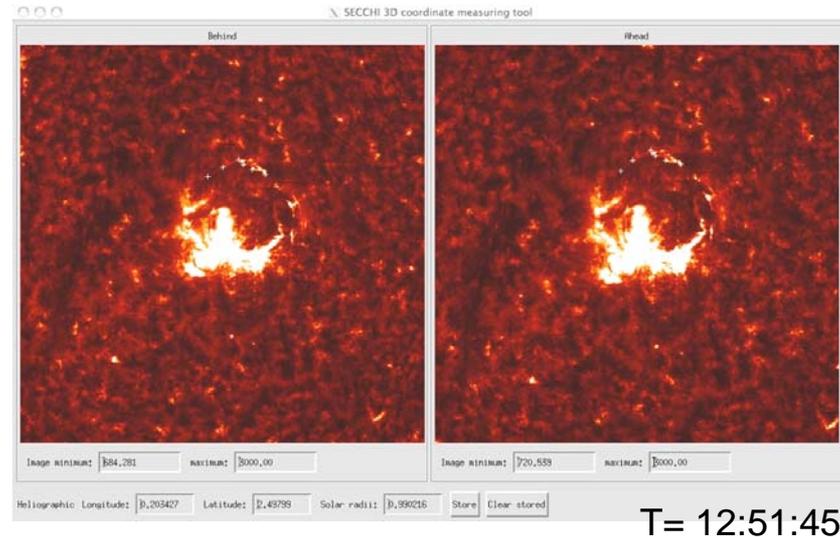


Stereoscopic Analysis of STEREO/EUVI Observations of May 19, 2007 Erupting Filament



*P. C. Liewer, E. M. DeJong, J. R. Hall, JPL/Caltech;
K. E. J. Huttunen, Y. Li, J. Luhmann, B. Lynch, UCB/SSL;
Angelos Vourlidas & R. A. Howard, NRL; W. Thompson, GSFC
SSL/UCB, Berkeley February 2008*



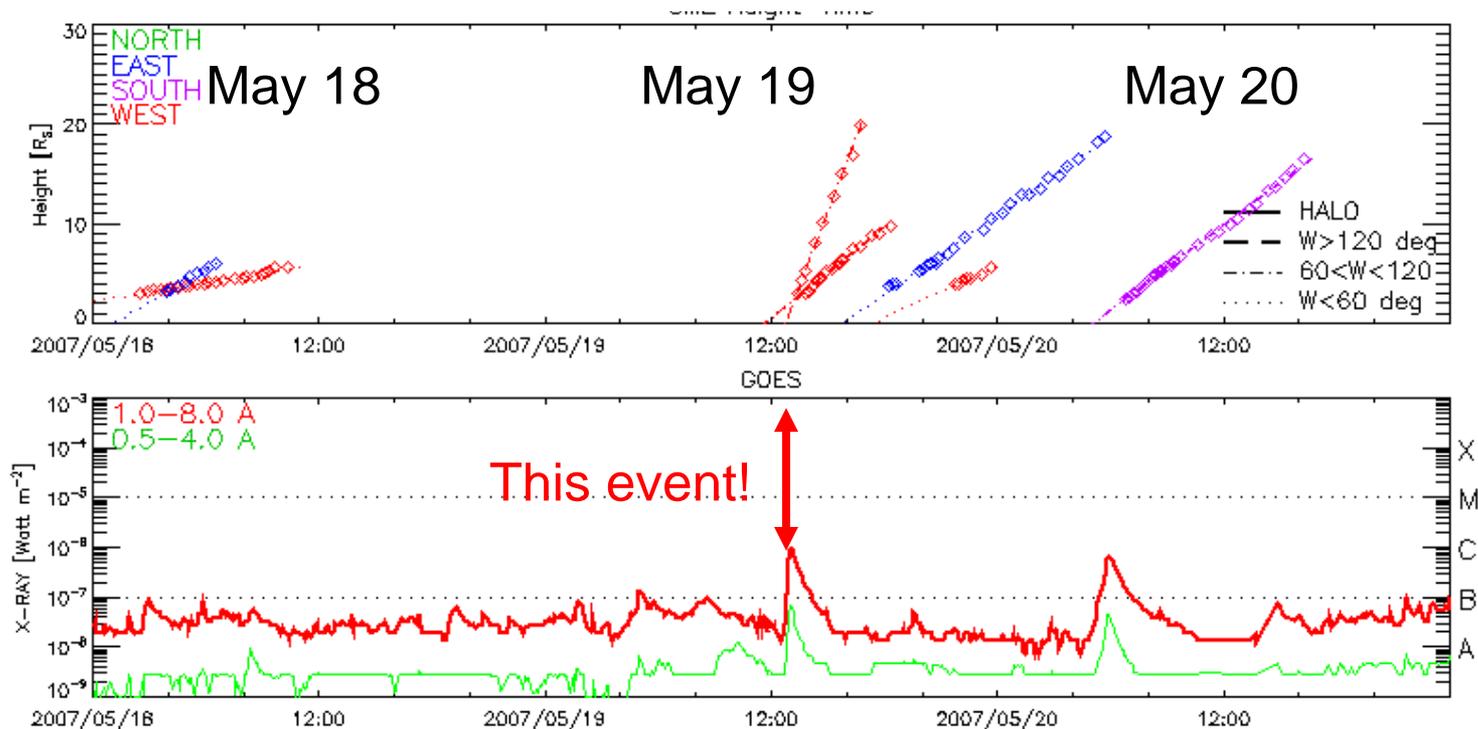
Summary

- Magnetic cloud observed at 1 AU May 21-22, 2007 (Huttunen et al 2008)
- We link this cloud to double CME on May 19 13UT with dimming, flare & filament eruption
- We use stereoscopy to analyze the filament before and during the eruption
- No “warning signs” of eruption observed



Linking the Cloud to May 19 Events

- Magnetic Cloud (ICME) at 1 AU has $V \approx 480$ km/s
- If constant speed of 480 km/s, CME left Sun midday May 18
 - But no significant CMEs on May 18
- May 19 had double CME at 13UT with \square X-ray flare, dimming and filament eruption
- LASCO catalog gives speed of **fast May 19 CME** as 980 km/s-
 - **We identify this CME as cause of magnetic cloud**

