CME Observations Involving a Coronal Wave and Magnetic Cloud

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INTRODUCTION

- **On 17 January 2010 active region 11041 was associated with an energetic CME, dimmings and global coronal wave.**
    - **- Later it rotated onto the Earth-facing disk producing a series of M-class X-ray flares.**

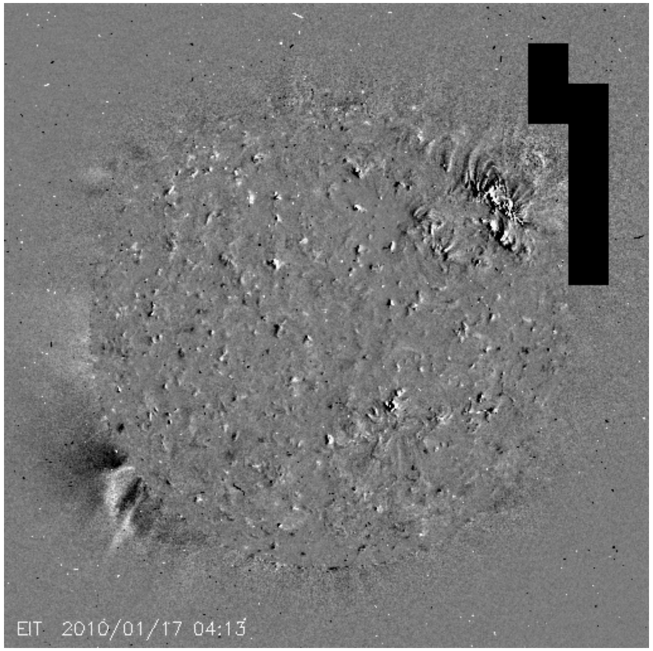
- **During launch the CME revealed an unusual circular profile viewed from STEREO-B with EUVI and extending into the COR1 field.**
    - **- Observed over the SE limb from SOHO EIT and LASCO as a partial halo.**

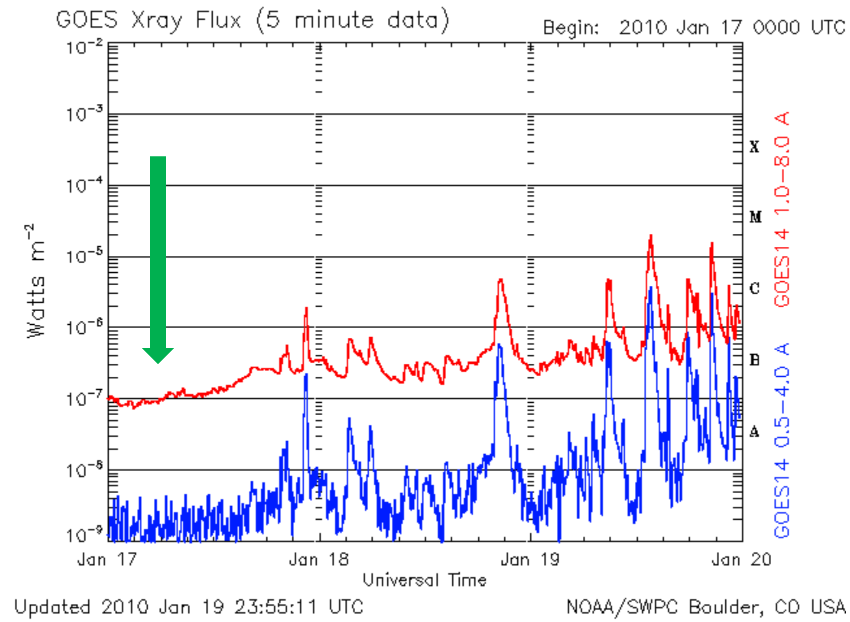
- **Importance of this event is in the multiwavelength observations with high time cadences of limb observations of an eruption and wave and its propagation to 1 AU.**
    - **- Important for understanding relationship between CME and wave.**
        Several popular ideas: 1) The coronal wave is a freely propagating MHD wave, initiated by either the CME or the flare
        2) that the wave maps the footprint of the CME in the low corona
        3) that both can occur yielding two or more different waves.
    - **- This event permits study of origin and driving of the wave(s) because the flanks of the CME and its relationship to the wave can be studied in detail.**

- **The STEREO and SOHO views near the Sun and HI-2A and SMEI views in the heliosphere suggest that at least part of the CME traveled toward ST-B**
    - **- Small magnetic cloud was observed at ST-B on 21 January**

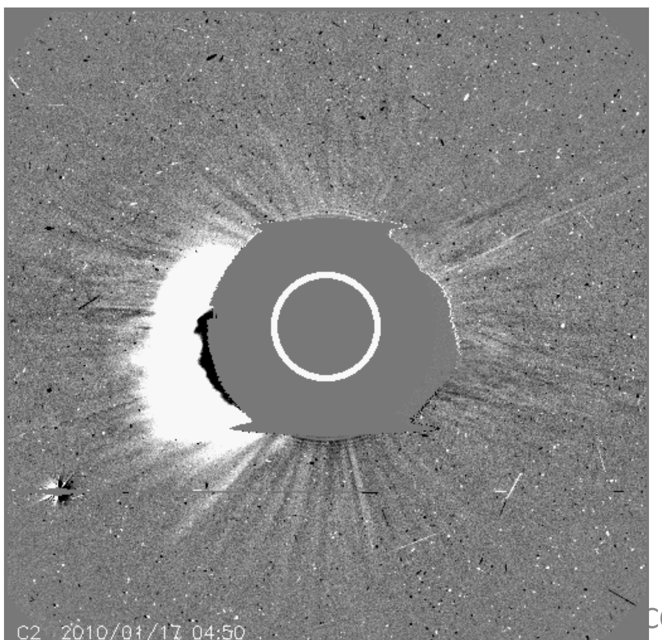
17 January Event Viewed from Earth/L1

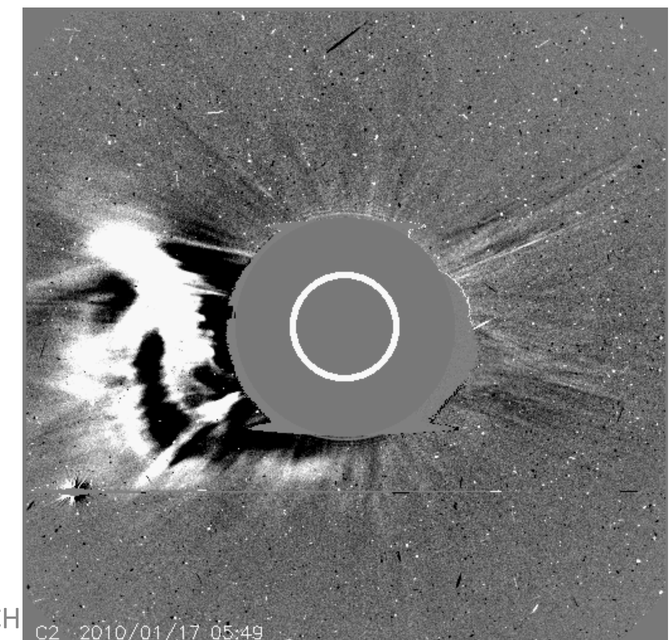
SOHO EIT; 04:13





SOHO LASCO; 04:50

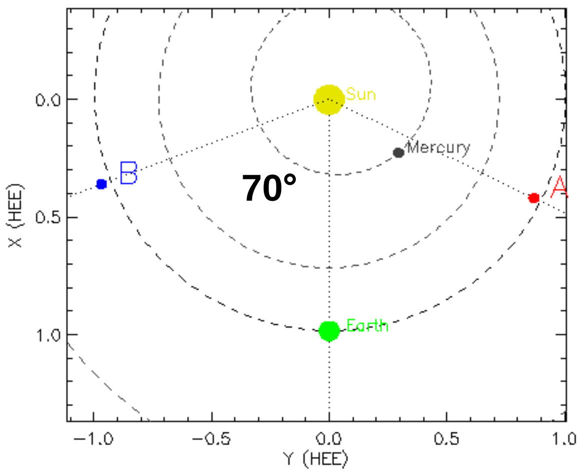




SOHO LASCO; 05:49

One complex event or 2 events?

