

Automatic CME Leading Edge Detection for SMEI and HI

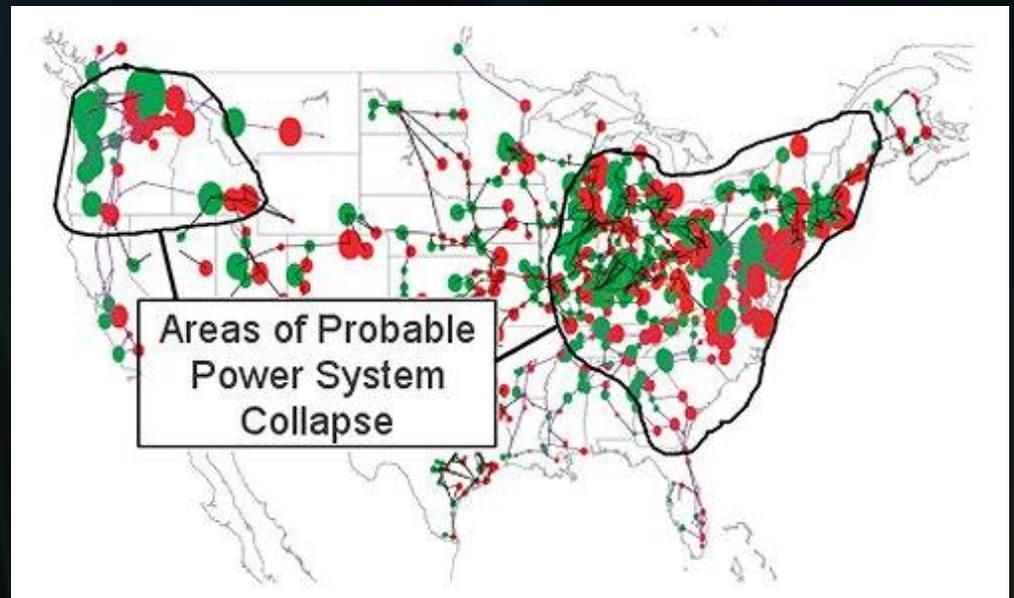
Christina Burns, University of Michigan

Dr. Tim Howard, Southwest Research Institute

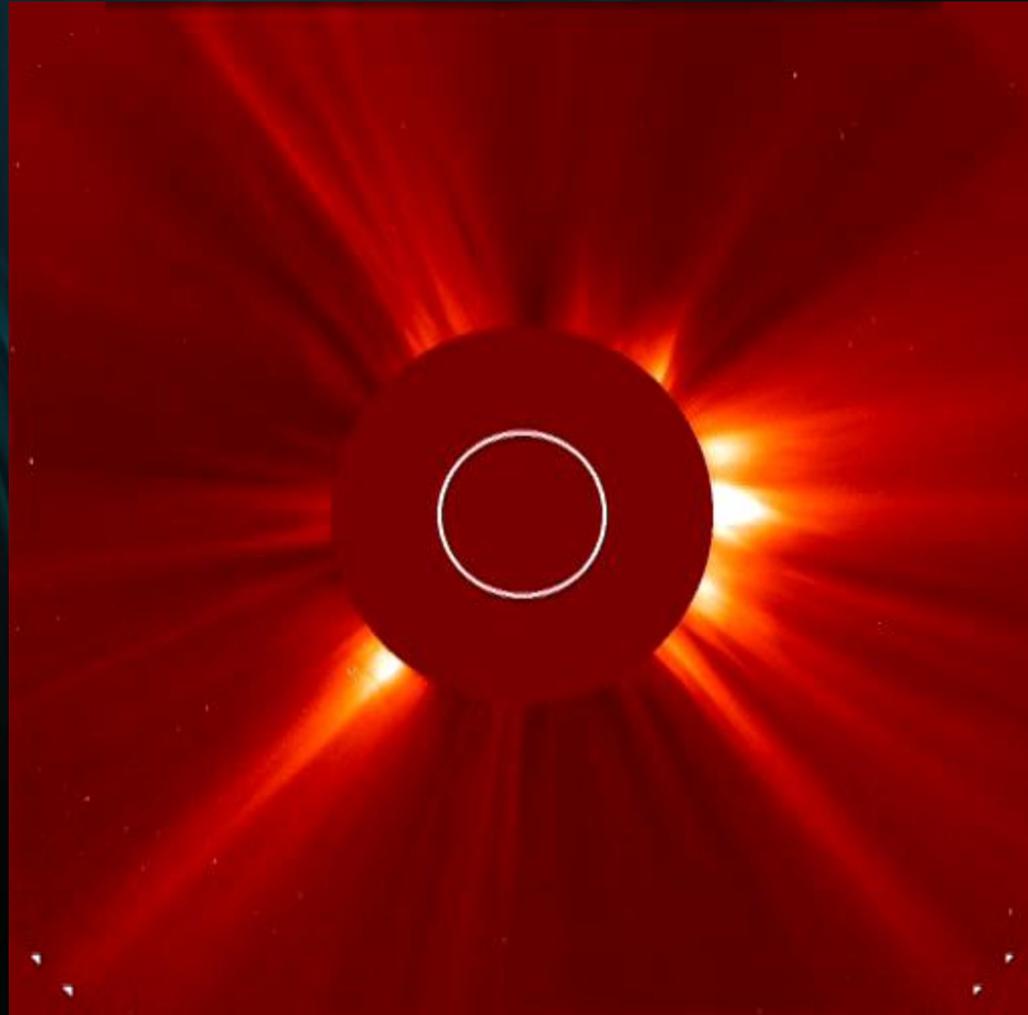


Coronal Mass Ejections (CMEs)

- Large magnetic plasma bubbles that are ejected from the sun over several hours
- Often associated with solar flares or prominences
- Can cause storms bringing huge problems to us on Earth
- Typical speed: 500-1000 km/s
- 1-5 days to impact Earth

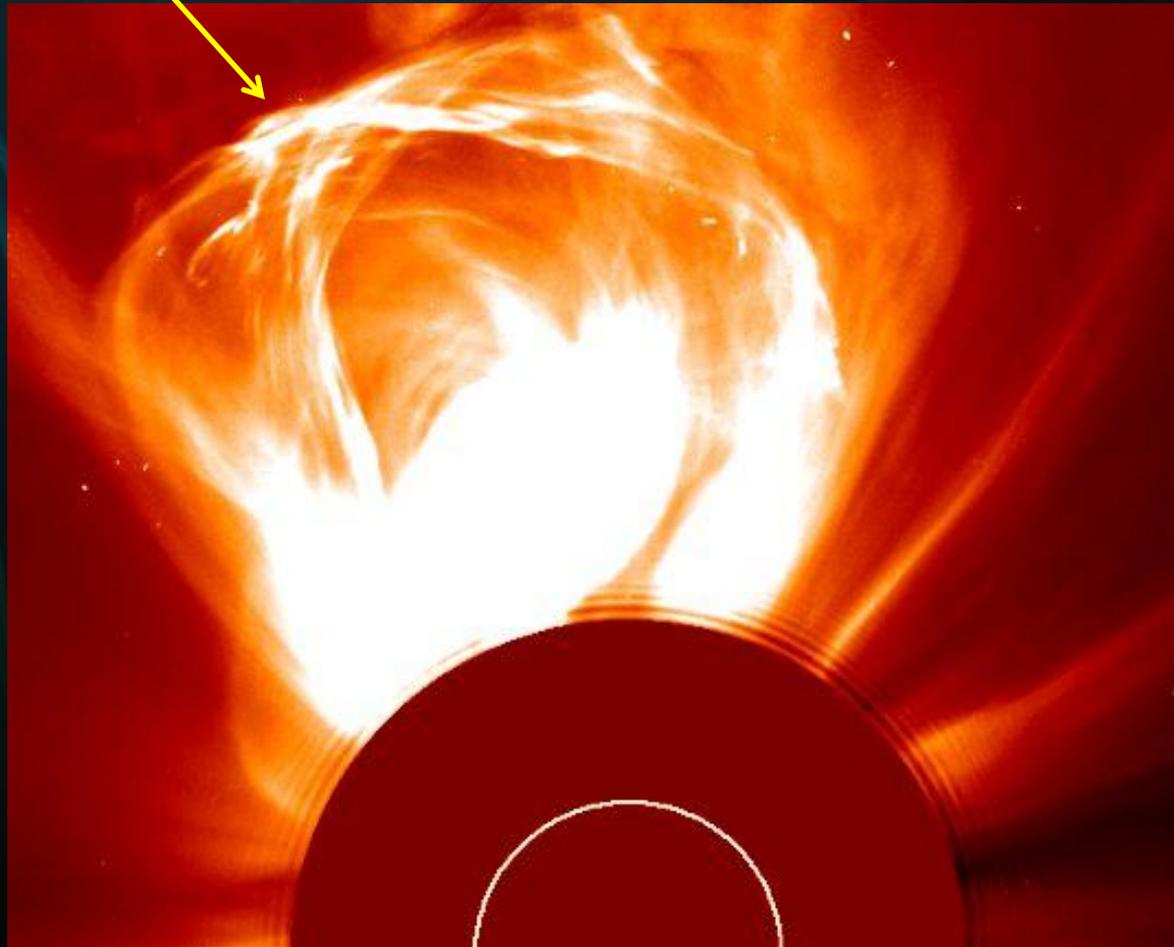


LASCO C2 (Nov. 22 - 28, 2000)