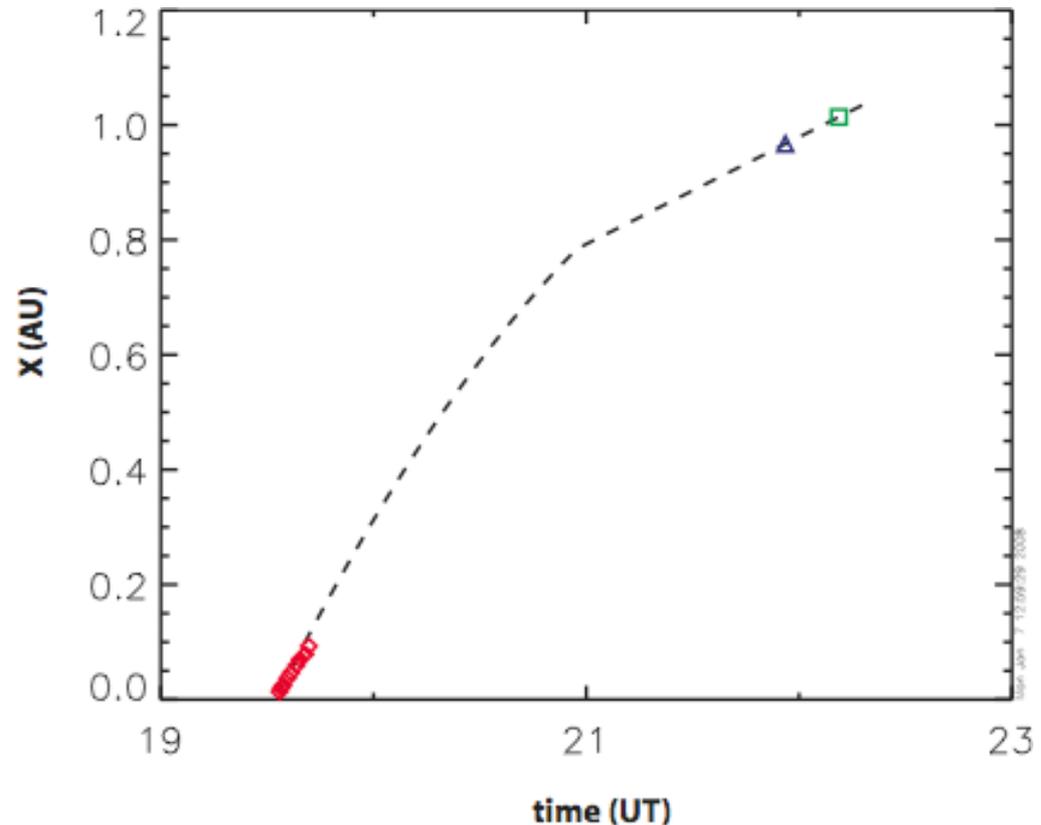


Linking the Cloud to May 19 Events

- If left Sun at 13:00 UT on May 19, $\langle v \rangle = 700$ km/sec, comfortably between 980 and 480 km/s
- Graph: empirical formula of Gopalswamy et al (2001) using above initial and 1 AU velocities
- Good fit supports 13:00 UT May 19 CME as source of Cloud

Red - LASCO May 18
 Blue diamond - Wind
 Green square - STEREO B

What about the Slow CME?
 Same event, but projection effects of Earth-directed CME?
 (Leblanc 2001)





May 19 STEREO B/SECCHI/ EUVI 195 A: CME Signatures ⁵

- Movie shows flare, dimming, EIT wave and post eruptive flare arcade

QuickTime™ and a
H.264 decompressor
are needed to see this picture.



May 19 STEREO B/SECCHI/ EUVI 304 A: Filament Eruption⁶

- Movie shows filament from May 18 (10UT) to May 19 (13UT) eruption and ejection of filament material

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

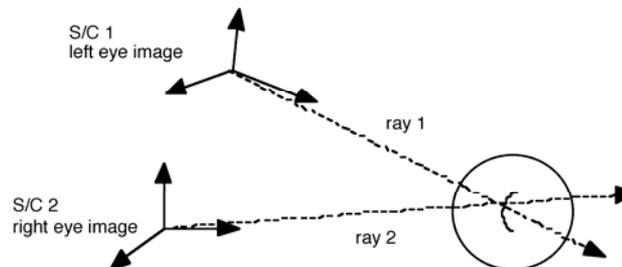
AR Prominence Eruption & CME May 19, 2007

Sequence of Events

Time UT May 19	Telescope	Event
12:31	EUVI 304 -195-171	Activity& brightening in filament
12:48	GOES X-ray	Begin sharp rise of B9.5 flare
12:51	EUVI 304, 171	Filament erupts
13:00	GOES X-ray	Flare peaks
13:02	EUVI 195	Dimming and post-eruptive arcade formation begin
13:12	EUVI 195	Dimming and post-eruptive arcade most evident
13:24	LASCO/C2	Fast CME leading edge visible at PA=270 deg
13:48	LASCO/C2	Slow CME leading edge visible at PA=306 deg
15:41	EUVI 304	Ejecta reaches disk limb
15:52	STEREO/COR2	CME visible as partial halo event

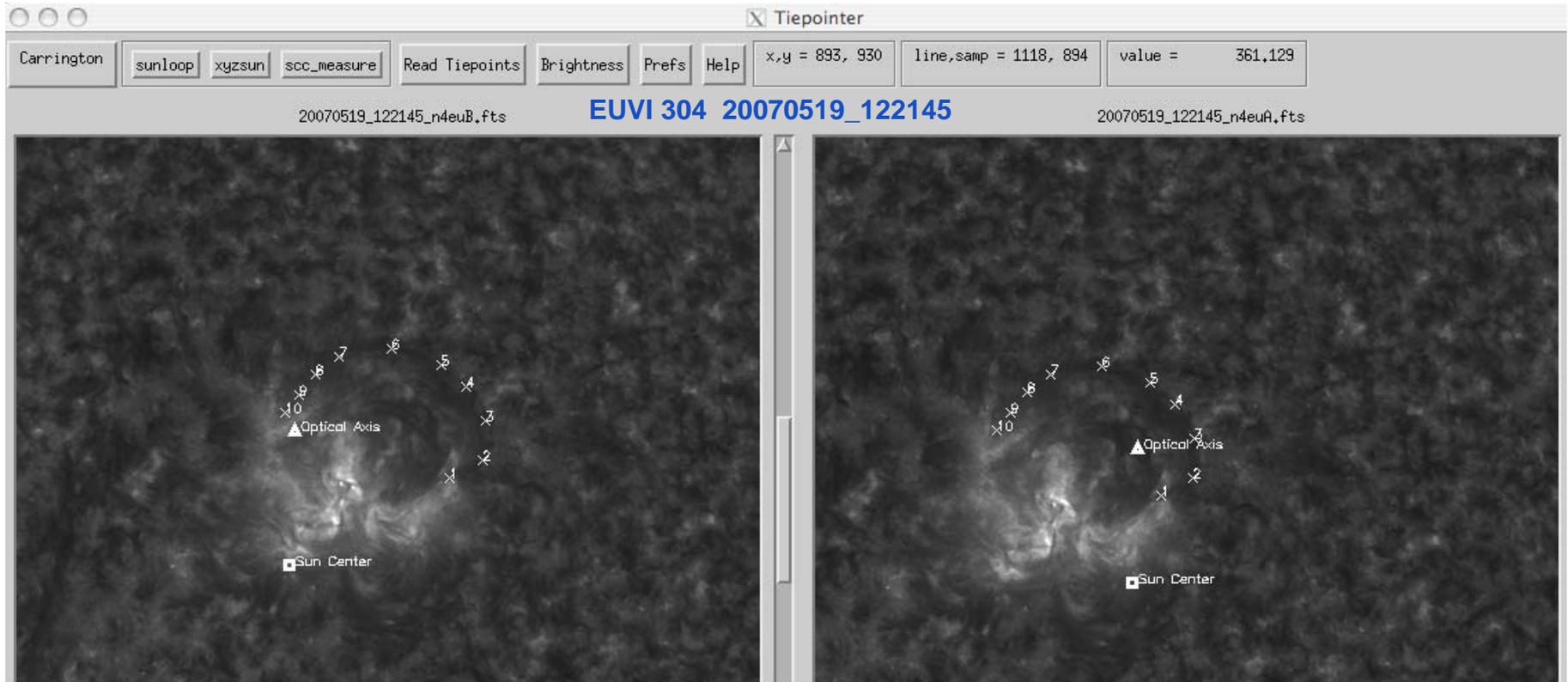
Stereoscopy and STEREO/SECCHI

- SECCHI uses World Coordinate System (WCS) solar soft routines to relate image plane coordinates to heliocentric coordinate systems (see *W. Thompson, A & A, 2005, MS 4262thom*)
 - Need location of spacecraft A&B (from ephemeris), pixel size (arcsec), and pixel location of Sun-center ($x_{\text{SUN}}, y_{\text{SUN}}$).
- Each pixel defines a unique ray
 - In a single 2D image, feature can be anywhere along ray
 - In 3D, if perfect tiepointing, rays intersect at feature
- Triangulation program locates feature at point of closet approach of the two rays