17 January Event Near Sun Viewed from STEREO-B

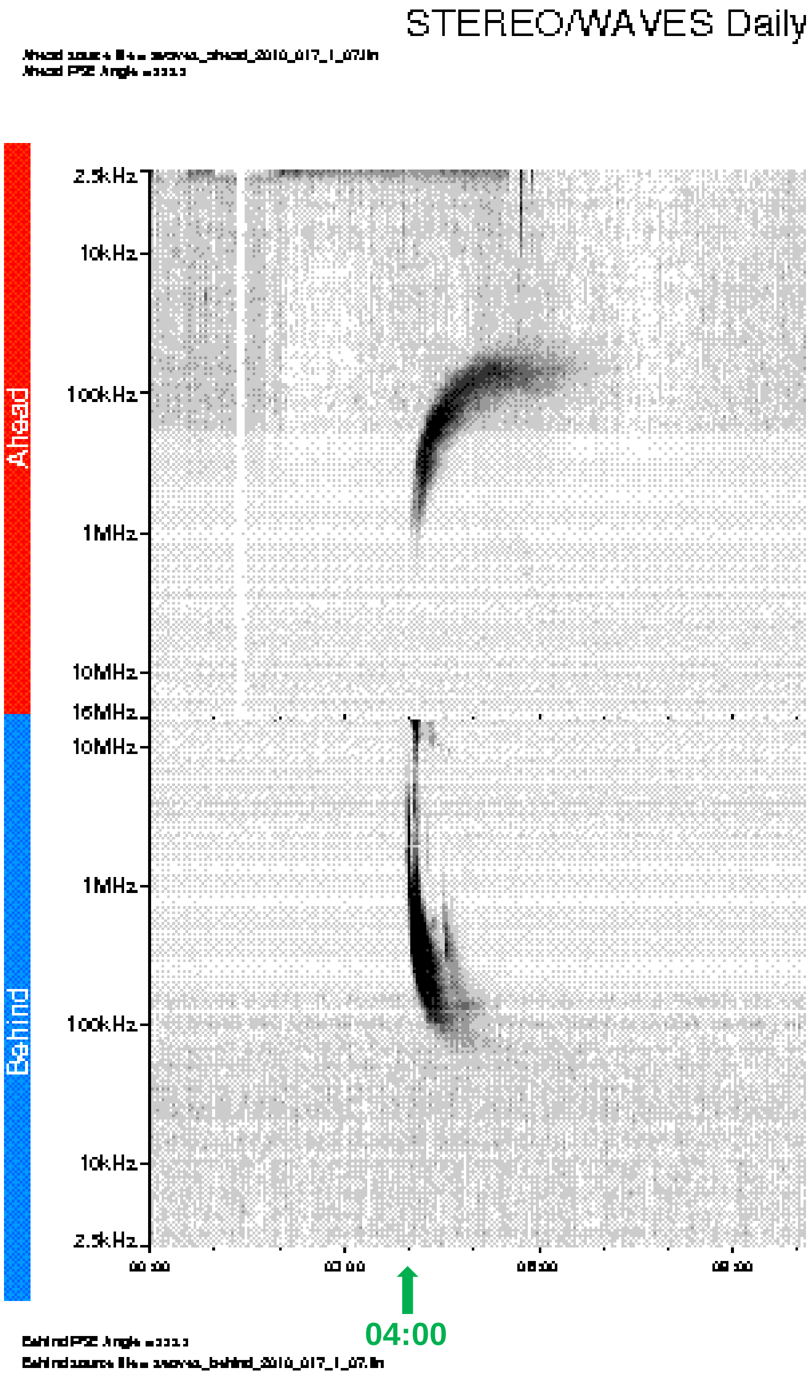


Nitta's EUVI-B 195 RD + COR1-B QT movie

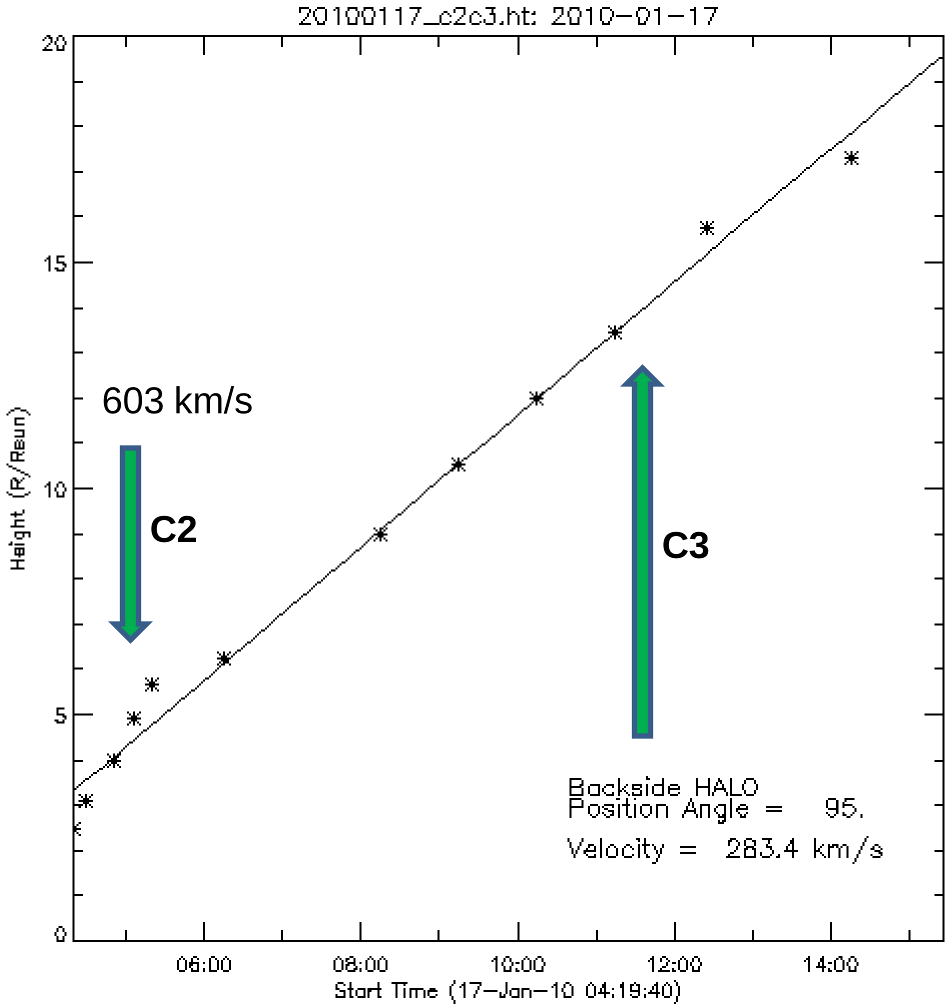
Nitta's EUVI-B 195 RD + COR1-B + COR2-B QT movie

A Type III radio burst was observed by S/Waves on both STEREOs. Its hi-frequency onset was < 04:00 UT; consistent with first image of event at 03:51 UT.

Unfortunately, there were no X-ray, Hα, or magnetic field data for the event, precluding detailed analysis of its impulsive phase, surface topology, energy budget, etc.

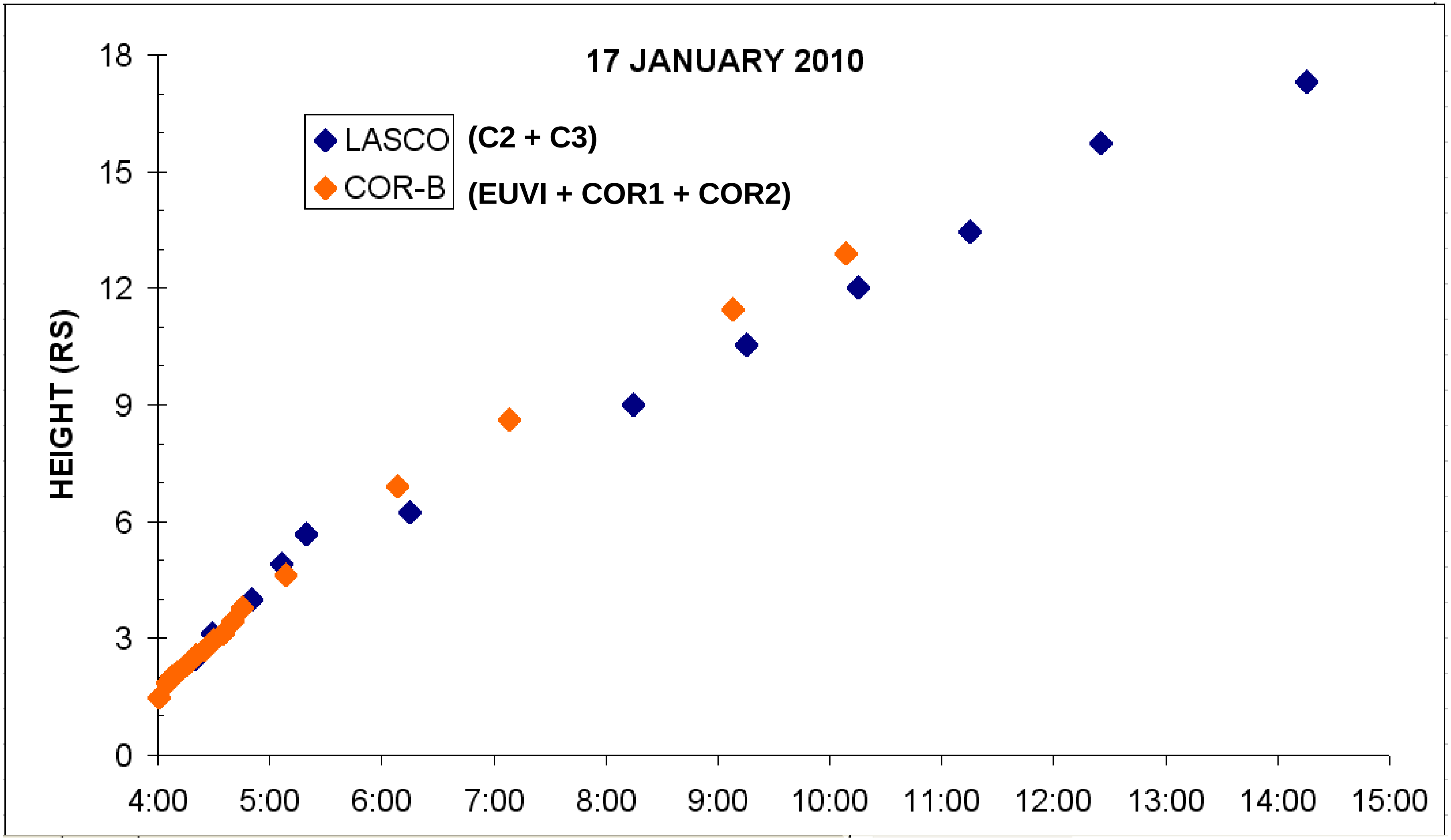


LASCO H,T: Fast Early Phase; 2 Events or Multiple Structures?