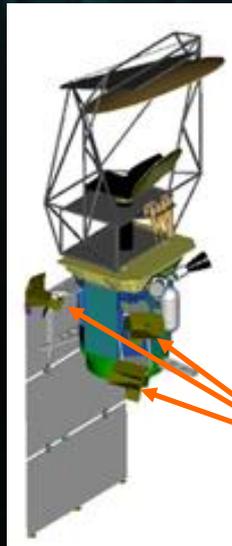
February 2000

Leading Edge

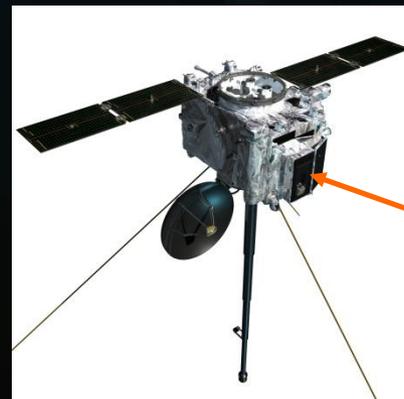


Process

- Created two programs to automatically detect the leading edge of a CME:
 - CLEDS: SMEI version
 - CLEDHI: HI version



*SMEI
(AFRL)*



*HI
(RAL)*

Why Was This Needed?

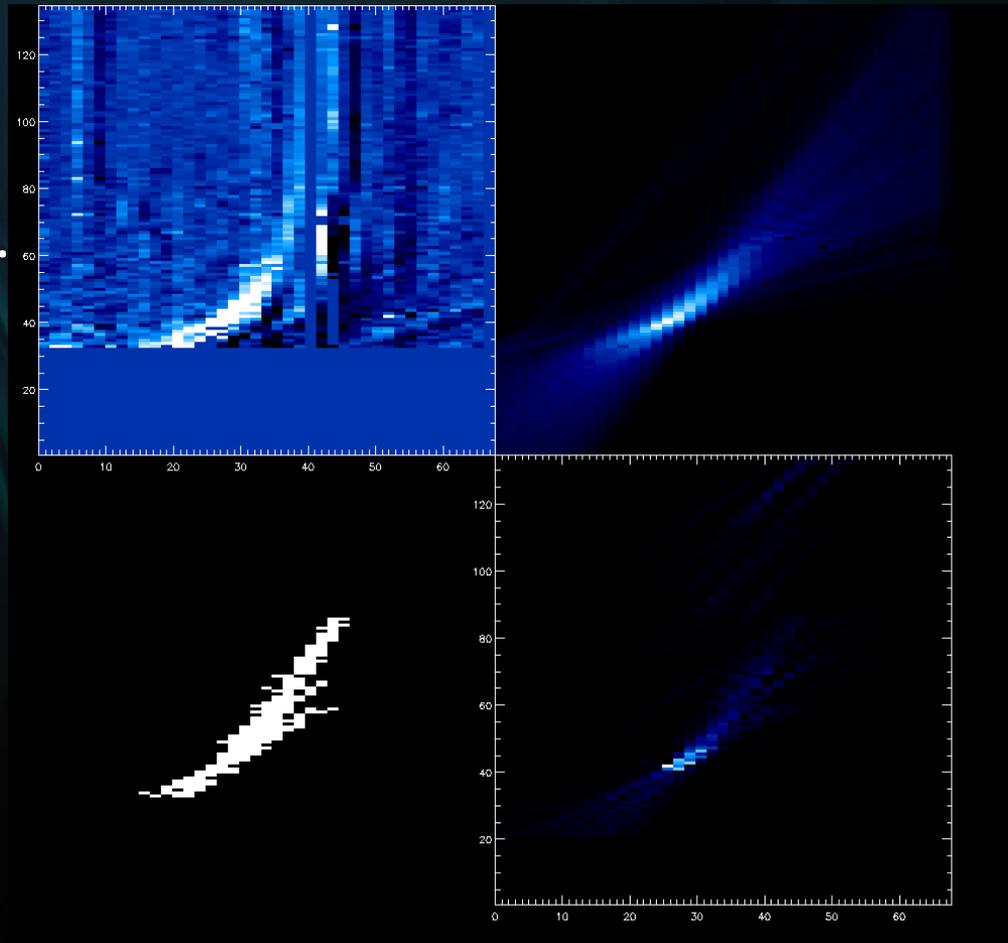
- Automatically detecting the leading edge of the CME with a program eliminates human error
- Automated, so able to run the program fast
- Results are fed to the Tappin-Howard (TH) model to form a reconstruction of the CME
- Ultimately provides a forecast for CME impact on Earth with an accuracy of +/- 5 hour

Method for Finding CMEs: Hough Transform

- Both versions used this concept to find CMEs
- Used as a mathematical image processing tool
- Picks out straight lines from images and calls them CMEs
- Very accurate at finding CMEs

Hough Transform Process

Original image containing CME in elongation vs. time



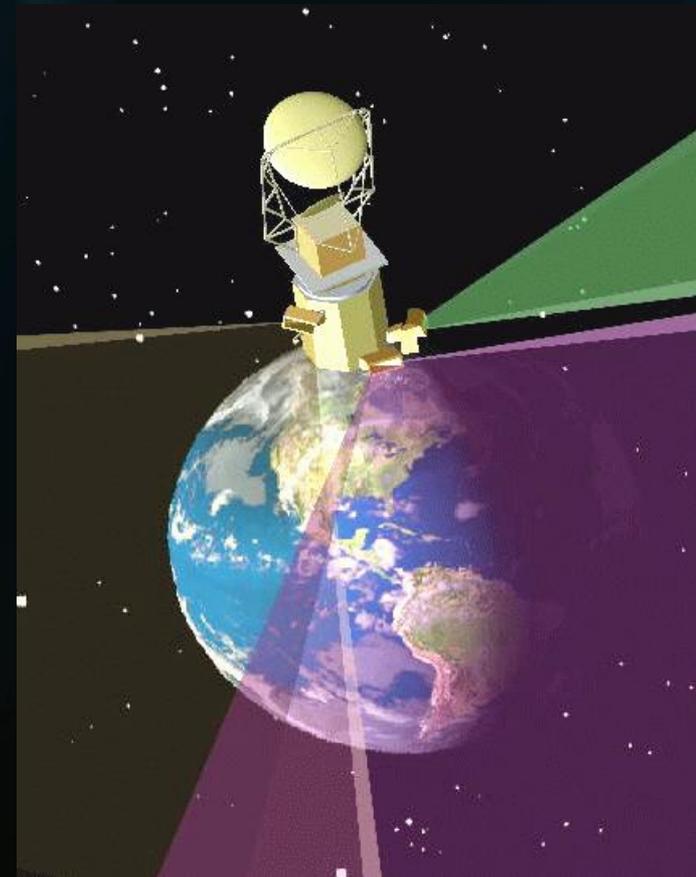
Transform to Hough space

Apply masking and filters

Final image transforming back to original coordinates

Solar Mass Ejection Imager (SMEI)