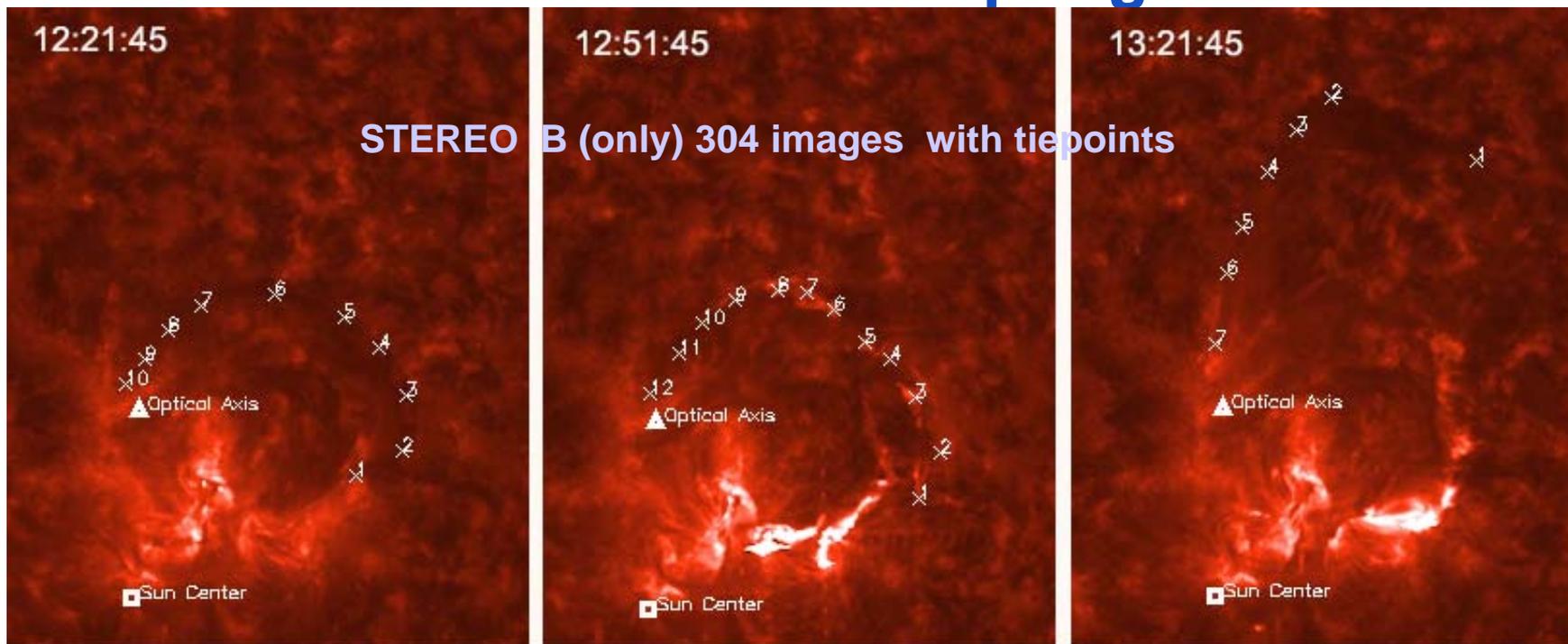


3D Reconstruction of Erupting Prominence

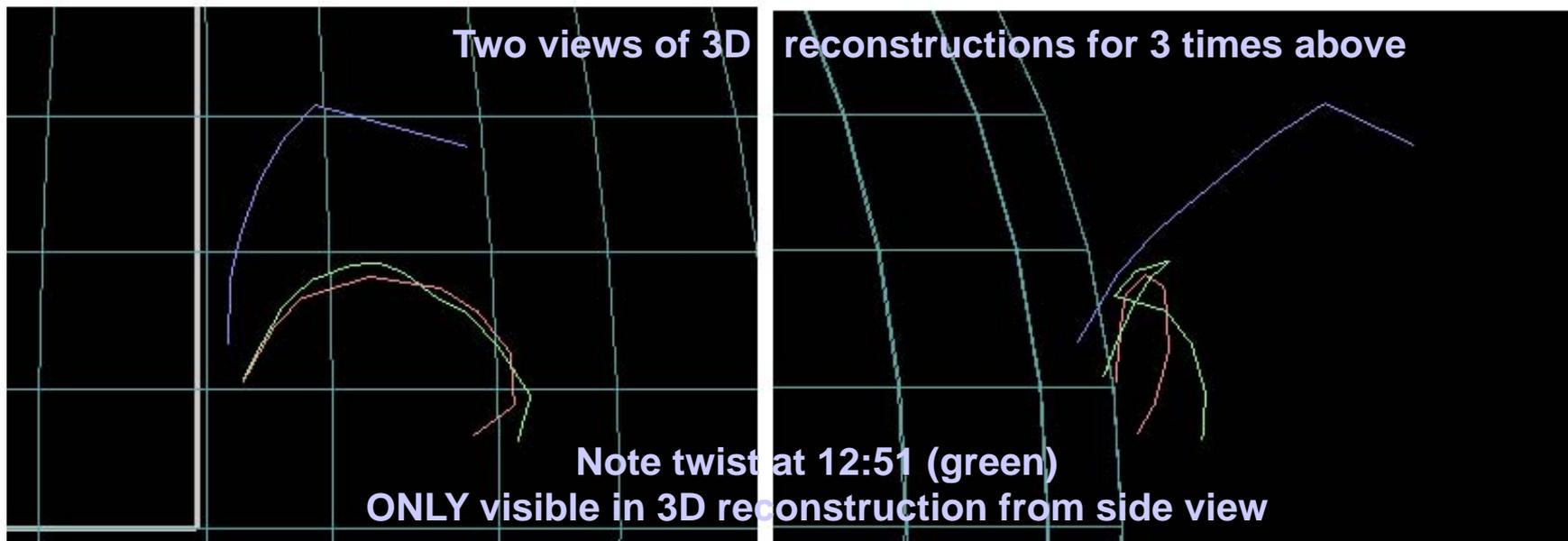
- Prominence visible in STEREO/EUVI data for ~25 hrs prior to eruption
- Reconstructed 3D prominence at 11 times using simultaneous AB Pairs
 - ~8.5° separation of STEREO A&B in mid May 2007
- User marks same features on filament in both images of EUVI 304 AB pair
 - Tiepoints are constrained to lie in epipolar line
 - Our tool rotates images to STEREO baseline
- Triangulation program finds 3D coordinates in heliocentric system



