Innovations in CME triangulation in the era of limited STEREO data

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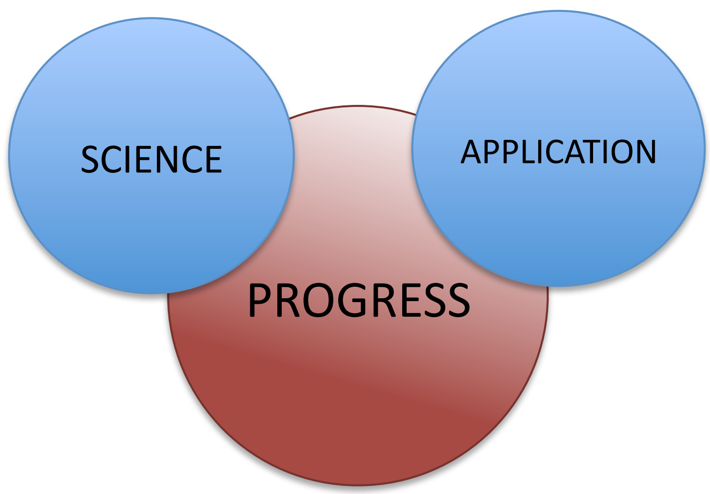


An R_2O Focus Topic

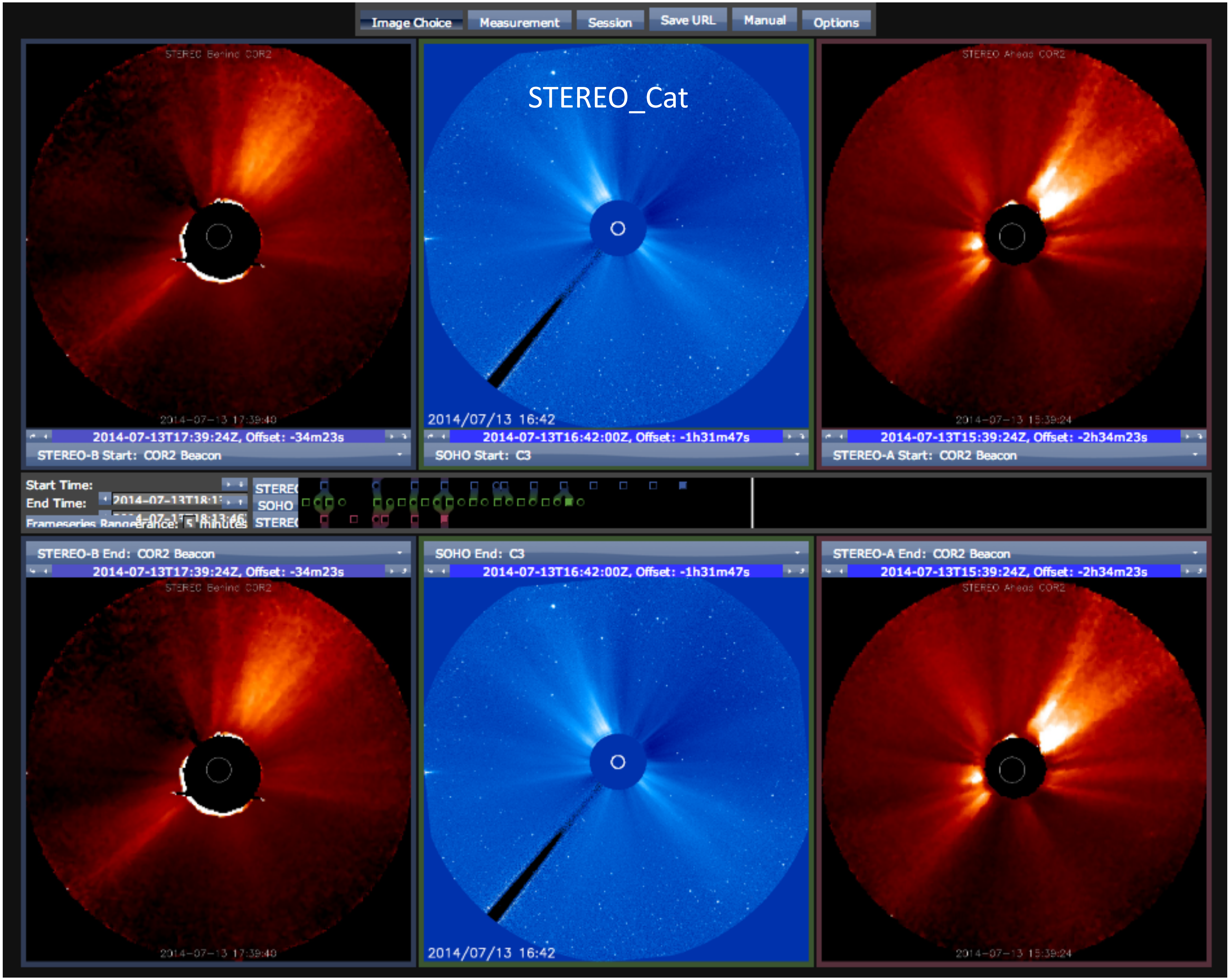


Image Choice
Measurement
Session
Save URL
Manual
Options
STEREO_Cat
STEREO Behind COR2
2014-07-13 17:39:48
2014-07-13T17:39:24Z, Offset: -34m23s
STEREO-B Start: COR2 Beacon
2014/07/13 16:42
2014-07-13T16:42:00Z, Offset: -1h31m47s
SOHO Start: C3
STEREO Ahead COR2
2014-07-13 15:39:24
2014-07-13T15:39:24Z, Offset: -2h34m23s
STEREO-A Start: COR2 Beacon
Start Time:
End Time:
SOHO
STEREO-B End: COR2 Beacon
SOHO End: C3
STEREO-A End: COR2 Beacon

