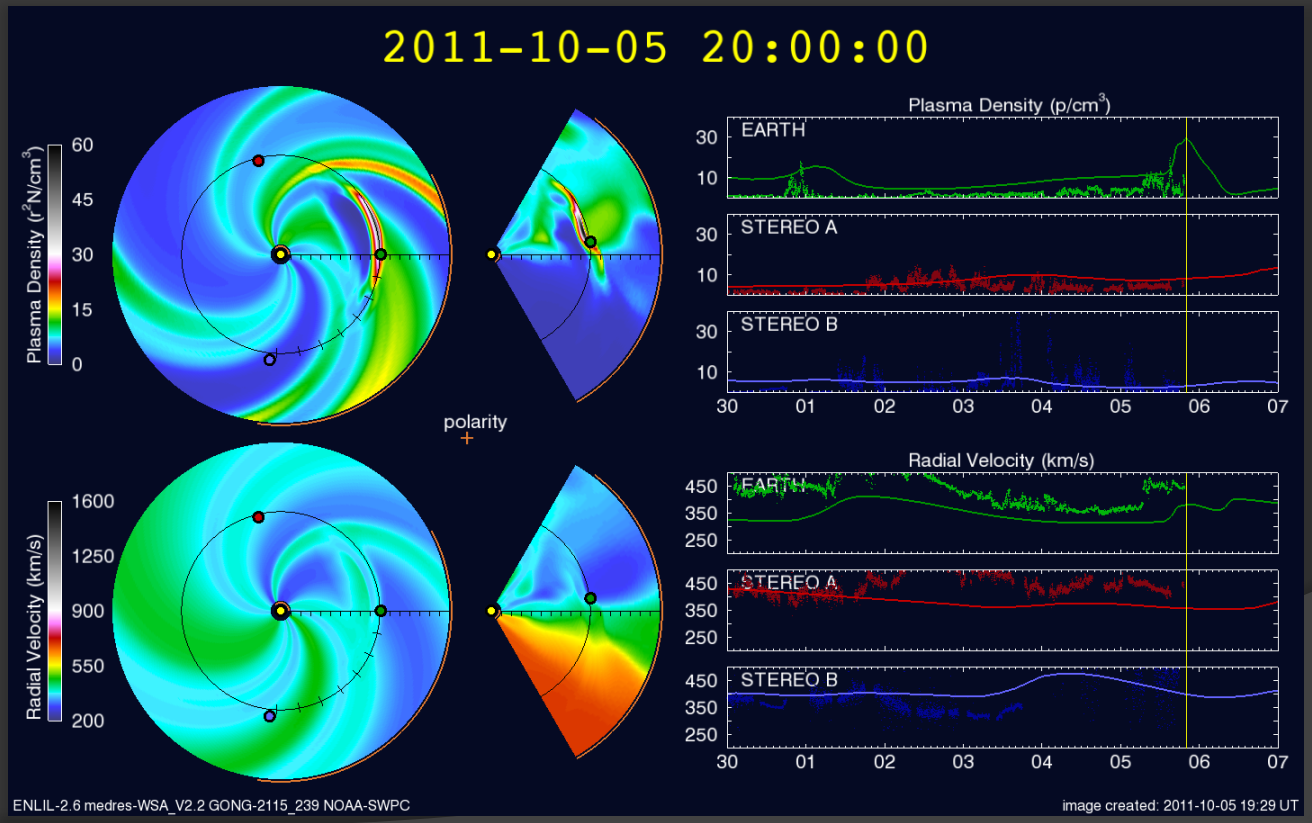
WSA-Enlil in Operations at the National Weather Service: Experiences, Results and Developments

George Millward (CU/NOAA)
Vic Pizzo, Doug Biesecker (NOAA), Curt de Koning (CU/NOAA)



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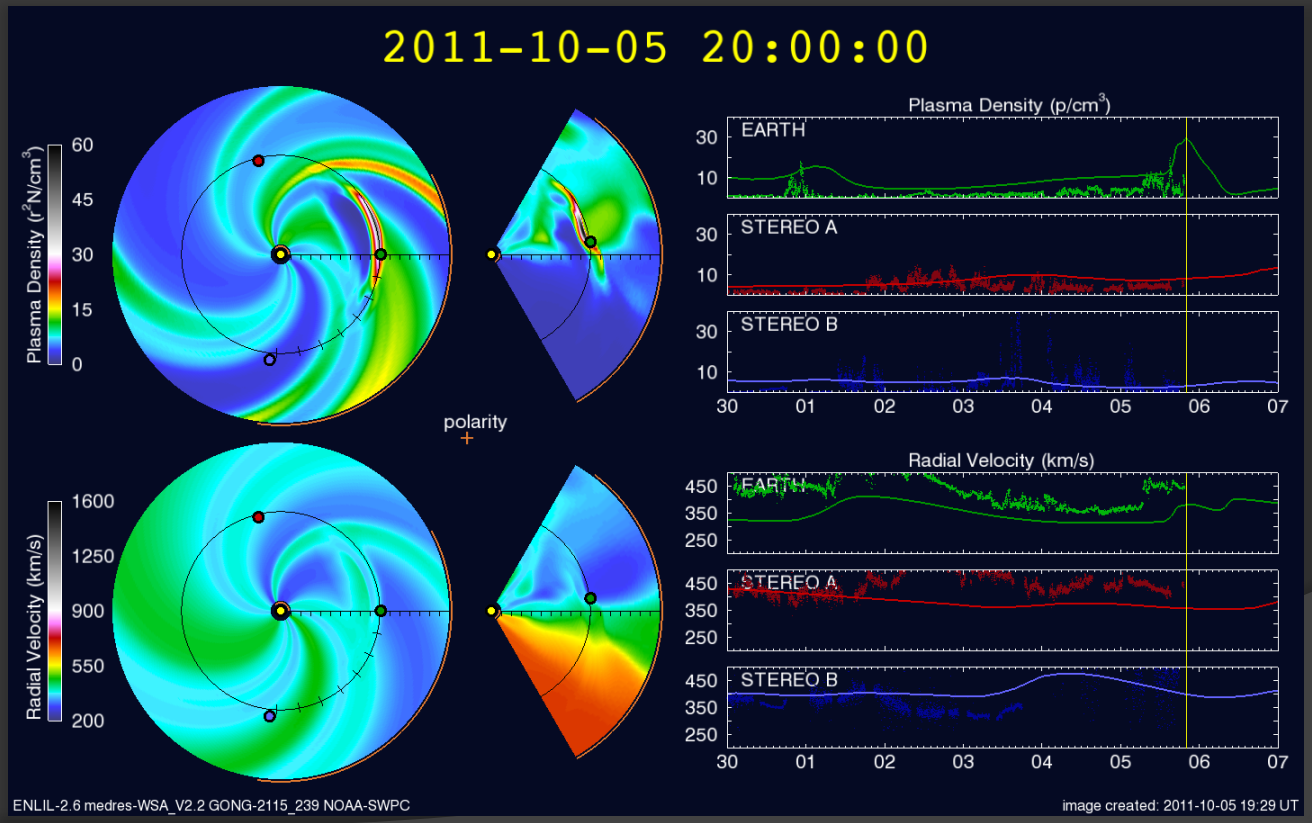
Transition to Operations



Transition to Operations

Transition to Operations

VALLEY OF DEATH

Transition to Operations

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Transition to Operations

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Transition to Operations

RUBBER HITS THE ROAD

Transition to Operations

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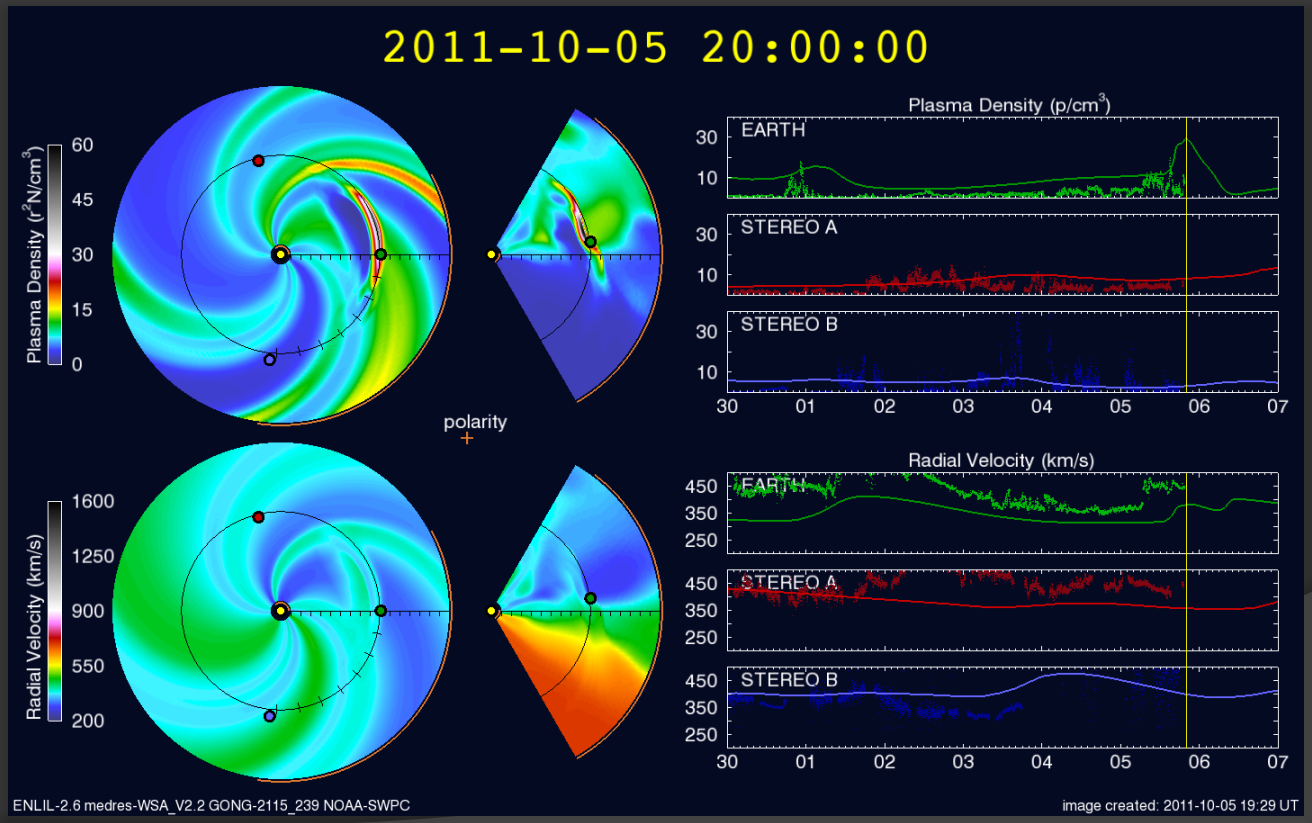


Intended Space Weather Benefits

- Provide improved warning of Co-rotating Interacting Regions (CIRs)

  General “situational awareness”
  Time of arrival at Earth
  Geomagnetic storm response

- Provide 1 to 4 days advance warning of oncoming CMEs

  General “situational awareness”
  Probability of an interaction with Earth (“direct hit very probable”, “possible glancing blow”)
  Time of arrival at Earth (Aiming for accuracy of +/- 6 hours)
  Storm intensity (Tricky, modeled CME has no information about B field magnitude or orientation)
  Storm duration

- Pave the way for future space weather model transitions:

  Geospace
  Upper atmosphere / ionosphere

WSA-Enlil at NWS: Timeline

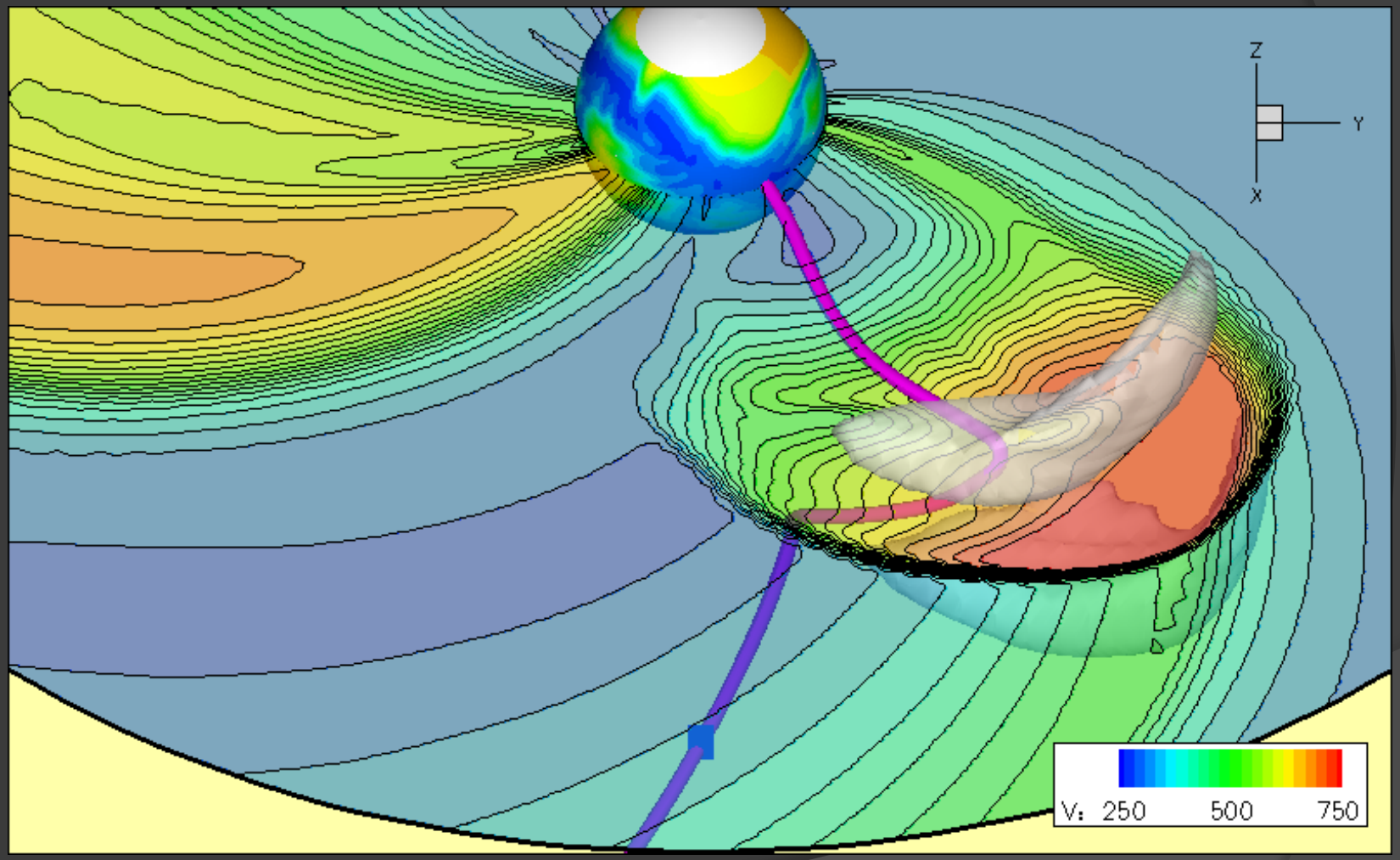
- October 2009 : Begin Transitioning project

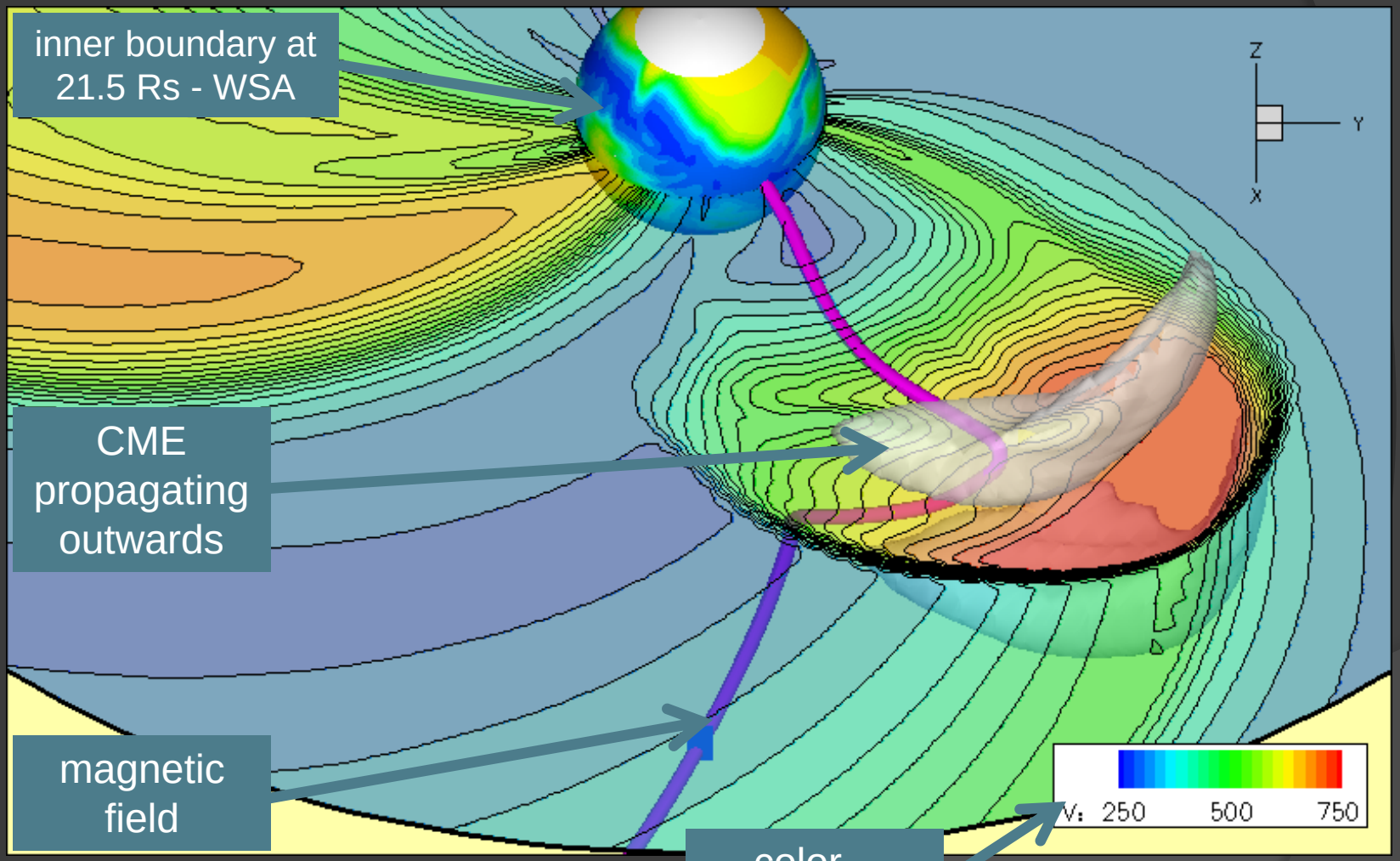
  Design of WSA-Enlil CONOPS
  Development / testing of CME ‘cone’ tools
  Installation of WSA-Enlil on DEVCCS
  Model run scripts / networking (etc.)
  Development of Solar Predictions Interface (SPI)
  Post-processing / output products