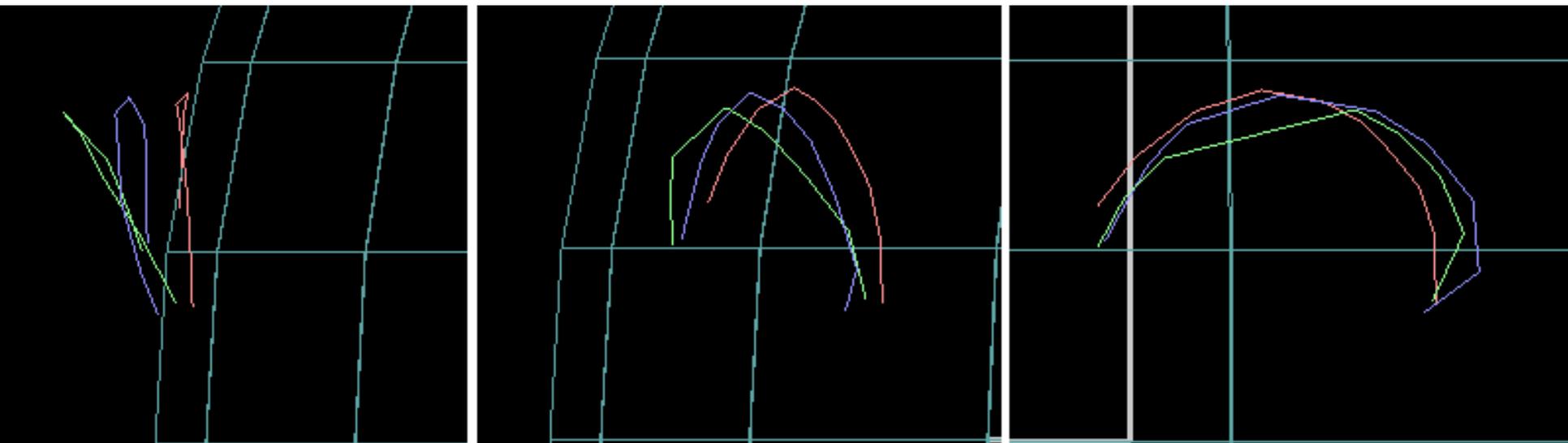
3D Reconstructions of Erupting Prominence



Two views of 3D reconstructions for 3 times above



3D Reconstructions of Pre-eruption Prominence



- 3 Views of reconstruction for 3 times prior to eruption:
 - 07:11 - red; 10:26- green; 12:21- blue
- Loop lies in a plane; little sign of kink, twist or writhe
- Highly inclined - pushed down by main AR loop system?
- Inclination of loop varies non-monotonically in time
- No slow rise prior to eruption as seen by others (more energetic event - Chifor et al 2006; polar crown filament-Zhou et al 2006)

Conclusions

- **Link MC seen at 1 AU to double CME of May 19, 2007 based on speeds and transit time**
- **May 19 CME event accompanied by flare, filament eruption, dimming, EIT wave - the “Usual Suspects”**
- **Reconstructed filament stereoscopically prior to and during eruption**
- **STEREO provides unique information on filament eruption**
- **No apparent warning signs of impending eruption -- activity just before eruption is similar to earlier episodes**

Backup Slides

Software Tools for Stereoscopy

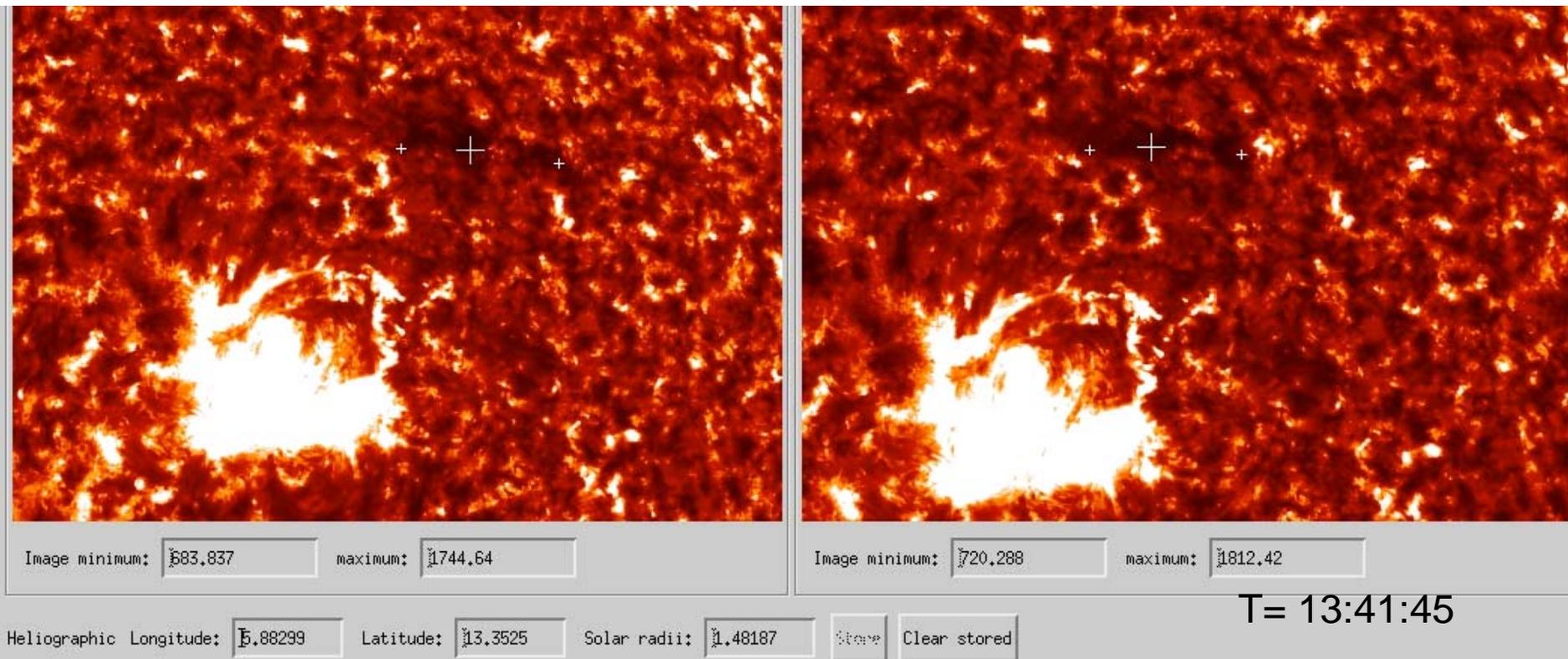
We use

- `scc_measure` - a Solarsoft program by Bill Thompson
 - `IDL>scc_measure,'fileA.fts','fileB.fts',out='outAB'`
 - User selects tiepoints (x_A, y_A) & (x_B, y_B) ; *2nd point constrained to lie on line parallel to STEREO baseline*
 - Returns 3D location (latitude, longitude, R/R_{SUN}) of each user-selected tiepoint pair
- Sunloop program developed at JPL
 - Also traces loops using edge-tracing algorithm
 - Rotates images so “up” is perpendicular to STEREO baseline & constrains feature to be with same pixel row
- We have obtained agreement between these programs

