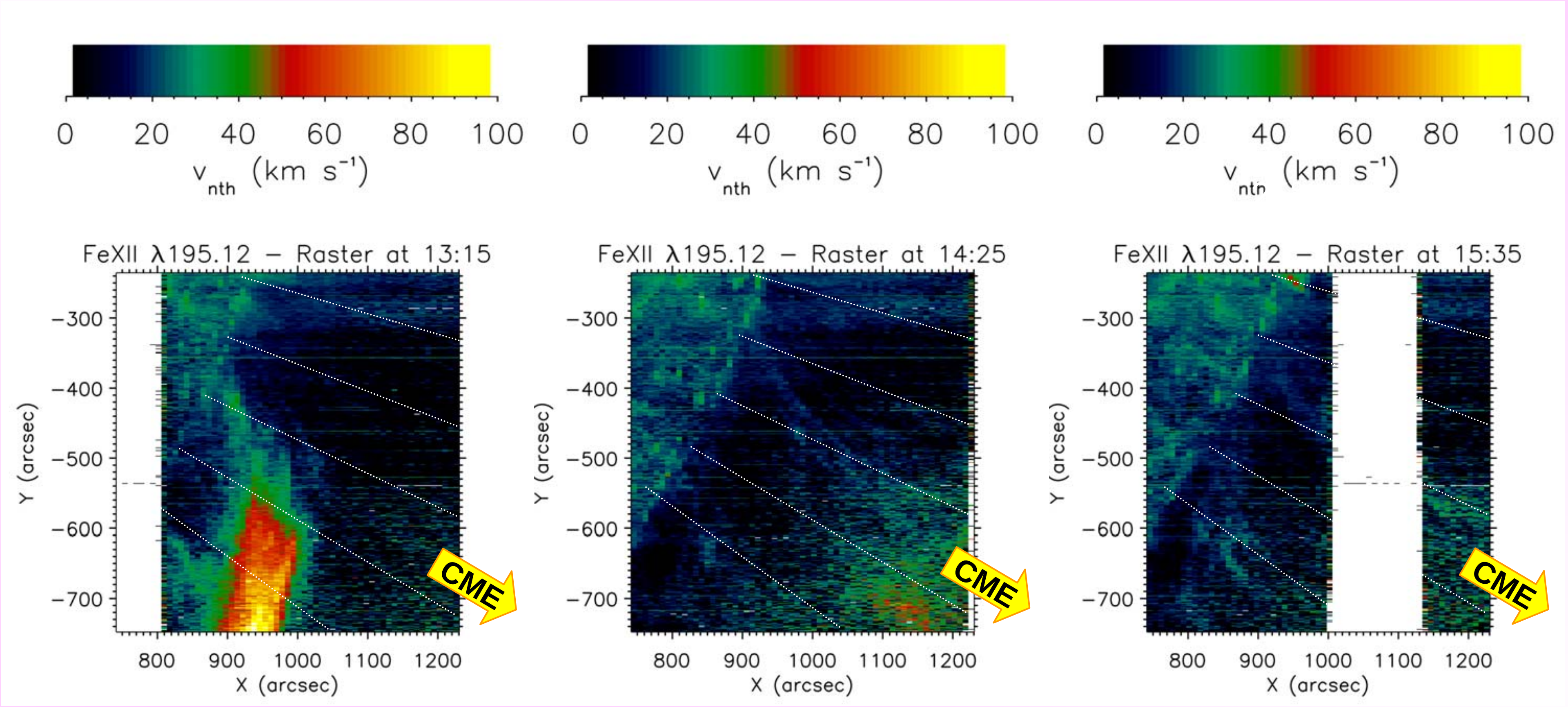


The cool filament material disappears above logT ~ 5.6 (**~ $4 \cdot 10^5$ K**)