- October 2011 : WSA-Enlil in ‘parallel operations’ at NWS
- December 2011 : WSA-Enlil fully operational on NCEP supercomputers
- April 2012 (ie, Now) : Deployment of SPI and Analysis tools into SWPC Forecast Office
- March – September : Forecaster Training
- October 2012 : Fully Operational (SWFO in full control)
- 2013 : Version 2 development (SWPT)

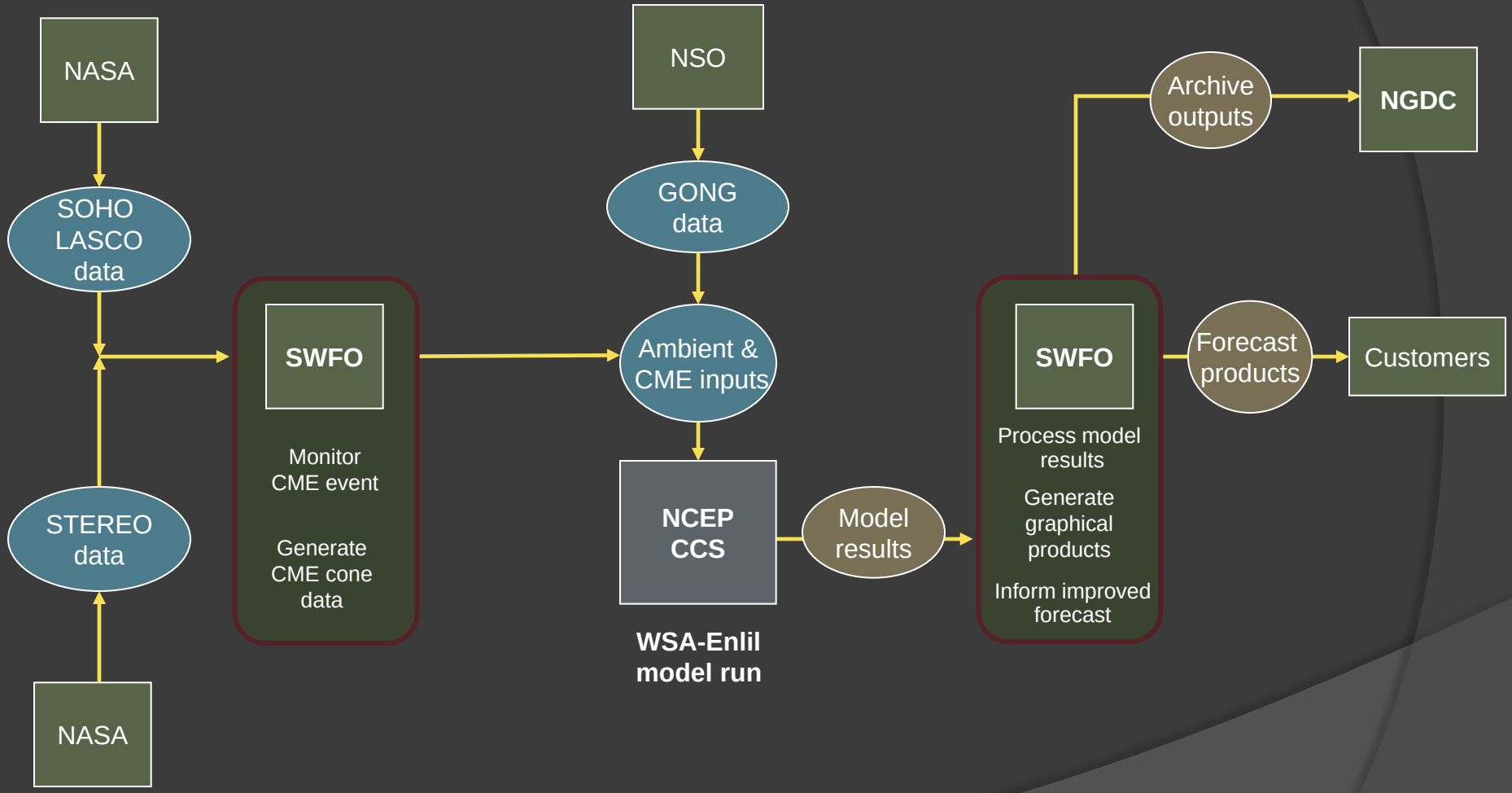
WSA-Enlil

A comprehensive, 3D, MHD, time-dependent, forecast model of the Heliosphere (solar wind)



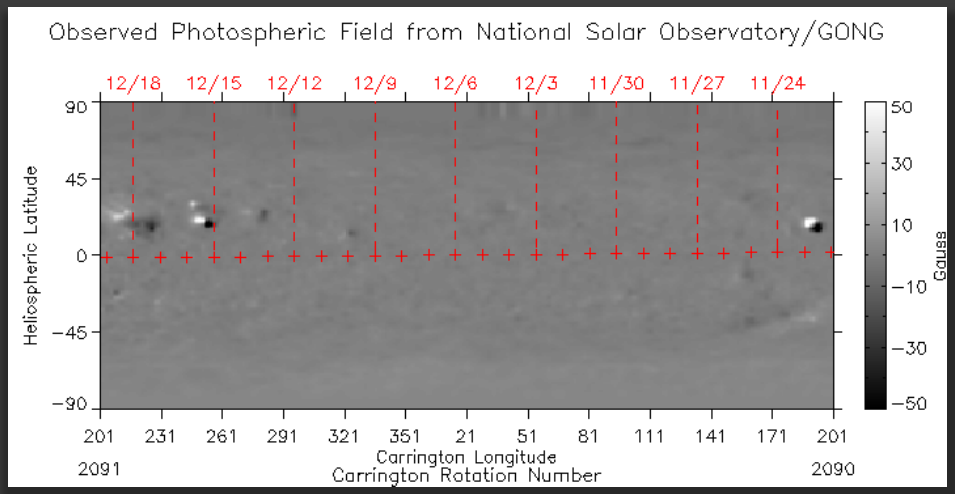

inner boundary at 21.5 Rs - WSA
CME propagating outwards
magnetic field
color – velocity field
Z
Y
X
V: 250
500
750

WSA-Enlil CONOPS

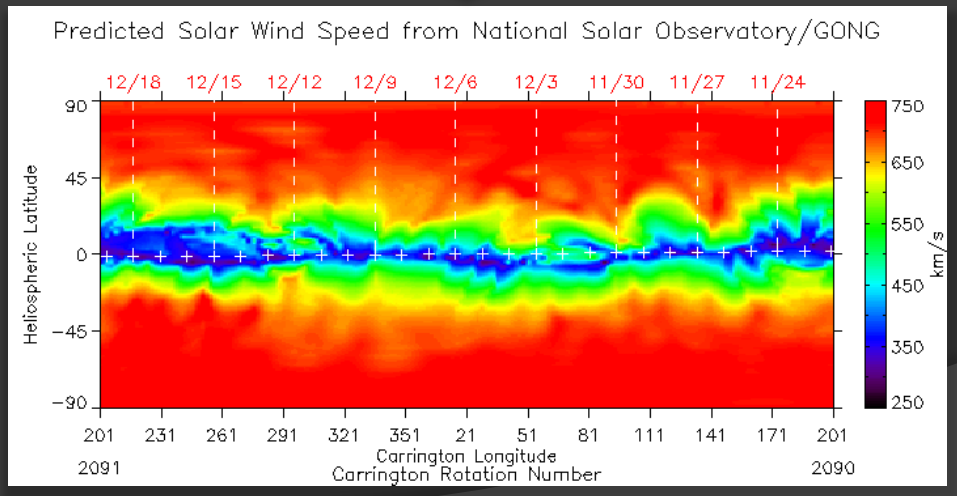


Wang-Sheeley-Arge (WSA) model:

INPUT:
Solar photospheric magnetic field (NSO, GONG)



WSA

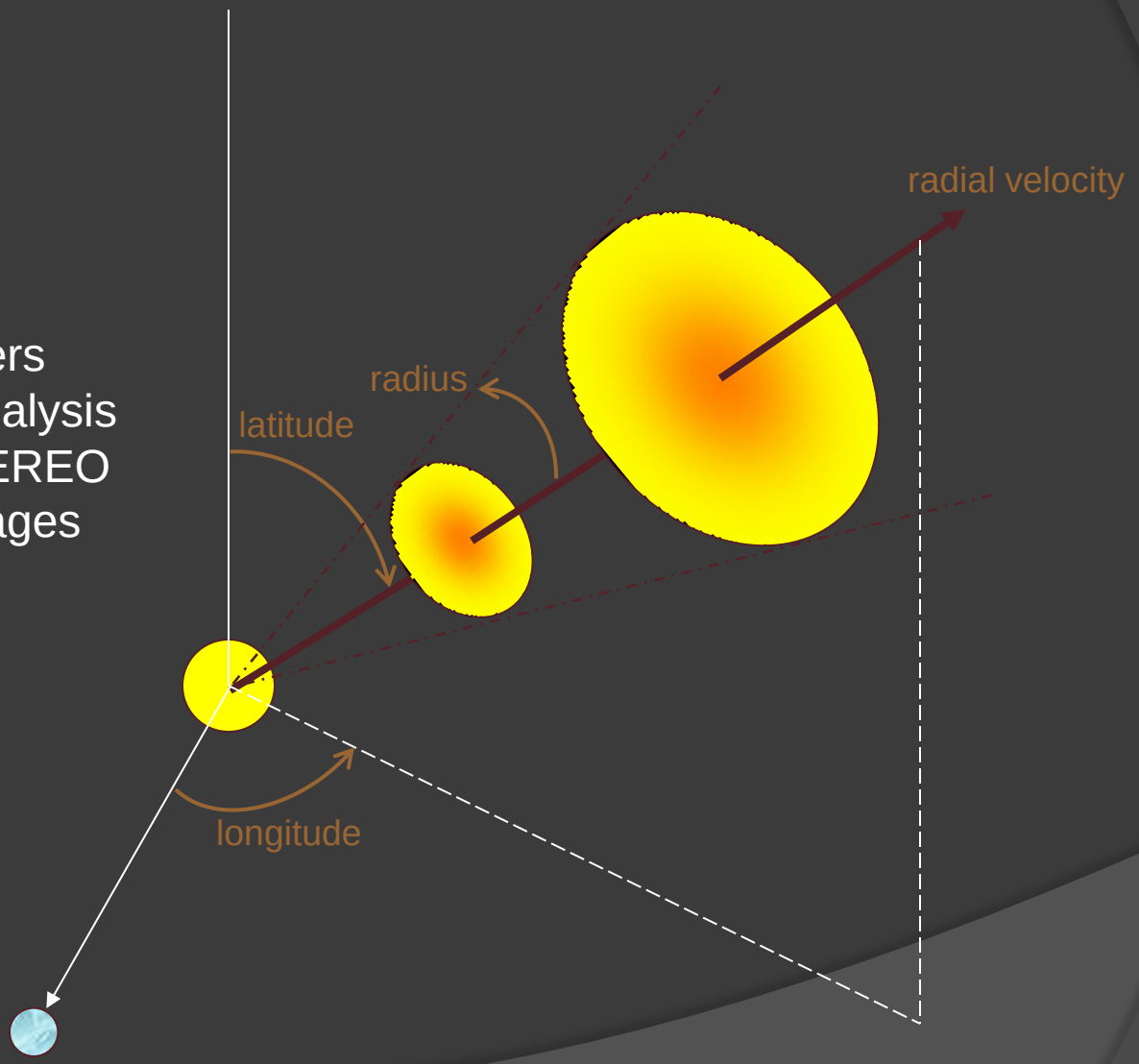


OUTPUT:
Global velocity and magnetic polarity

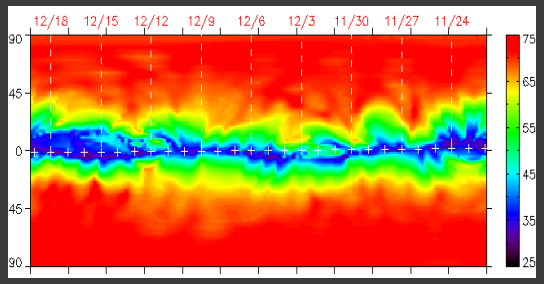
Steady, co-rotating “ambient” background flow at 21.5Rs