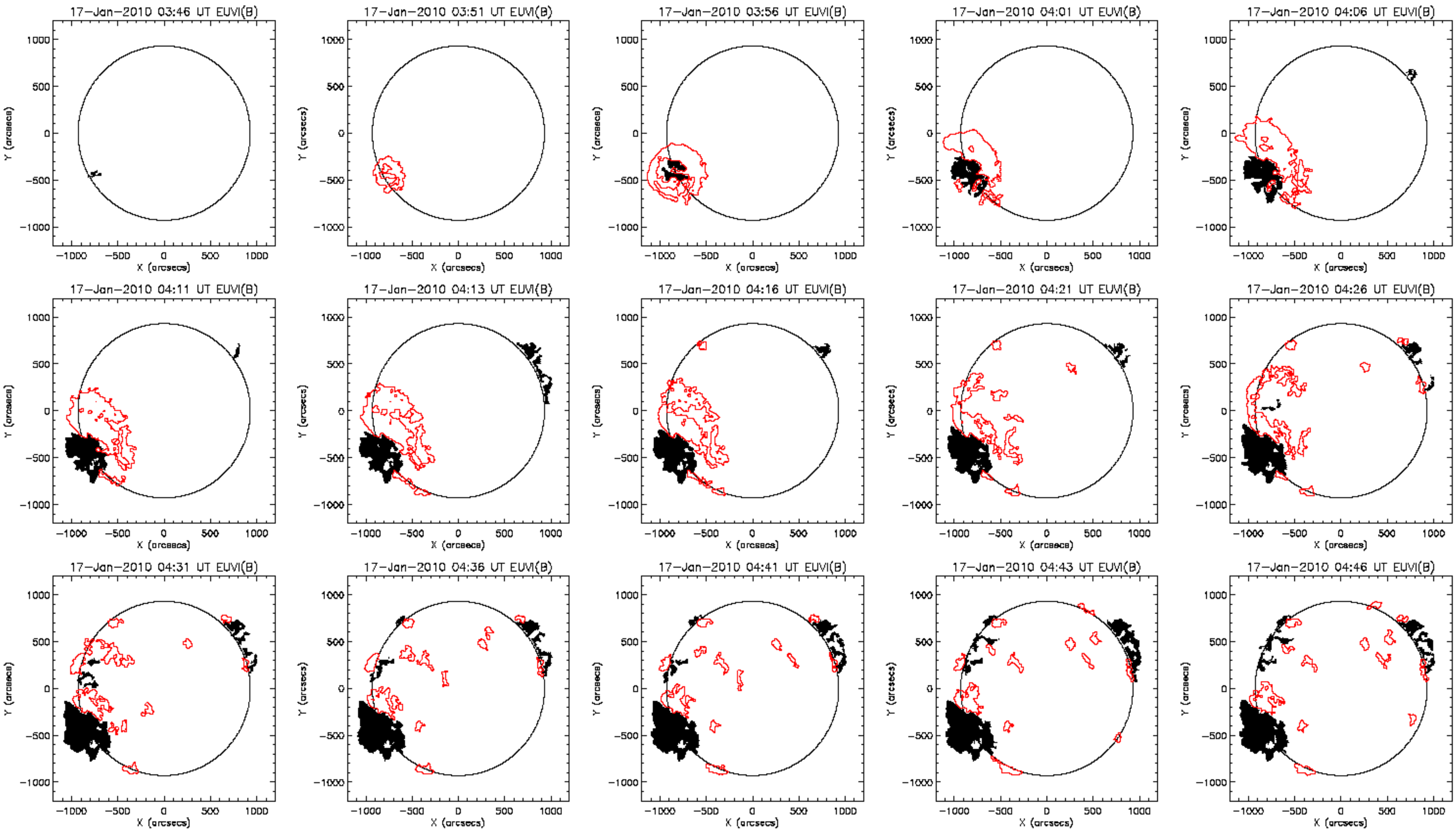
Courtesy K. Schenk, GSFC

STEREO-B + LASCO H,T's: Remarkably similar despite 70° separation. Suggests a large, geometrically symmetric CME?



N. Nitta & T. Howard

Extracted dimming (black) & brightening (red) areas (areas > 1 arc-min^2)



G. Attrill

CME Mass Derived from Dimming Areas (G. Attrill)

- To calculate the mass removed from the event dimmings, we included only dimmings to the east of central meridian, those likely involved in the CME.

- Calculated change in intensity between pre-event data at 03:41 and 04:41 UT when the dimming was well established, but before recovery was underway.

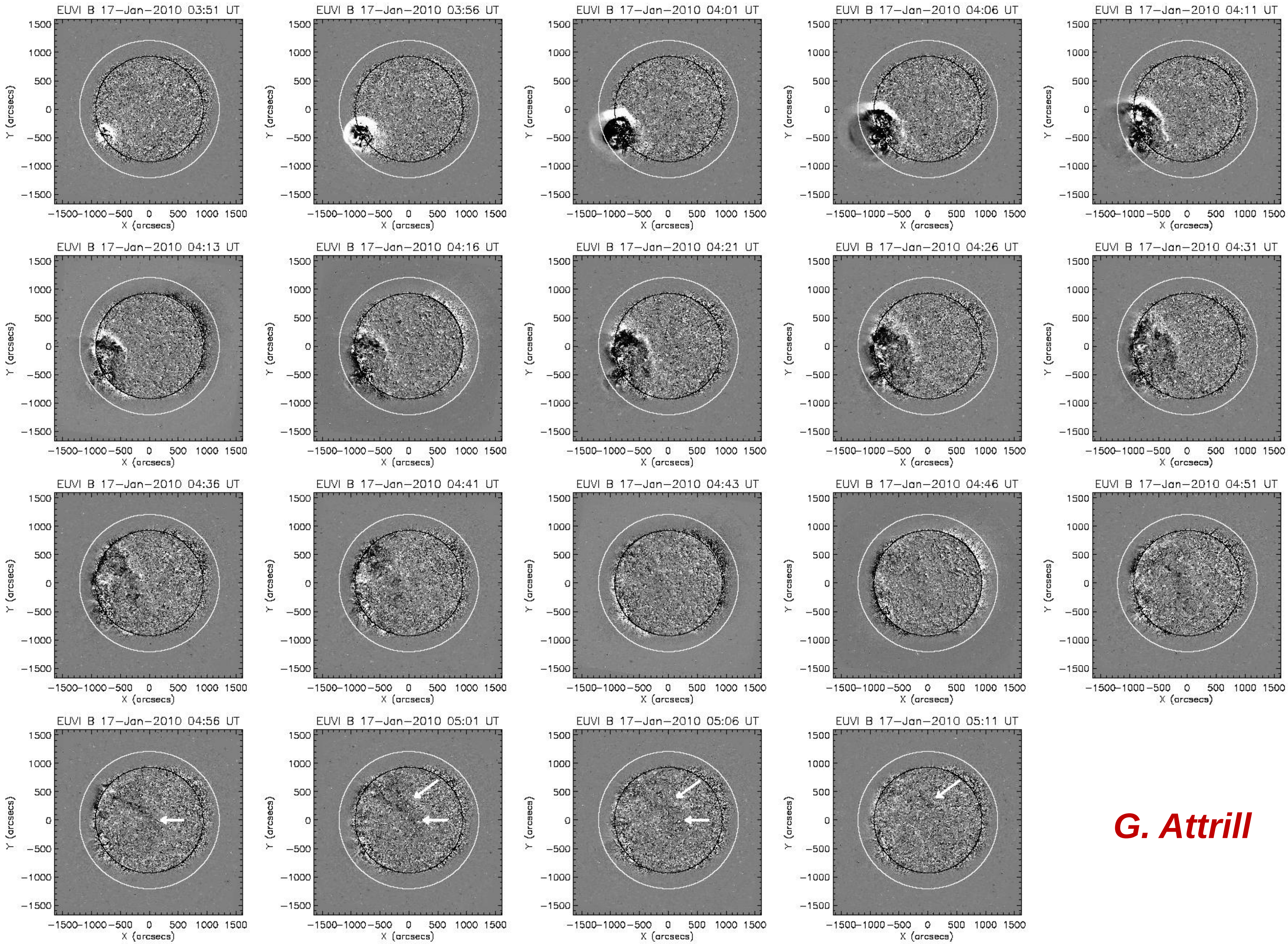
- Using standard coronal density range of $5 \times 10^8 – 1 \times 10^9$ cm^{-3}, the mass removed from the dimmings ranges from: $2.7 - 5.4 \times 10^{16}$ g.

- Using a modified coronal density range of $2.4 - 3.0 \times 10^8$ cm^{-3} (as derived by Aschwanden et al. [2009] for the coronal background density in EUVI 195Å data), the mass removed from the dimmings is in the range: $1.3 - 1.6 \times 10^{16}$ g.

- These values are typical of masses of large CMEs derived from white light data; e.g., Vourlidas et al.

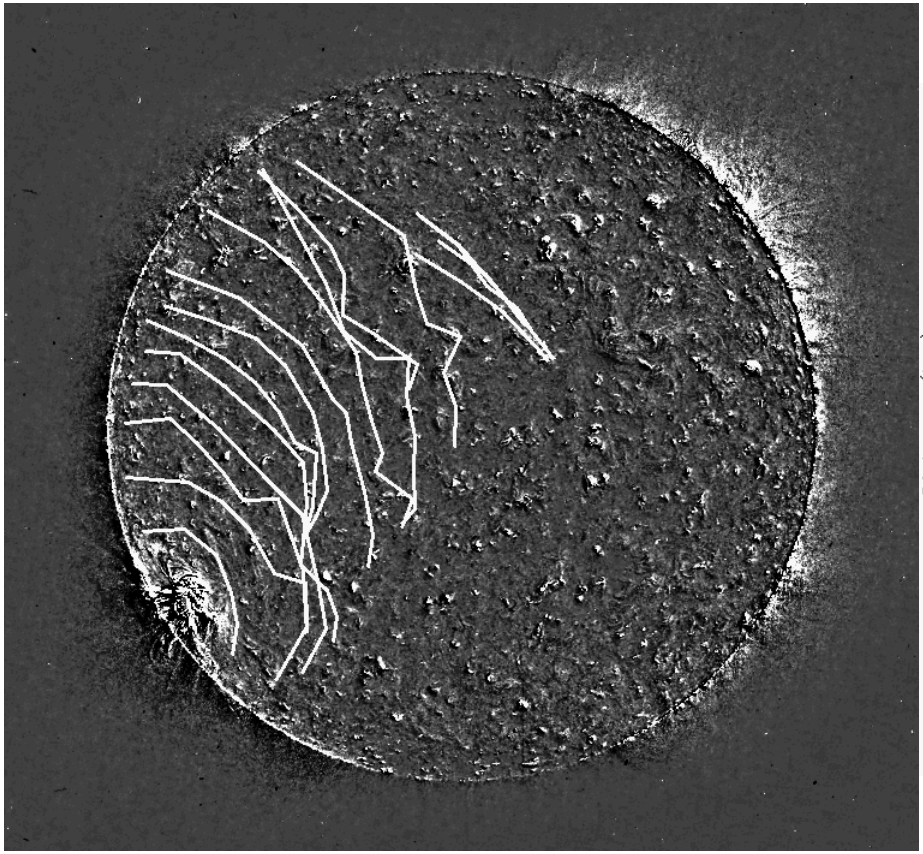
- Following Attrill & Wills-Davey (2009), these calculations assume that the quiet coronal height of 100 Mm (one pressure scale height) is analogous to the intensity of most of the pixels in the pre-event data. The corresponding column depth for each pixel is then normalized with respect to this value.