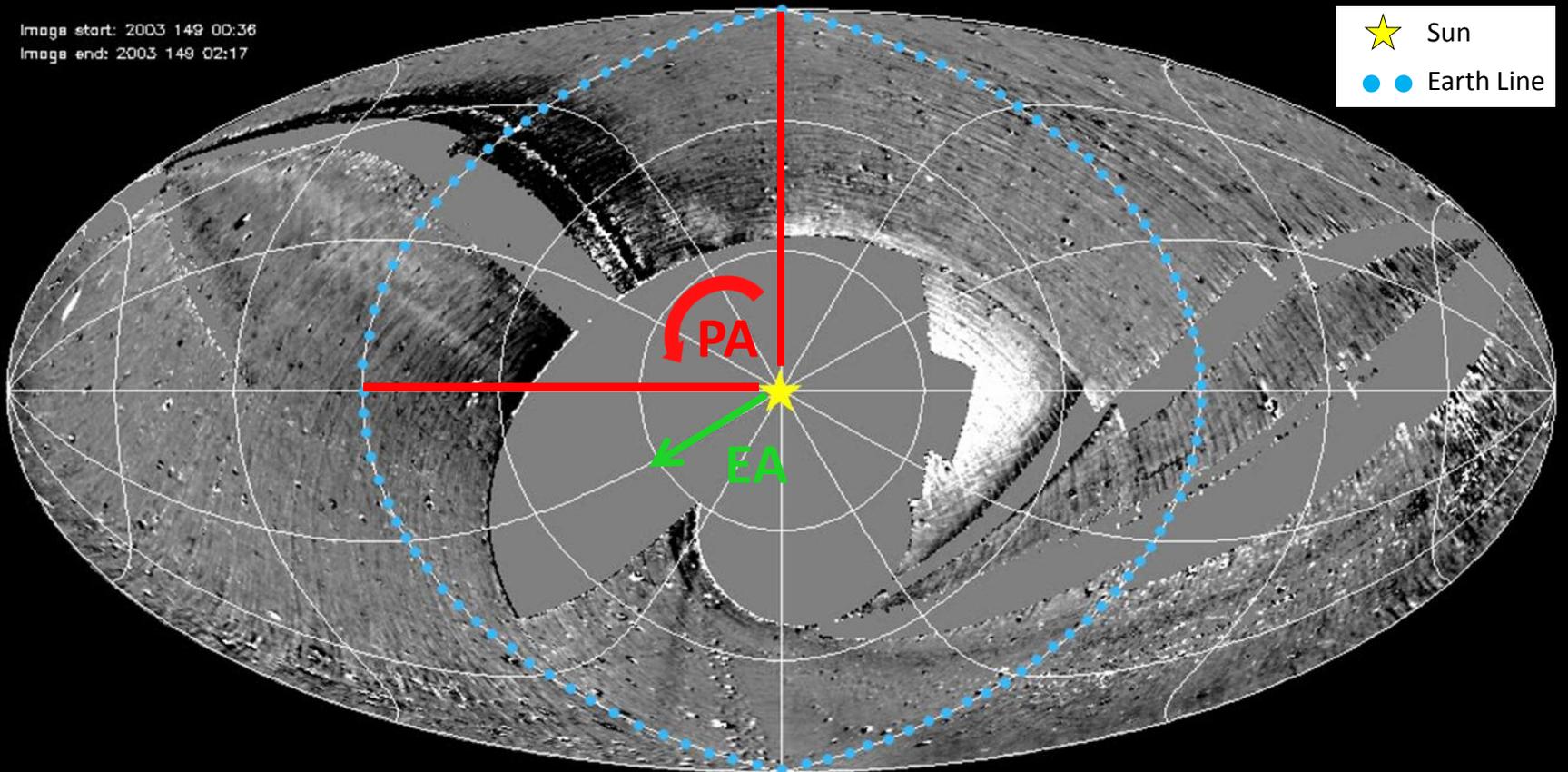
- Aboard the Coriolis spacecraft
 - Polar orbit around Earth
- SMEI directed toward Sun
- Creates a whole-sky image as an Aitoff projection every 101 minutes
- Sun is in the middle
- Earth is at 90 degrees



SMEI Coordinates

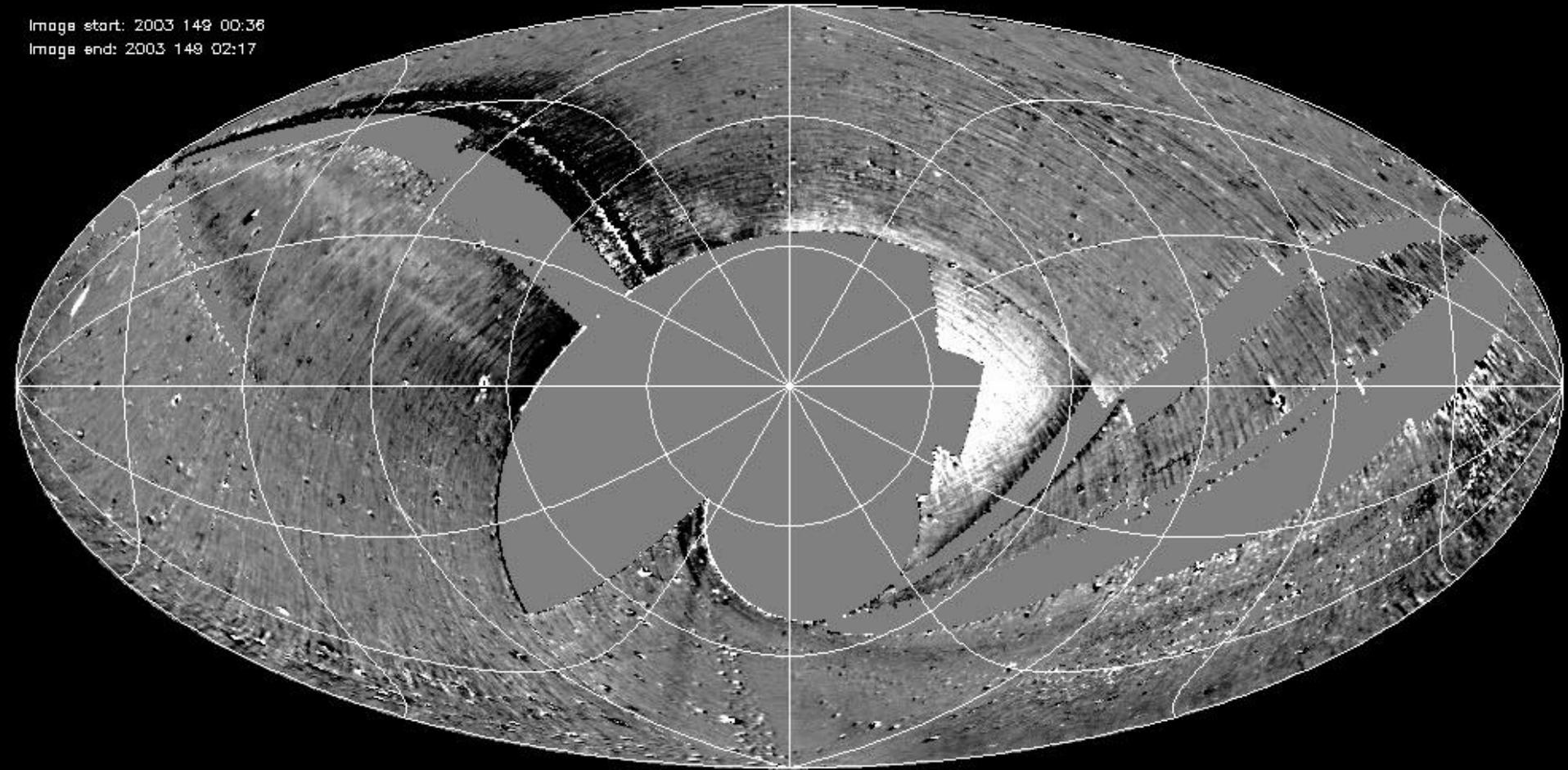
- Whole sky projection with Sun at center
- Position Angle (PA) ranges 0° to 360°