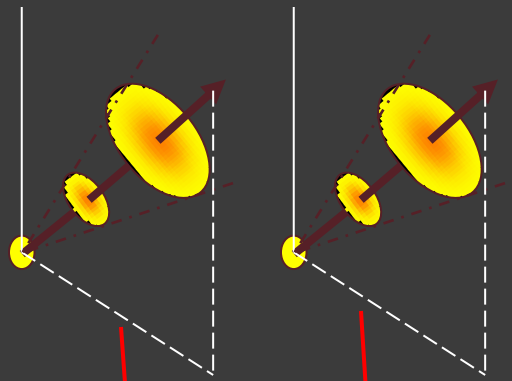
CME ‘Cone’ Geometry

CME parameters calculated from analysis of SOHO and STEREO coronagraph images



WSA-Enlil Model Run Schematic





CME 1

CME 2

10 day model startup

5 days CME injection

forecast

T = -15

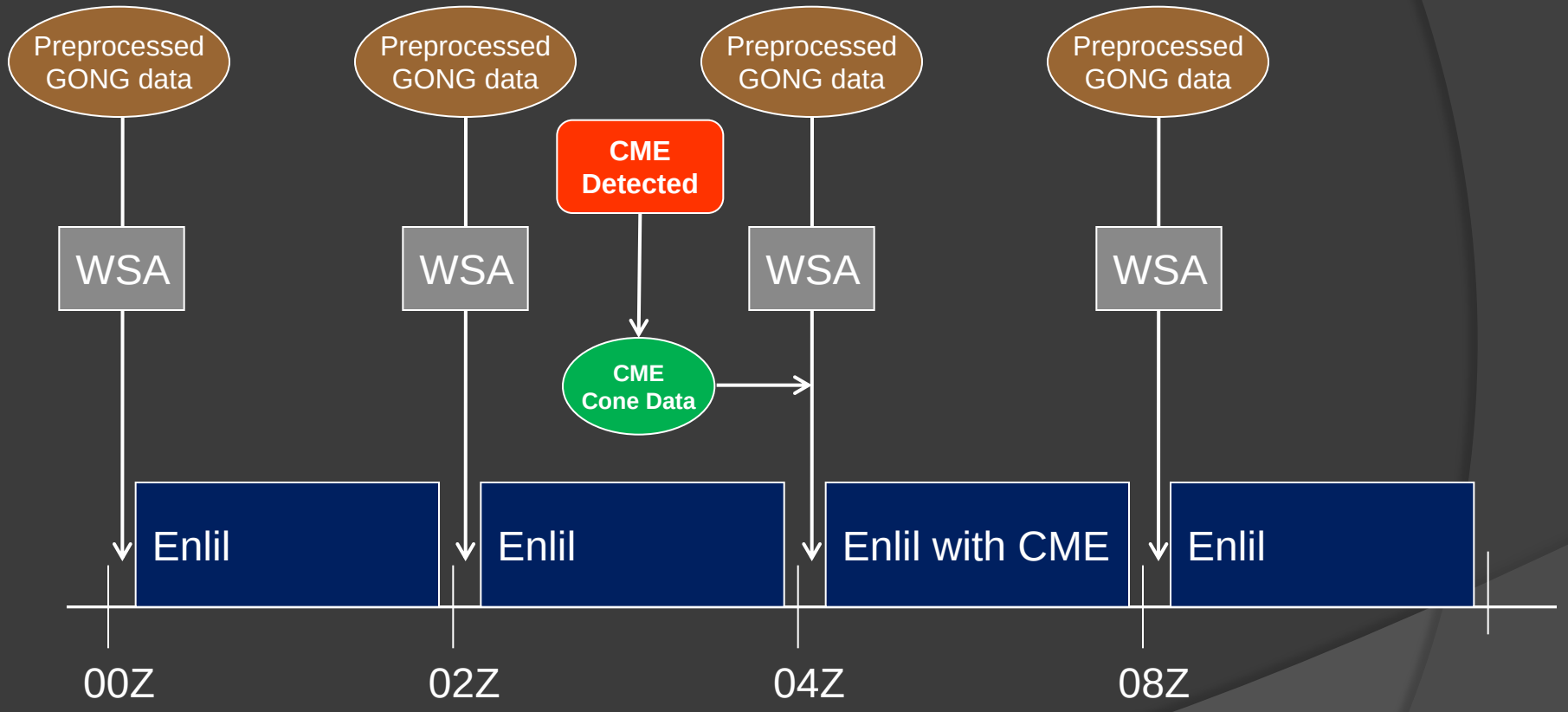
T = 0

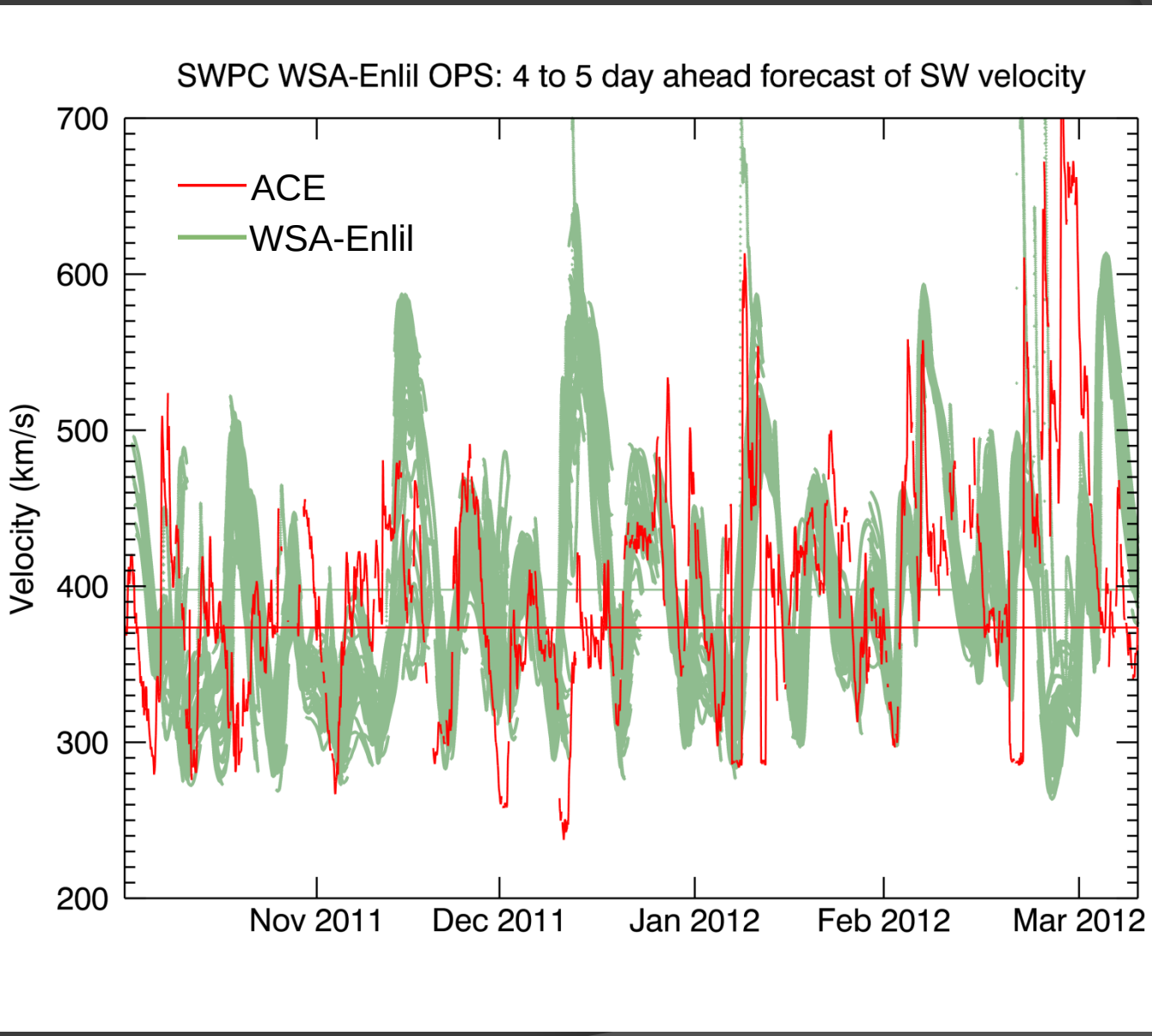
T = 5 days

1.5 hours Wallclock time on NWS CCS

WSA-Enlil production run cycle at NCO

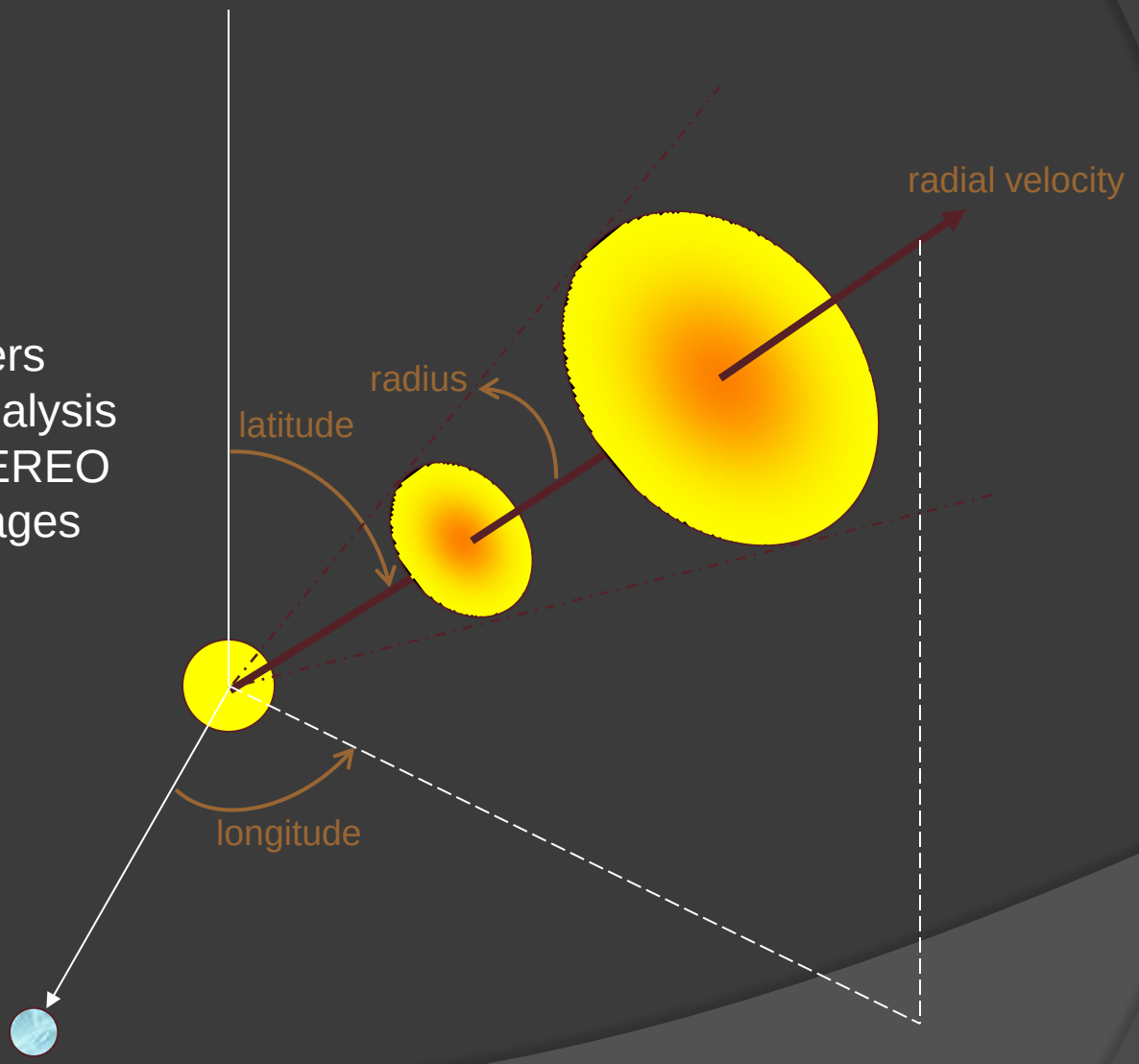
model runs every 2 hours

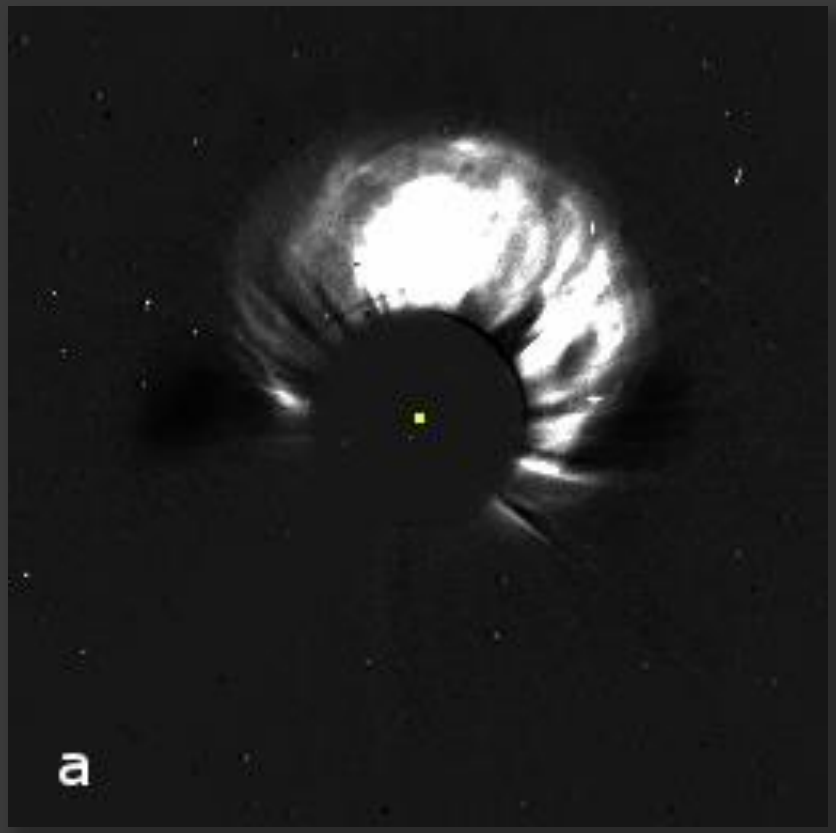


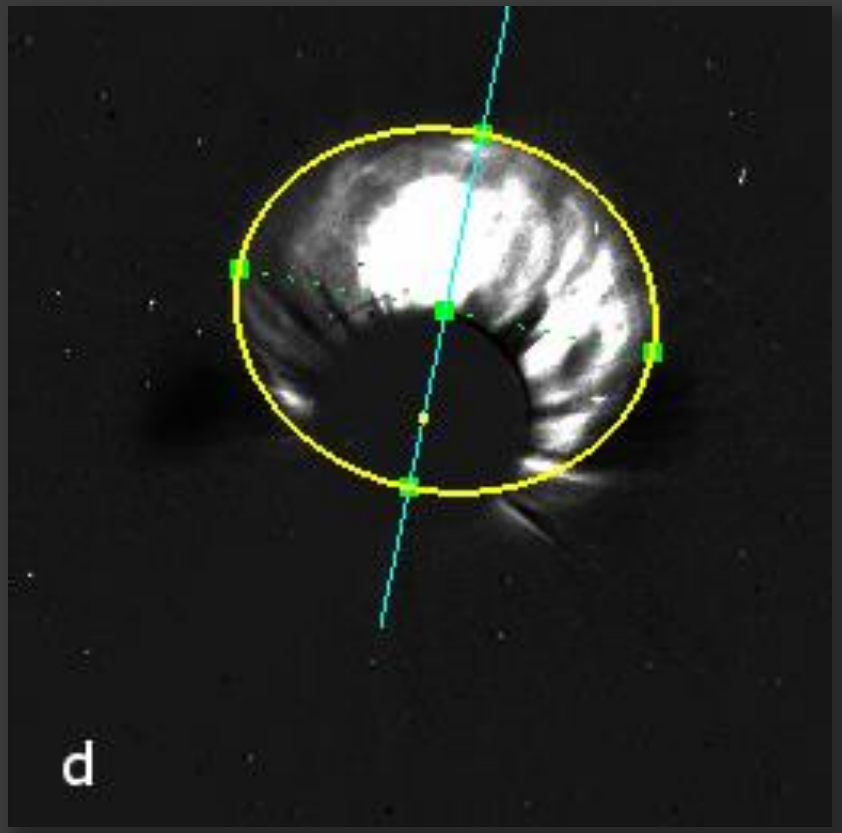

SWPC WSA-Enlil OPS: 4 to 5 day ahead forecast of SW velocity
ACE
WSA-Enlil
Velocity (km/s)
700
600
500
400
300
200
Nov 2011
Dec 2011
Jan 2012
Feb 2012
Mar 2012

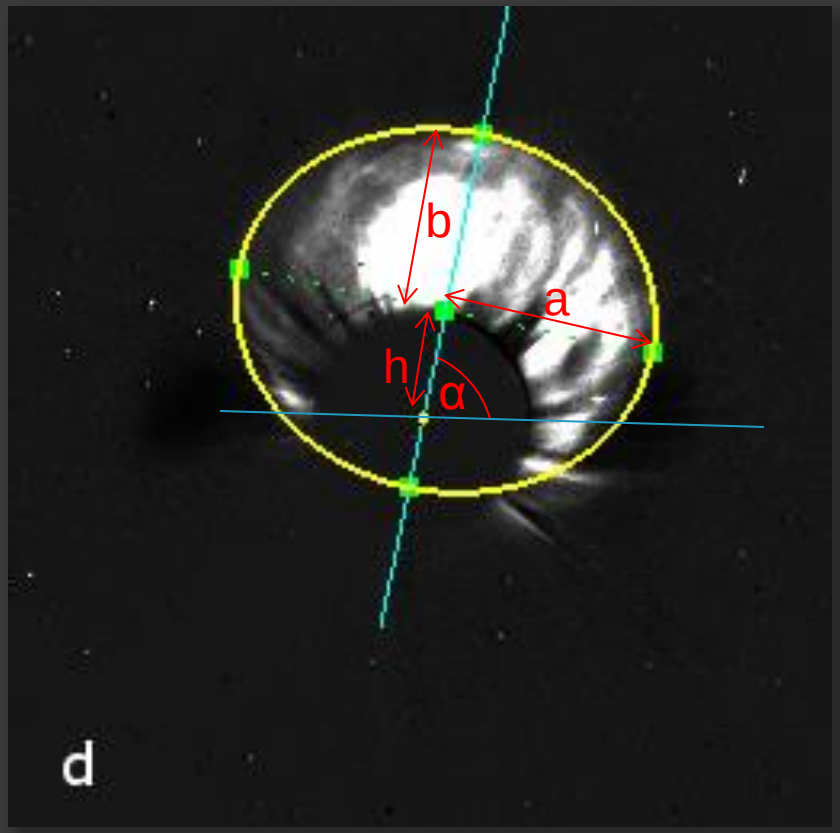
CME ‘Cone’ Geometry

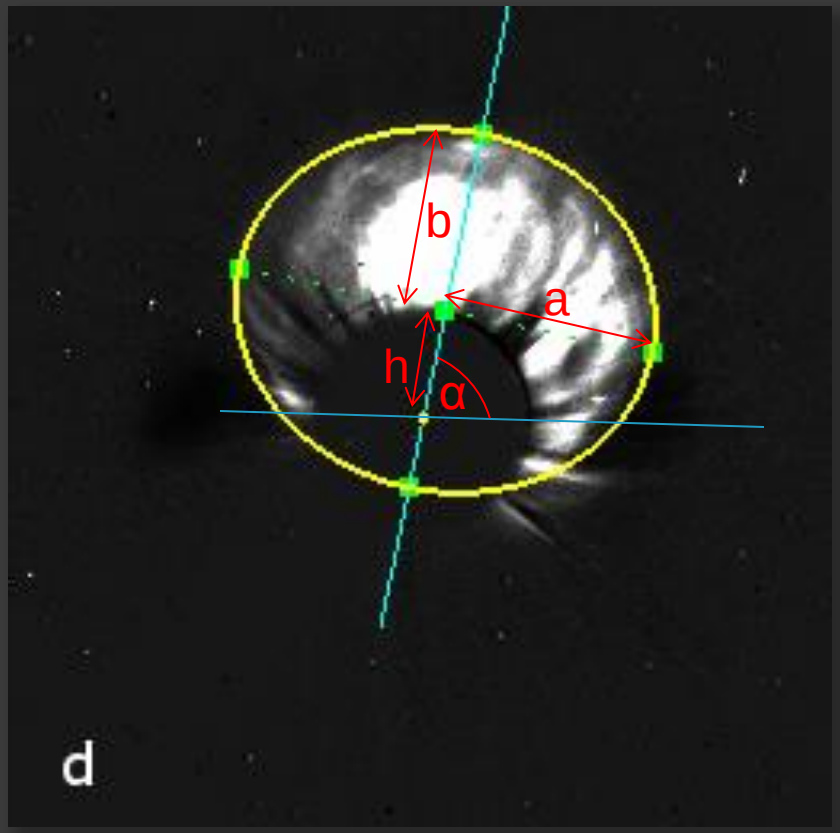
CME parameters calculated from analysis of SOHO and STEREO coronagraph images




a

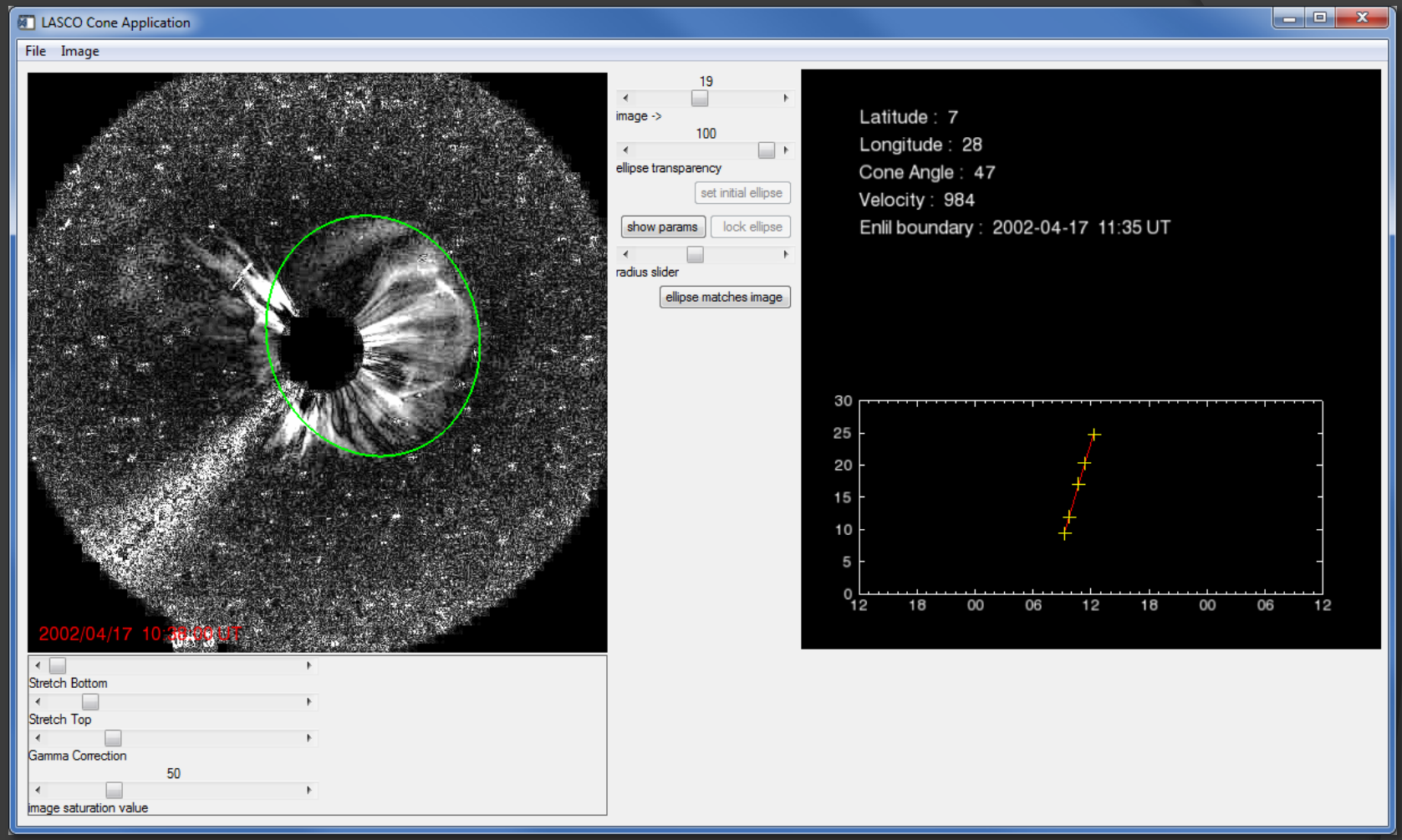

d


b
a
h
α
d



Ellipse parameters gives CME propagation direction and cone angle.