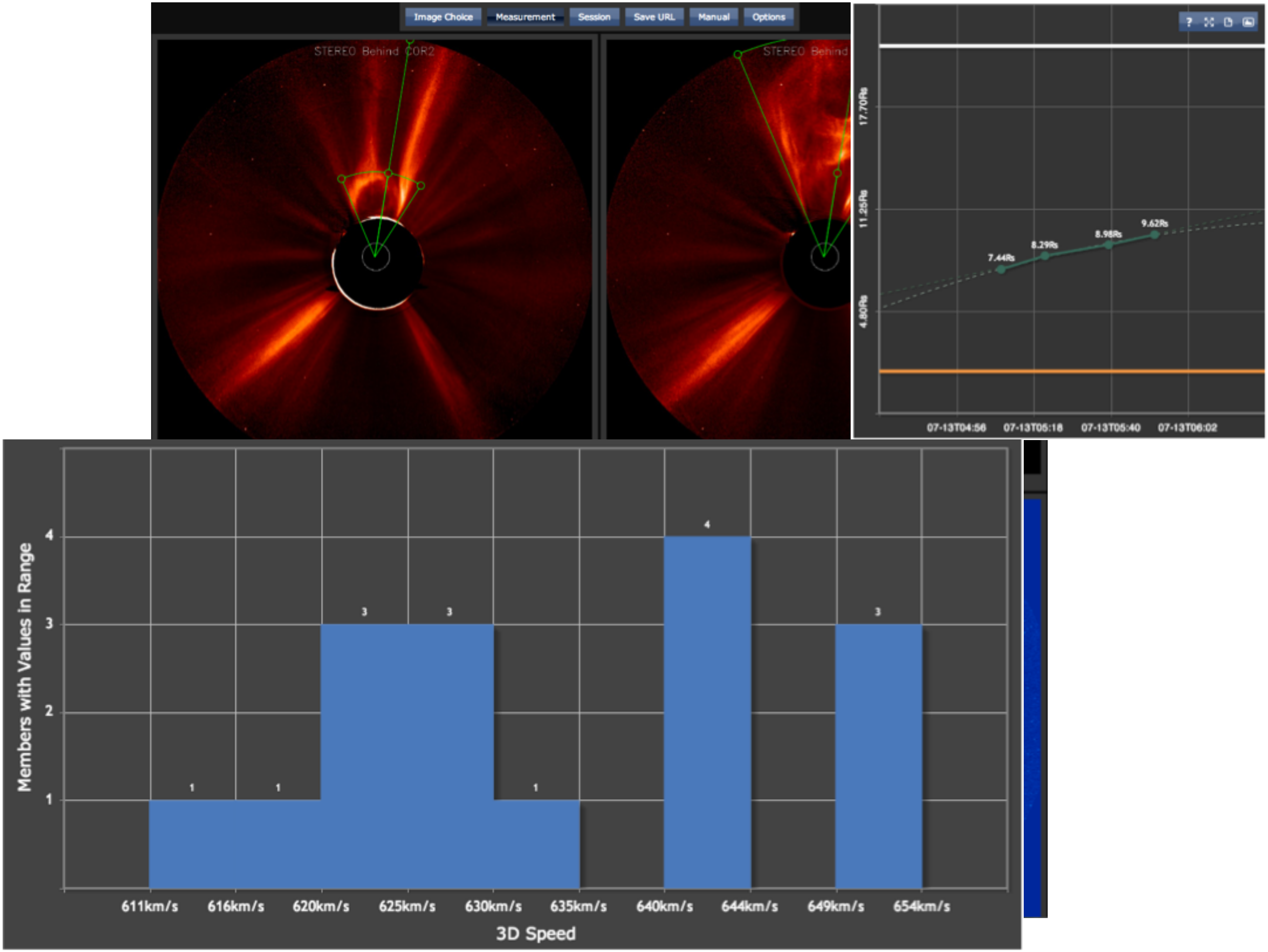


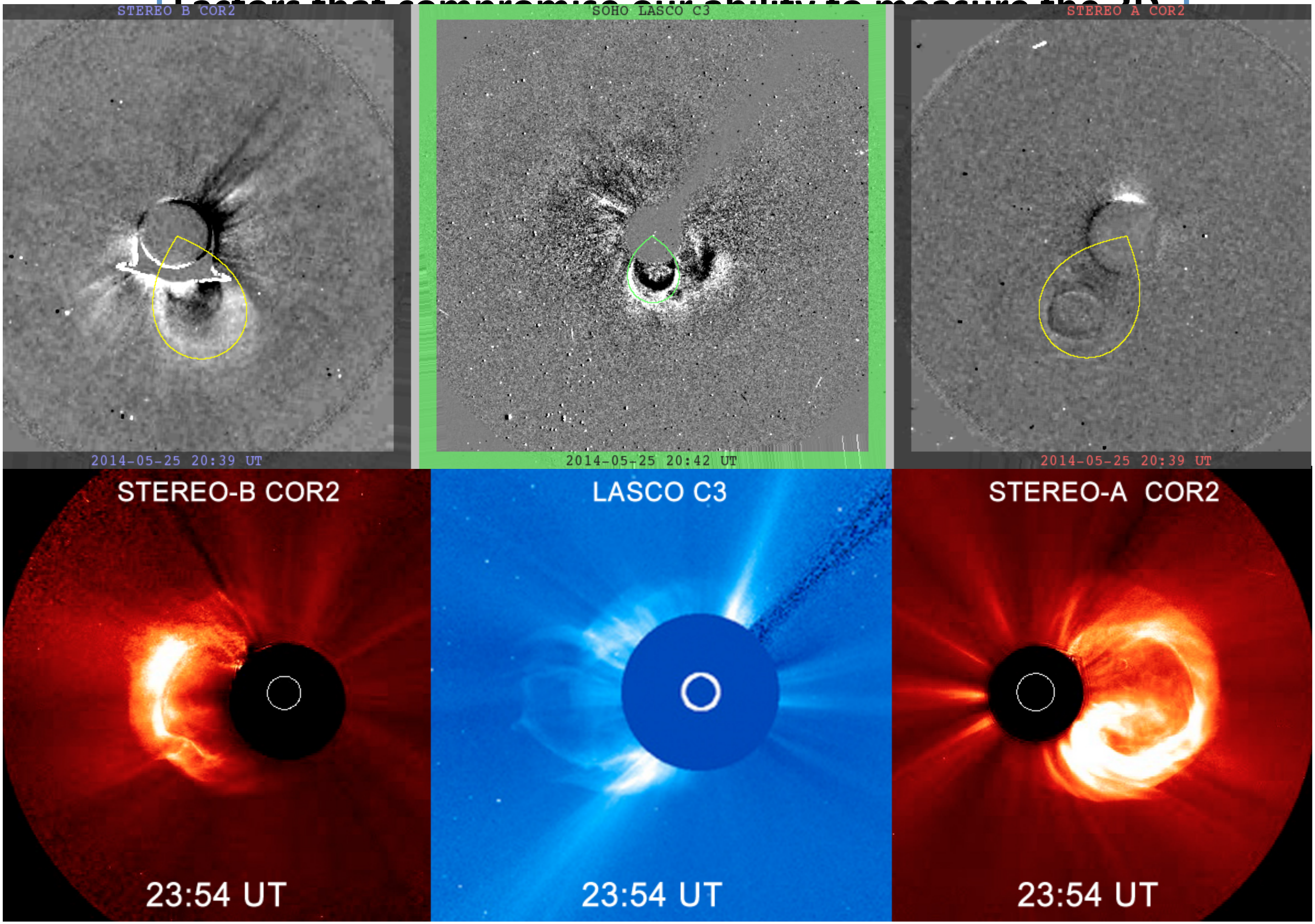
Image Choice
Measurement
Session
Save URL
Manual
Options
STEREO Behind COR2
STEREO Behind
17.70Rs
11.25Rs
4.80Rs
7.44Rs
8.29Rs
8.98Rs
9.62Rs
07-13T04:56
07-13T05:18
07-13T05:40
07-13T06:02
Members with Values in Range
4
3
2
1
1
1
3
3
1
4
3
611km/s
616km/s
620km/s
625km/s
630km/s
635km/s
640km/s
644km/s
649km/s
654km/s
3D Speed

Problem:
How to determine the "true" 3D properties (speed, direction, width) based on the resources available.

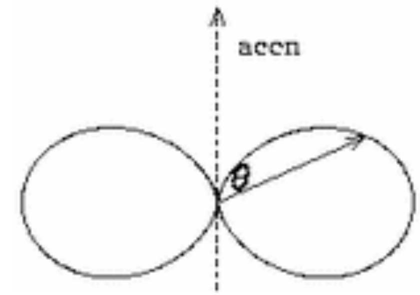
Added difficulty:
How to do this with minimum latency (i.e. forecasting timescales).

Perhaps the best way to start is to discuss why it's so hard (even with near-ideal observations) to determine the speed and direction of a CME.

Factors that compromise our ability to measure the 3D

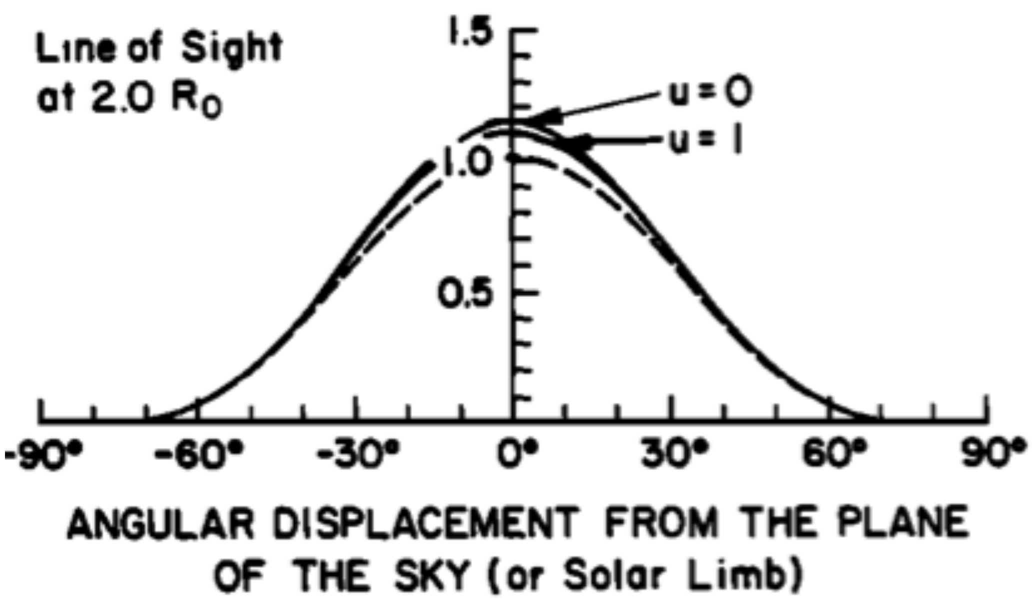


How Coronagraphs Work



An important thing to know about coronagraph observations:

We are not viewing light emitted from the CME itself. We are viewing light from the Sun that is scattered off of electrons in the corona. Thomson scattering is not isotropic, so the brightness of coronal mass varies with viewing angle.