The detection of non-thermal velocities

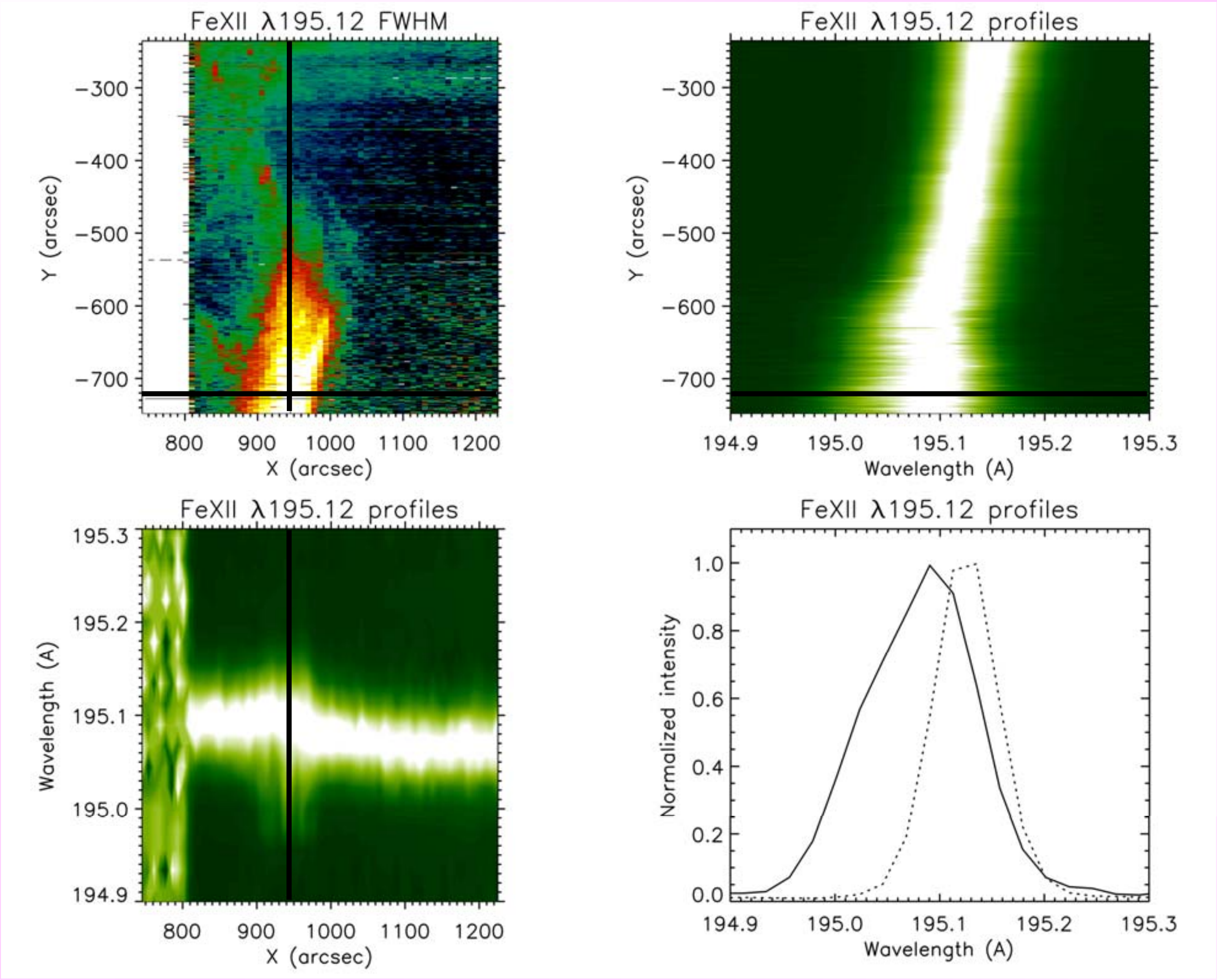


Non-thermal velocity evolution



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

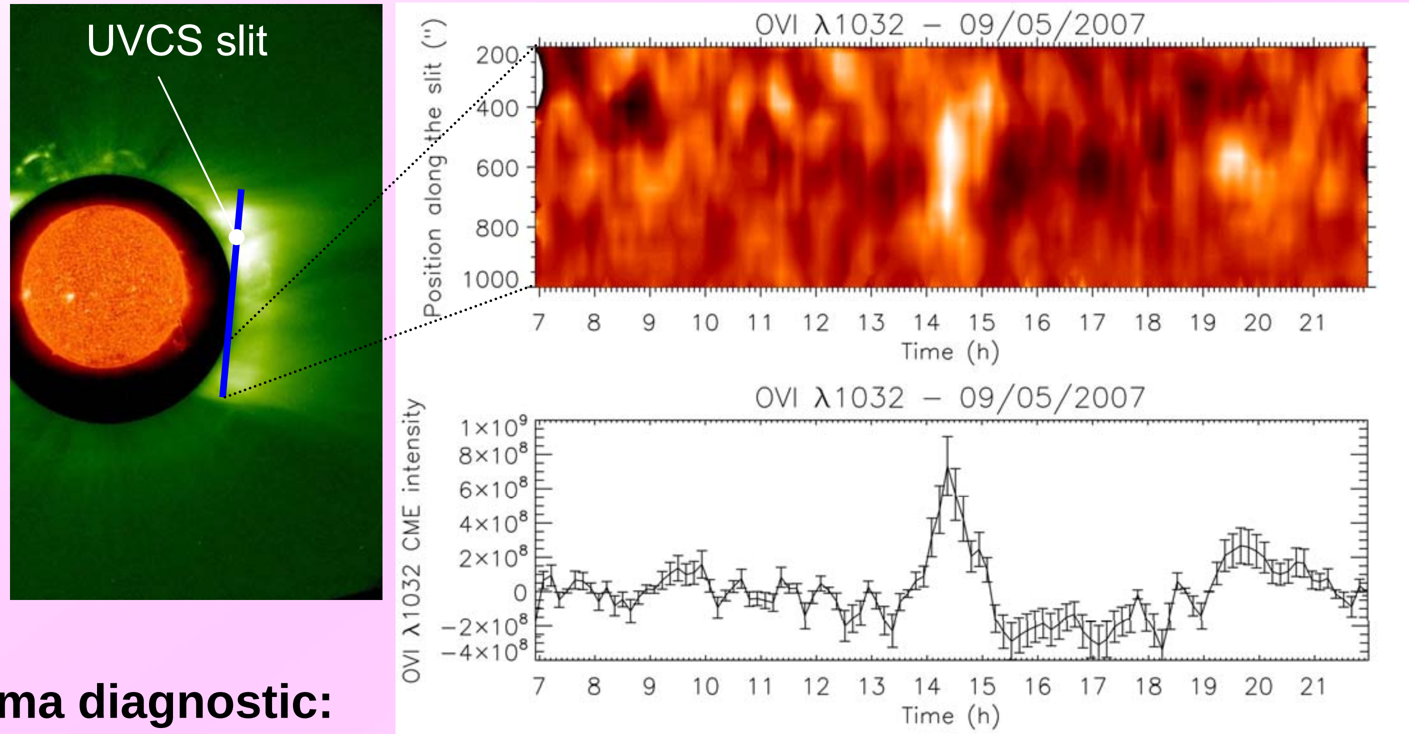
2) Outflows along field-lines opened by the CME (suggested by the line asymmetry? But why v_{nth} changes for different ions?)

3) Plasma turbulence related to reconnections after the CME

The eruption as seen by SOHO/UVCS

ion	λ (Å)	$\log T_{max}$
HI Lyβ	1025.72	4.5
OVI	1031.91	5.5