AR Prominence Eruption & CME May 19, 2007

3D tiepointing & tracking of ejected prominence material

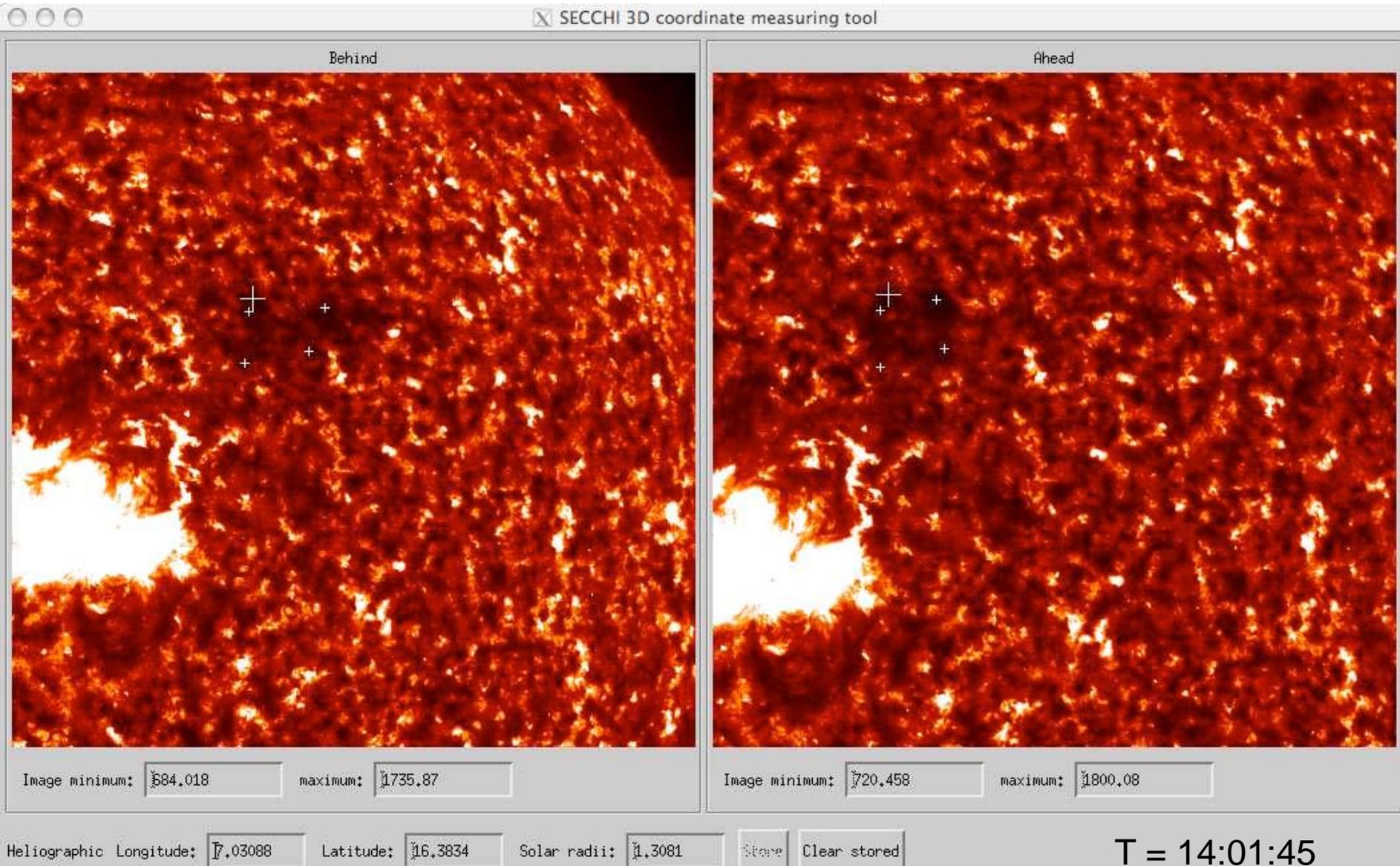
- Can track from 12:51 to 14:41 in EUVI 304
- Can SEE ejecta with 3D viewing until 15:41, but can not track - features are lost against surface pattern - Need better tools & techniques!
- Find prominence material initially moving outward at ~200-300 km/sec



AR Prominence Eruption & CME May 19, 2007

3D tiepointing & tracking of ejected prominence material

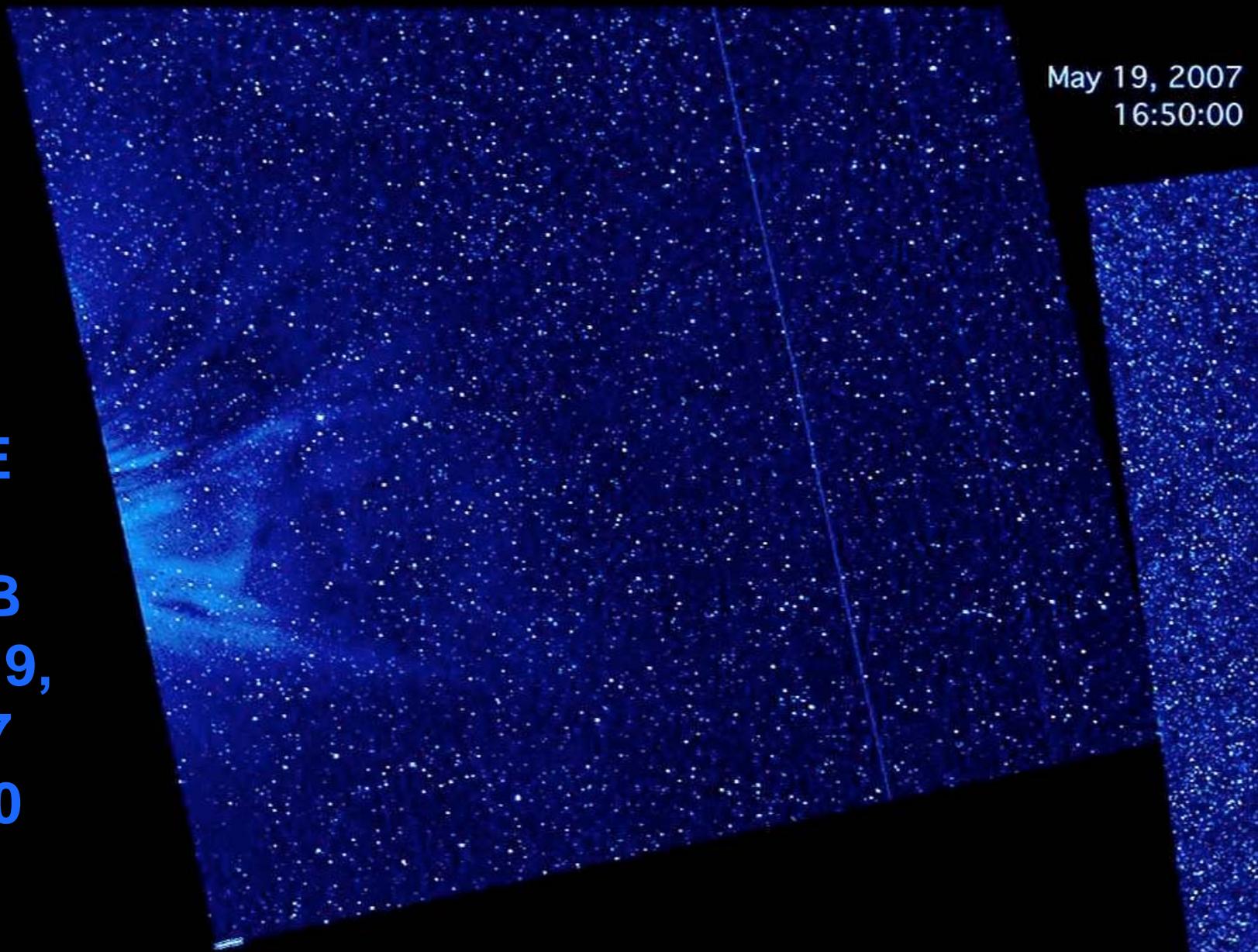
- Find prominence material initially moving outward at $\sim 200\text{-}300$ km/sec