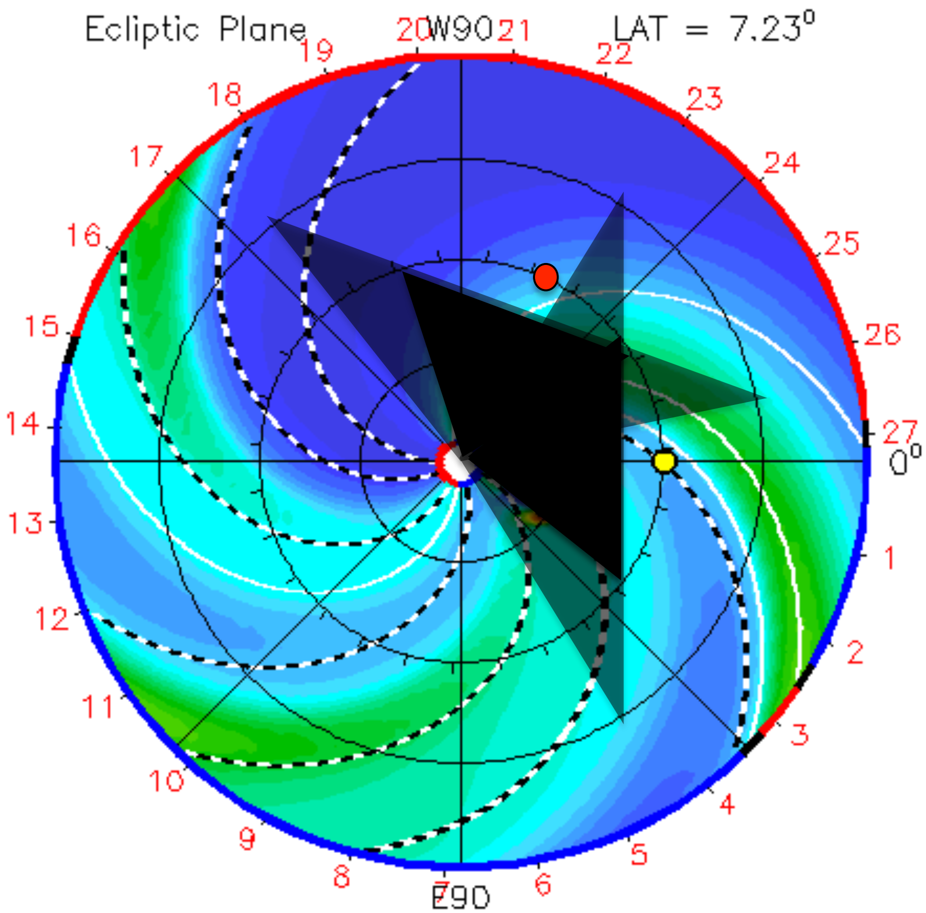


← Thomson scattering efficiency of a point as a function of angle from the plane of the sky. Curve is normalized relative to plane of sky scattering from "point source" Sun.

A feature 30° out of the plane of the sky has only half the overall scattering amplitude of a feature in the plane of the sky. For points >45° , scattering amplitude is very low.

Features >60° away will not be seen in coronagraph images, and are effectively invisible.

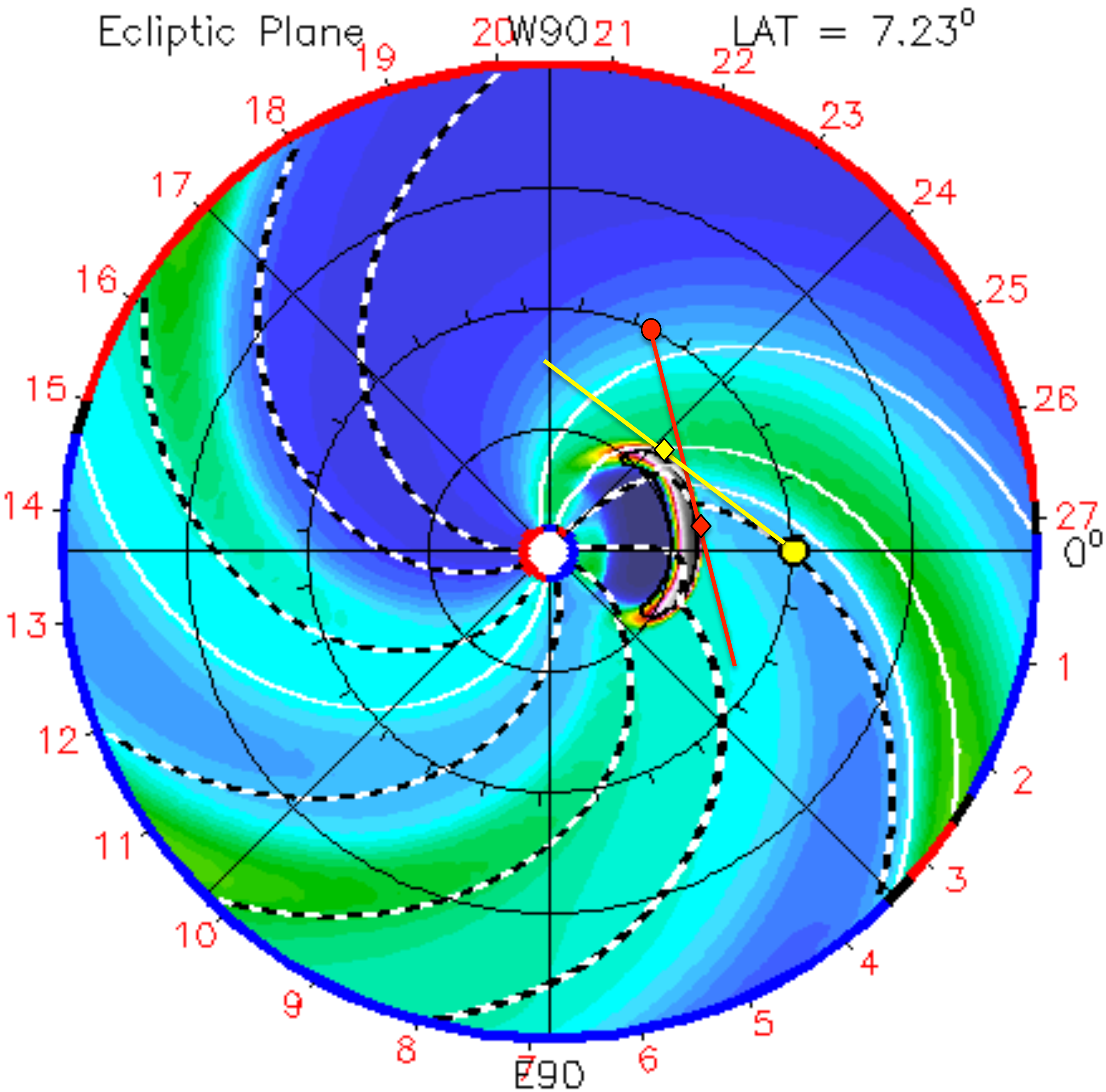
What does this mean??



The CMEs that are the hardest to see are the ones that are moving directly towards (or away) from the observation.

It also means that a CME viewed from two different angles can look very different. In fact, you could be looking at completely different parts of the CME!

Fortunately, fast CMEs are usually nice and wide. Unfortunately...



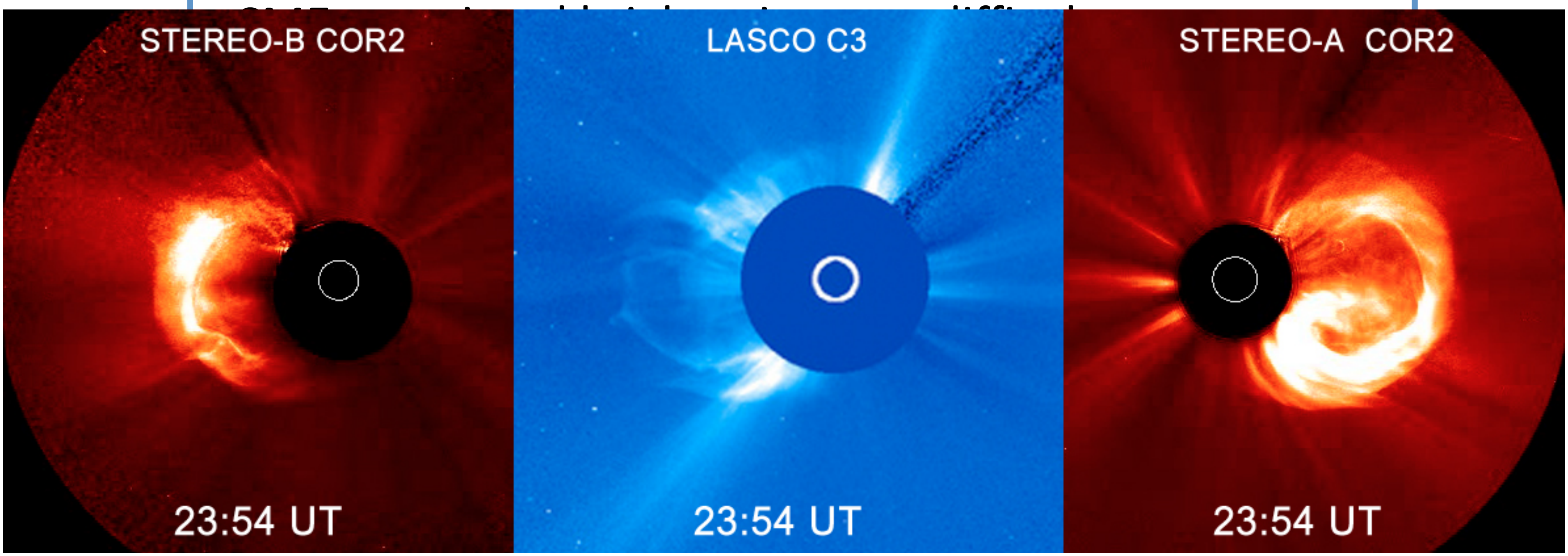
Unfortunately viewing angle projection effects are more complicated for wide CMEs.