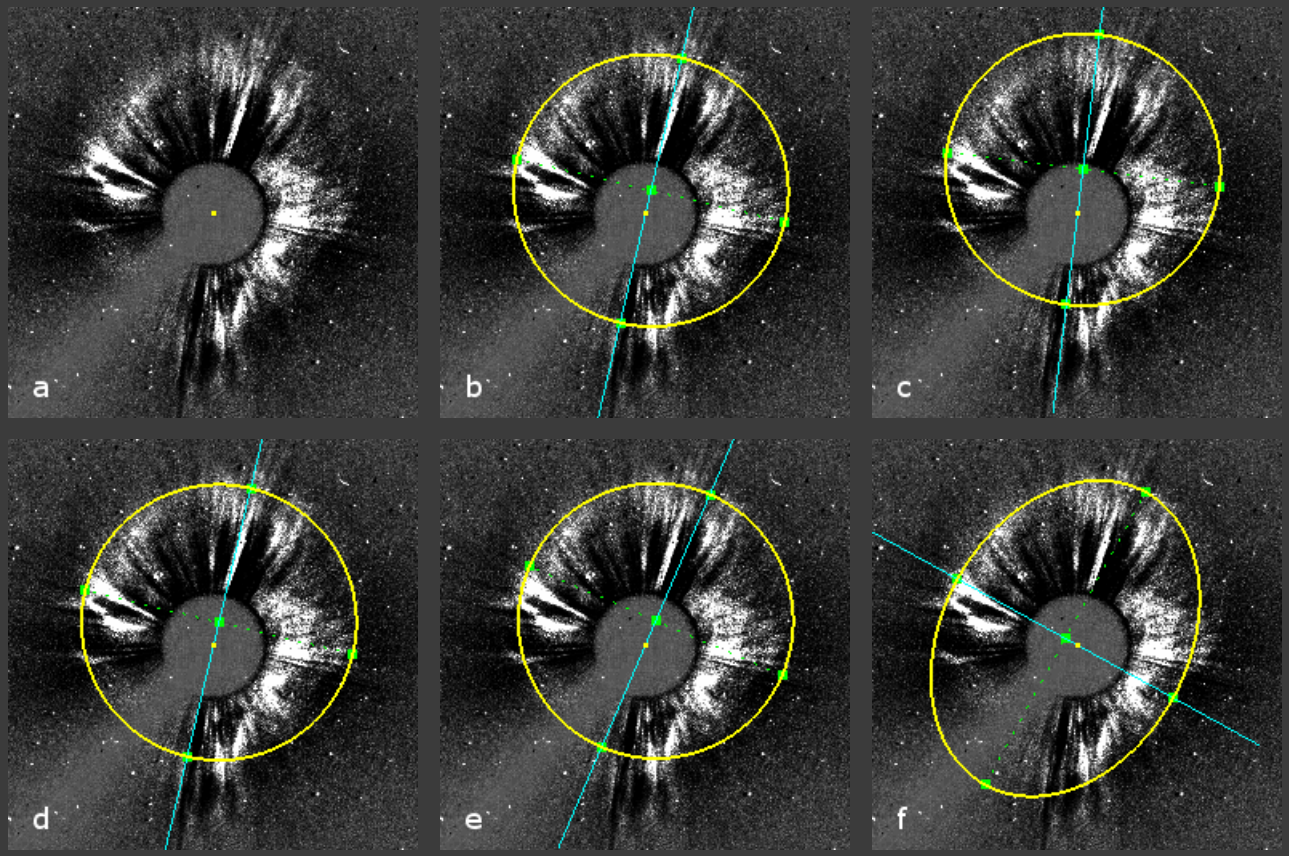
A second coronagraph image yields propagation velocity.



- Built the ellipse formulation into an operational tool.

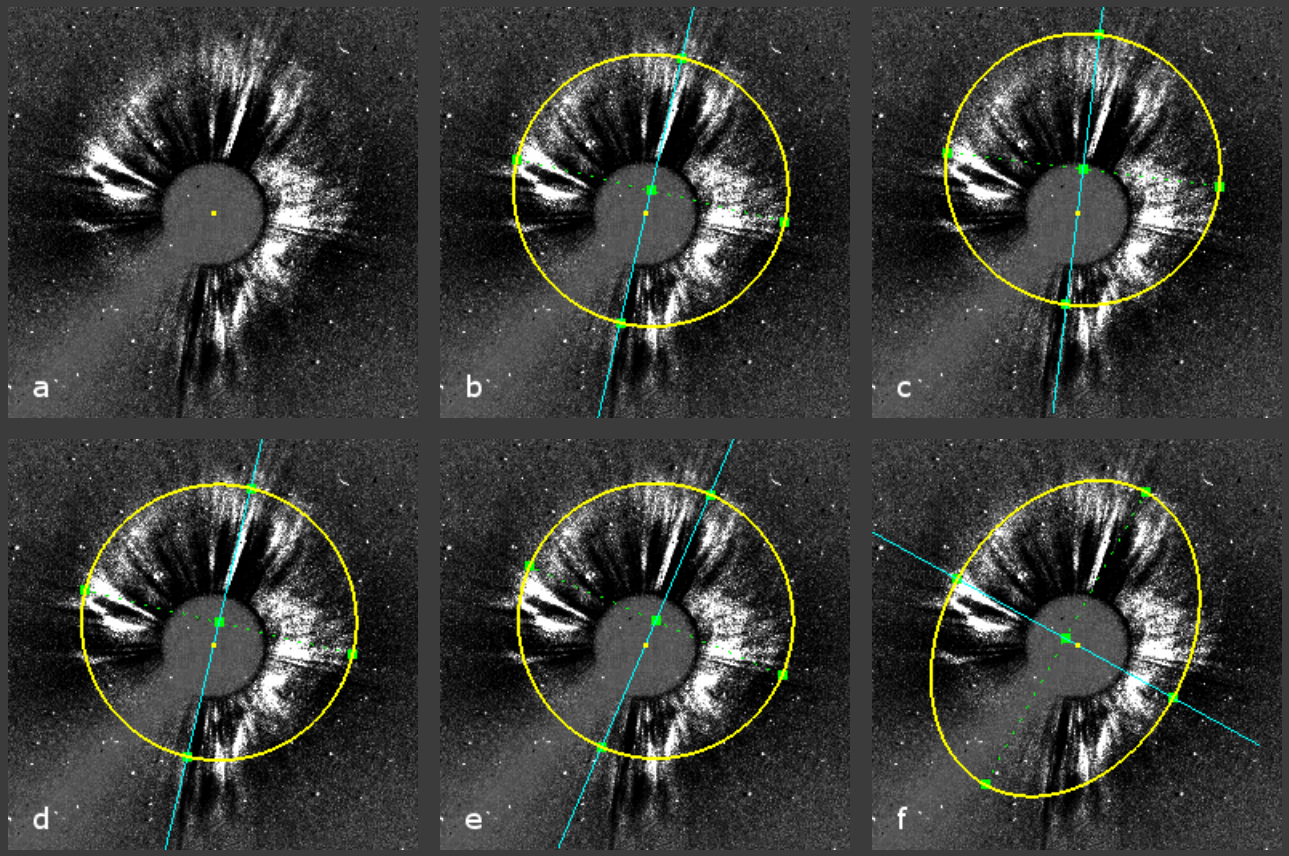
- Subsequent V&V studies revealed the technique to be highly problematic in many real world situations.

Problem: Which ellipse ?



	Latitude (deg)	Longitude (deg)	Cone ½ Angle (deg)	Radial distance (Rs)
b	9.1	2.3	43.2	14.7
c	9.4	1.3	26.9	22.3
d	0.7	0.2	4.4	132.4
e	3.8	1.7	20.3	29.0
f	20.8	-37.8	83.0	12.3

Problem: Which ellipse ?



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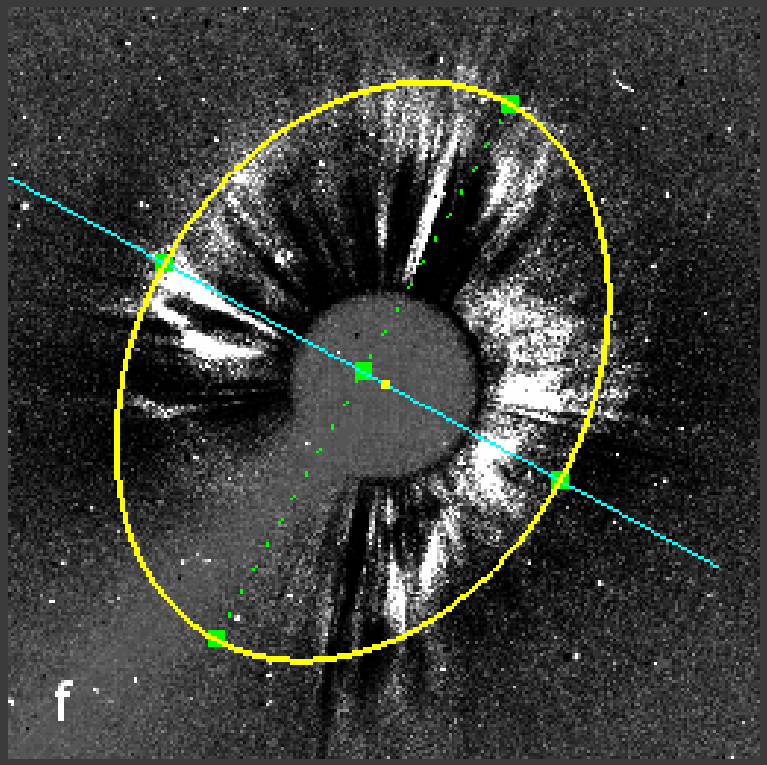
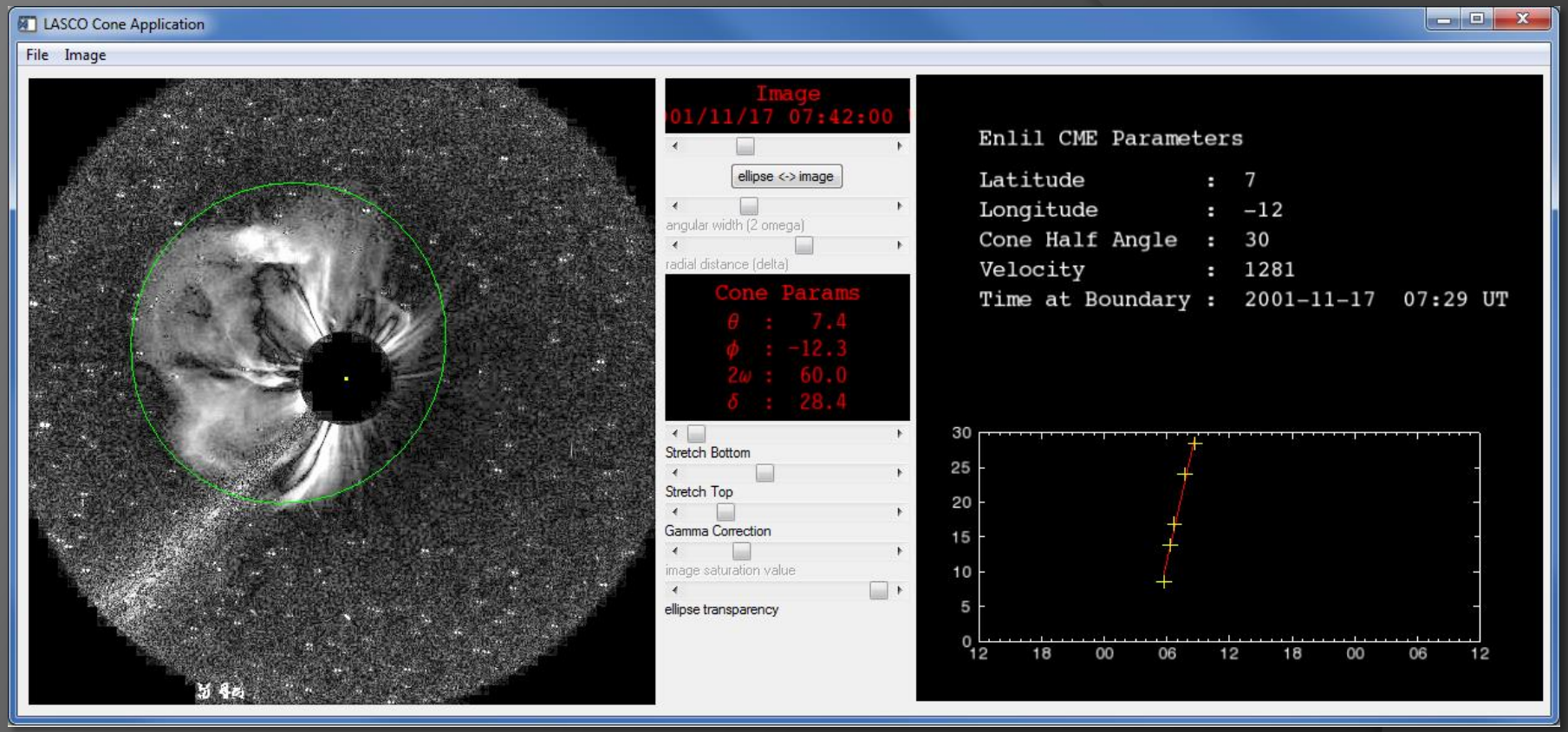
Problem: Ellipses are “freeform” – no constraints on eccentricity vs offset



Cone ½ Angle = 83 degrees (full Angle 166 !!)

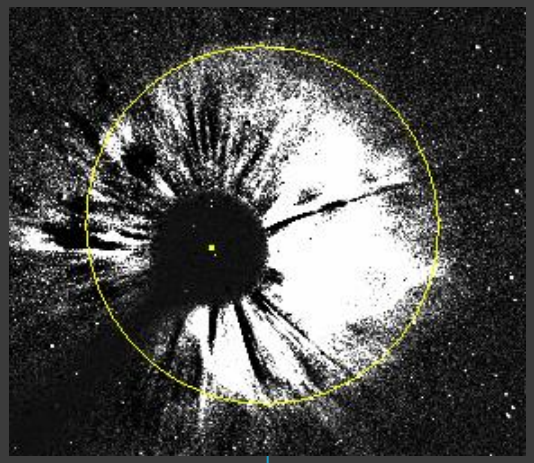


- Full 3D graphics solution – can only represent ‘correct’ cones originating at the Sun
- Need to know the cone angle
- Big problem since cone angle inversely proportional to *velocity (roughly)*

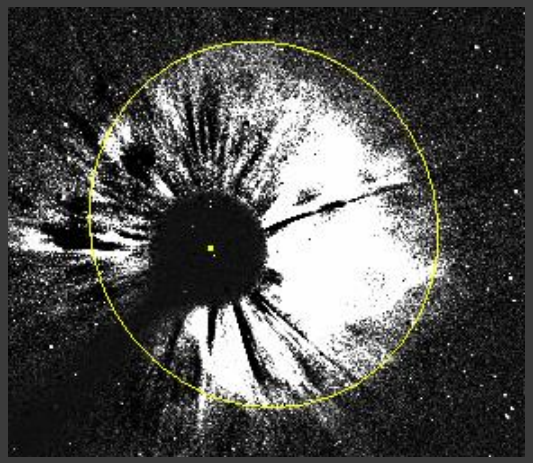
Again: Which ellipse ?