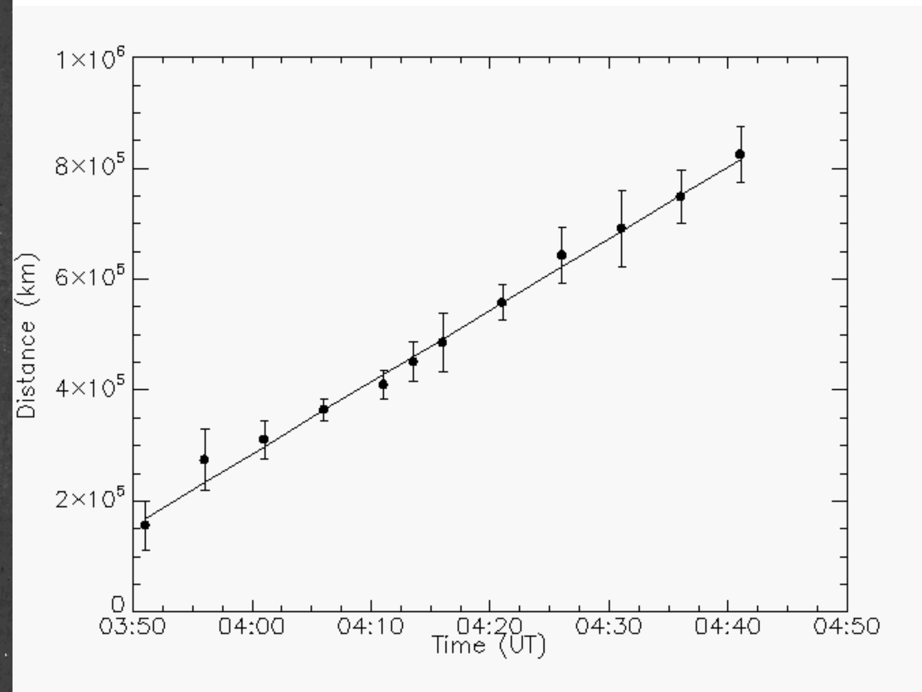
EUVI-B 195Å Running Difference Images: 17 January 2010 Event



G. Attrill

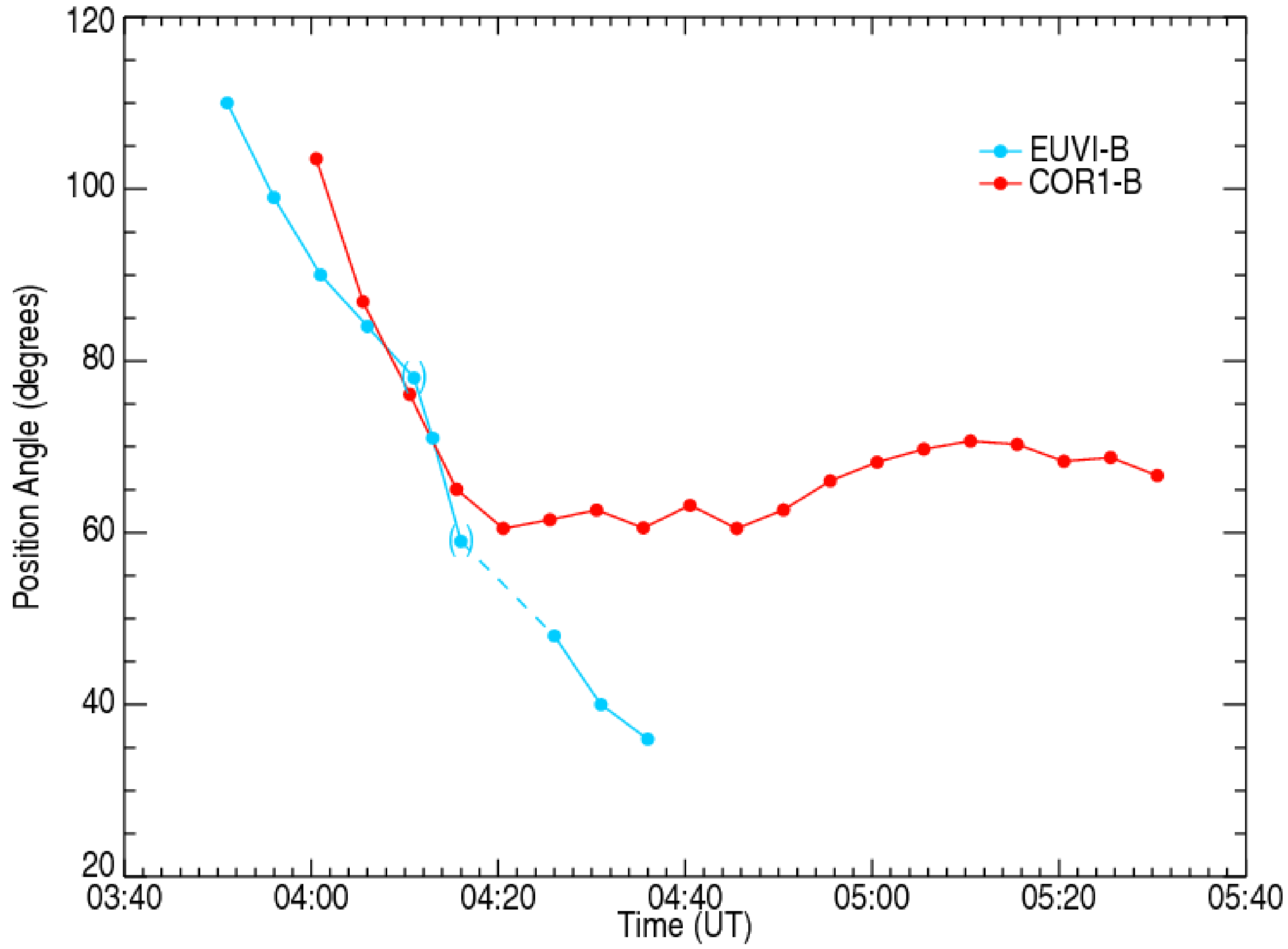
EUVI-B Wave Kinematics





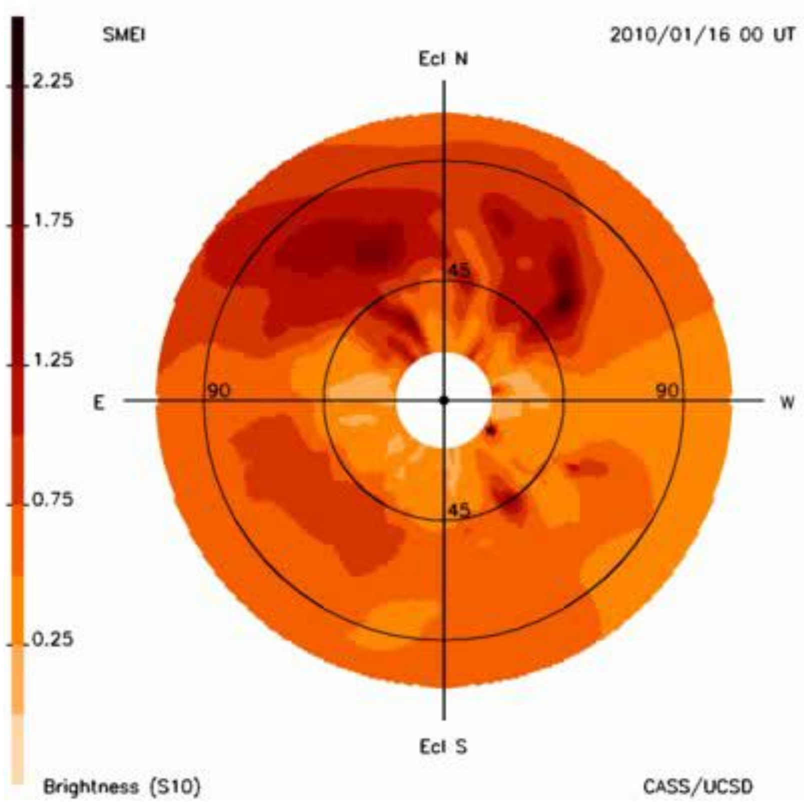
Left: **Track of 195Å wave front vs time on pre-event R-D image at 03:46 UT.**
Right: **Wave velocity = 216 ± 14.5 km/s. Used fitted-centroid technique (e.g., Veronig et al., ApJ, 2006; Muhr et al., ApJ, 2010). Errors are from the range of distance values along a given frontal track.**

CME Flank Expansion vs EUV Wave



PA vs time of northern CME flank (COR1B-red) and surface wave (EUVIB-blue) near limb from RD images. Wave and CME flank are contiguous until 60° when CME expansion stops. During first ~30 minutes, the "wave" mapped the CME footprint as far as ~ 1Rs from the source region. For next ~20 minutes, a weak disturbance expanded from the final location of the CME flanks, consistent with it being a freely propagating wave. Our interpretation is that the wave is initially driven by the CME and then becomes freely propagating after the CME lateral expansion ends.

SMEI 3-D Reconstruction of Heliospheric Density in Fisheye View: 16-22 January 2010



Note looplike structure starting ~17 January. This may be associated with the 17 Jan. east limb CME but most material is north and it seems slow.