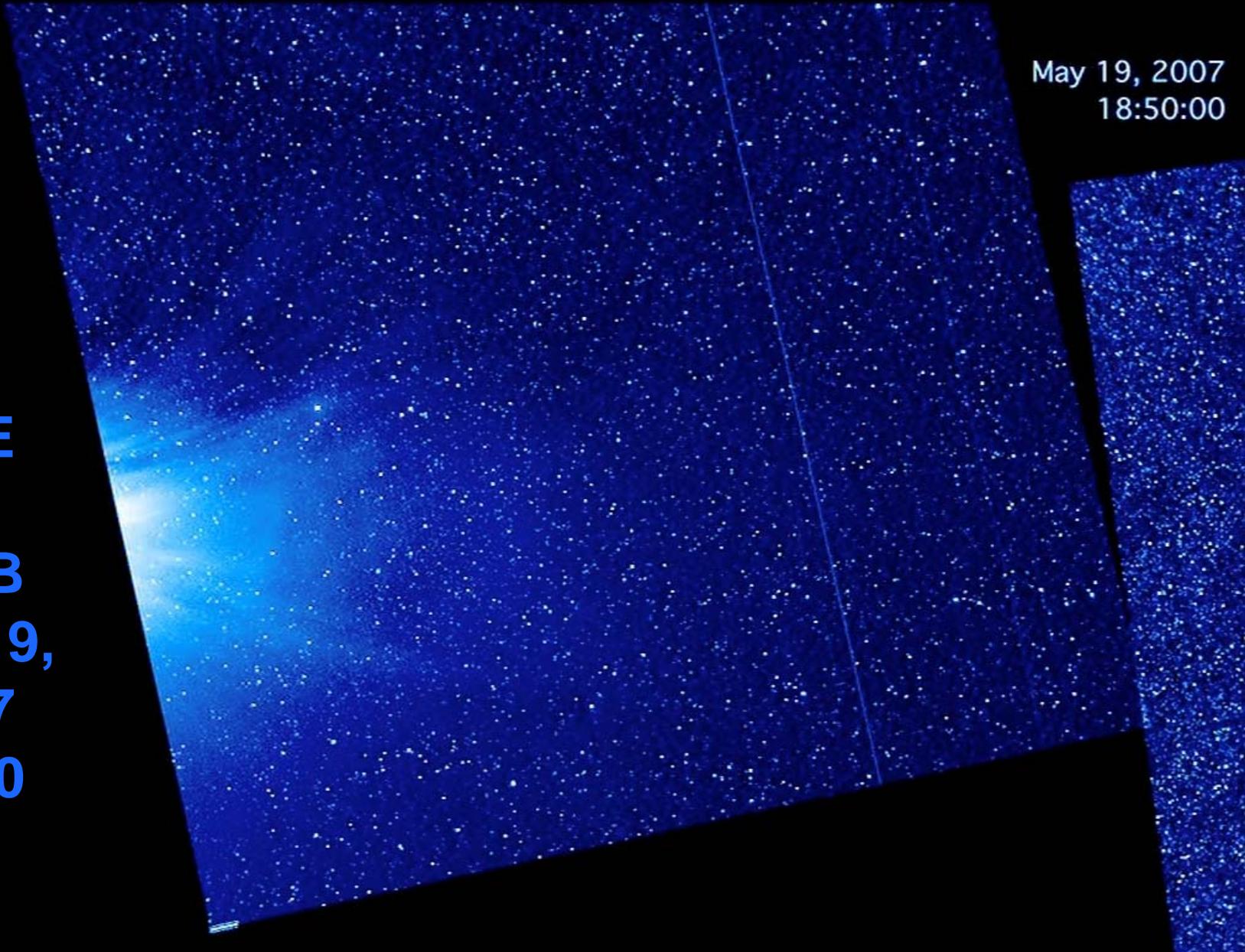
May 19, 2007
16:50:00

**CME
in
HI1 B
May 19,
2007
16:50**

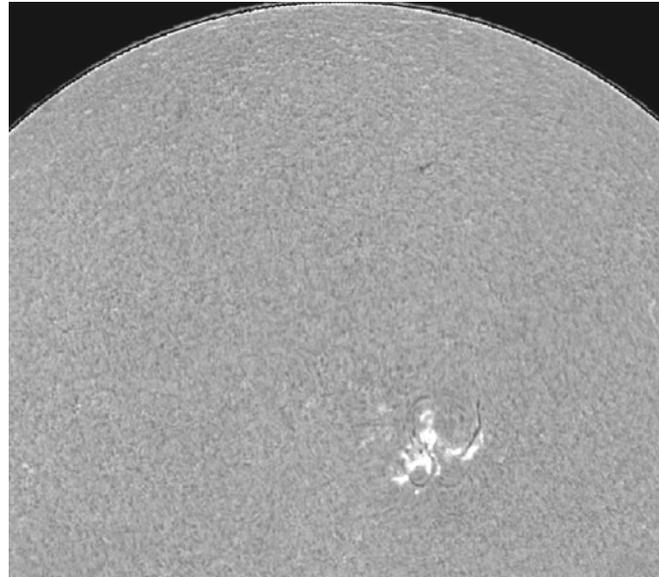
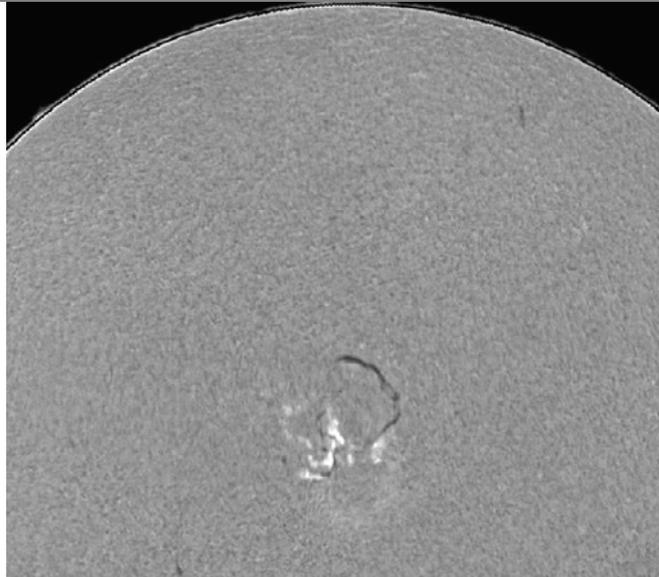
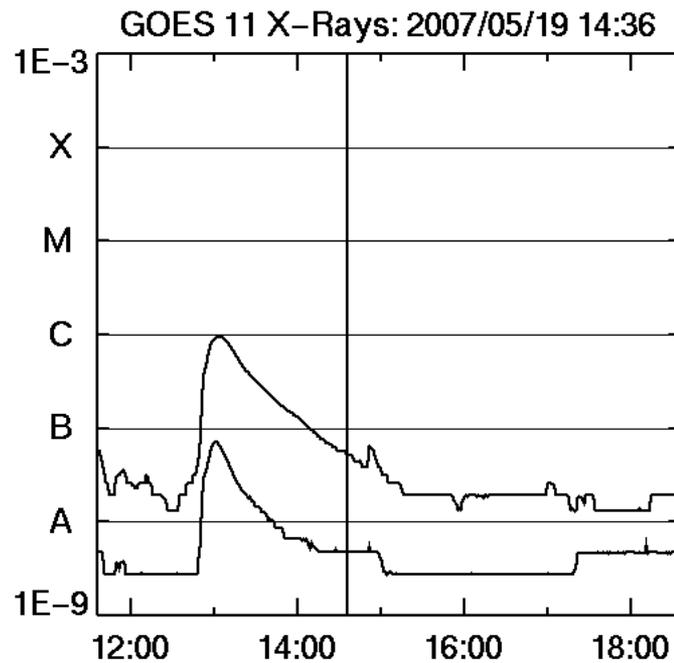
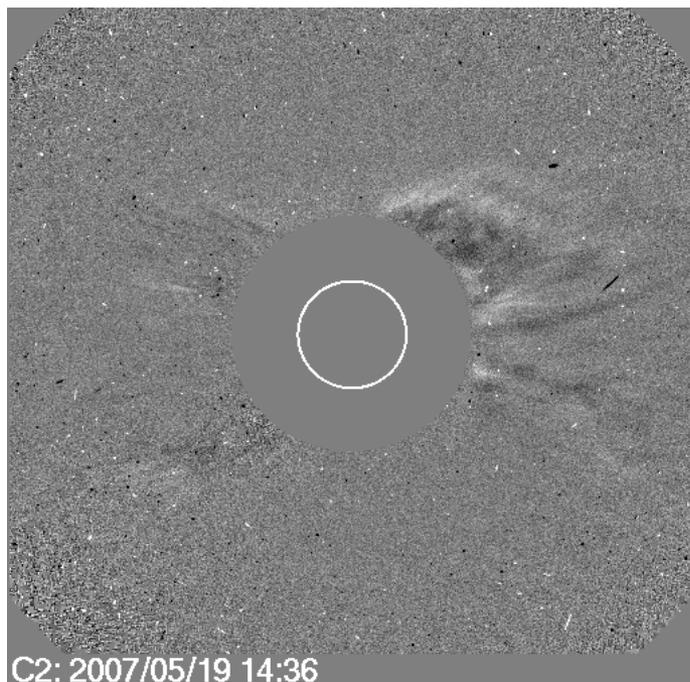