Cone ½ Angle

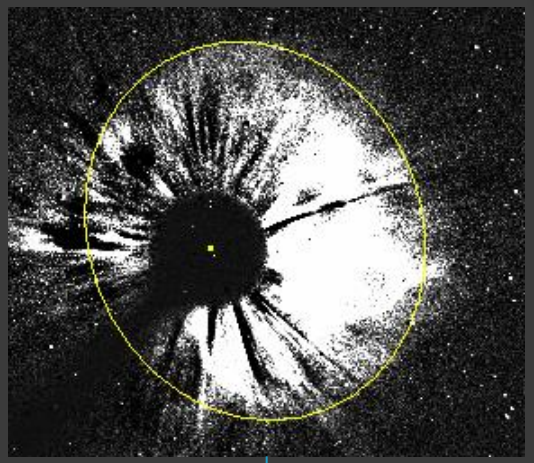
30 degrees



45 degrees

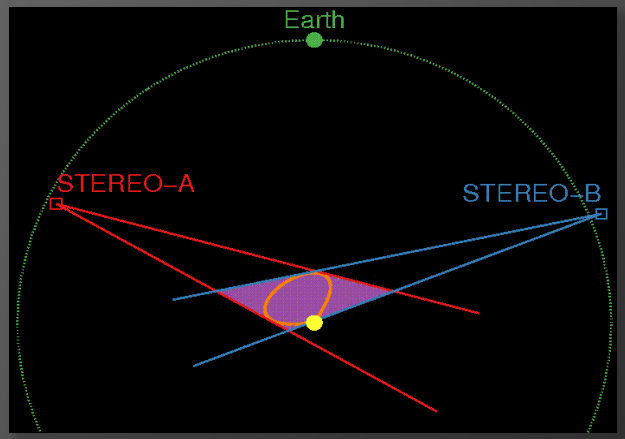


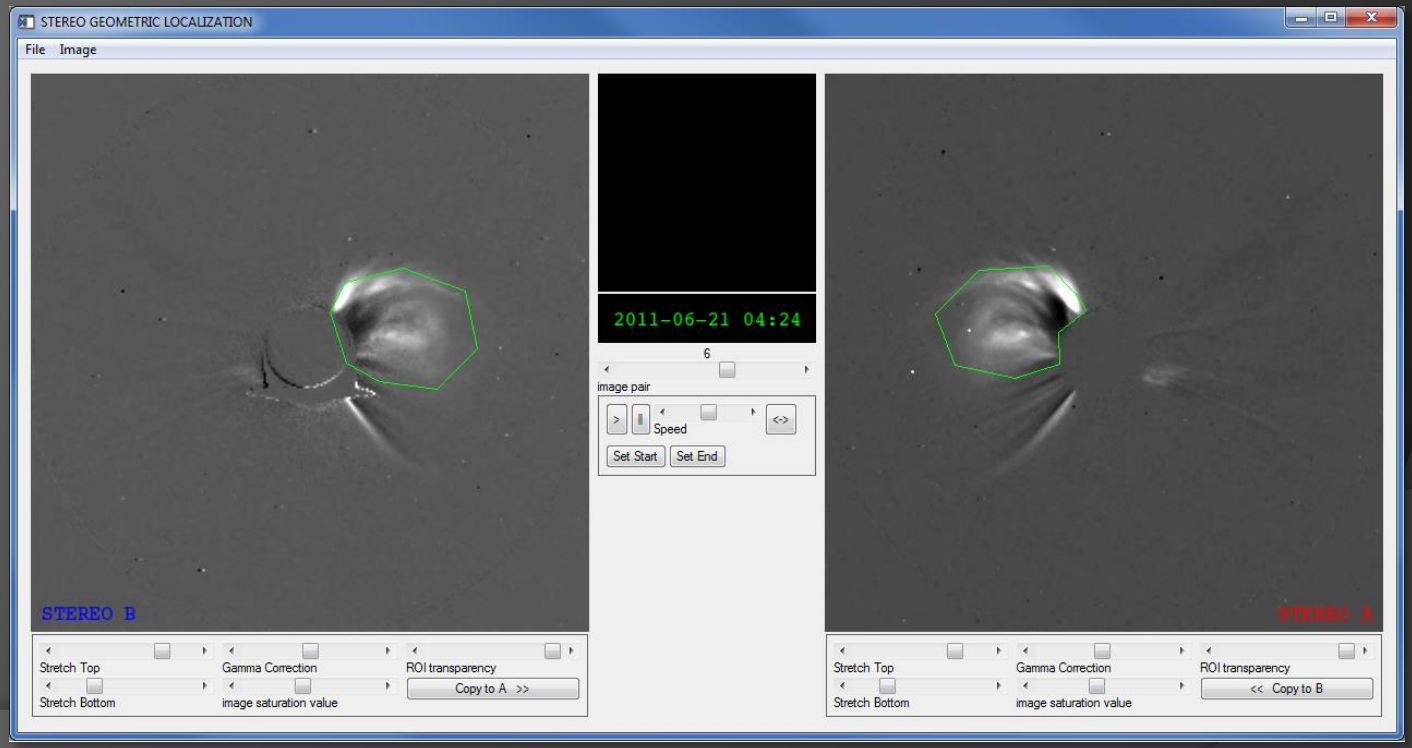
60 degrees



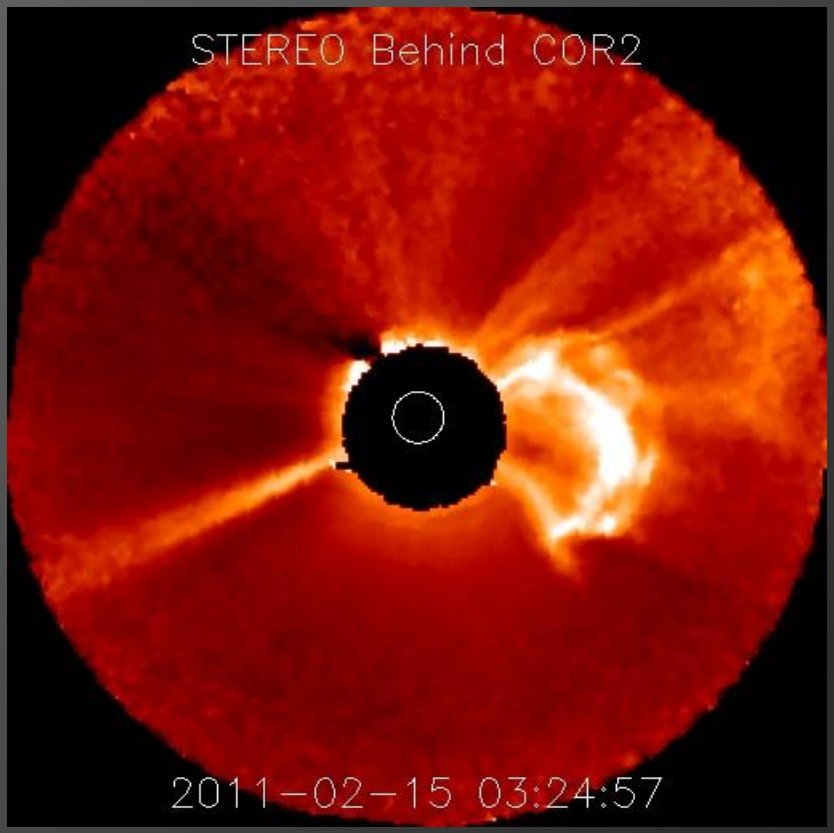
factor 2 difference
in velocity

STEREO geometric localization Tool





Estimation of Cone Angle from a side view (STEREO B)



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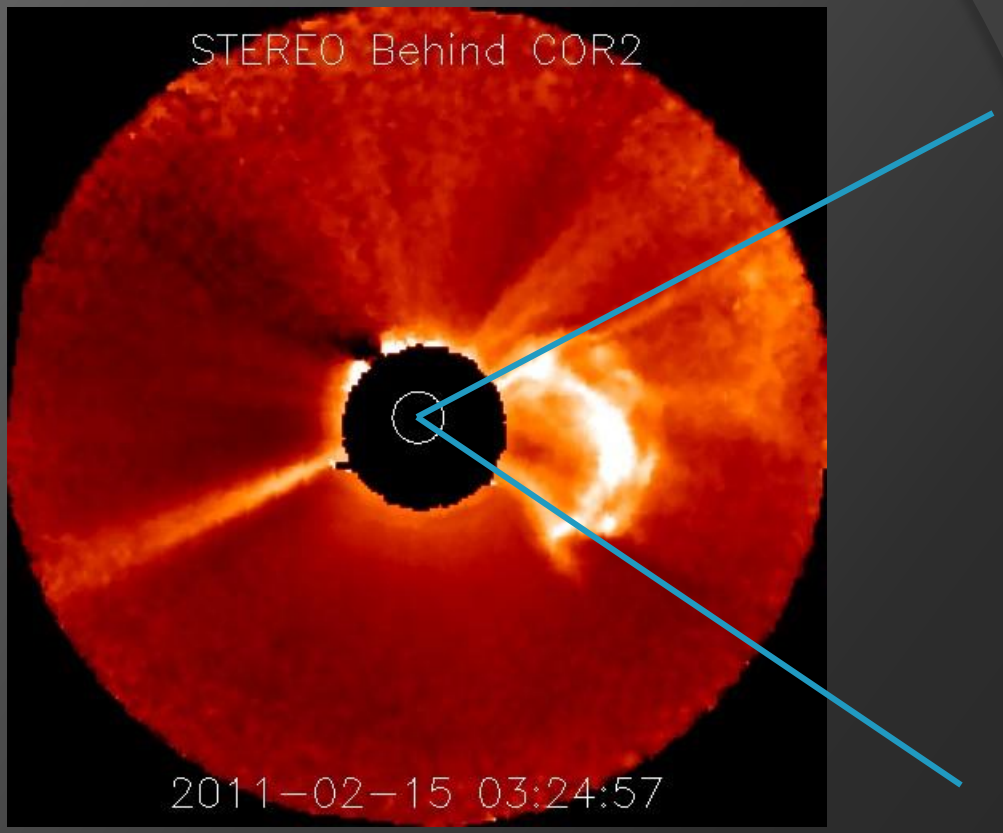
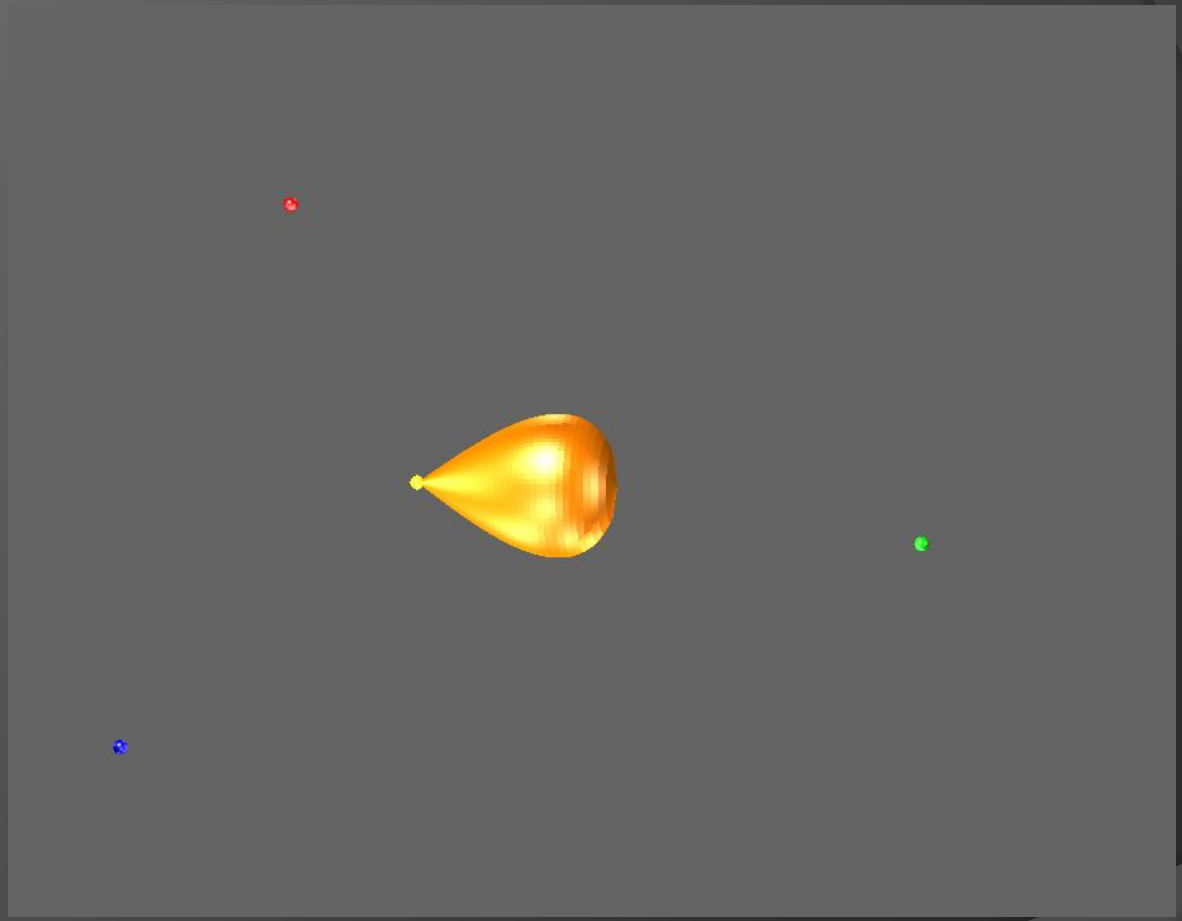
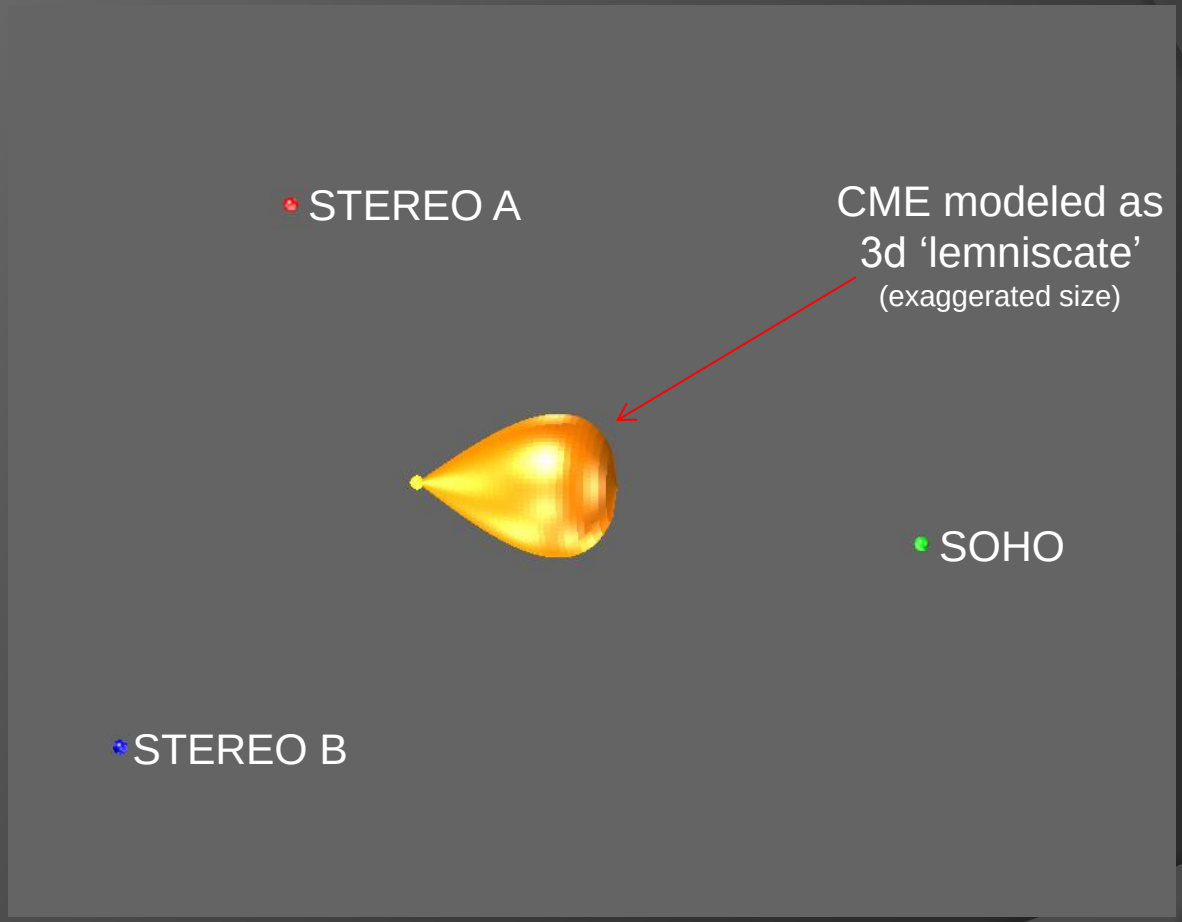