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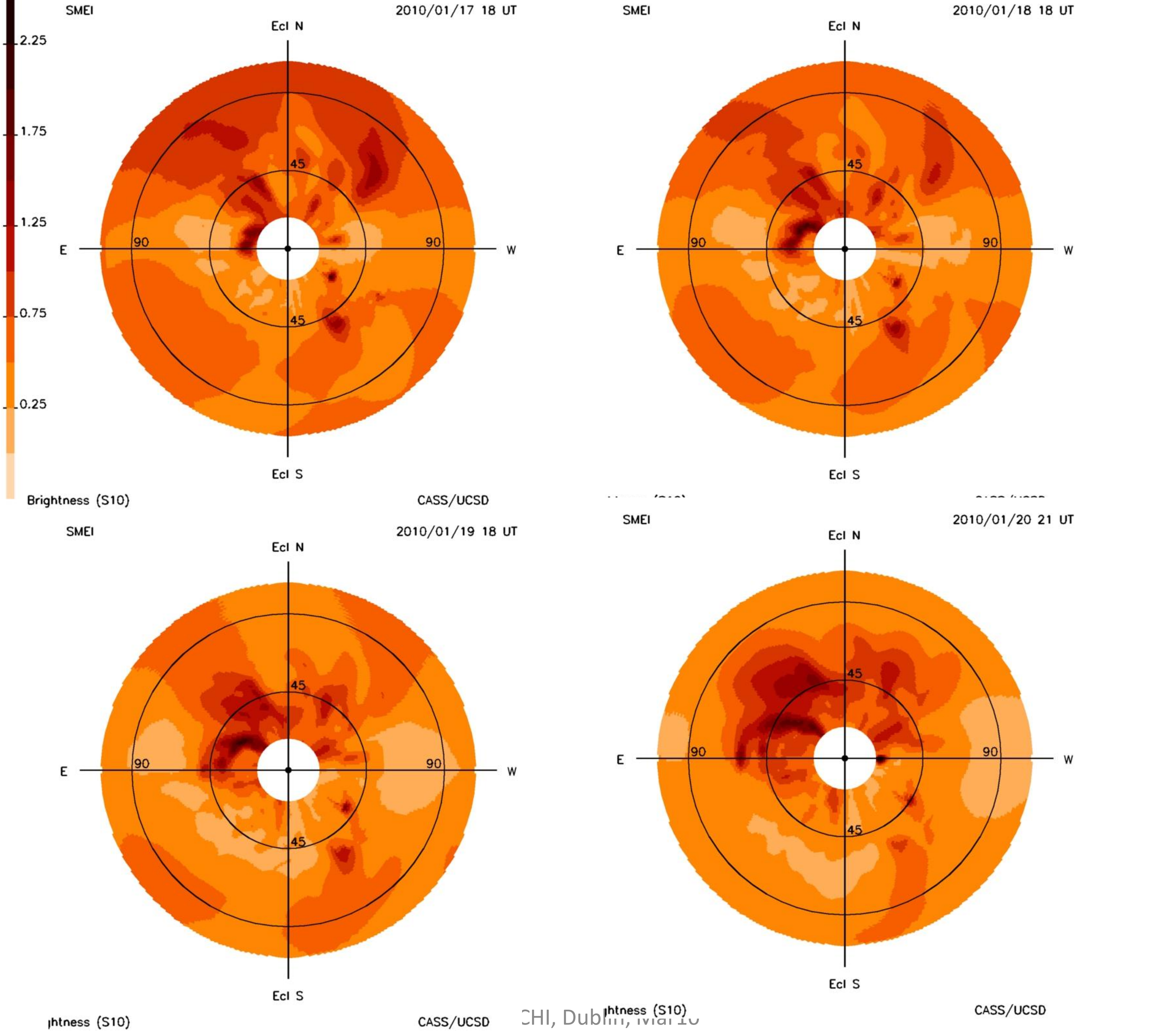
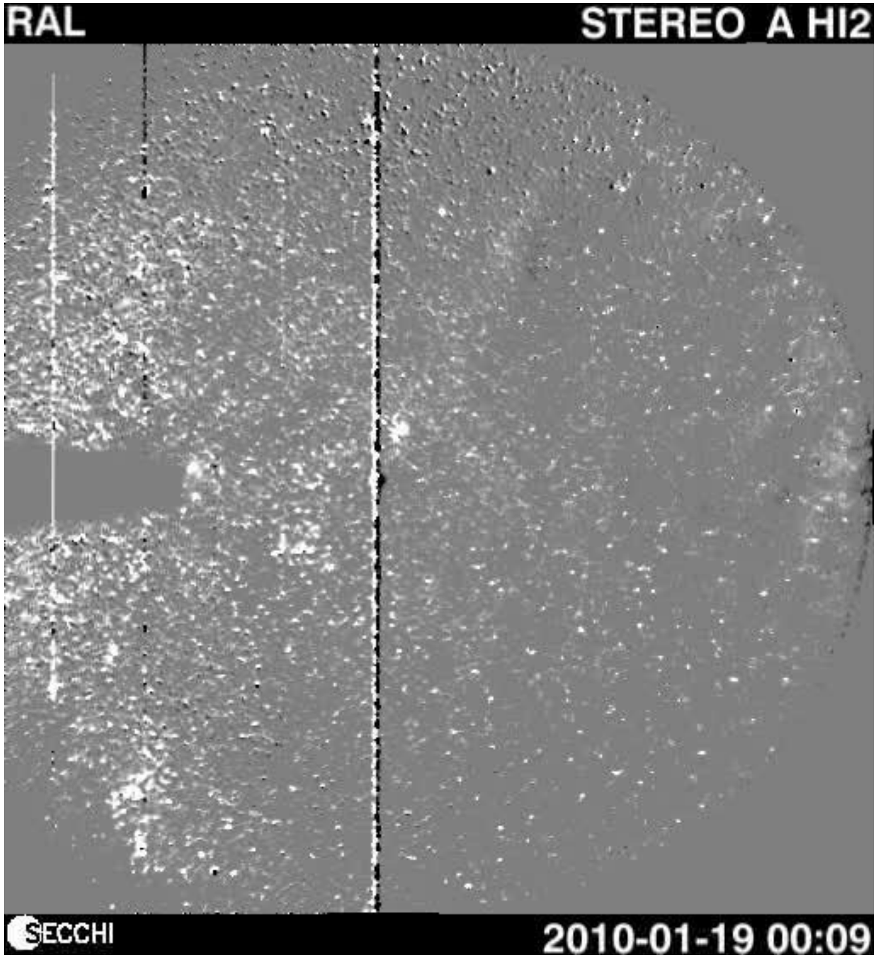
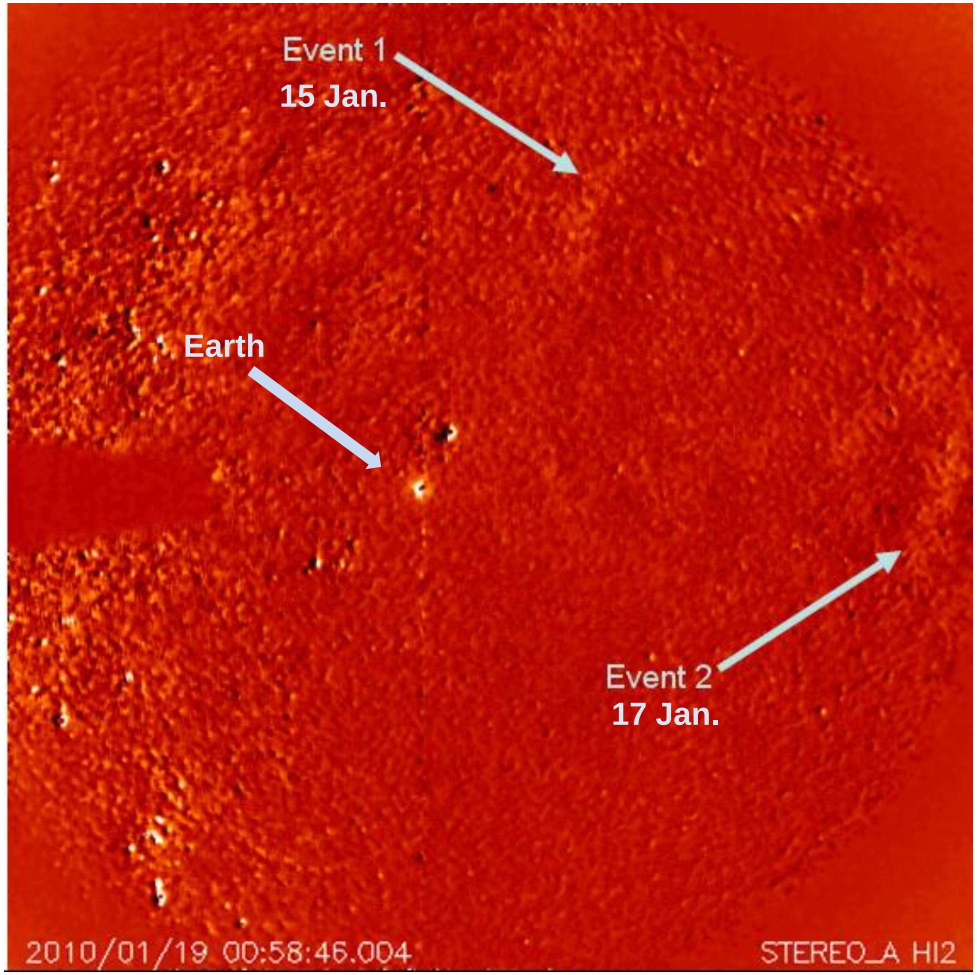

SMEI
2010/01/17 18 UT
Ecl N
Ecl S
E
W
90
45
2.25
1.75
1.25
0.75
0.25
Brightness (S10)
CASS/UCSD
SMEI
2010/01/18 18 UT
SMEI
2010/01/19 18 UT
SMEI
2010/01/20 21 UT

HI-2A confirms SMEI density structures near ecliptic, including northern extent of leading band. Event 2 more likely to be related to MC at ST-B.