OVI	1037.62	5.5
SiXII	520.67	6.3

UVCS slit: centered at 5°S, 1.7 R_{sun}
Spatial resol.: 56"
Time resol.: 120s



UVCS coronal plasma diagnostic:

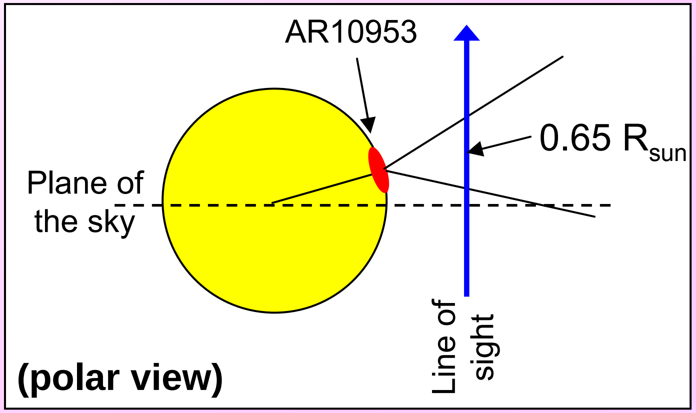
- OVI λλ1032-1037 intensities due to both collisional and radiative excitation;
- By assuming v_{out} ~ 0 the I_{rad} and I_{col} of both lines can be easily separated;
- $I_{col} \propto n_e^2 L$, $I_{rad} \propto n_e L \rightarrow I_{col} / I_{rad} \propto n_e$ ⇒ n_e
- Given n_e and by assuming O and Si abundances:

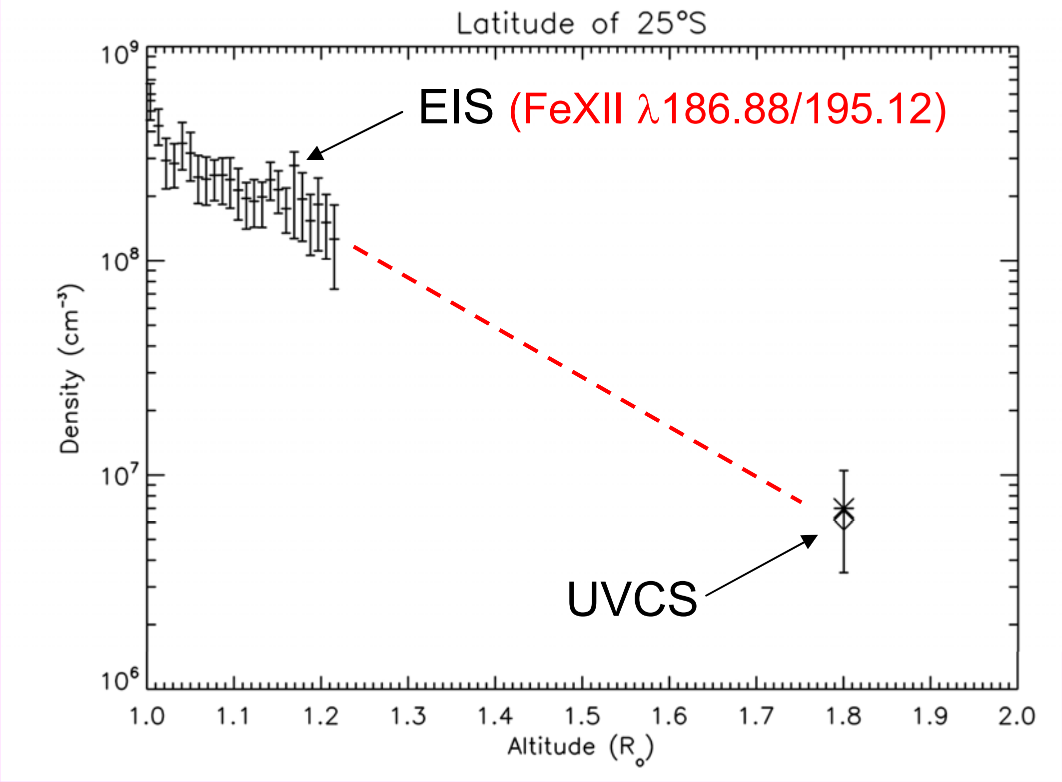
$$\frac{I_{col}(OVI)}{I(SiXII)} \propto \frac{A_O}{A_{Si}} \frac{C_{line1}(T_e, n_e)}{C_{line2}(T_e, n_e)} = f(T_e)$$ ⇒ T_e

Results: Coronal & CME plasma parameters

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

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





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

CME plasma: $EM_{CME} \sim 8 \cdot 10^{23}$cm^{-5} $= n_e^2 L_{CME} \rightarrow n_e$(CME) $\sim 4.2 \cdot 10^6$ cm^{-3}
By assuming a **volume** of $(4\pi/3) \cdot 3R_o \times 0.65R_o \times 0.65R_o \rightarrow$ **$m_{CME} \sim 3.3 \cdot 10^{16}$ 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 $\mathbf{m_{CME} \sim 3.3 \cdot 10^{16}\ g}$.