Image start: 2003 149 00:36
Image end: 2003 149 02:17



SMEI Movie May 2003

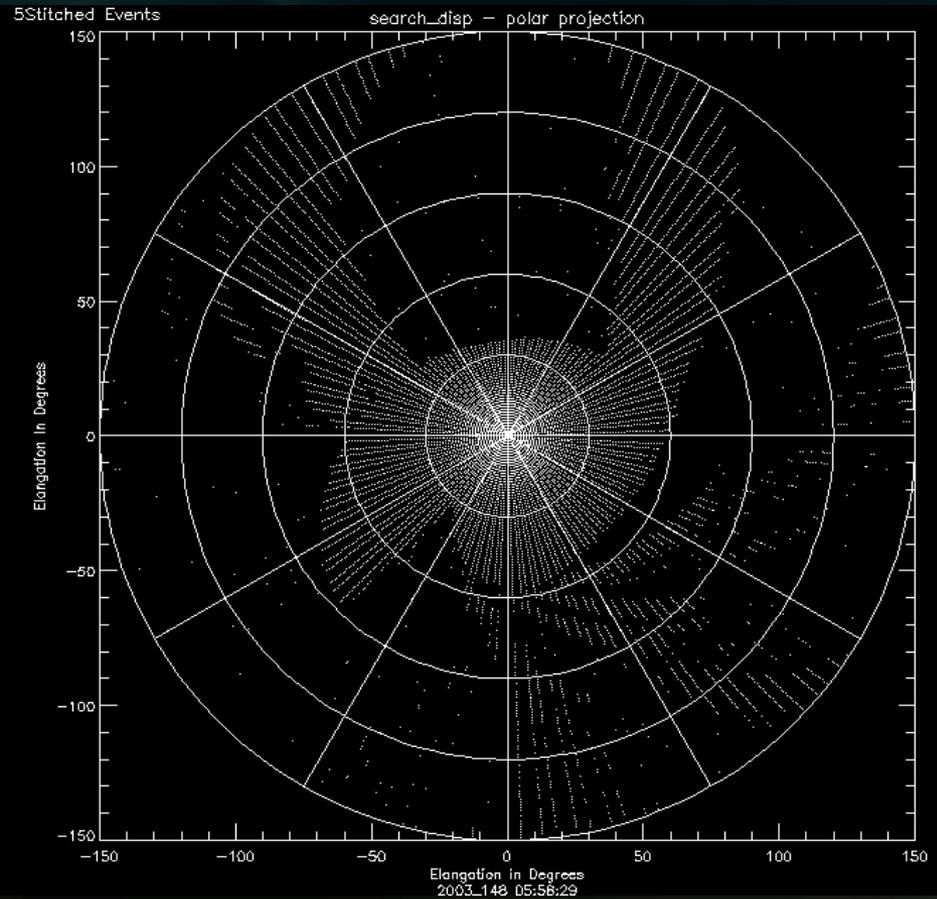
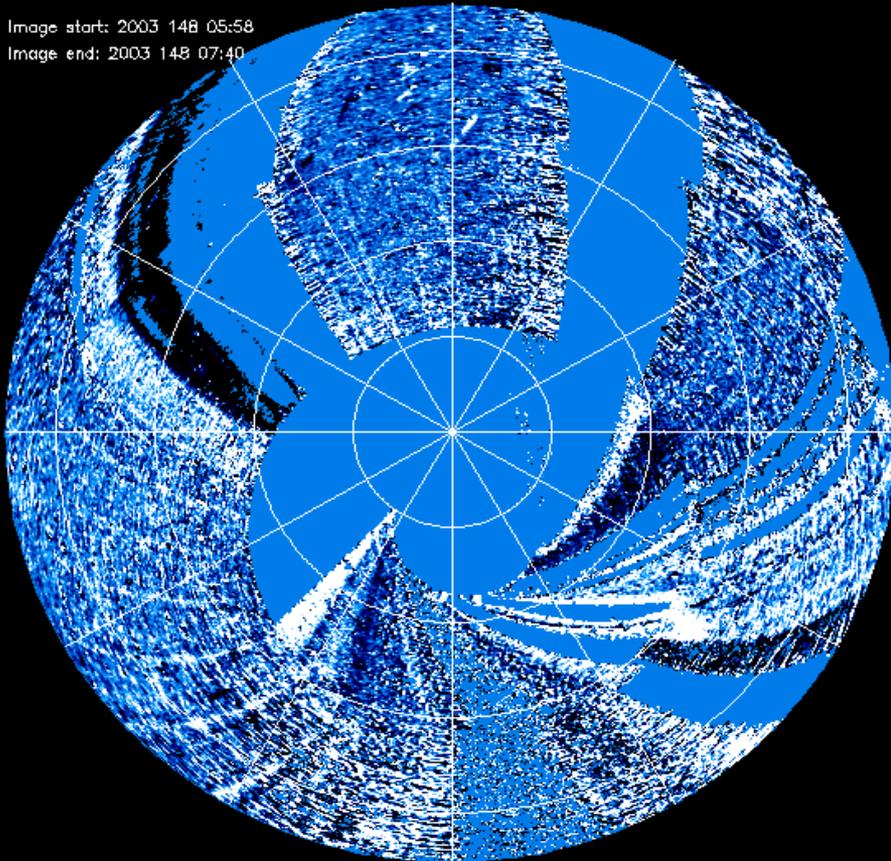
Image start: 2003 149 00:36
Image end: 2003 149 02:17



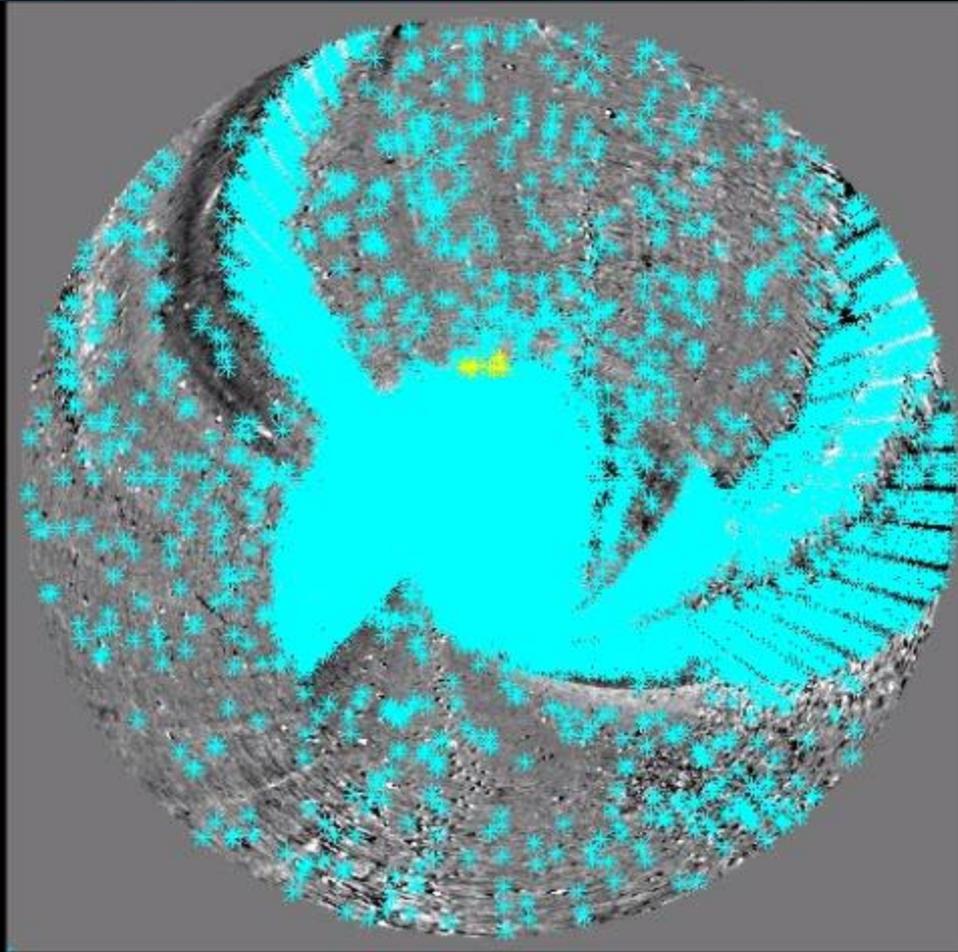
Can you spot the CME(s)?