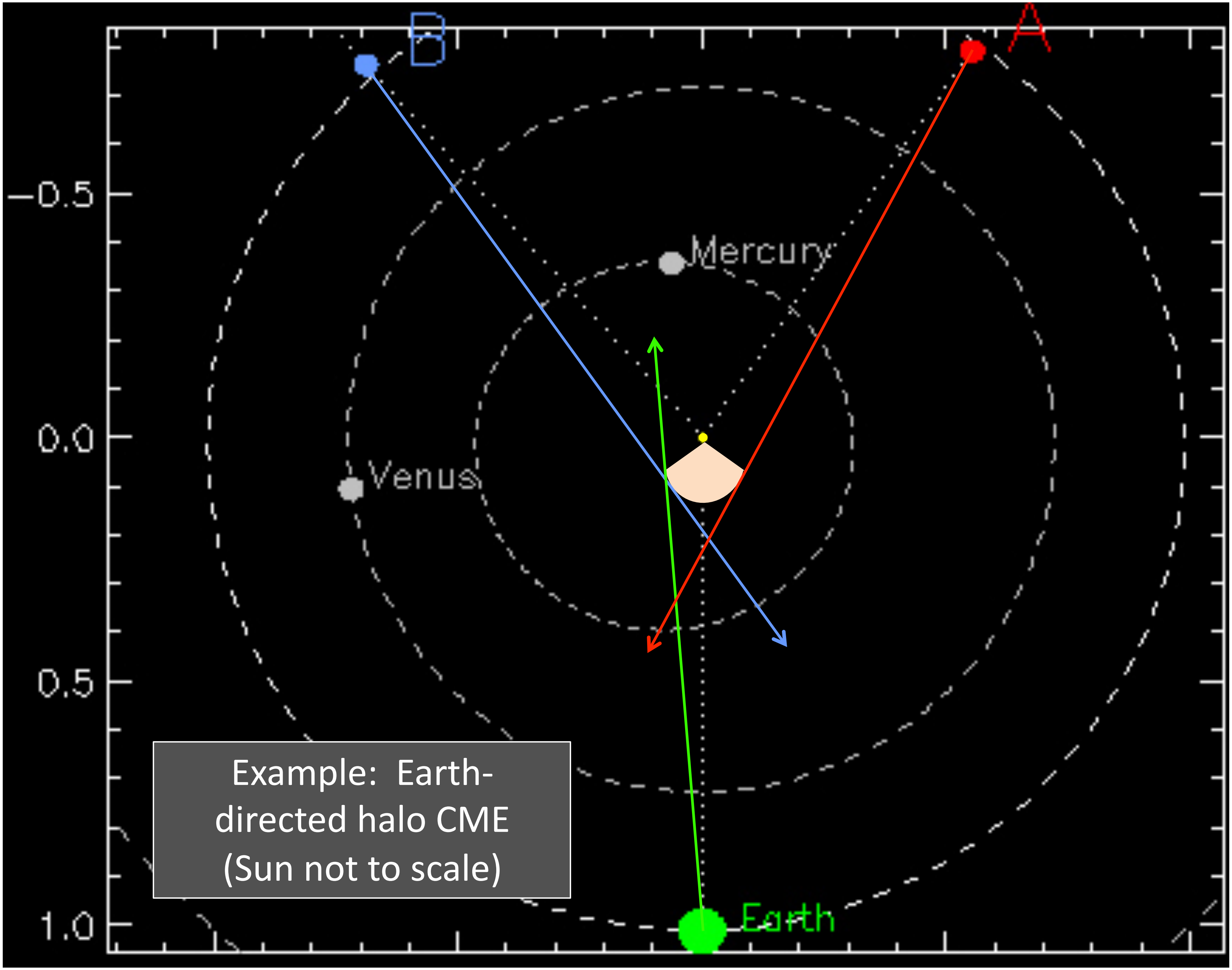
Factors that compromise our ability to measure the 3D kinematics of a CME

- Image availability
- How coronagraphs work
- CME structure and extent
    - CMEs are large and diffuse
    - The brightness is not homogeneous
    - They can have a variety of shapes

Do the best with what you've got : (

Fold this into the measurements



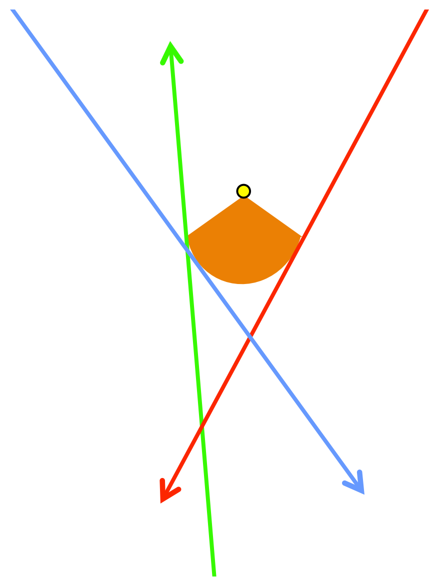


B
A
−0.5
Mercury
0.0
Venus
0.5
1.0
Earth
Example: Earth-directed halo CME (Sun not to scale)

Example: 50 degree half-width CME, halo CME pointing at Earth

STEREOCat user clicks on apparent leading edge from the point of view of SOHO, STEREO-A and STEREO-B.

Actual location of CME front:
45 RSun, -1 lon (so CME is slightly faster to east from LASCO POV)



Red/Blue triangulation point:
74 RSun, 4 longitude
(most accurate longitude, but 65% off by height)

Red/Green triangulation:
117 RSun, -10 longitude
(>150 % off in height!)

Green/Blue triangulation:
49 RSun, -46 lon

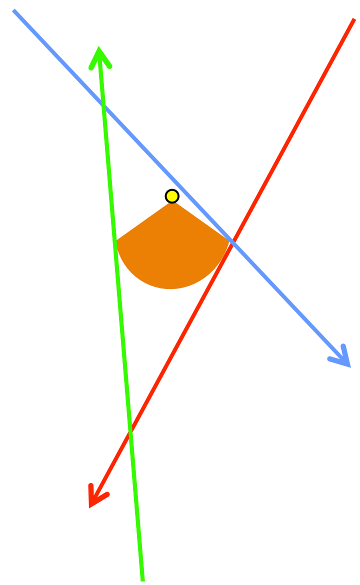
Let's say the user chooses the other side in STEREO-B as the leading edge (for some hypothetical reason).