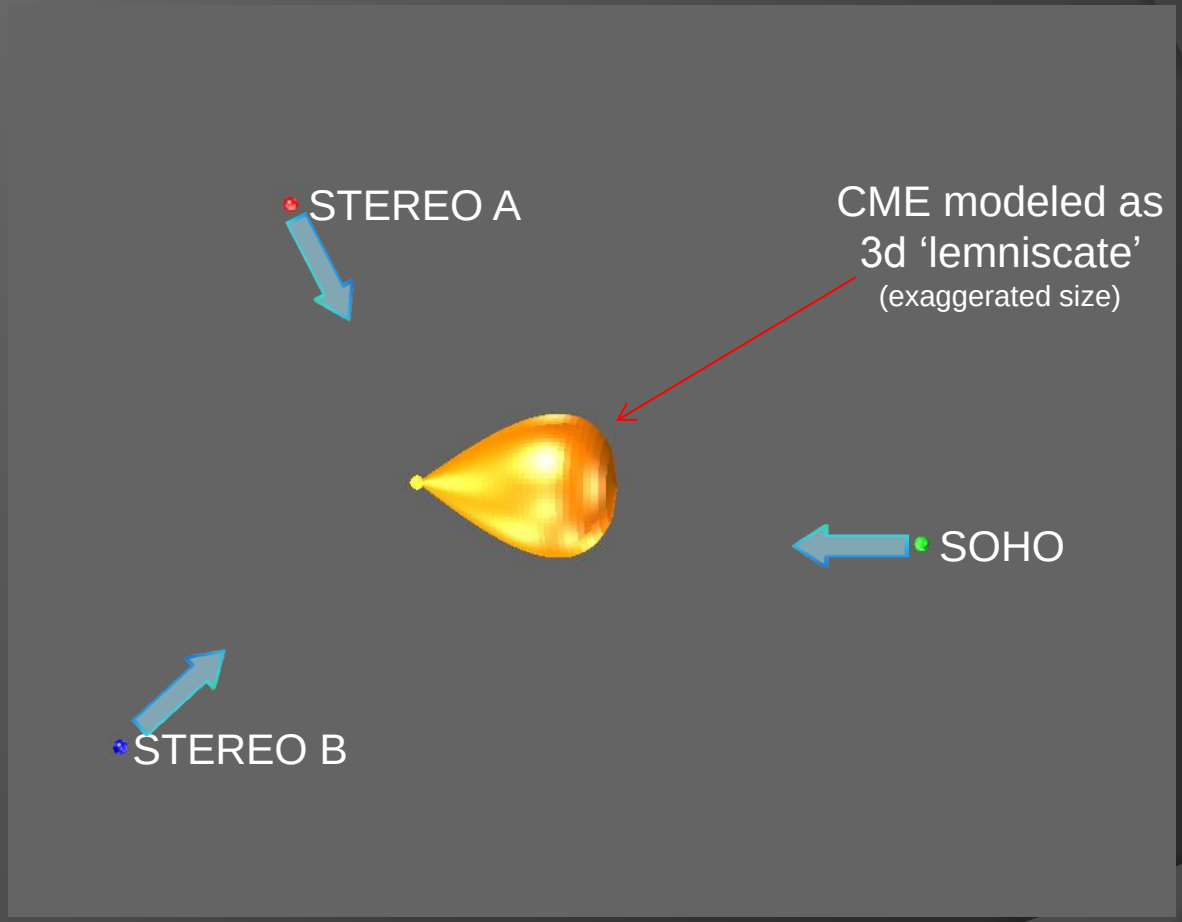
3D Graphics modeling



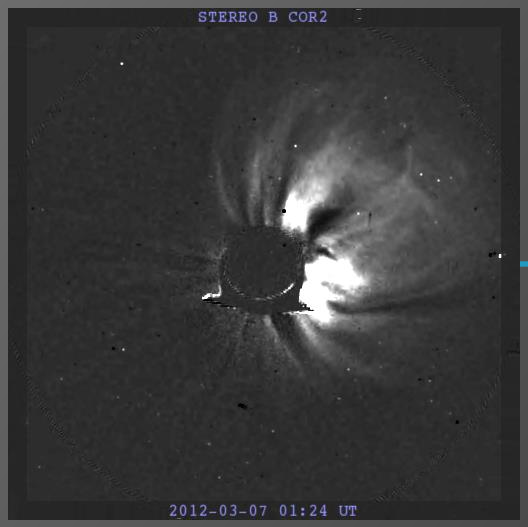
3D Graphics modeling

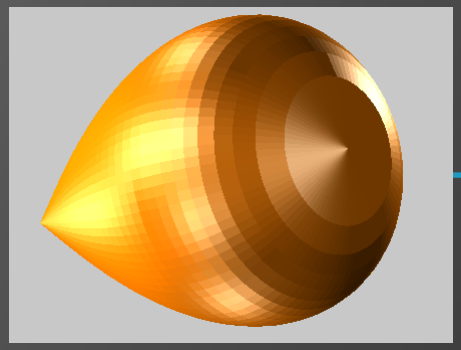


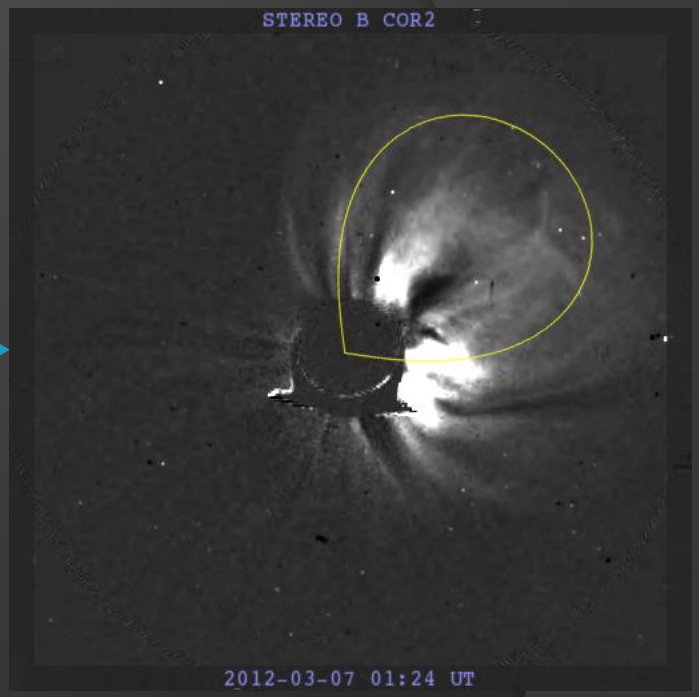
3D Graphics modeling



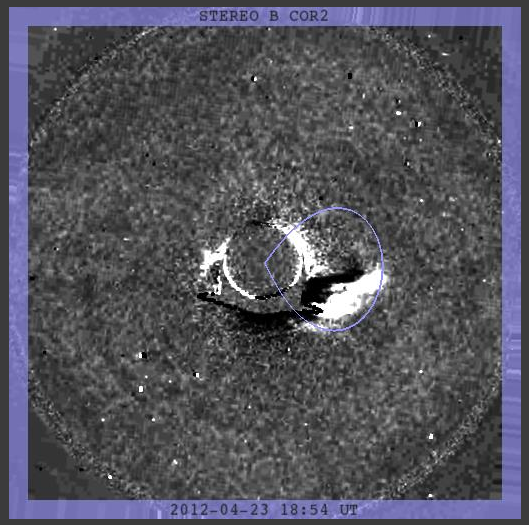
Overlay 3D model on coronagraph image

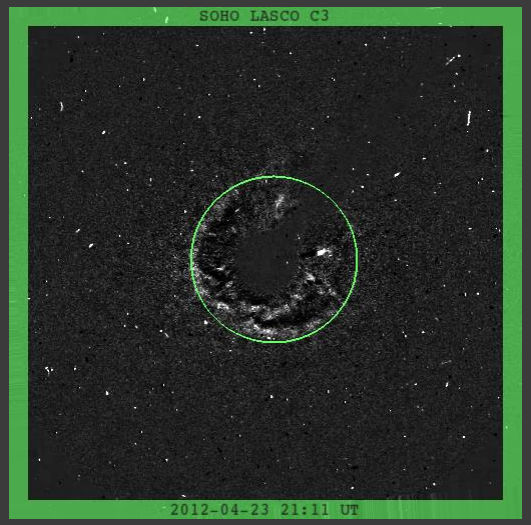




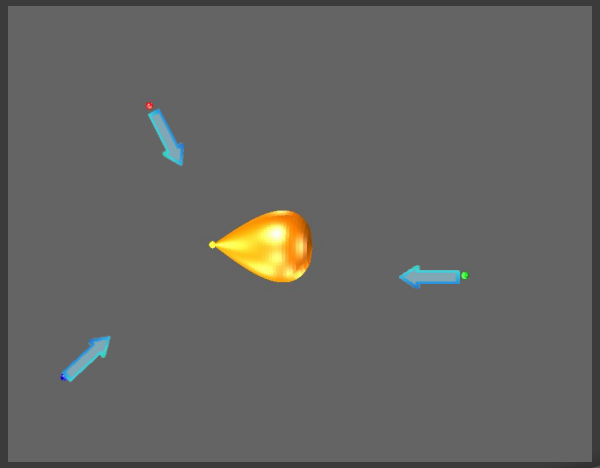


‘3 view’

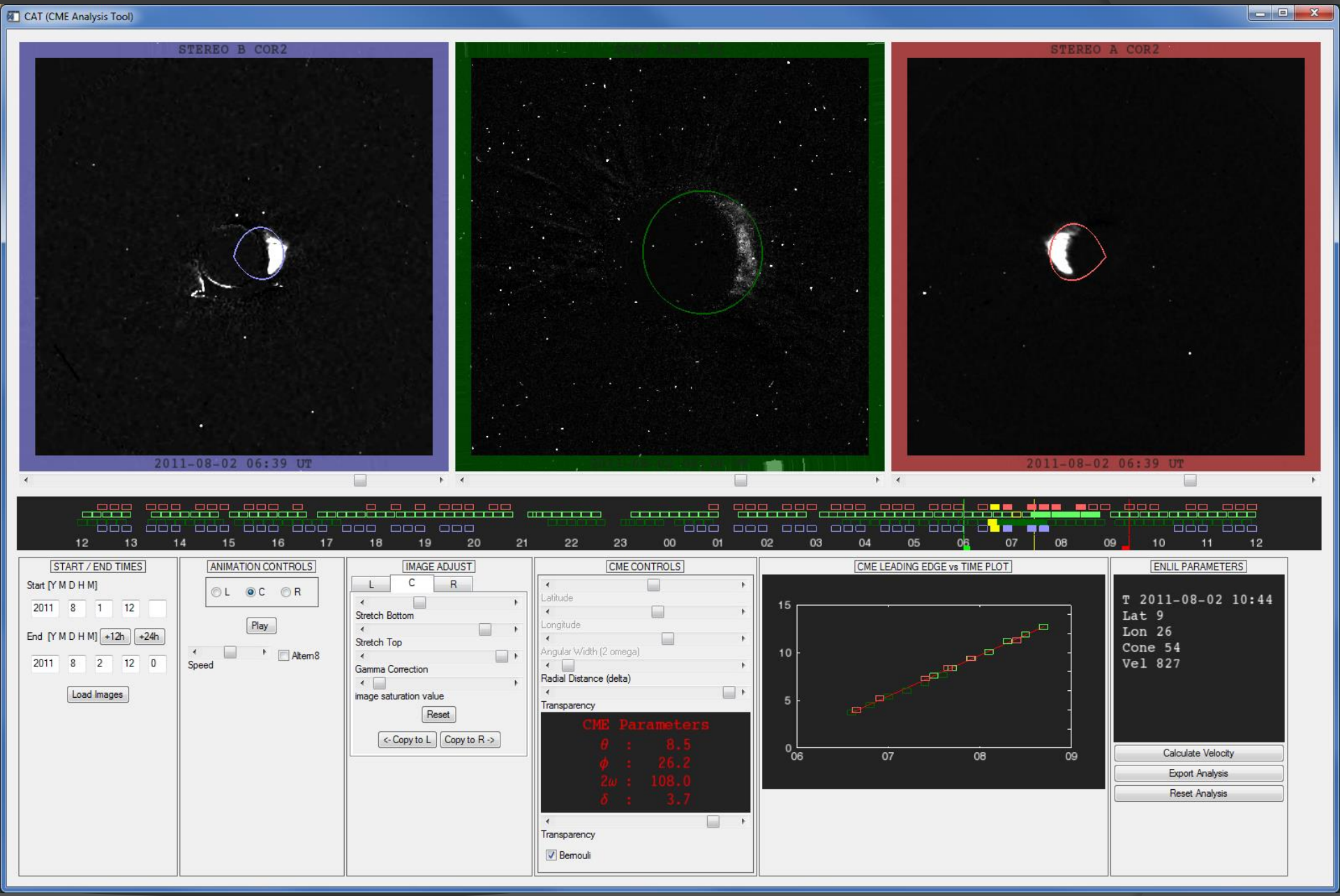

STEREO B COR2
2012-04-23 18:54 UT


SOHO LASCO C3
2012-04-23 21:11 UT

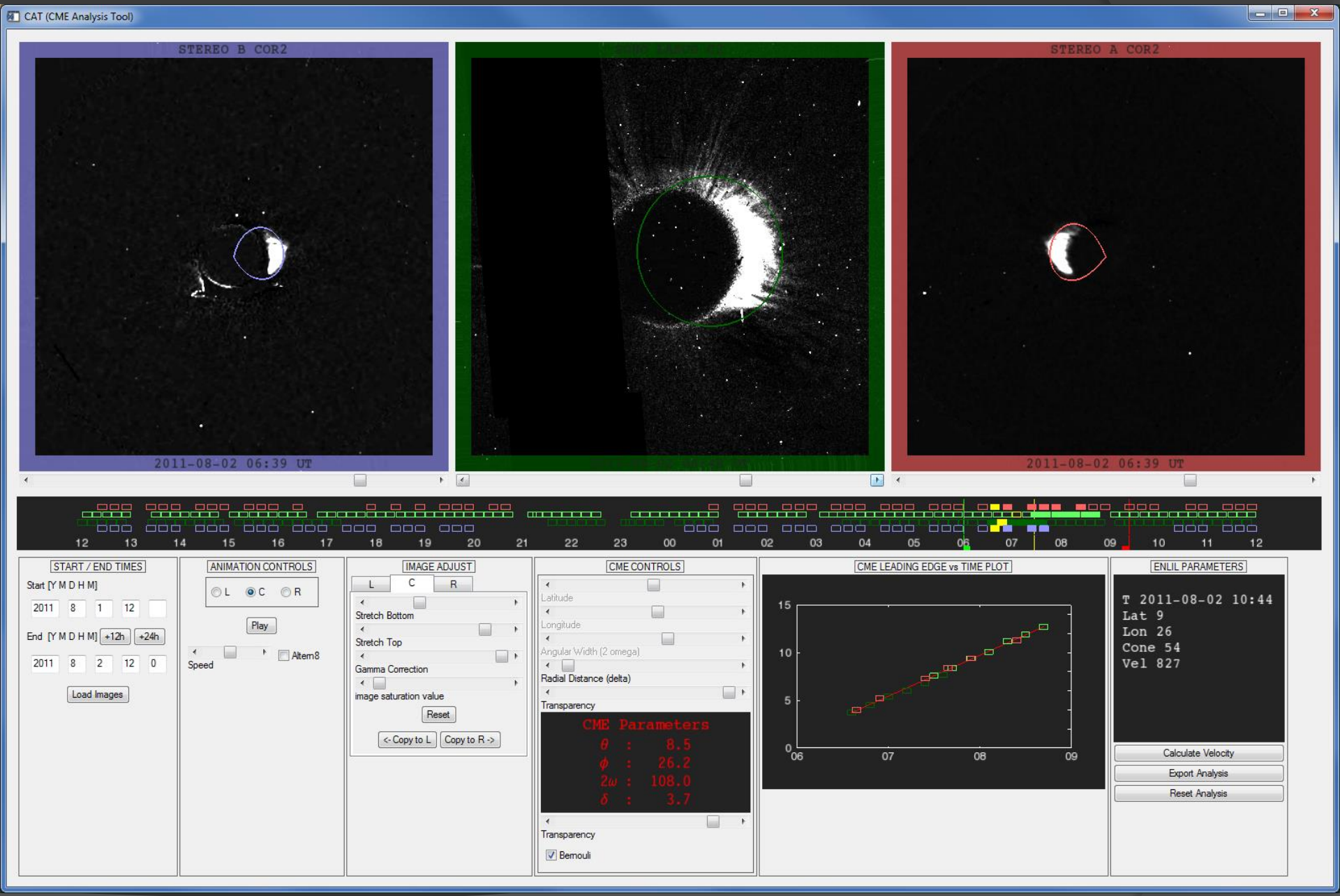

STEREO A COR2
2012-04-23 18:24 UT



CME Analysis Tool (CAT)



CME Analysis Tool (CAT)