Detecting all of the CME

Image start: 2003 148 05:58
Image end: 2003 148 07:40

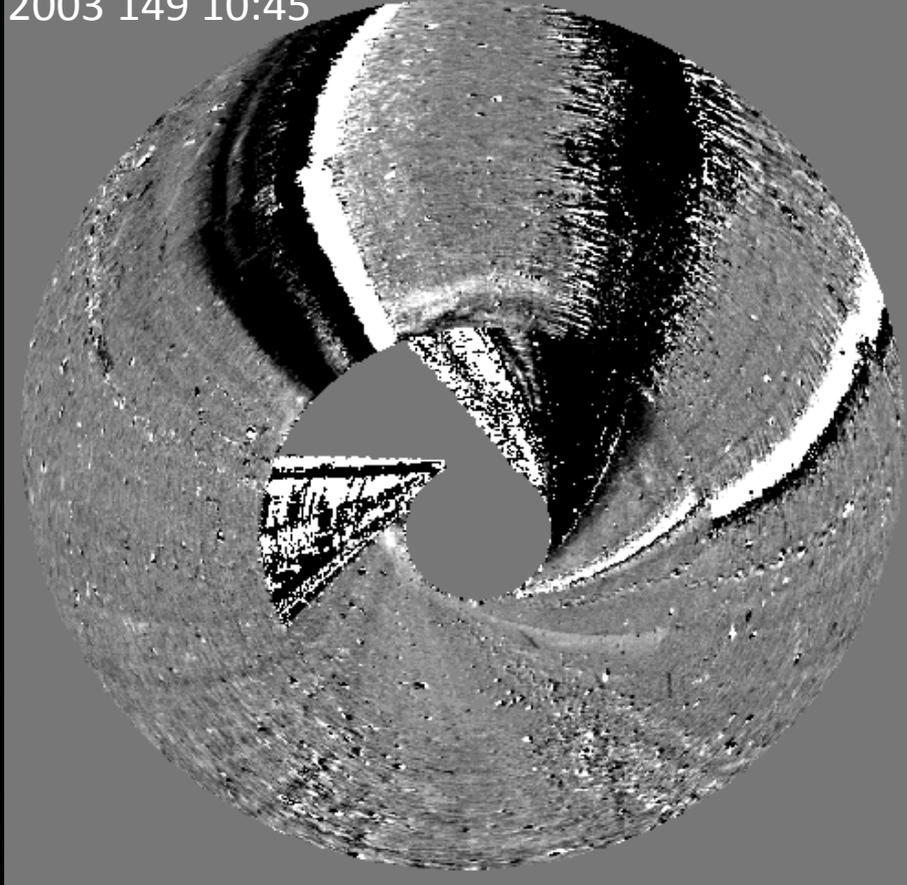


Detecting Just the Leading Edge

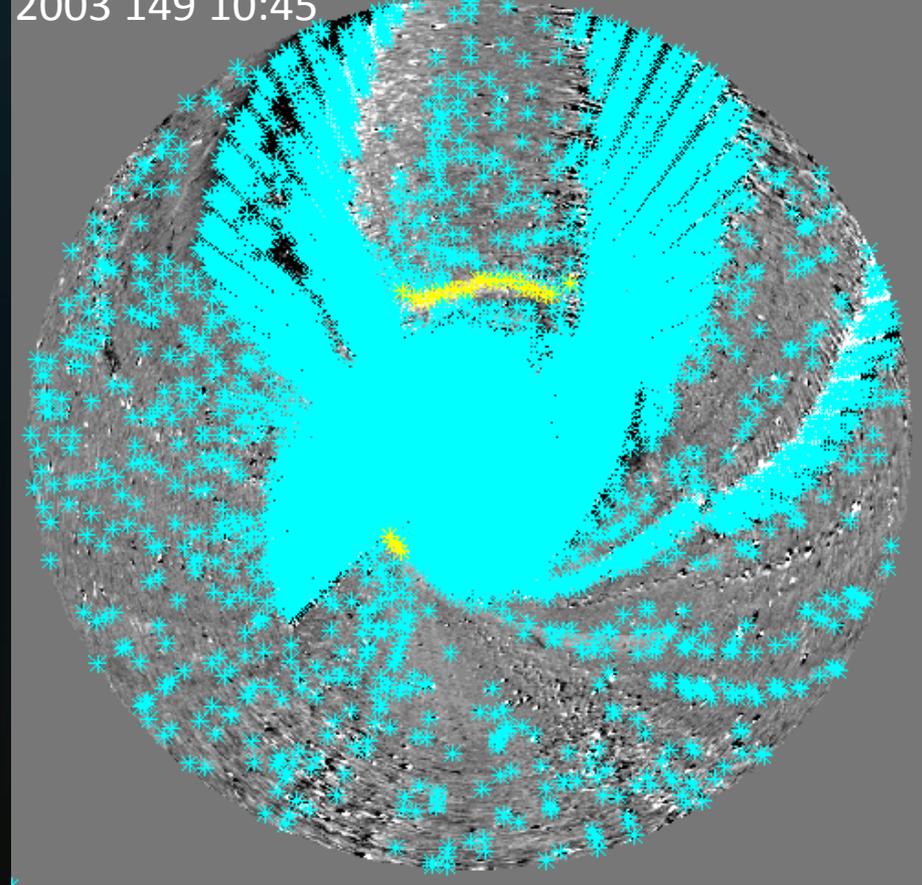


Leading Edge

2003 149 10:45

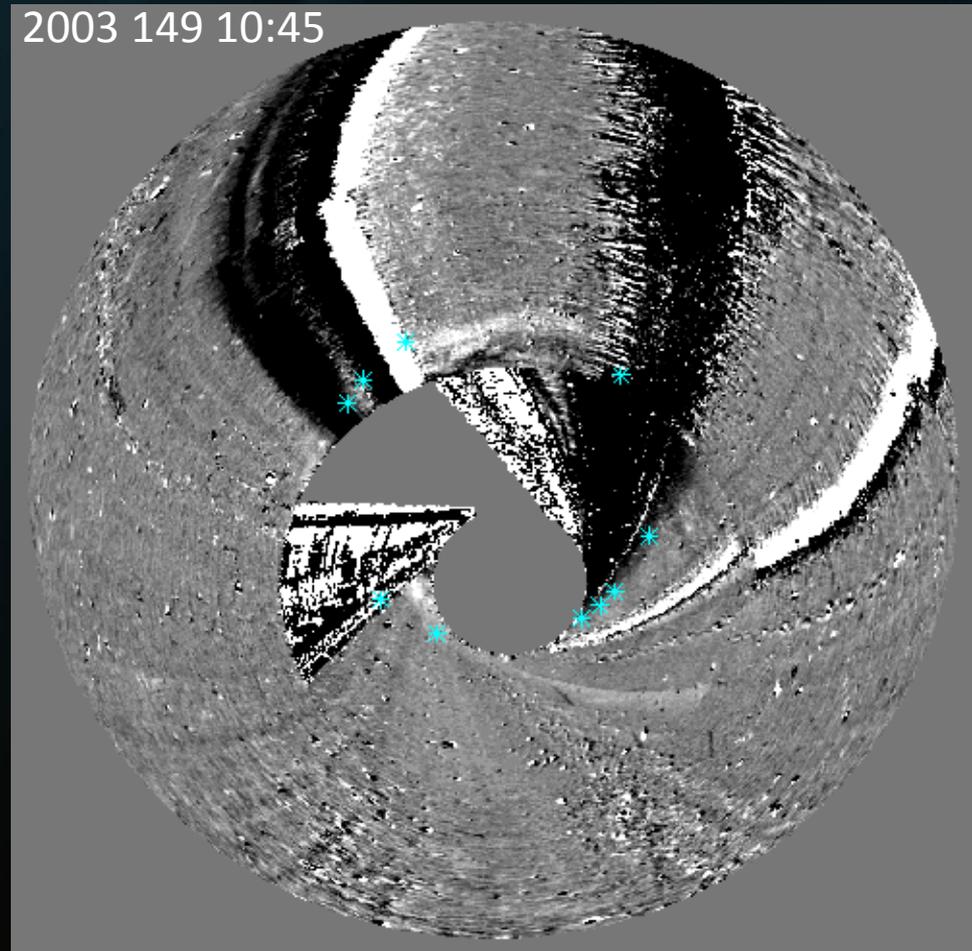


2003 149 10:45



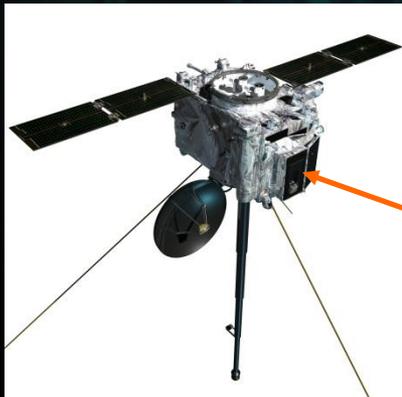
Noise Gaps

- SMEI images are VERY noisy
- Noise gaps are crucial for correct detection of CMEs
- Some CMEs could be hiding behind the noise and we wouldn't know it