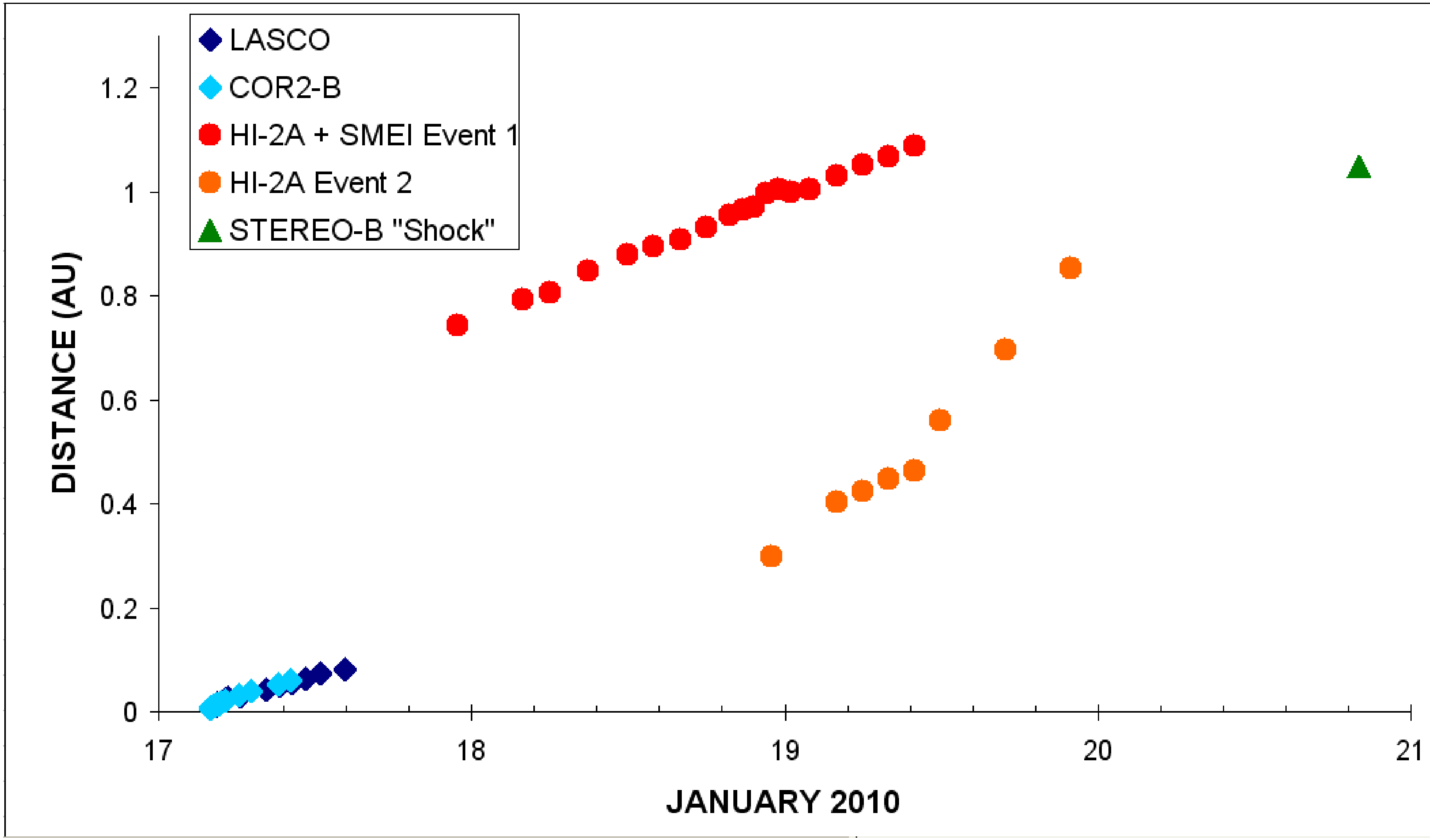


HI-2A daily movie for 19 January



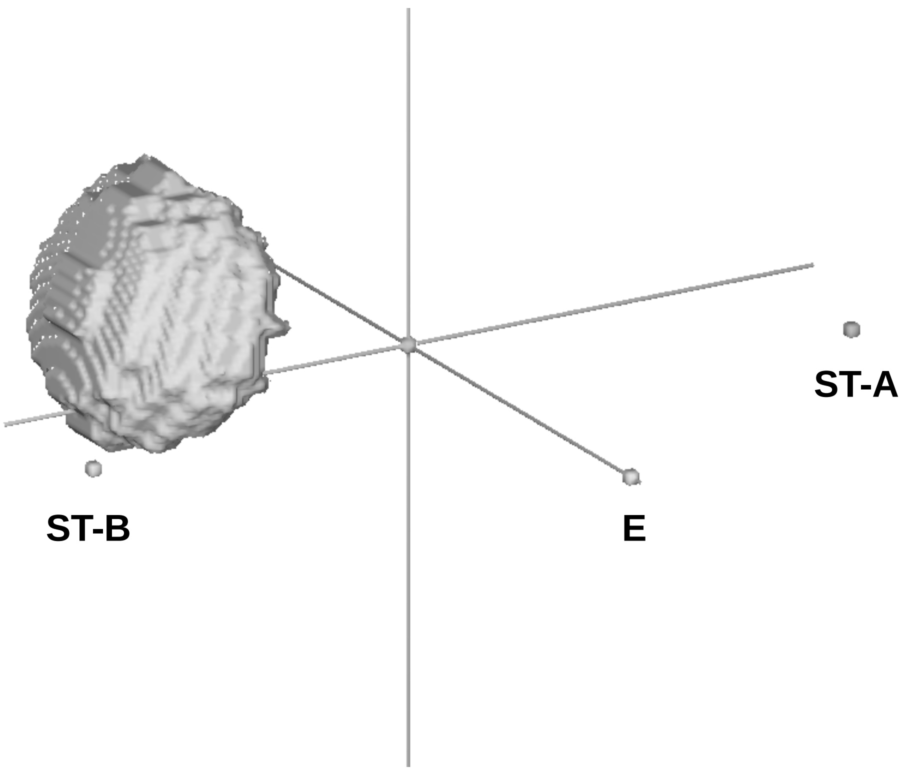
Event structures tracked for TH model runs. Image: 19 January, 00:58

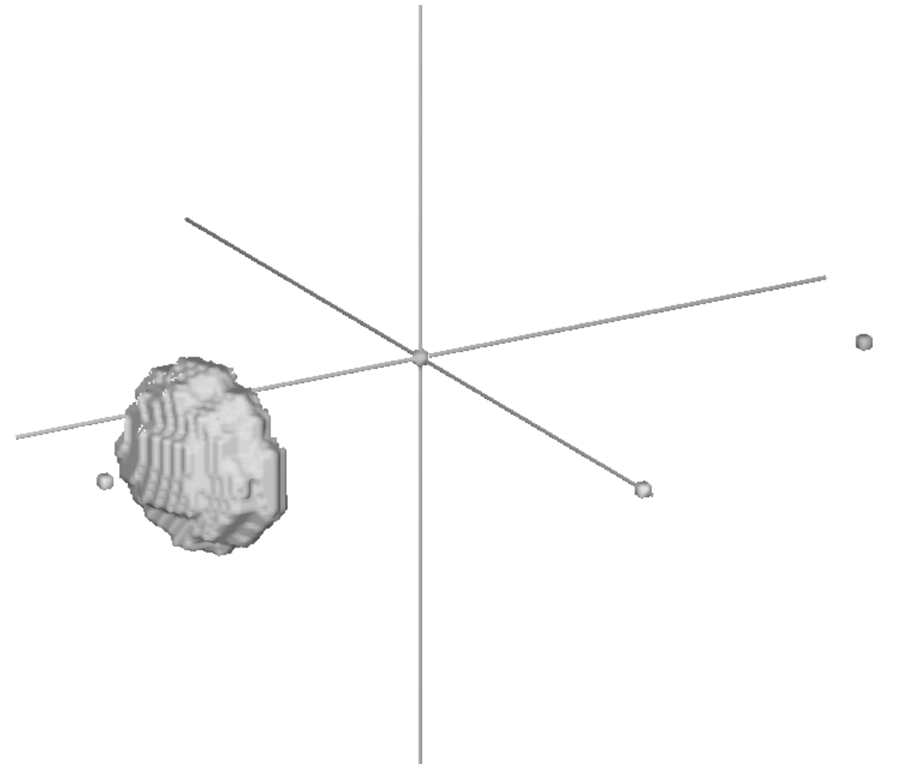
Distance-Time Track from LASCO-COR & in-situ ST-B data and TH Model Fits to Heliospheric Data



T. Howard

3-D Reconstruction of 2 Events Using TH Model Launched on 15 and 17 January



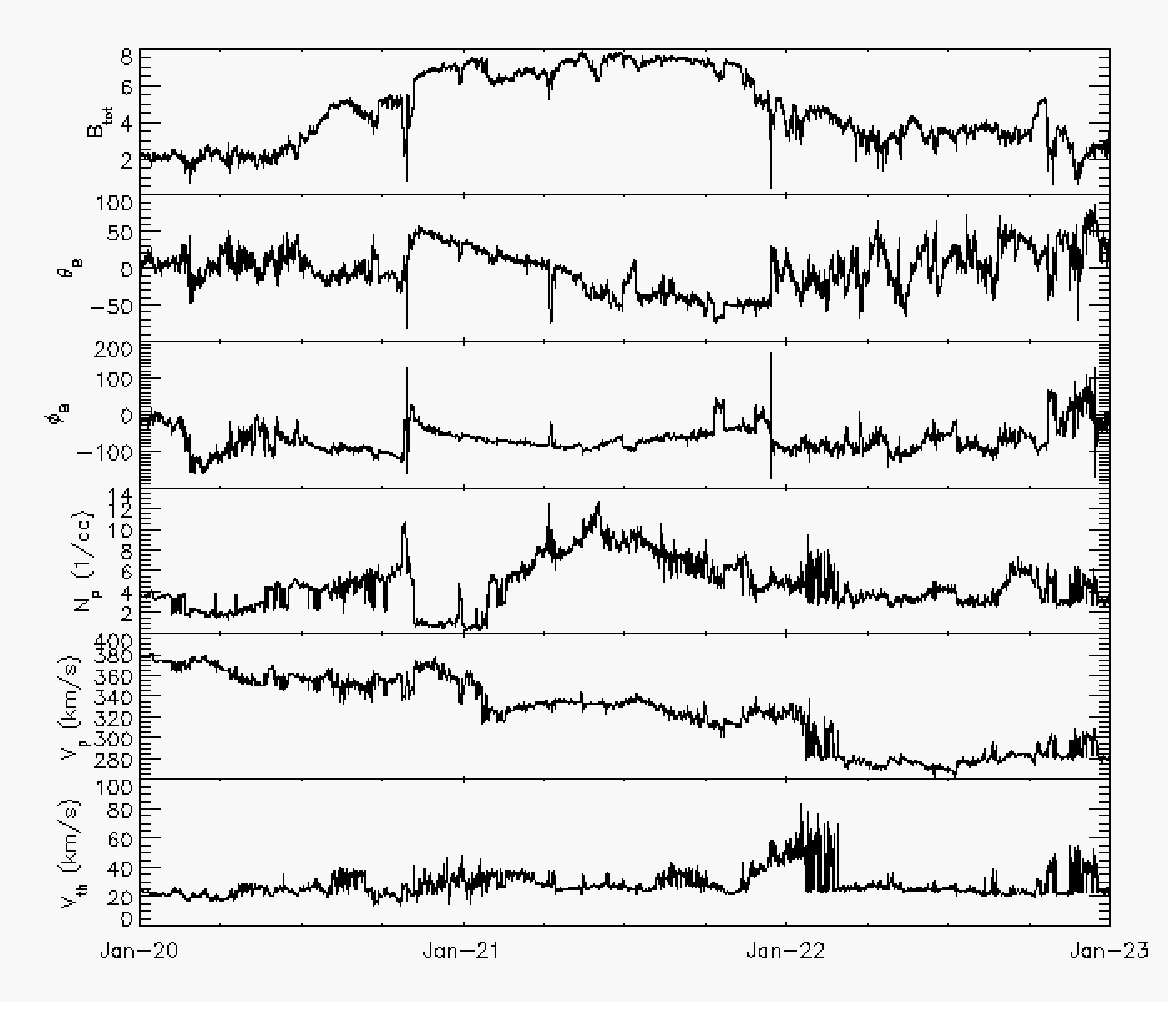


CME launched 15 January
Image on 18 Jan., 15:58 UT.