May 19, 2007
18:50:00

**CME
in
HI1 B
May 19,
2007
18:50**

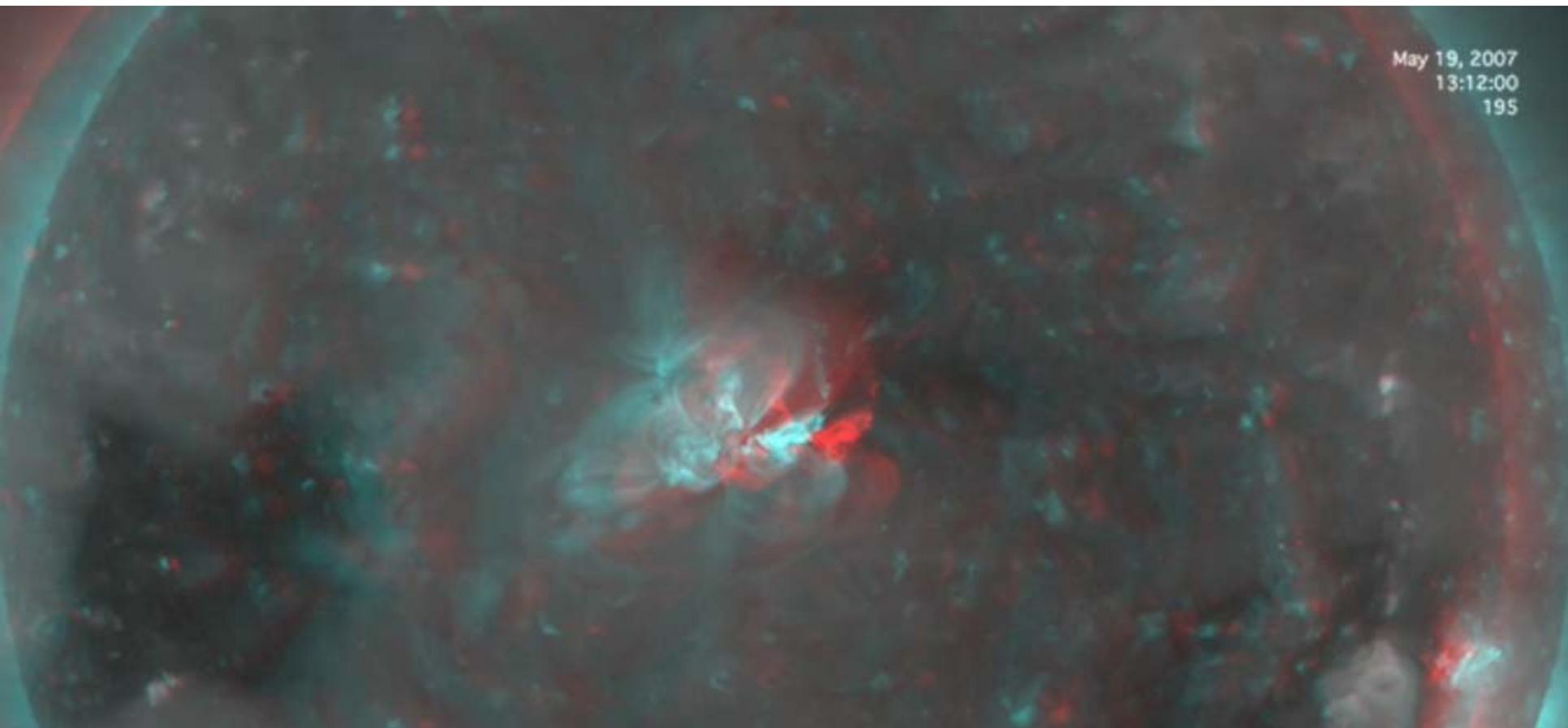


AR Prominence Eruption & CME May 19, 2007



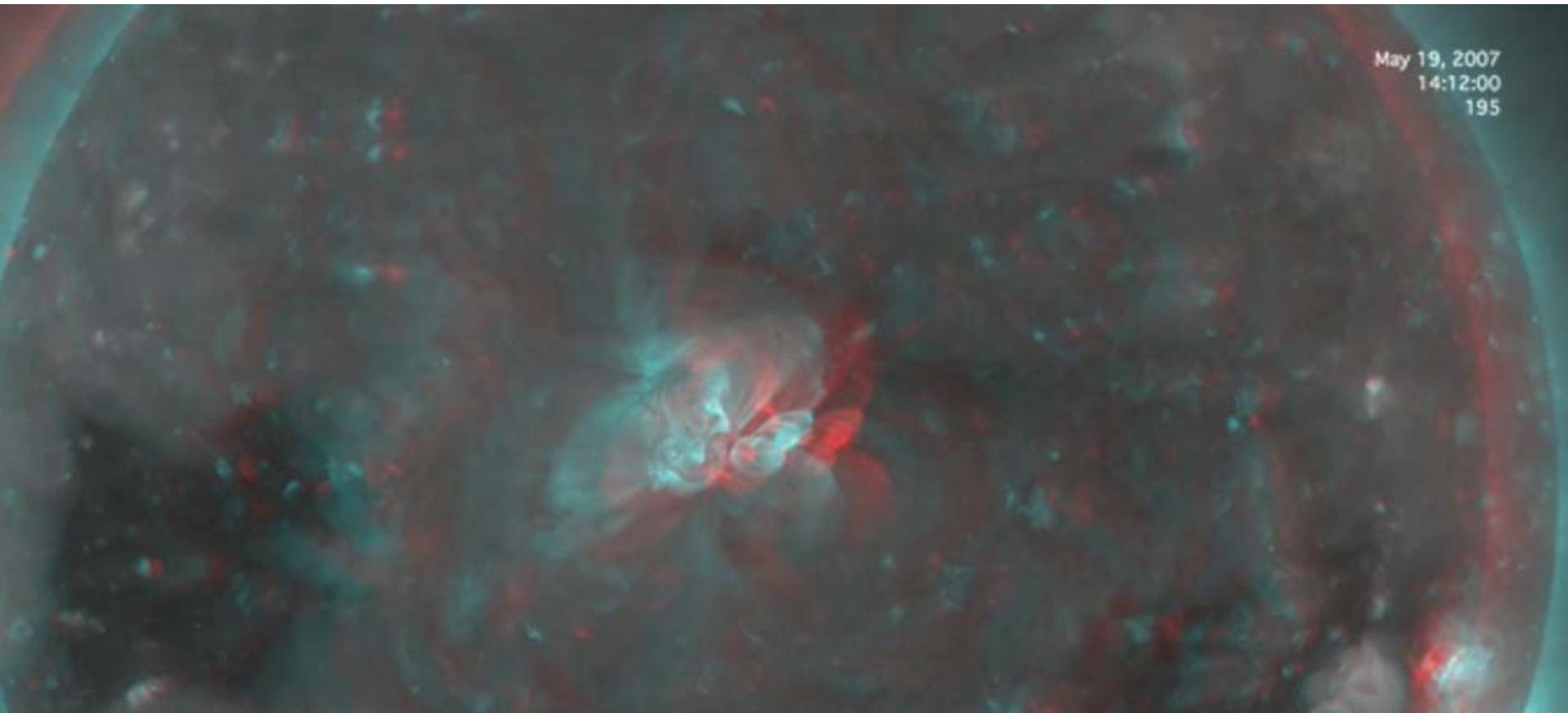
AR Prominence & CME May 19, 2007