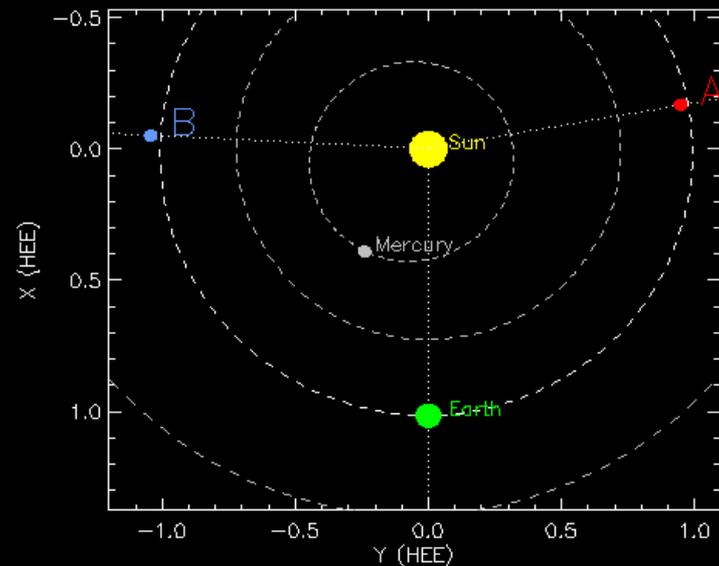


Heliospheric Imager (HI)

- Onboard the STEREO A and STEREO B spacecrafts
- Using the HI is beneficial because you can see what the CME does after takeoff, enabling a better space weather prediction



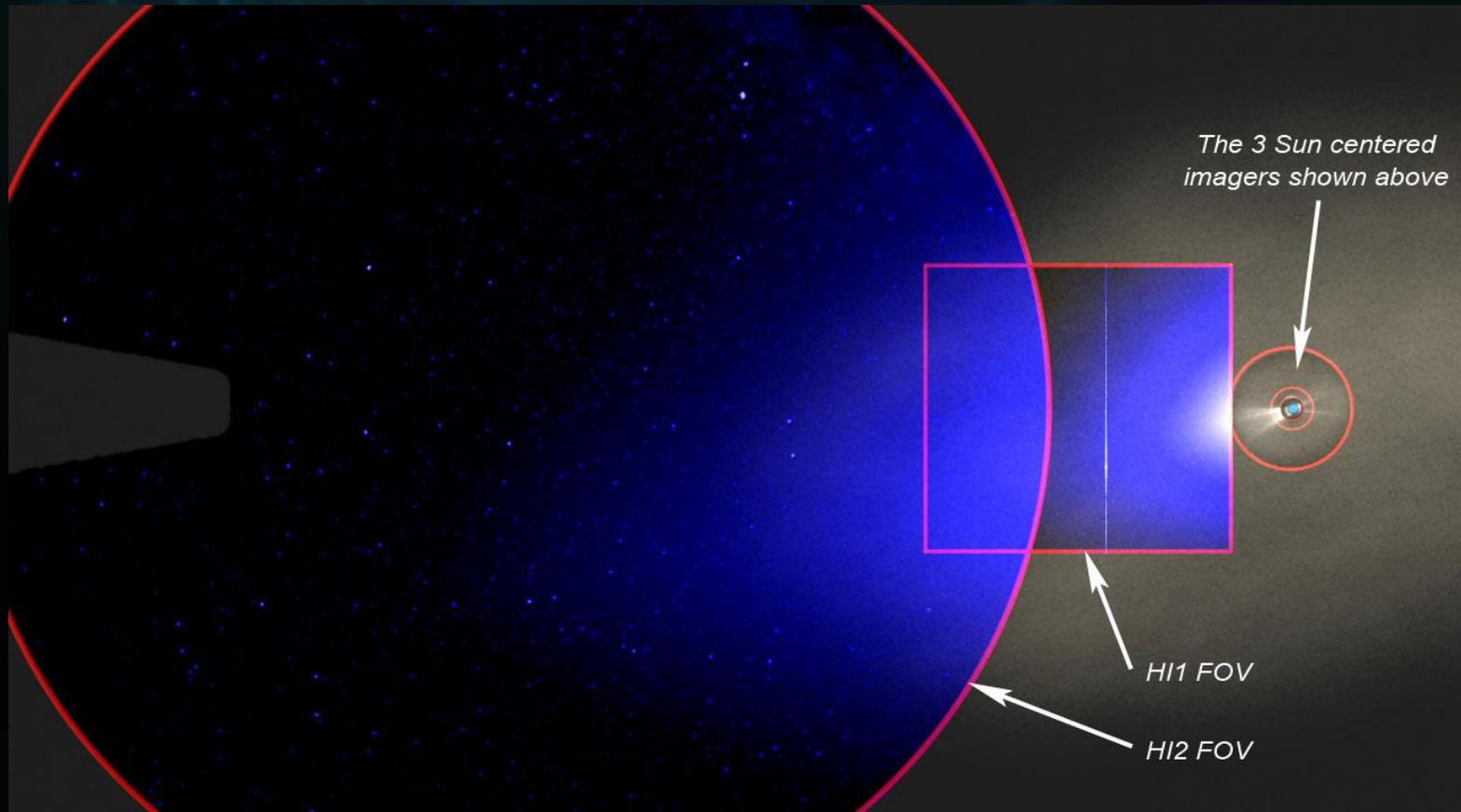
HI
(RAL)