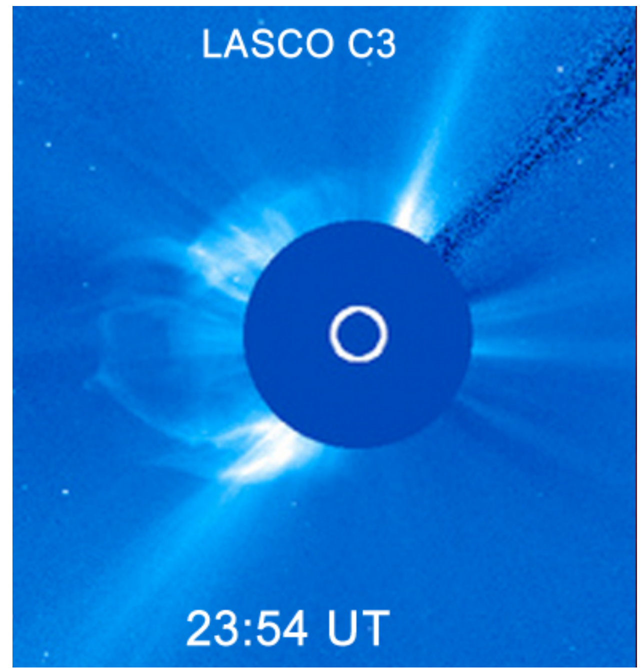
Actual location of CME front:
- 45 RSun, -1 lon

Red/Blue triangulation point:
- 40 RSun, 50 lon

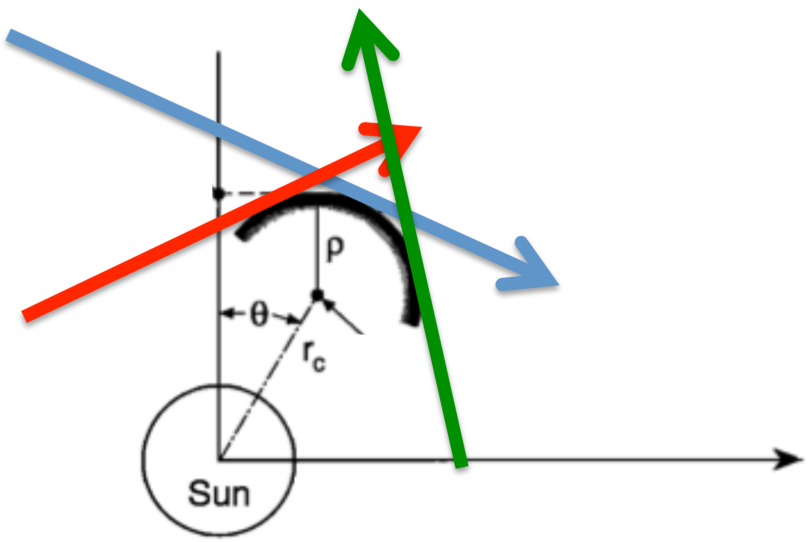
Red/Green triangulation:
- 117 RSun, -10 (>100 % off in height!)

Green/blue triangulation:
- 55 RSun, -143 lon (!!)



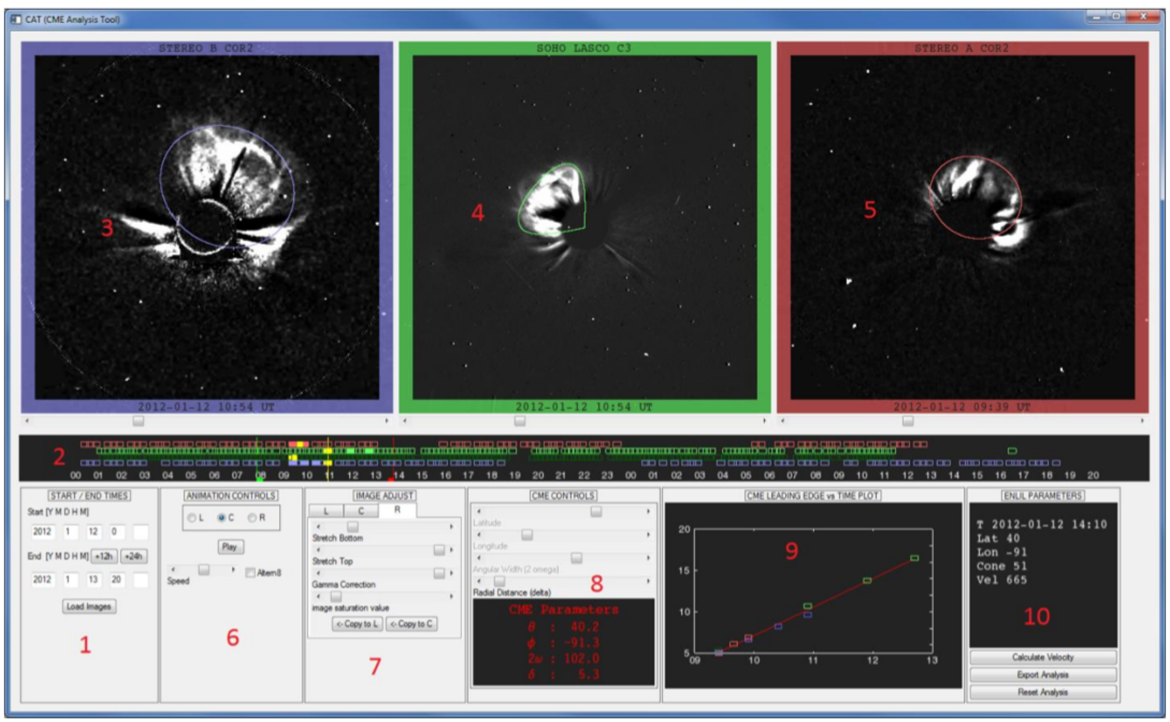


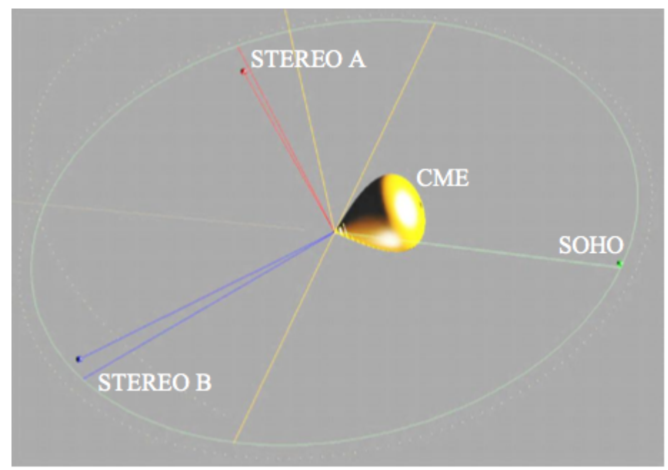
Geometry-dependent CME models



Advanced analysis tools use a 3D CME geometric model that can be projected onto the different observation planes.

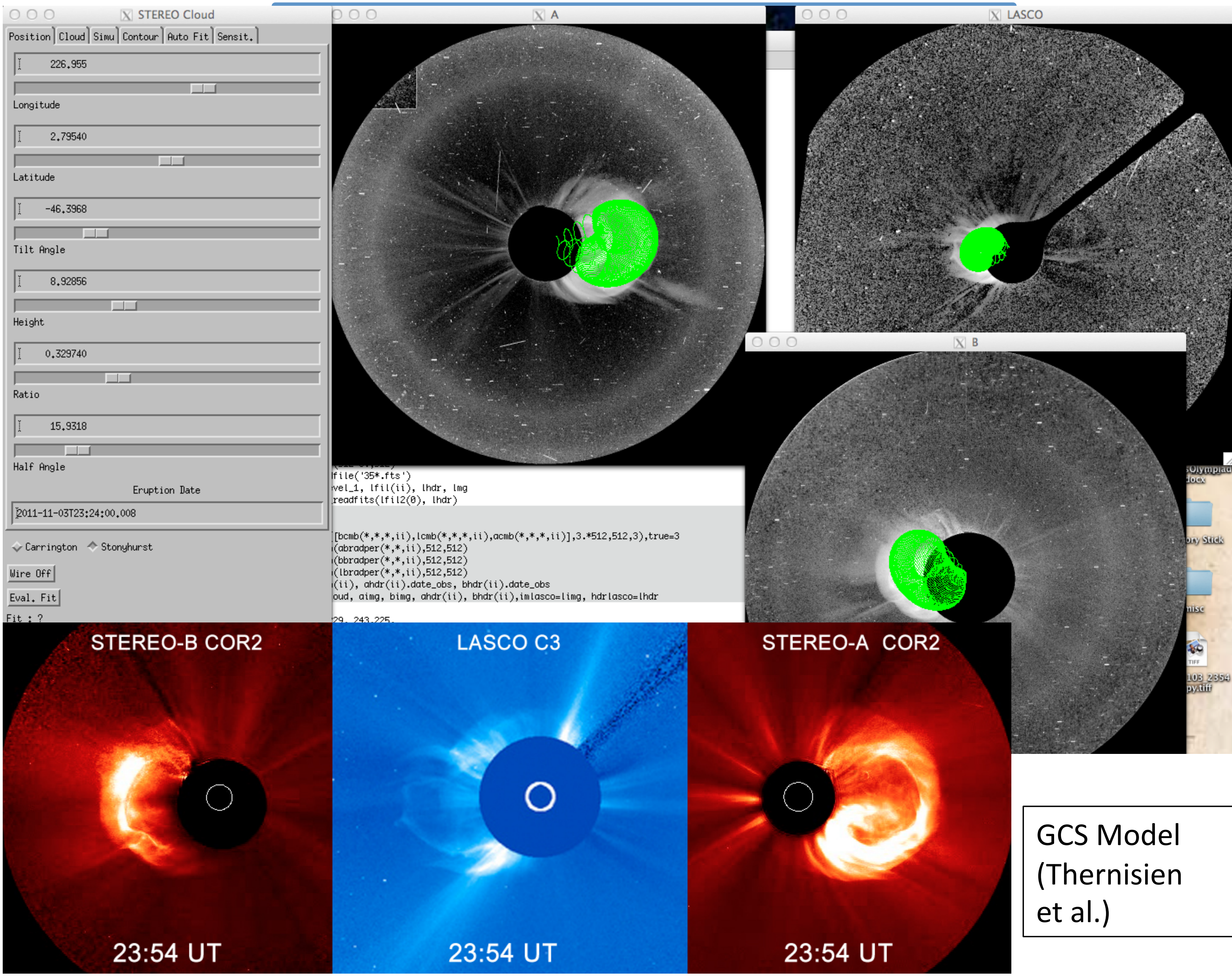
We vary the projection parameters to see what produces a model CME that best matches observations.