At time of X-ray flare peak

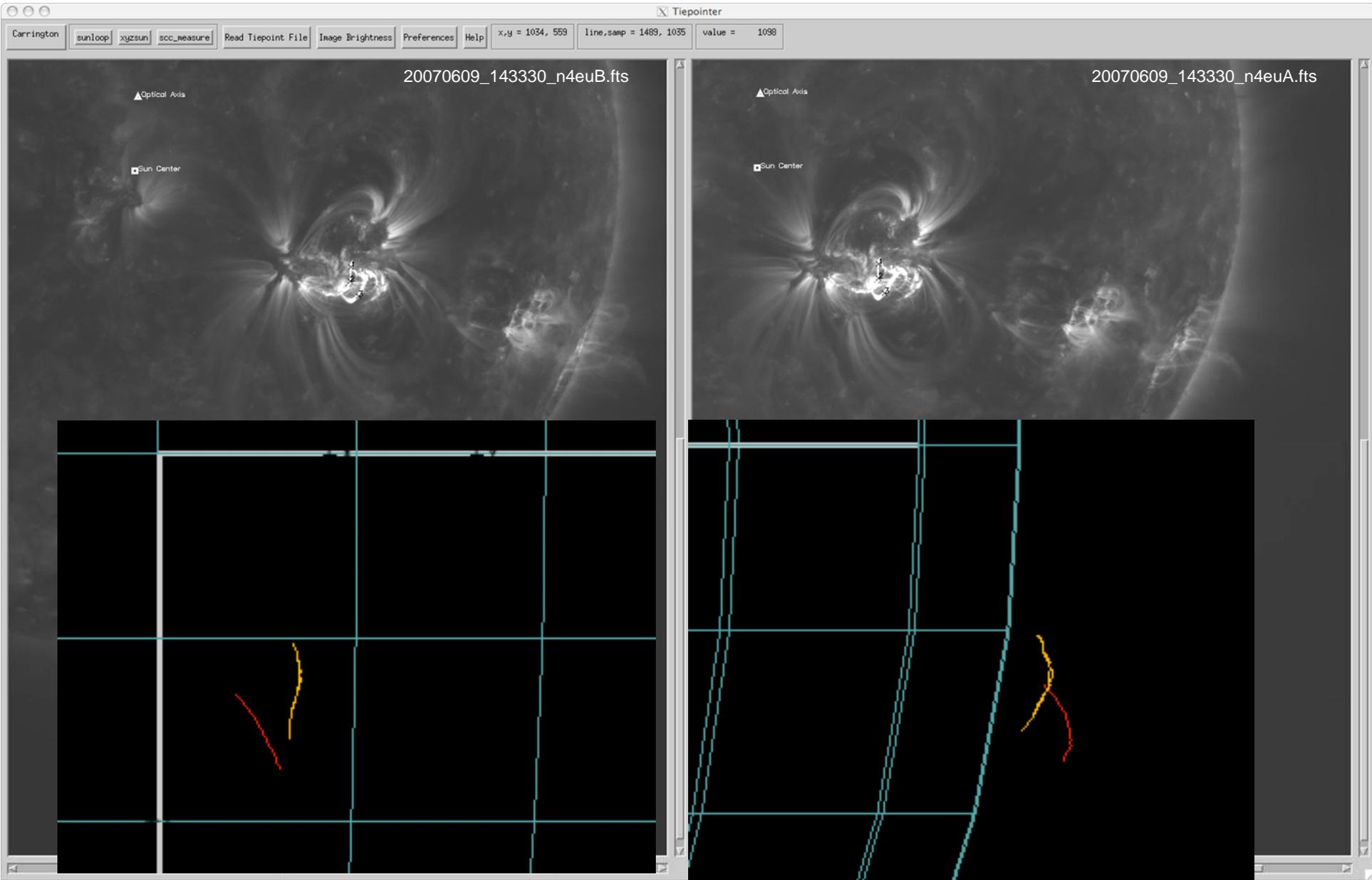


AR Prominence & CME May 19, 2007

Post-flare arcade



Sunloop Reconstruction of June 9 Non-Potential Flare Loops



May 19, 2007
23:30:00

CME
in
HI1 B
May 19,
2007
23:30