As of August 2, 2011 22 UT

SECCHI

- HI is part of the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) suite

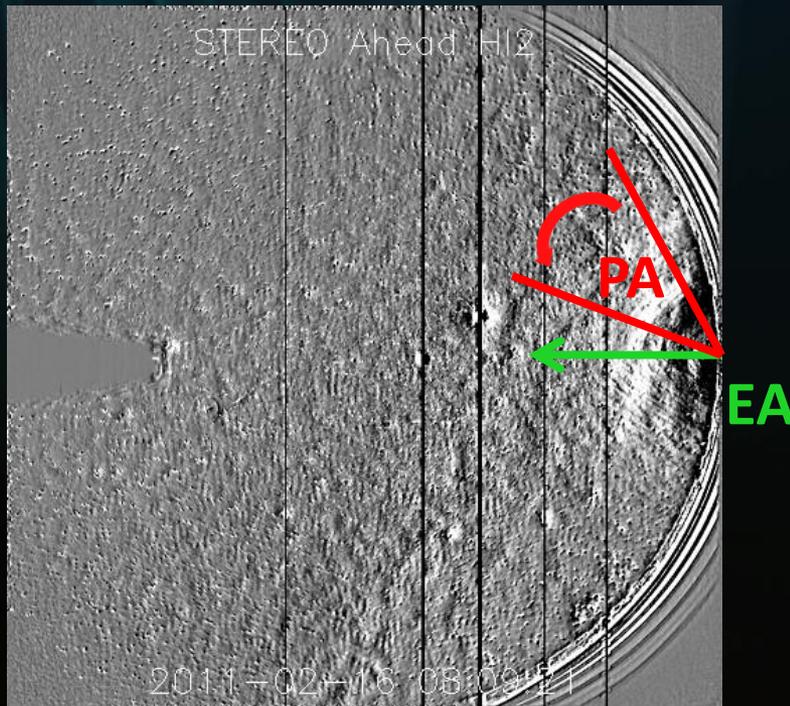


CME as Seen by SECCHI

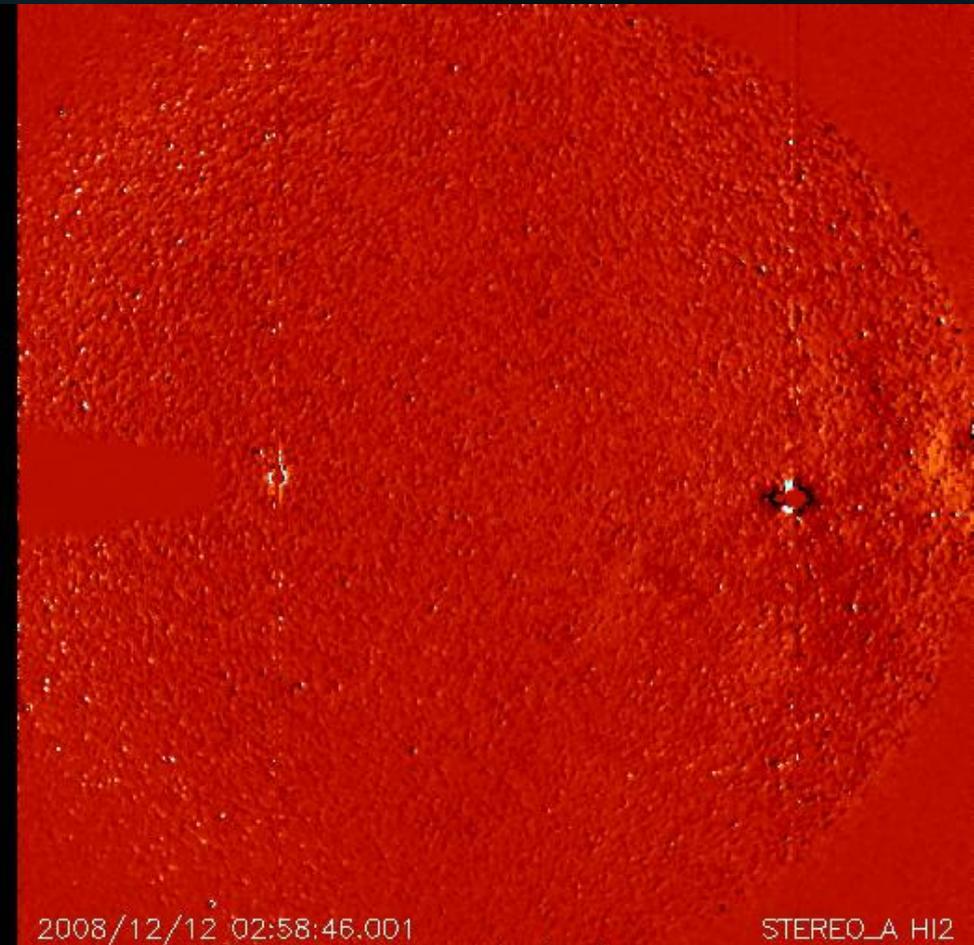


STEREO HI-2A Coordinates

- PAs only range from 30° to 150° , not 0° to 360°
- The sun is not in the center of the image



STEREO HI-2A Dec 2008



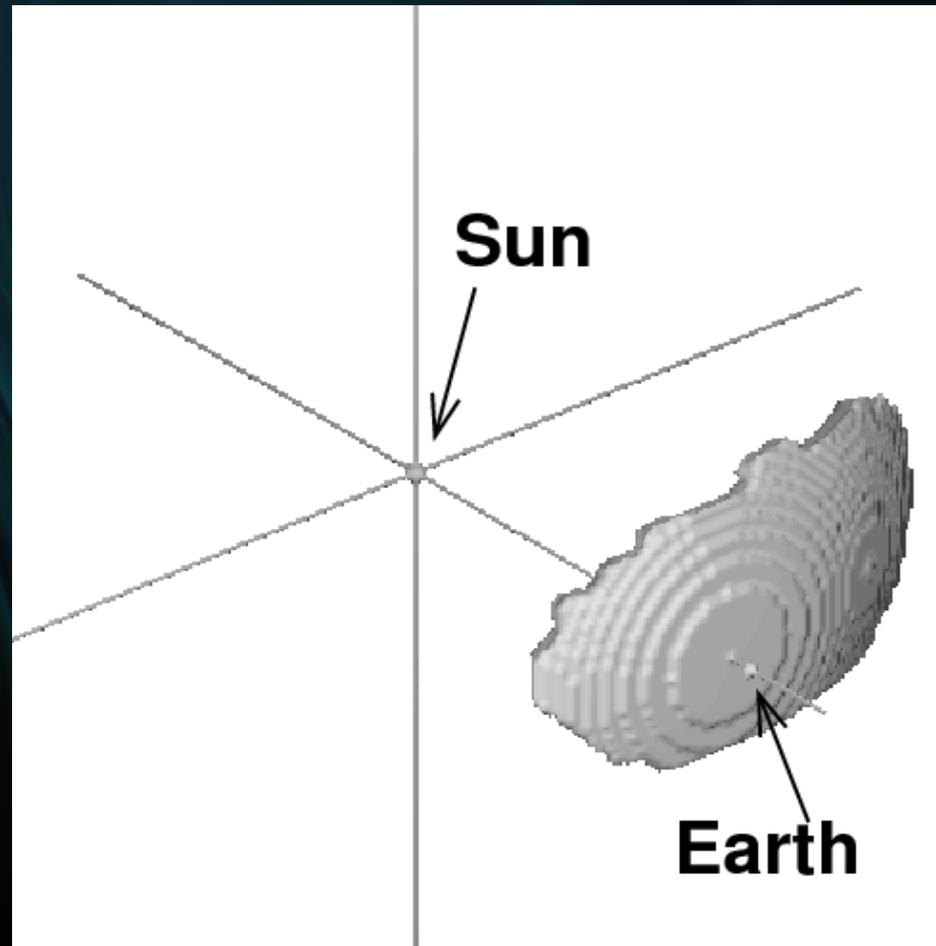
CME Detection With STEREO HI-2A

- The CLEDHI program could identify CMEs using the same method as CLEDS
- It identified the feature shown in HI-2A movie on December 12, 2008
- Only tried with STEREO HI-2A data for now
 - STEREO B is blurry

Tappin-Howard (TH) Model

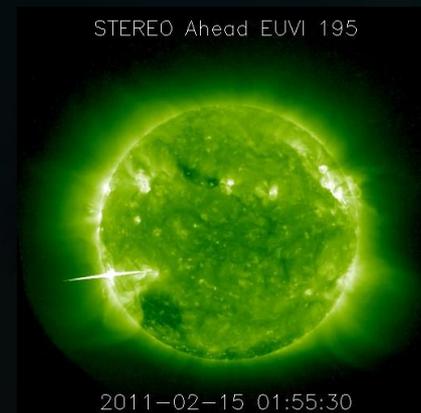
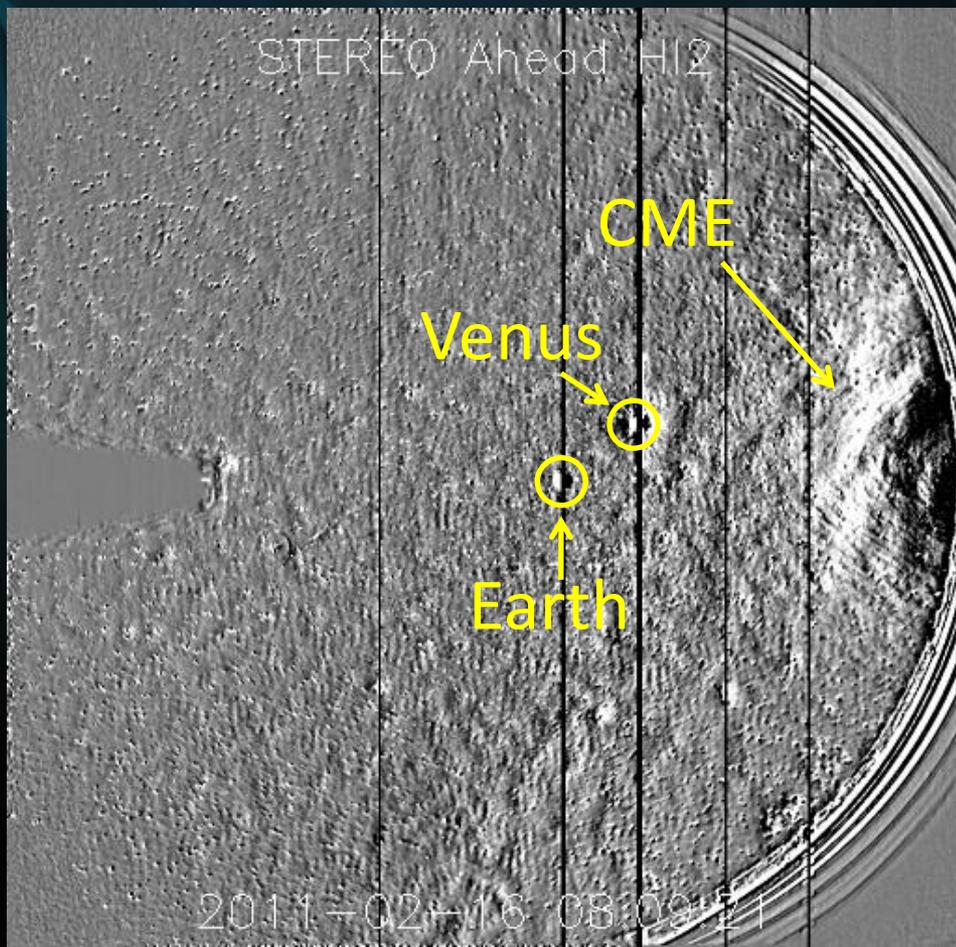
- TH model takes the CLED outputs of the CME leading edge and noise gaps as inputs
- Compares the measured leading edge data with those from simulated CMEs to create an estimation of CME geometry and kinematics
- All done automatically