<u>TH Output</u>
Central long. = 87E
Width = 30°
Speed = 420 km/s
AT ST-B: 19 Jan., 21:05

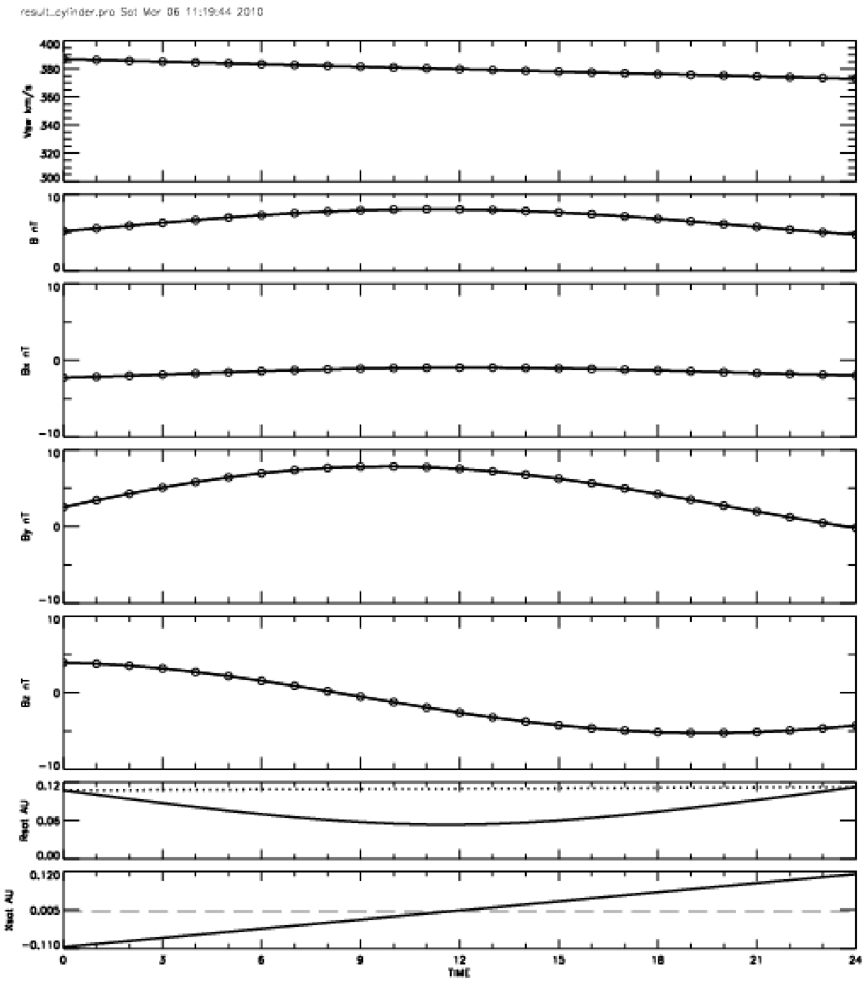
CME launched 17 January
Image on 19 Jan., 21:58 UT

<u>TH Output</u>
Central long. = 72E
Width = 20°
Speed = 850 km/s
AT ST-B: 20 Jan., 09:32



IMPACT MAG; Beacon *PLASTIC; Courtesy L. Ellis & K. Simunac, UNH*

Marubashi Cylindrical Flux Rope Fit



2010/01/20/2100 – 2010/01/21/2100

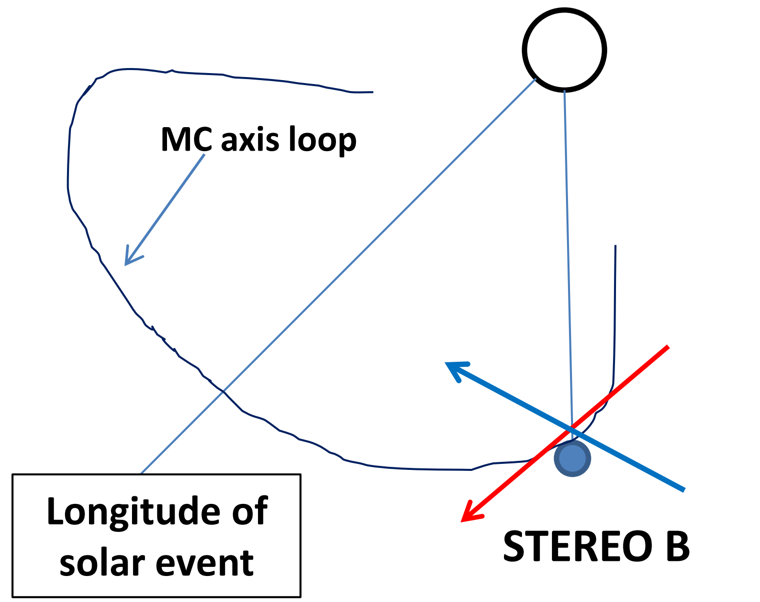
Usw	=	380.000	B_axis	=	10.00
Ro	=	0.1072	LAT	=	−15.000
p	=	−0.5000	LONG	=	60.000
To	=	487.1	SGN	=	1

RMS(Vsw) = 0.00 RMS(Bvec) = 0.00

RMS_B/Bmax = 0.000

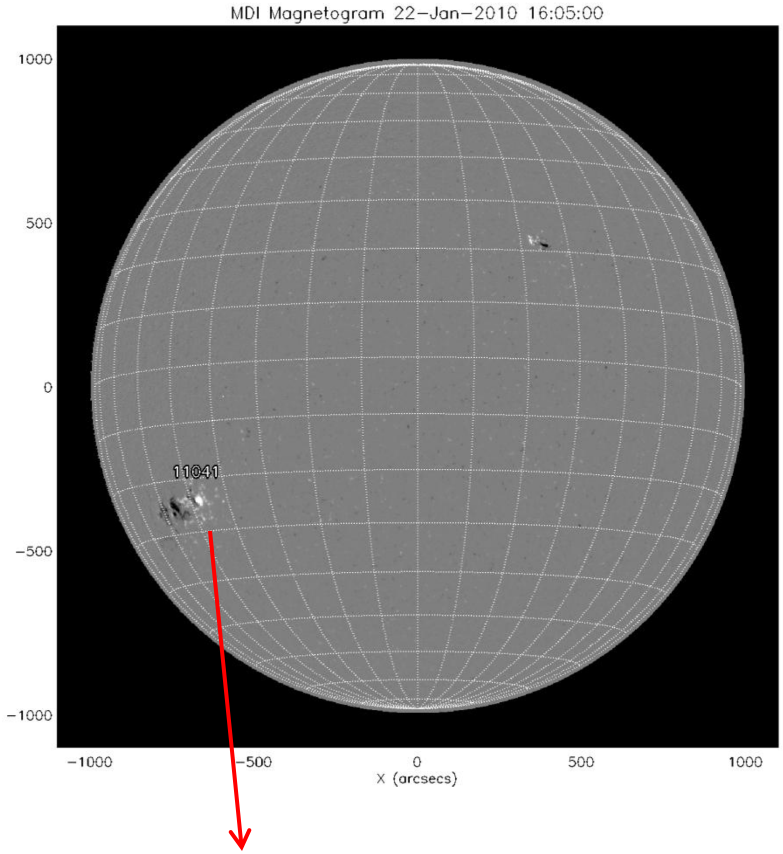
This is a cylinder-fitted result with a "pseudo data", which consists of model values with Bx being replaced with –Bx. (Dots - data points, curves - fitted results.)

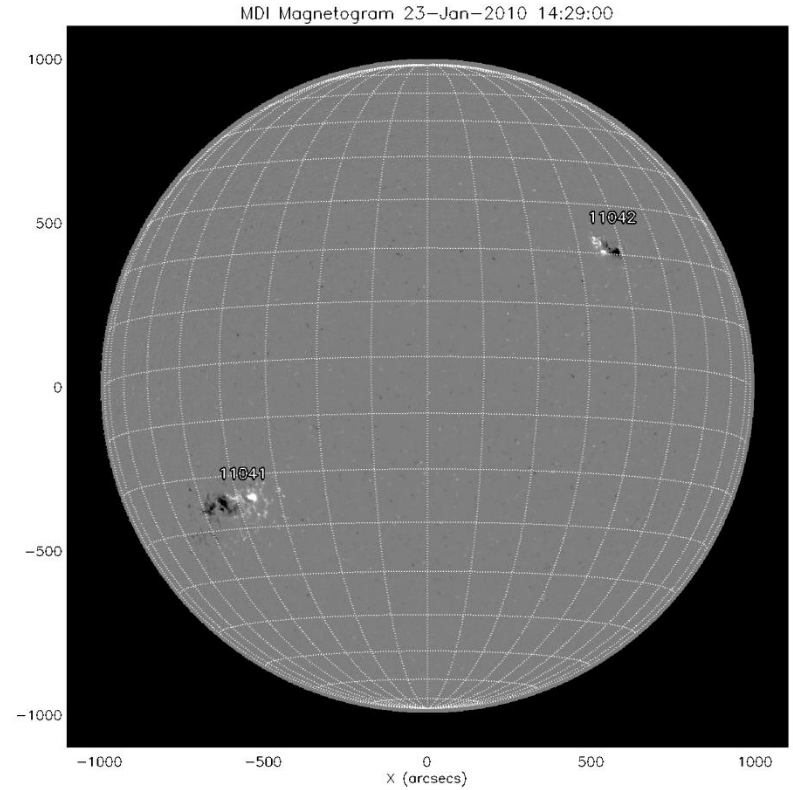
The direction of MC axis obtained (blue arrow) seems inconsistent with the expected direction (red arrow).