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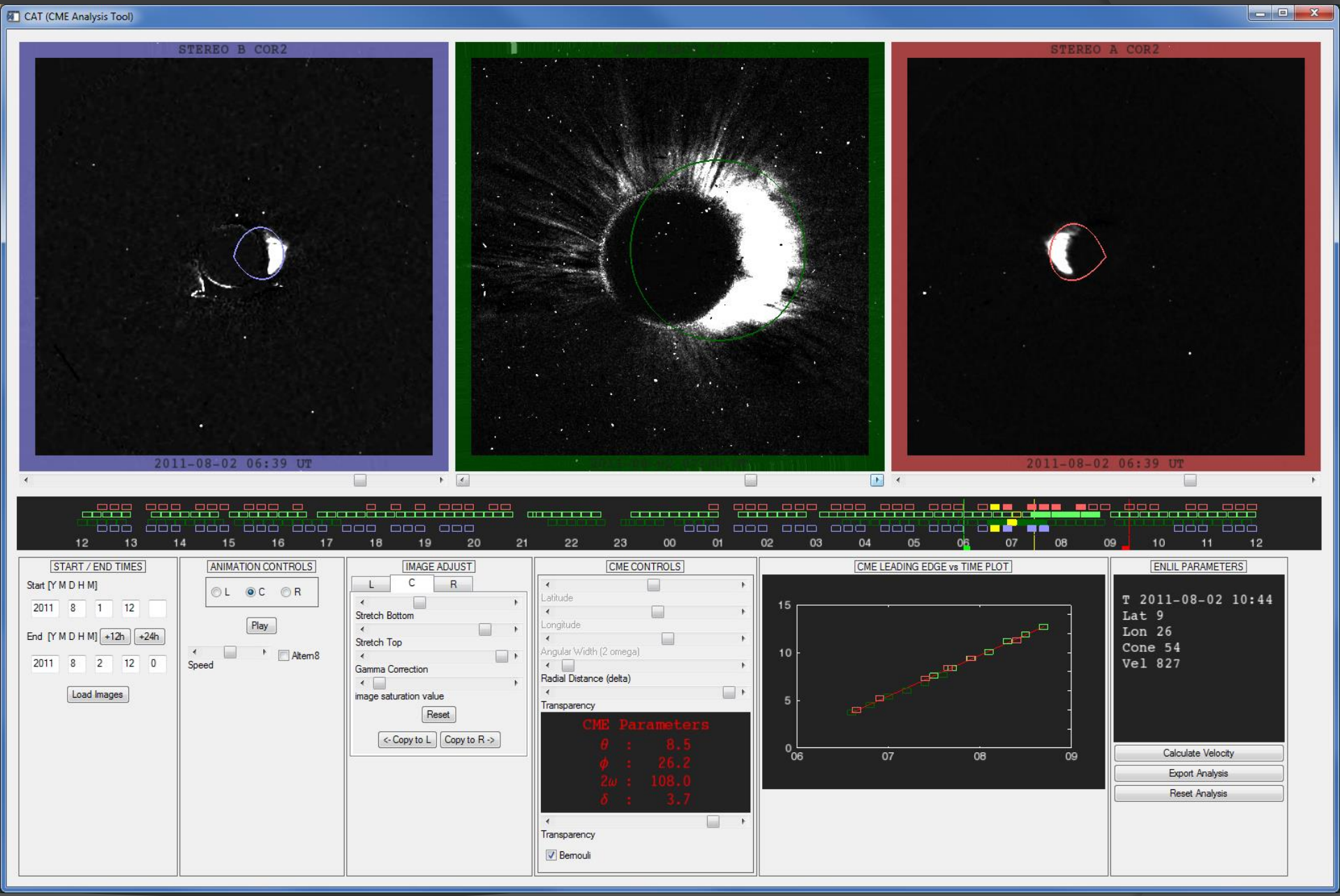
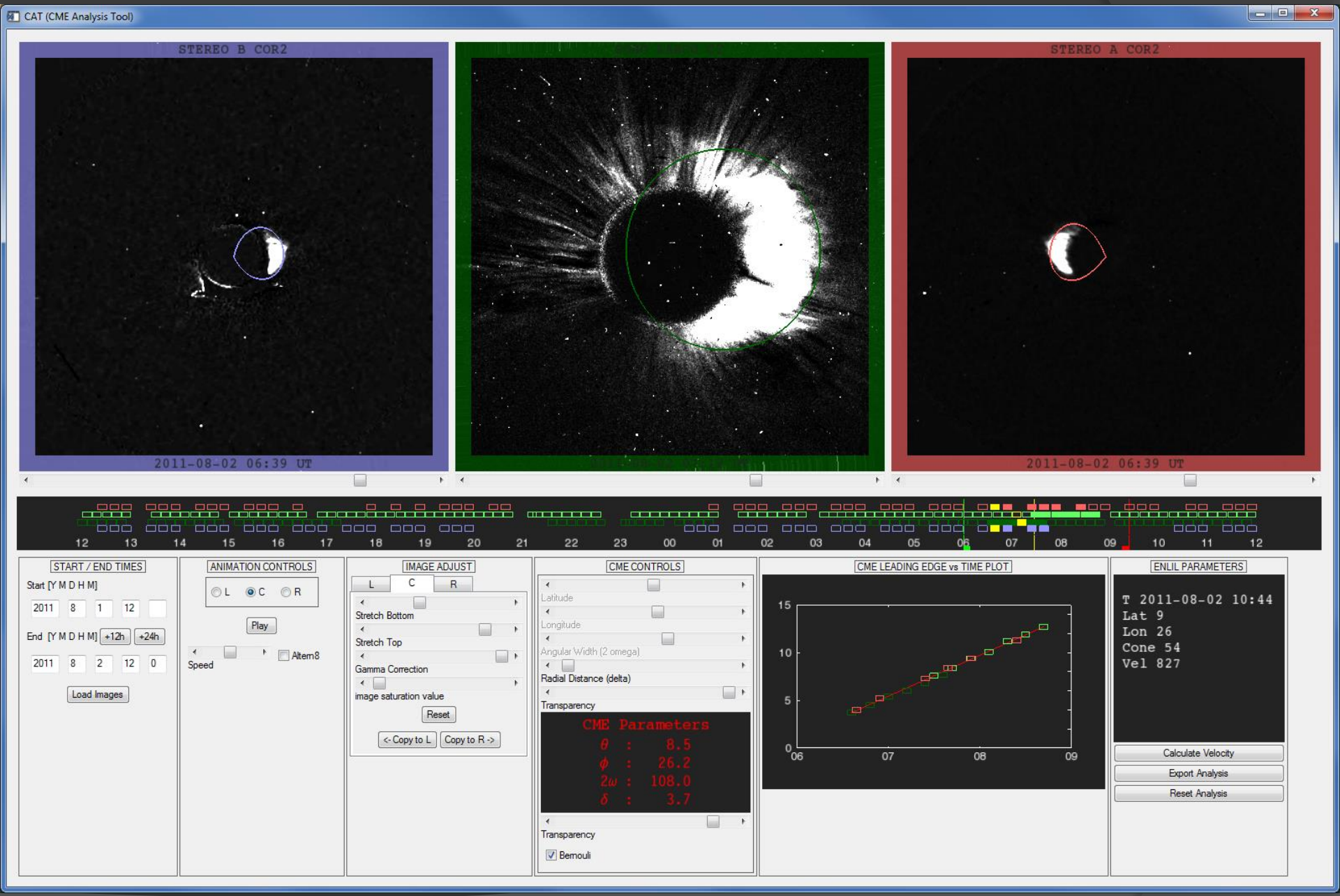
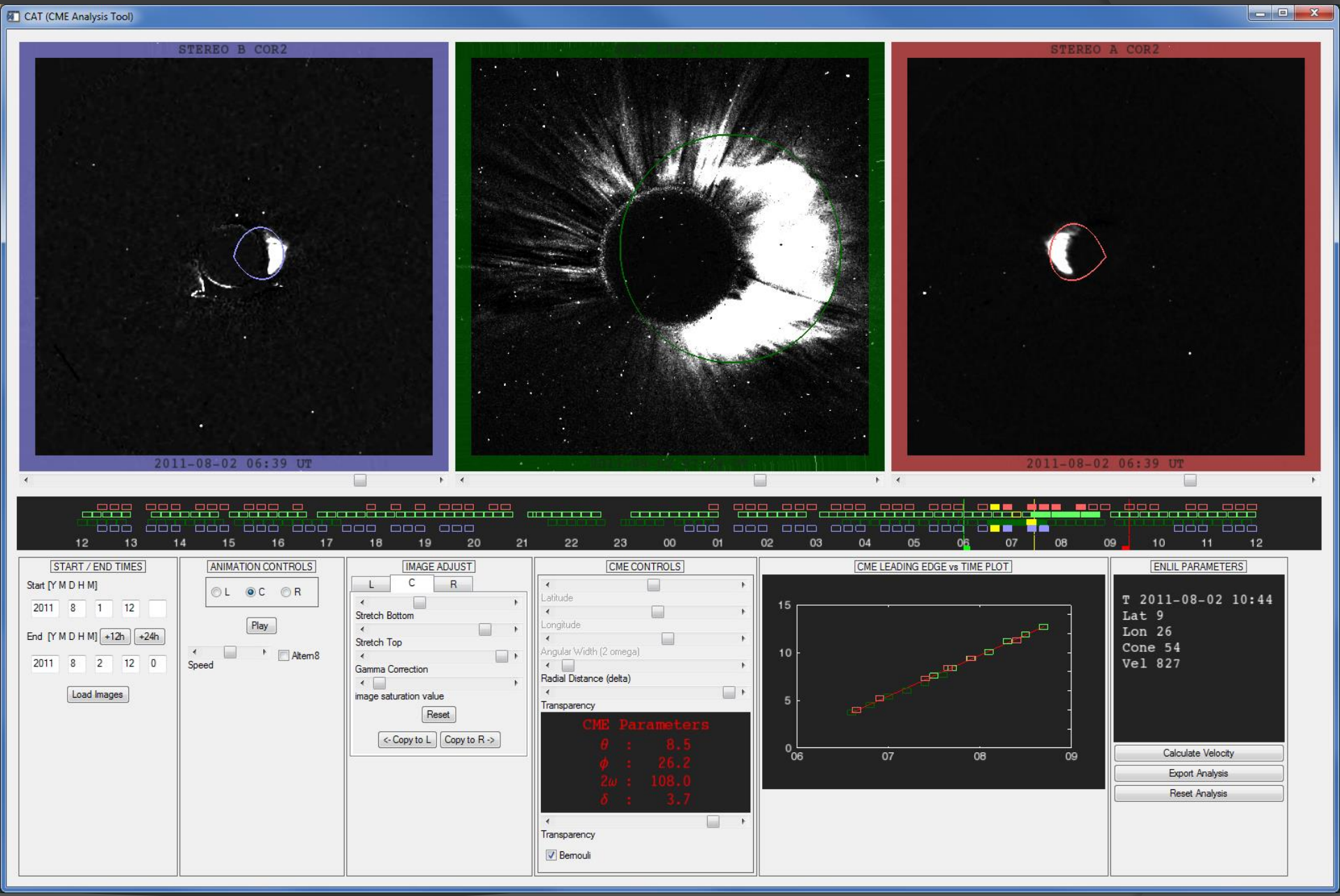


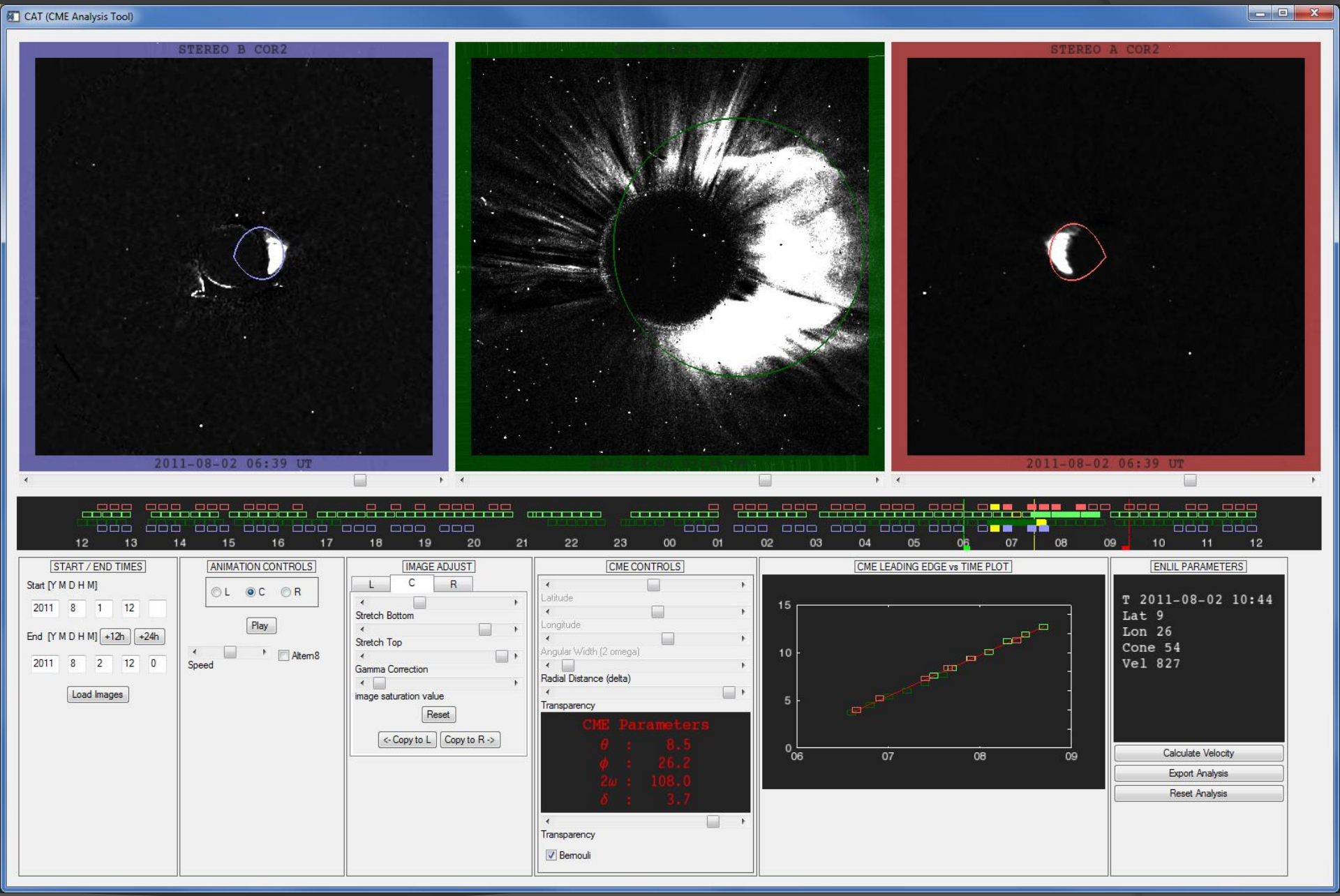
CME Analysis Tool (CAT)



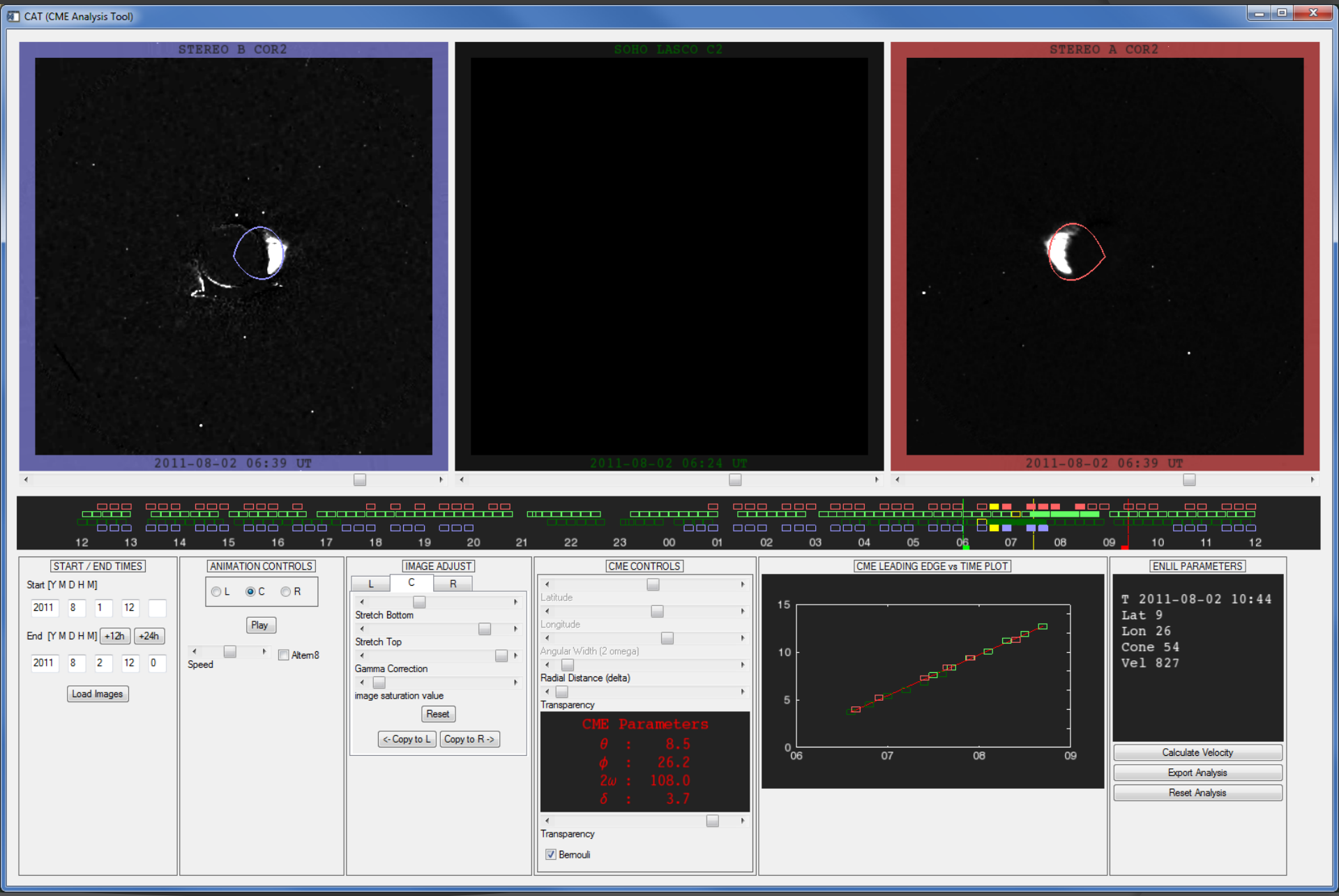
CME Analysis Tool (CAT)



CME Analysis Tool (CAT)



CME Analysis Tool (CAT)



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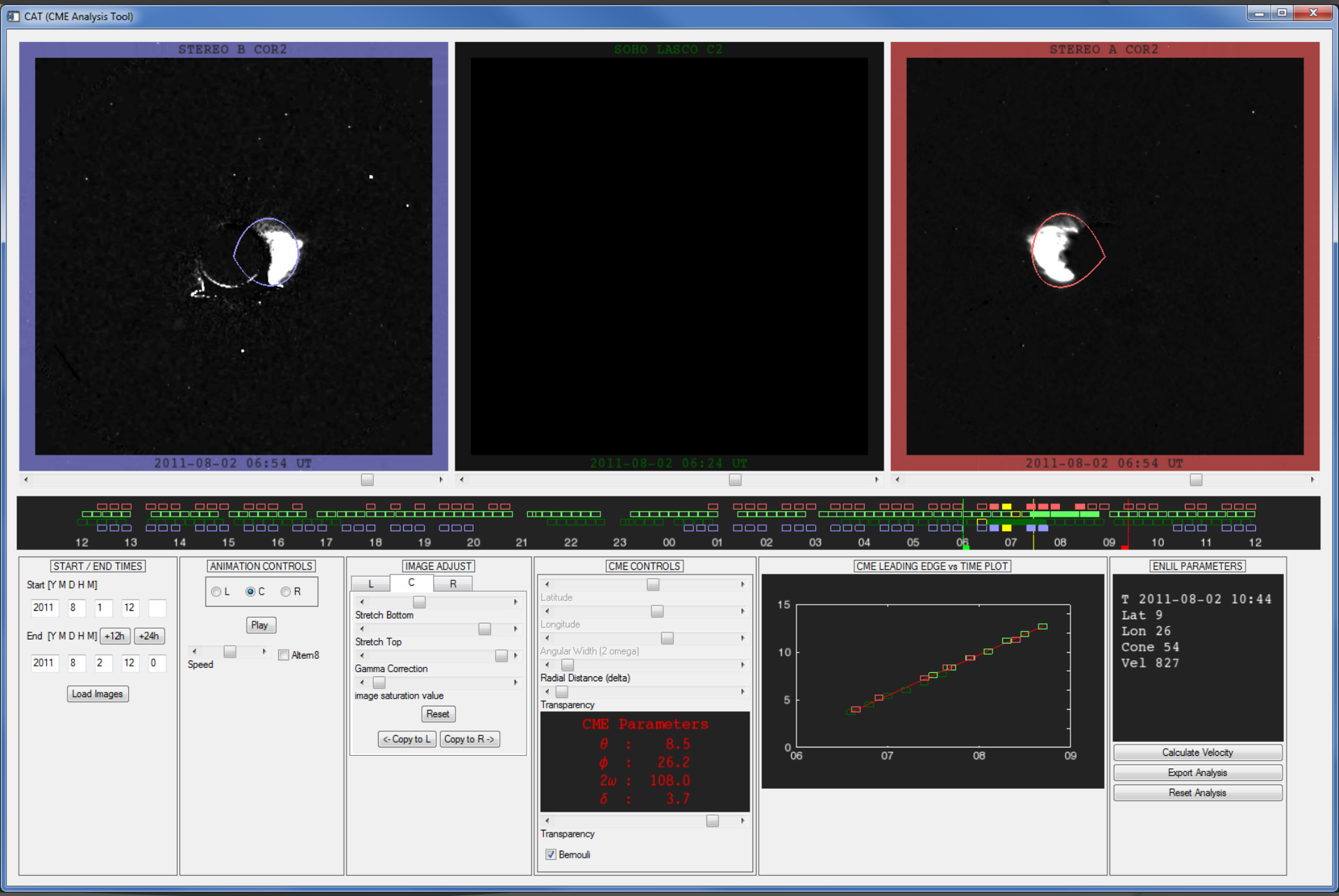