SWPC_Cat

(DeKonig et al.)



GCS Model (Thernisien et al.)

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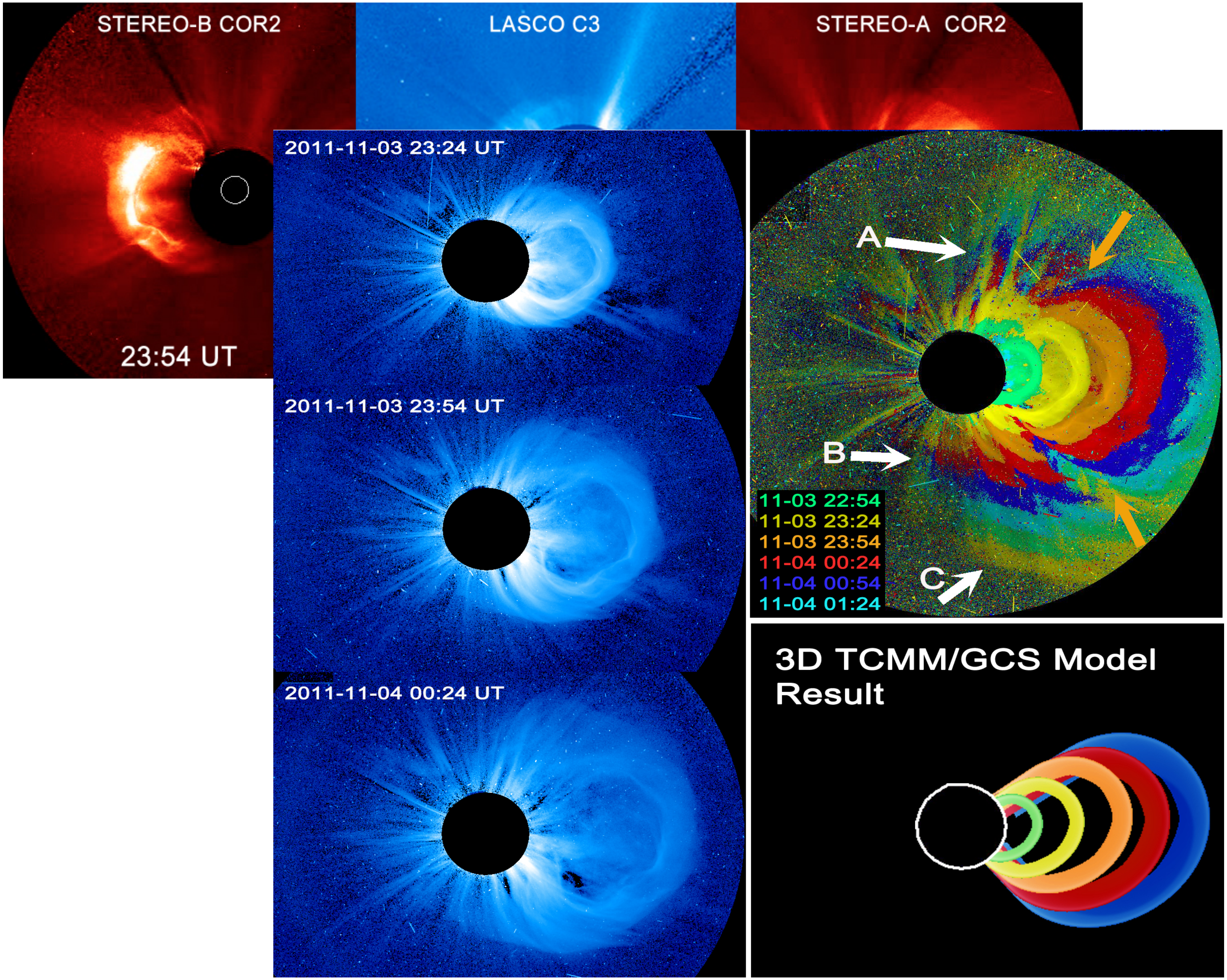
    - They can have a variety of shapes
- CME-associated brightenings are difficult to separate from the "true" CME mass
- The inner coronal signatures (flares, loops, eruption signatures) don't always directly map into the coronagraph CME

Do the best with what you've got : (

Fold this into the measurements

3D reconstruction geometries


STEREO-B COR2
23:54 UT
LASCO C3
STEREO-A COR2
2011-11-03 23:24 UT
2011-11-03 23:54 UT
2011-11-04 00:24 UT
A
B
C
11-03 22:54
11-03 23:24
11-03 23:54
11-04 00:24
11-04 00:54
11-04 01:24
3D TCMM/GCS Model Result