Reconstruction of May 2003 CME

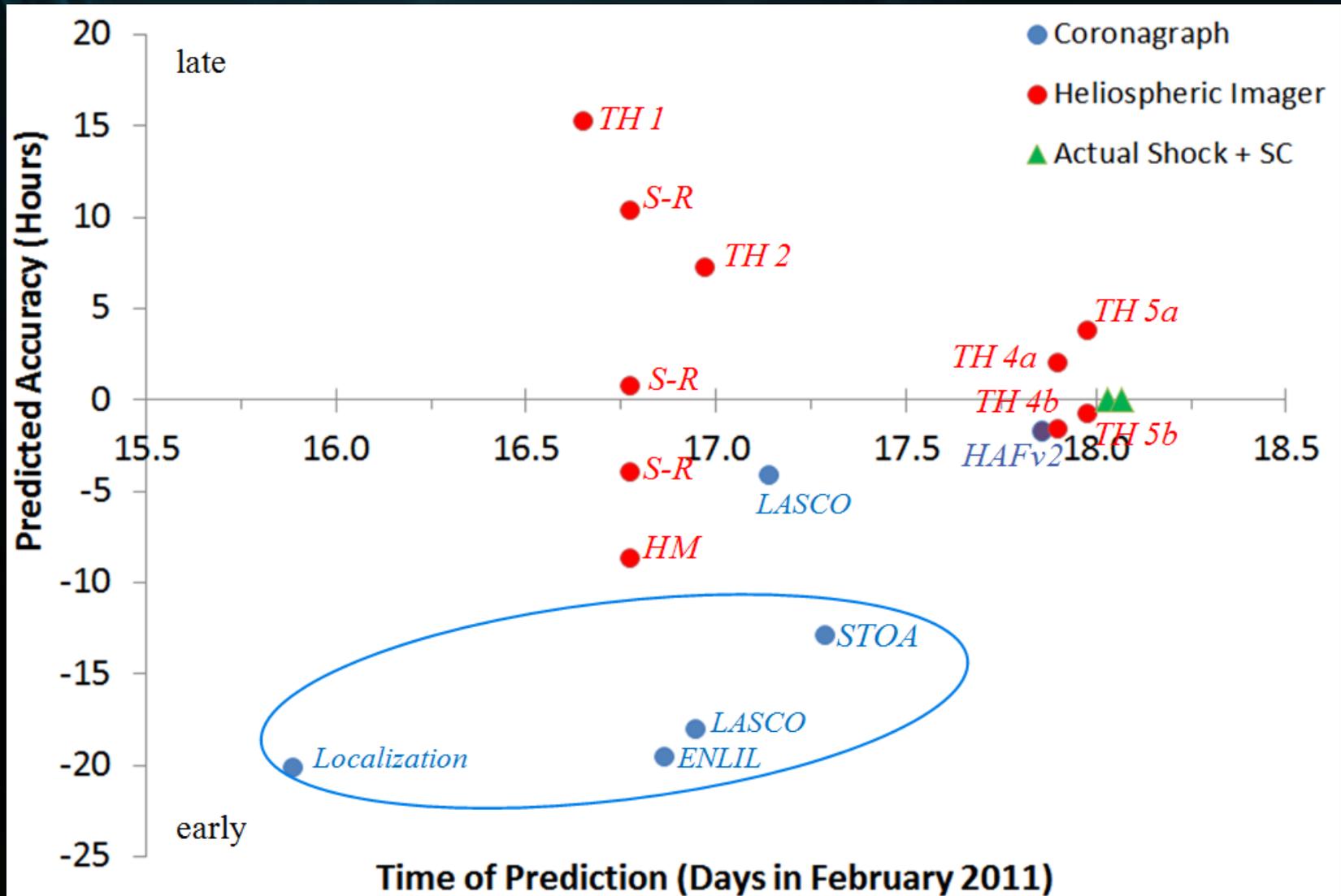


STEREO HI-2A

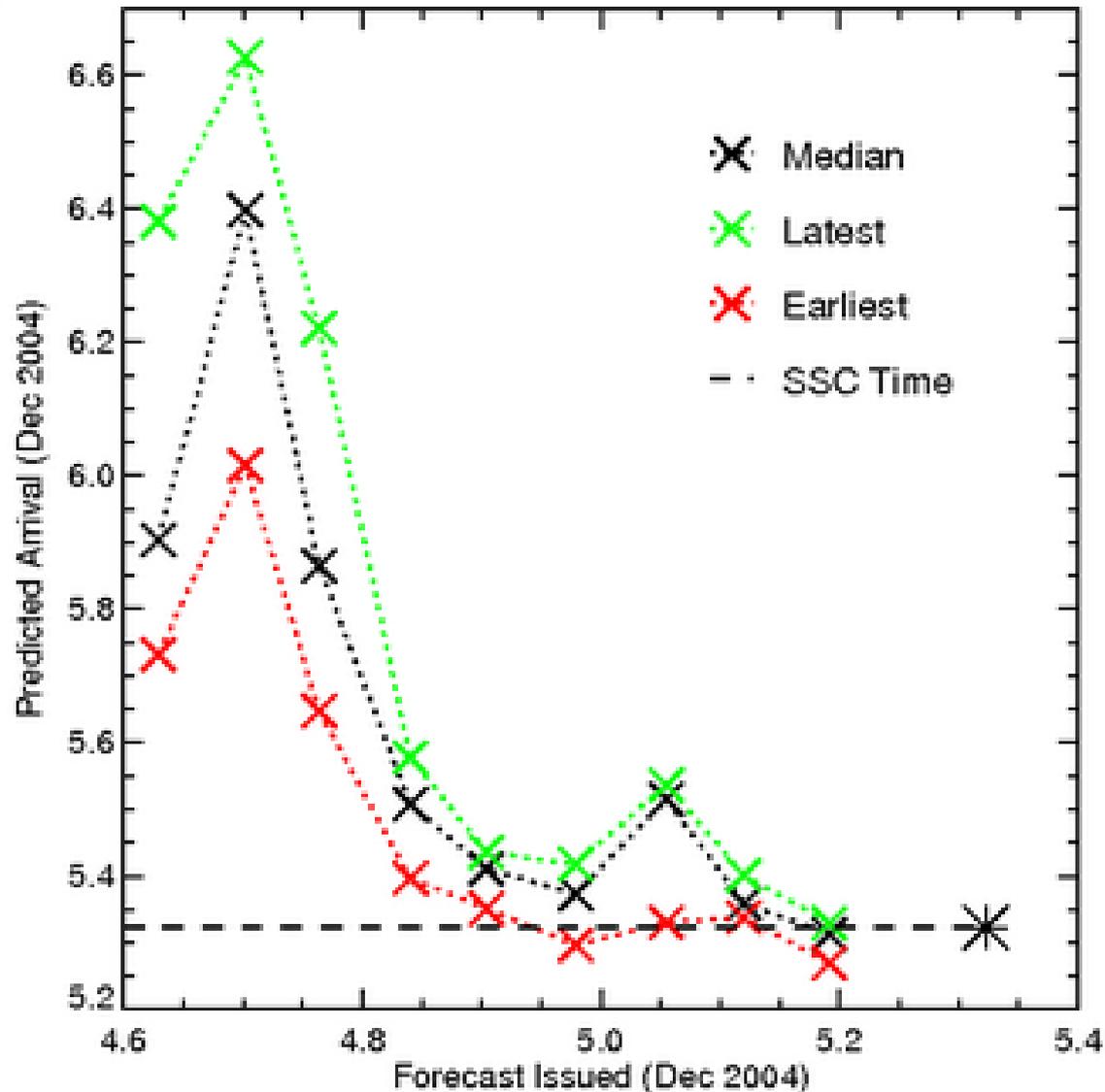
February 16, 2011 (Valentine's Day Storm)



Real-Time Predictions for the Valentine's Day Storm



TH Model Best Prediction Dec 2004



Conclusion

- Using heliospheric imagers to make a CME impact prediction can produce more accurate results because it is possible to see how the CME might change over time
- We have produced programs to automatically detect the leading edge of a CME and the noise gaps associated with SMEI images to feed to a CME prediction model
- Automating the prediction makes it possible to create many predictions over a short period of time

Acknowledgements

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