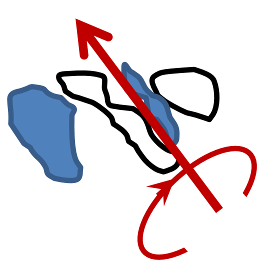


SOHO/MDI image on Jan. 22

MDI image on Jan. 23; AR clearly dipolar

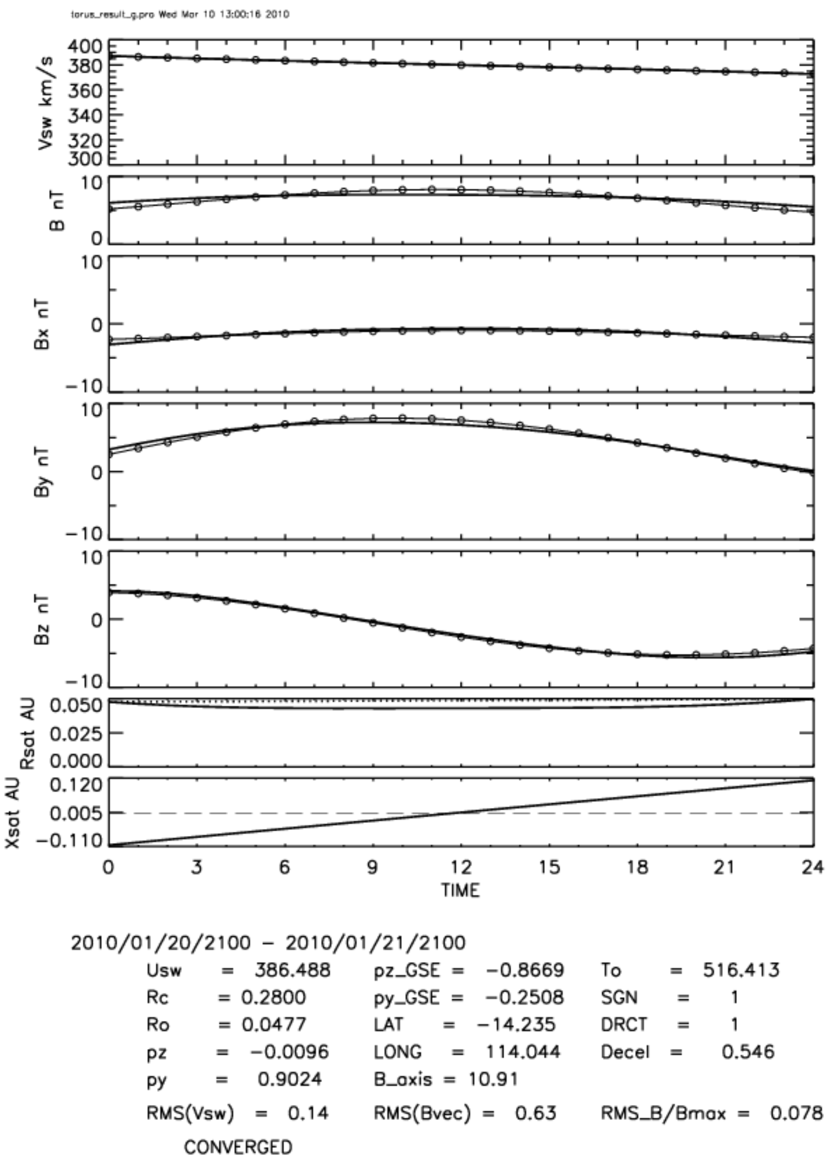




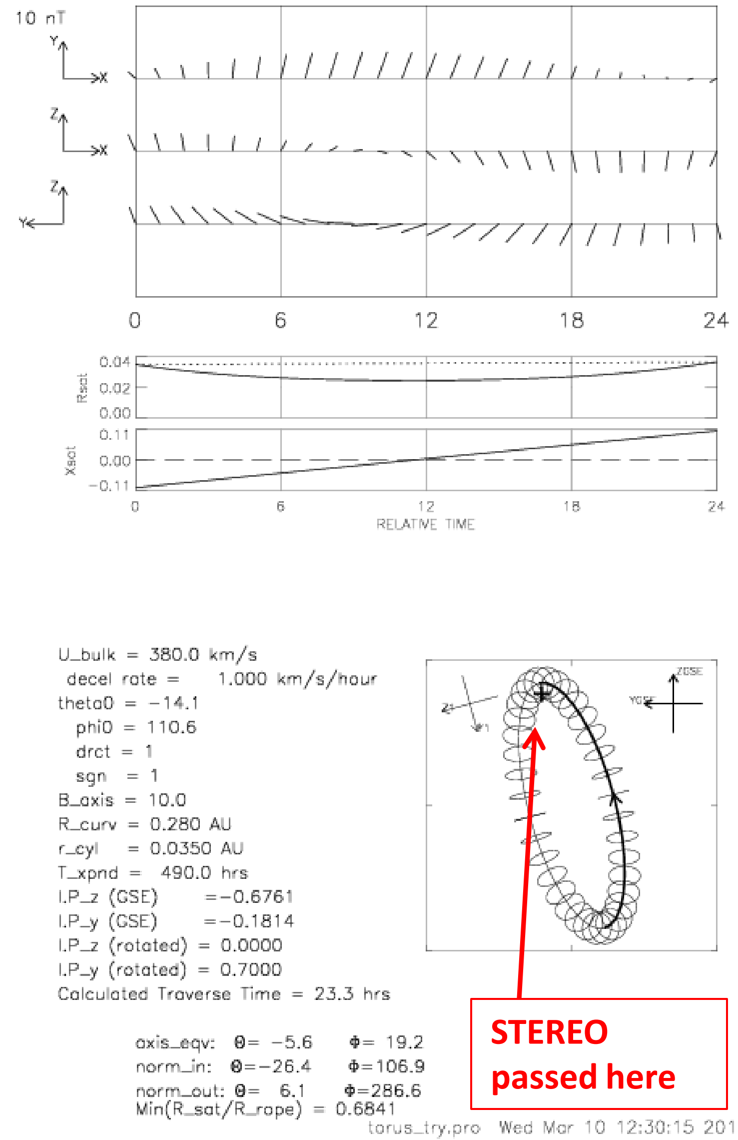


If the magnetic structure was like that observed on Jan. 22 (SOHO/MDI) and if the eruption occurred at the inversion line schematically shown here, the orientation of the MC axis loop obtained from the fitting seems consistent.

Better torus-fitting result



Torus encounter geometry



CONCLUSIONS

- ***Importance of event:***
  - **- Multiwavelength observations with high time cadences**
  - **- Limb observations of a CME, dimmings & a coronal wave in low corona**
  - **- ICME/MC observed & modeled at ST-B 3.5 days later**
  - **- Heliospheric observations & modeling of event**

- ***Dimmings & CME Mass:***
  - **- Mass loss calculated from dimming areas → 1.3 – 5.4 x 10^{16} g; typical of large CME.**

- ***Wave results:***
  - **- Wave speed typical of EIT waves: 216 km/s.**
  - **- EUVI wave not clearly detected in EIT despite some overlap.**
  - **- Wave closely tracks CME lateral expansion, then smoothly continues after expansion stops. Results suggest that there is a single wave and that the CME flank and wave are closely coupled early. Our interpretation is that the wave is initially driven by the CME and then becomes freely propagating after the CME lateral expansion ends.**

- ***Heliospheric results:***
  - **- Early phase of CME suggests launch near ecliptic plane & an elongated NE-SW structure; e.g., partial halo to S from Earth and initial circular structure from ST-B.**
  - **- Heliospheric density obs. affected by earlier Jan. 15 CME.**
  - **- Modeling of later, fainter structure with SMEI & HI data shows consistency with interaction with MC at ST-B.**
  - **- Flux rope fits of ST-B data somewhat consistent with launch orientation of CME. Need to compare with FR forward-modeling like Thernisien's.**

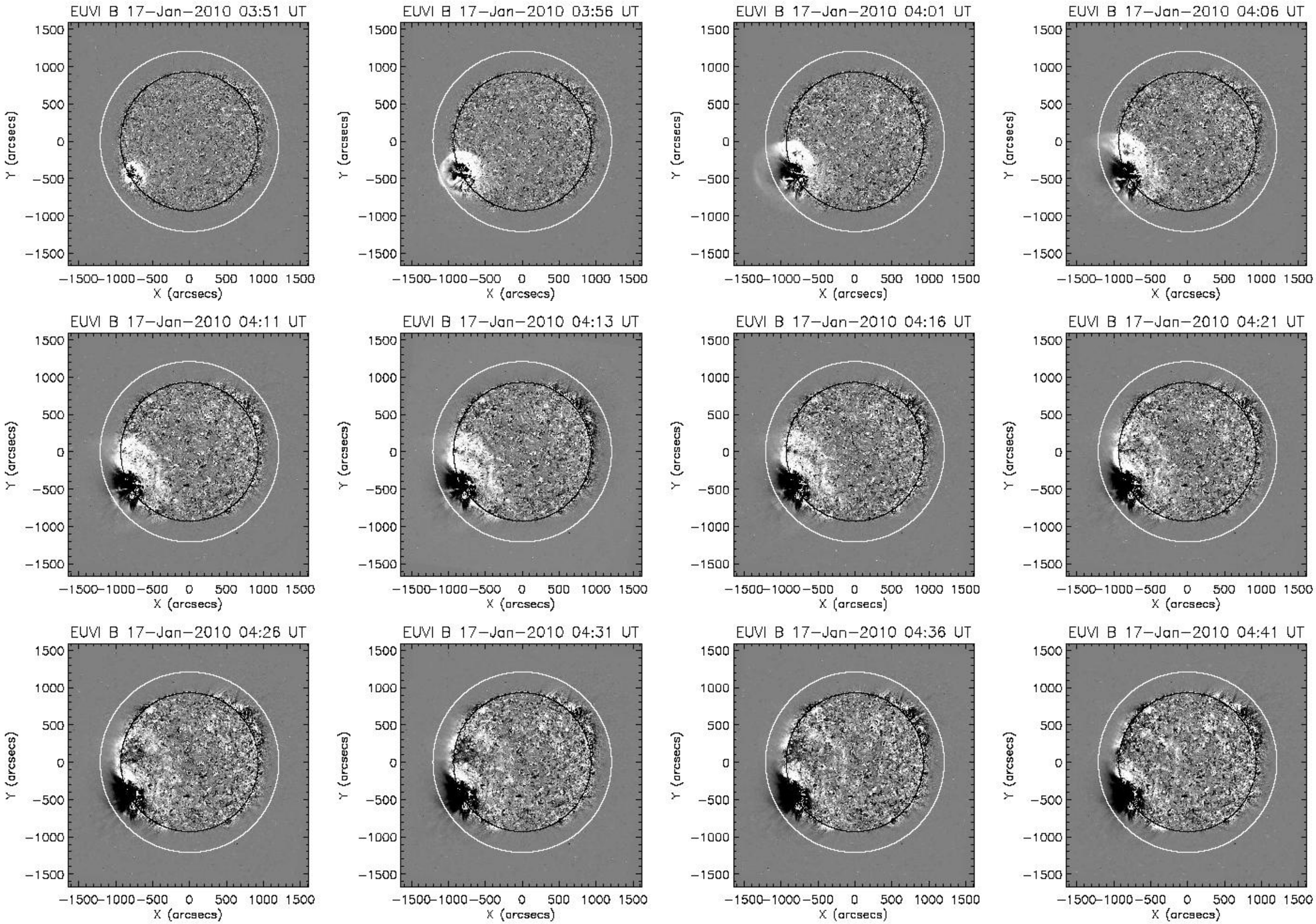
Thanks for assistance from:

Ed Cliver (AFRL), Alan Ling (AER) & John Clover (UCSD)

and

THANK YOU FOR YOUR ATTENTION!

EUVI-B Base Difference Images: 17 January 2010 Event



SMEI 3-D Reconst. of Heliospheric Density in Ecliptic Plane: 16-22 Jan. 2010

Note: Material seems to arrive late at ST-B.