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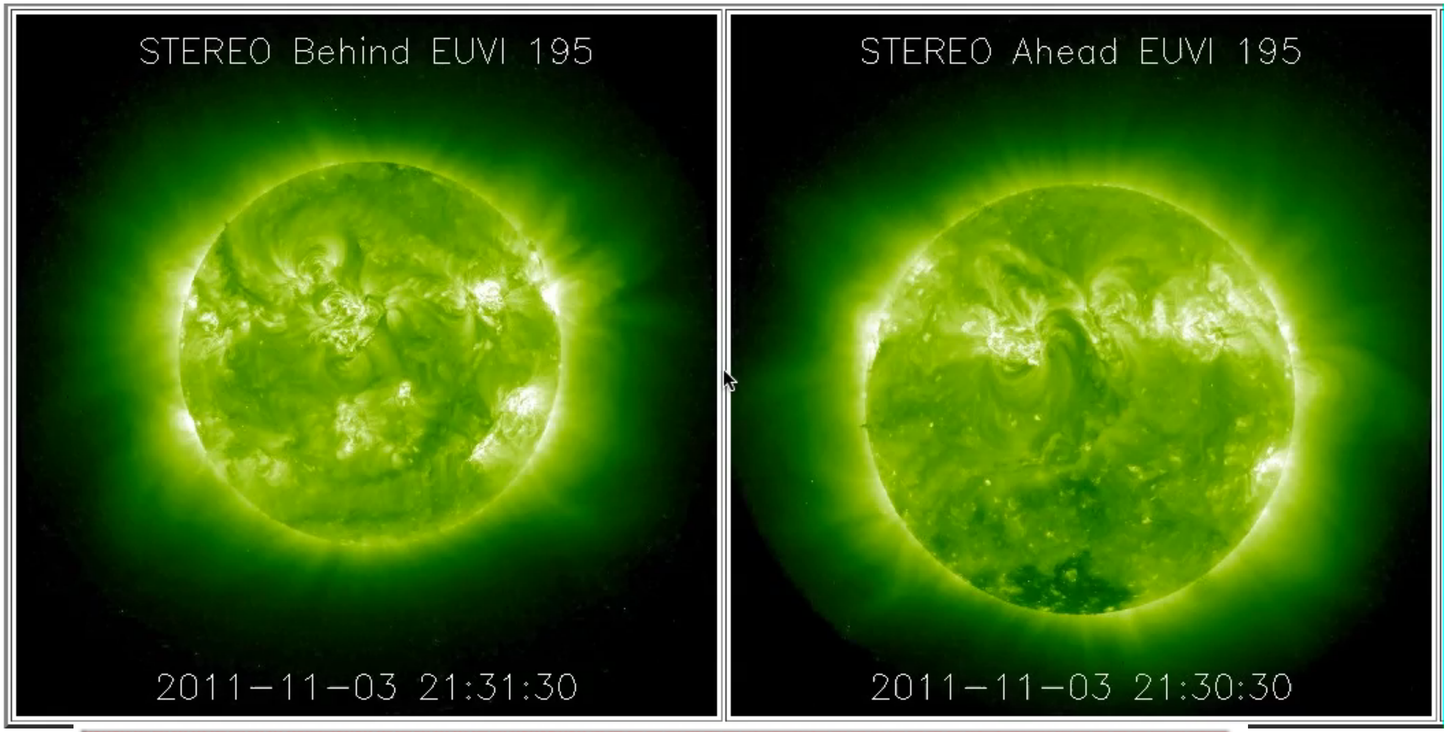
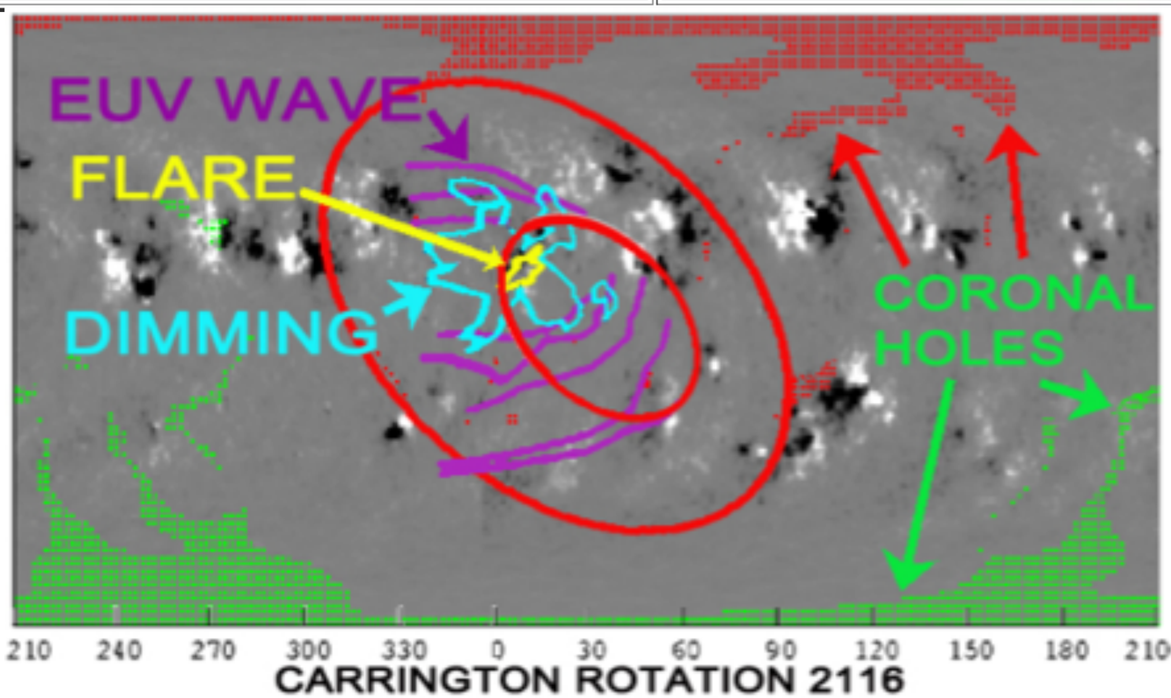
Advanced image processing techniques


STEREO Behind EUVI 195
2011-11-03 21:31:30
STEREO Ahead EUVI 195
2011-11-03 21:30:30


EUV WAVE
FLARE
DIMMING
CORONAL
HOLES
210 240 270 300 330 0 30 60 90 120 150 180 210
CARRINGTON ROTATION 2116

nes)

es)

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coronagraph CME

Do the best with what you've got : (

Fold this into the measurements

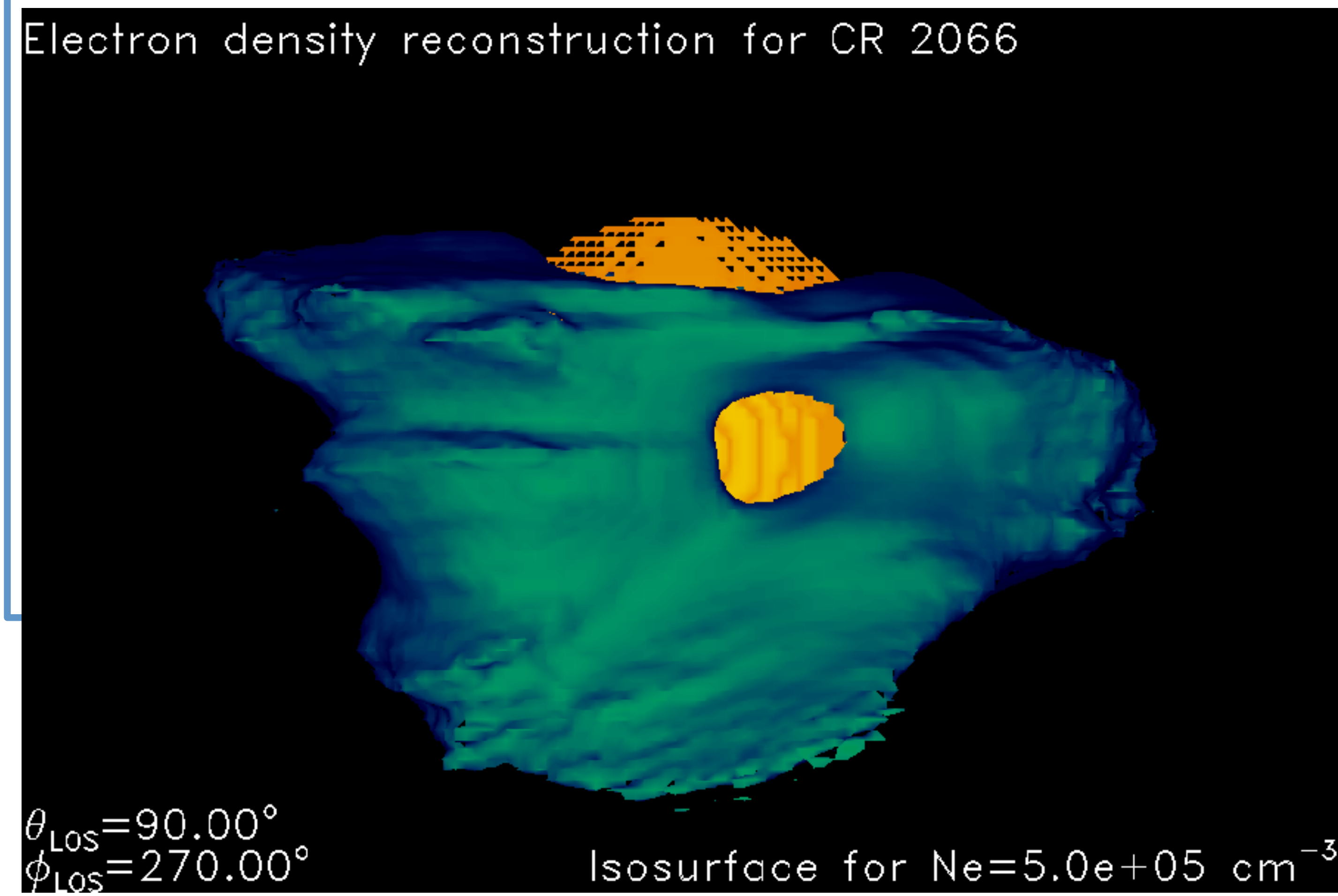
3D reconstruction geometries

Advanced image processing techniques

Hope that the CME you're measuring isn't one of the weird ones (and also research)

New Frontiers for R_2O

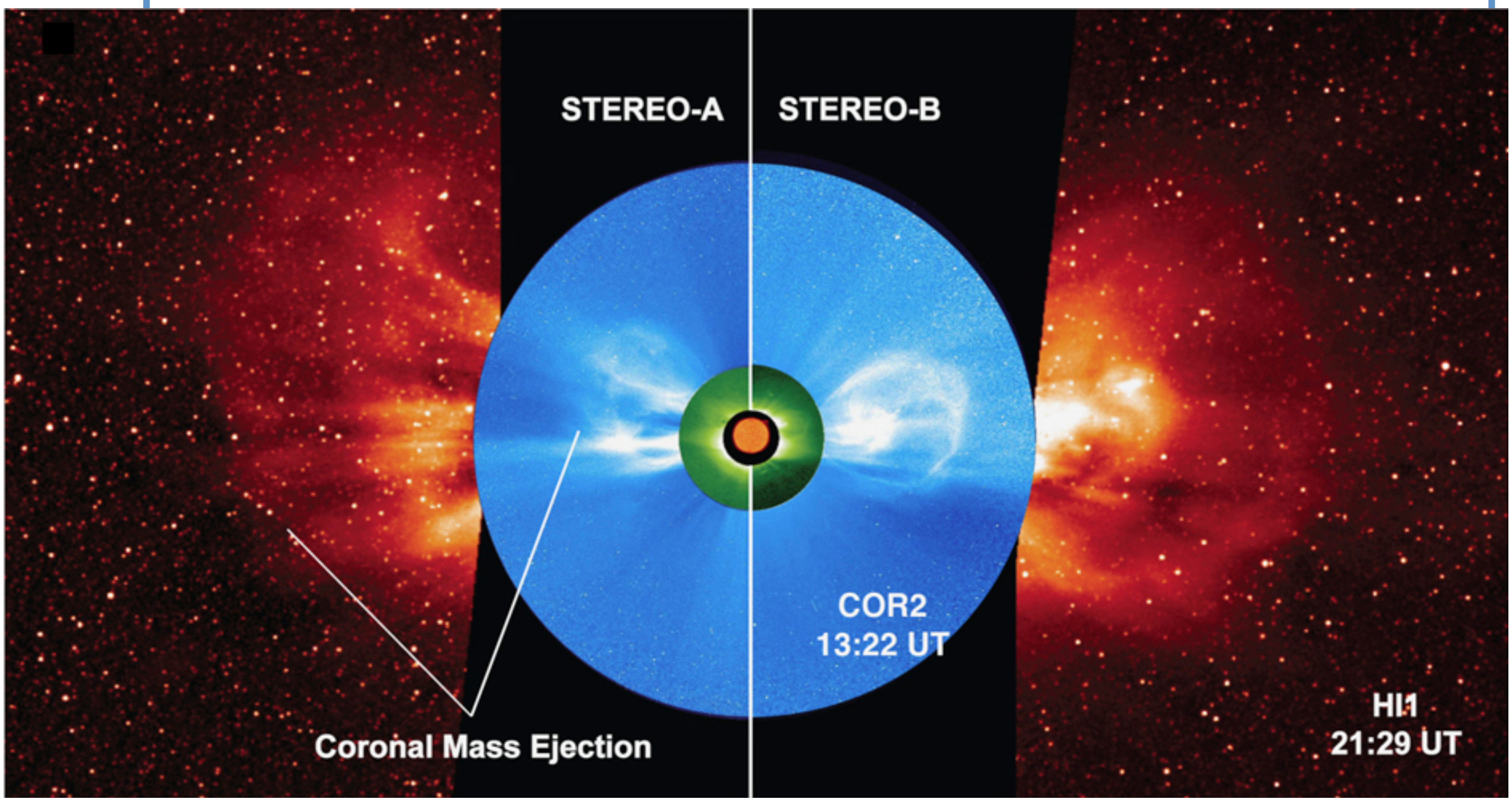
- Inner coronal structure



Kramar & Airapetian

New Frontiers for R_2O

- Inner coronal structure
- Magnetic structure studies and predictions
- "Updates" from the inner heliosphere:
    - STEREO Heliospheric Imager data



Byrne et al., 2010

New Frontiers for R_2O

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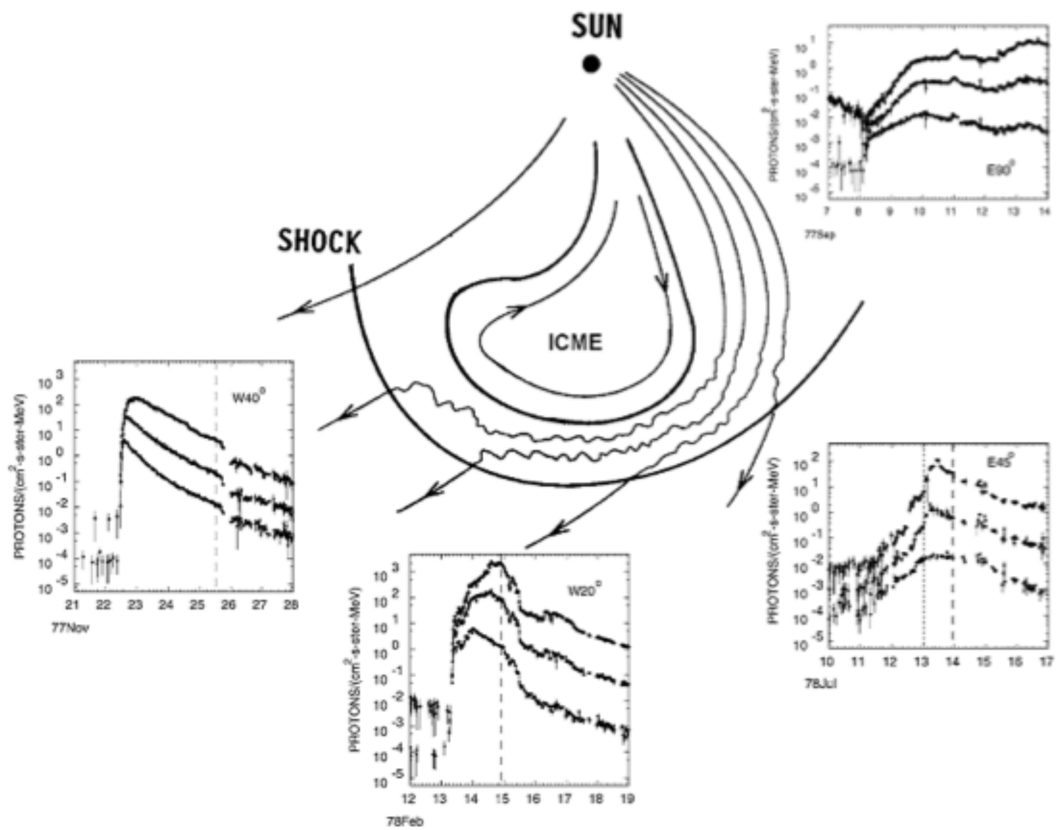
  - SEP Flux



Cane et al., 1988; Cane & Lario, 2006

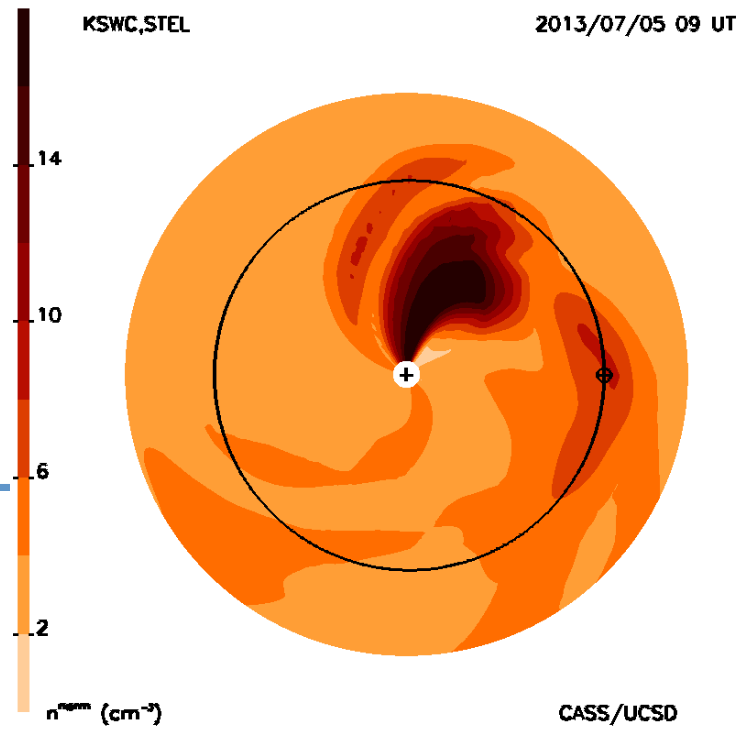
New Frontiers for R_2O

- Inner coronal structure
- Magnetic structure studies and predictions
- "Updates" from the inner heliosphere:
    - STEREO Heliospheric Imager data
    - SEP Flux
    - Radio Type II Bursts

Next week's STE Forum

New Frontiers for R_2O

- Inner coronal structure
- Magnetic structure studies and predictions
- "Updates" from the inner heliosphere:
  - STEREO Heliospheric Imager data
  - SEP Flux
  - Radio Type II Bursts
  - Interplanetary Scintillation



Courtesy of B. Jackson and STELab

THANK YOU!!!