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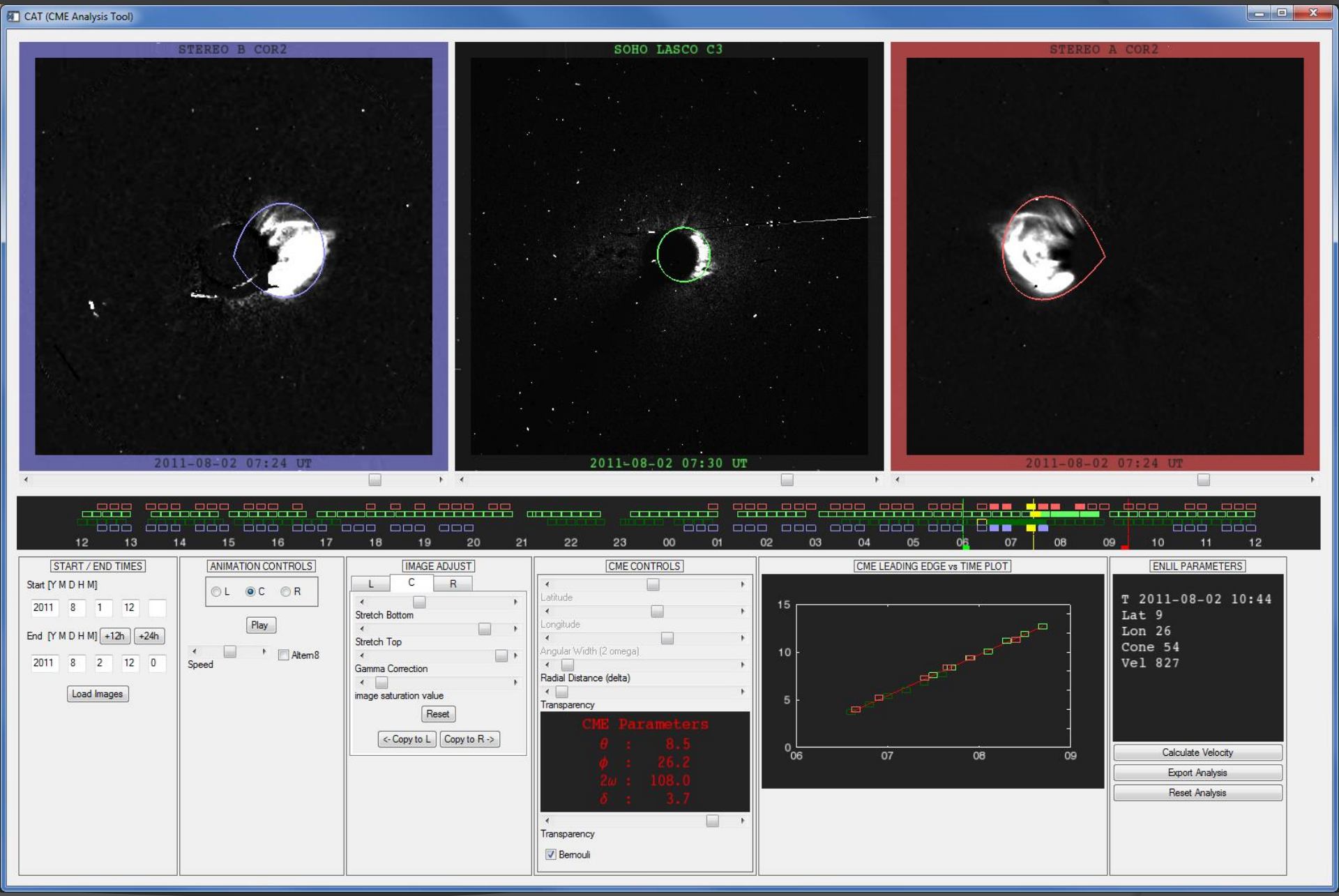
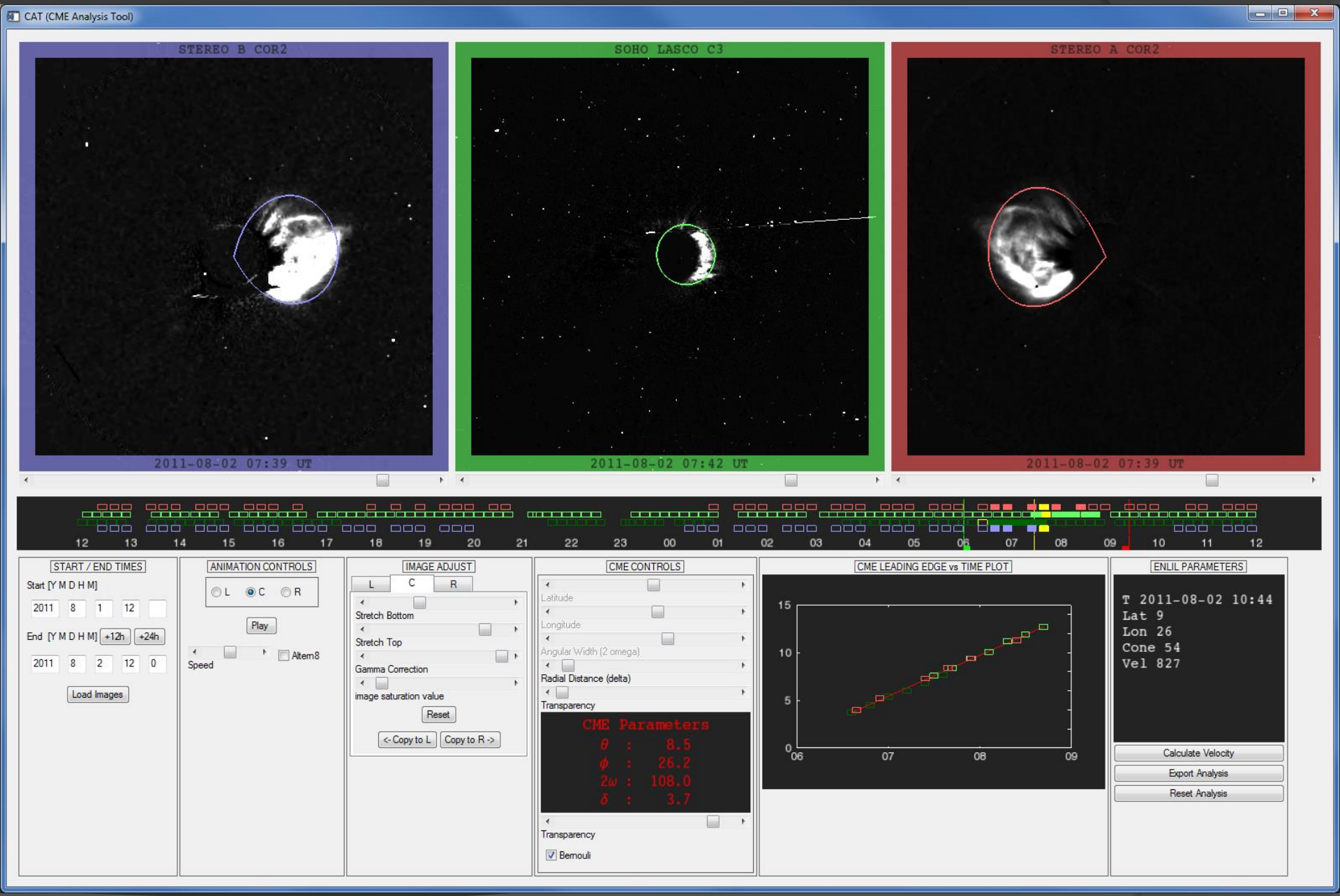
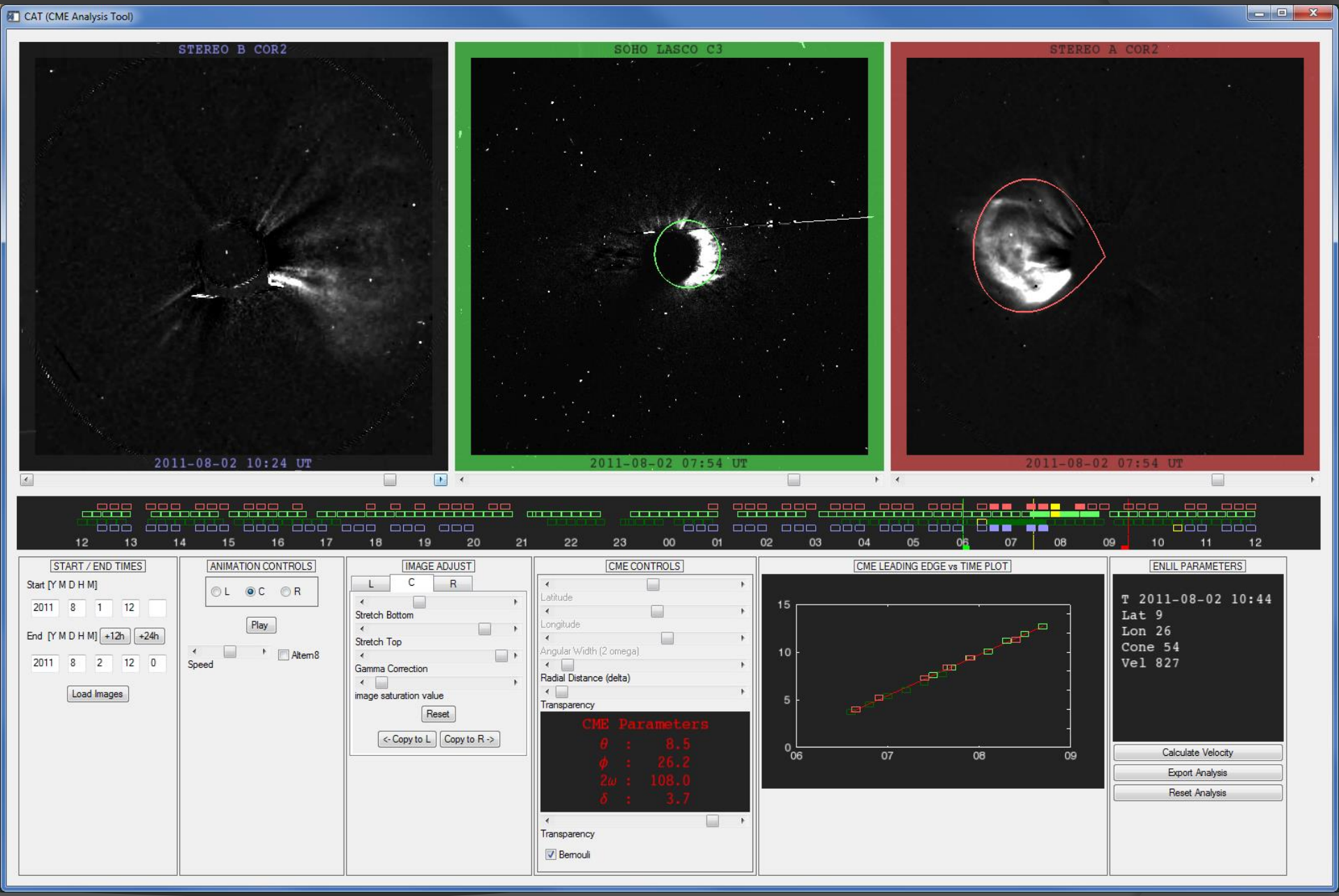


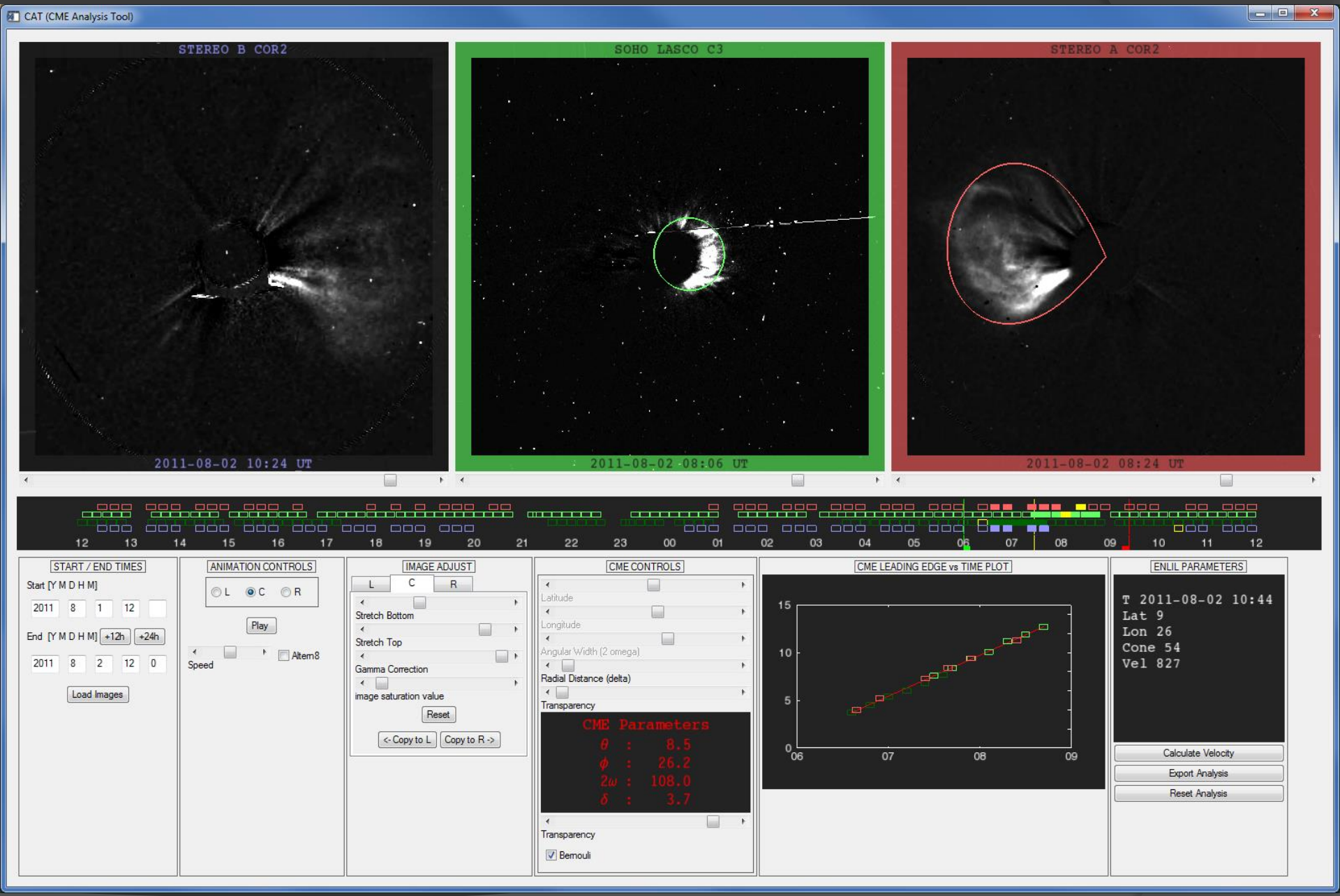
CME Analysis Tool (CAT)



CME Analysis Tool (CAT)



CME Analysis Tool (CAT)



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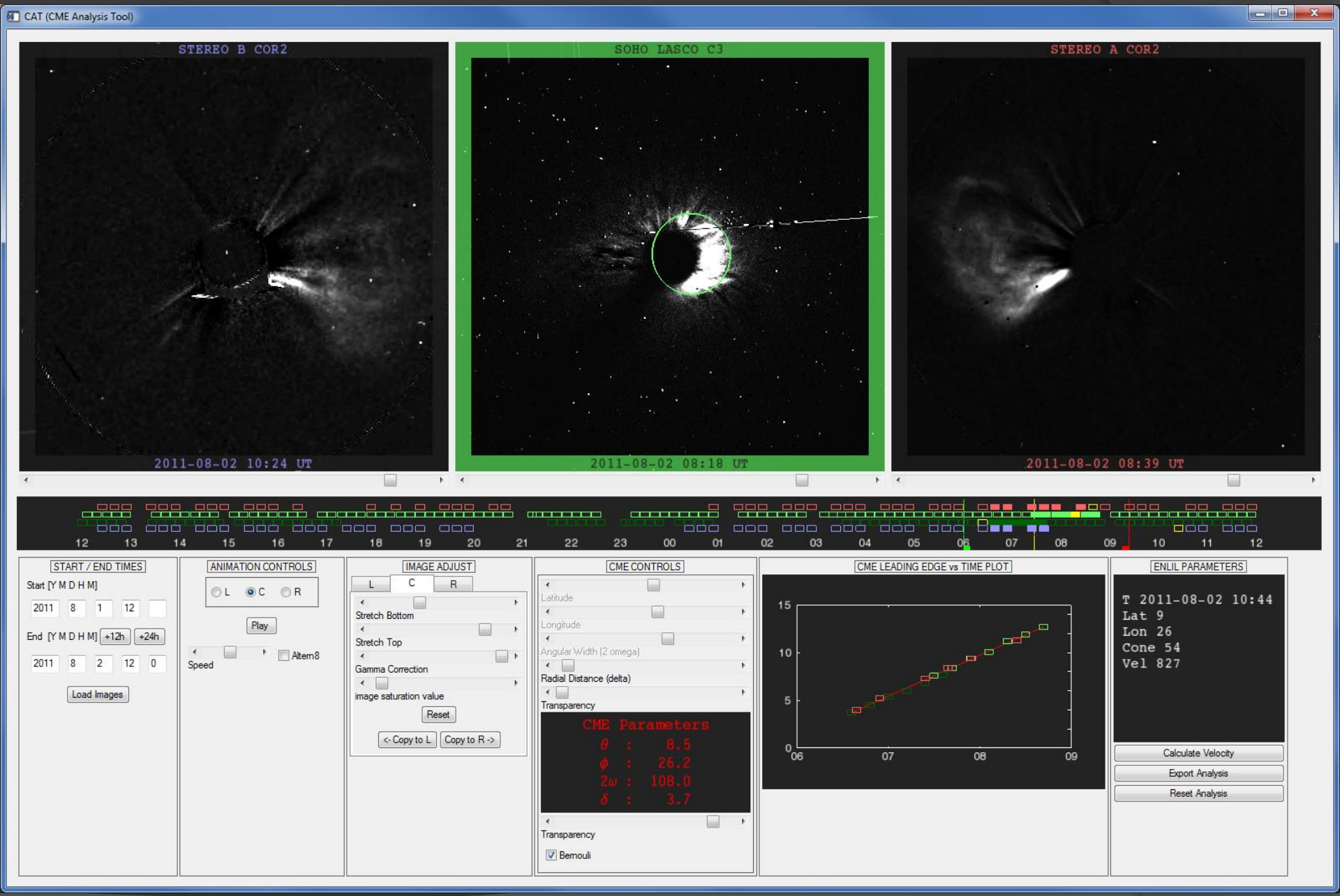
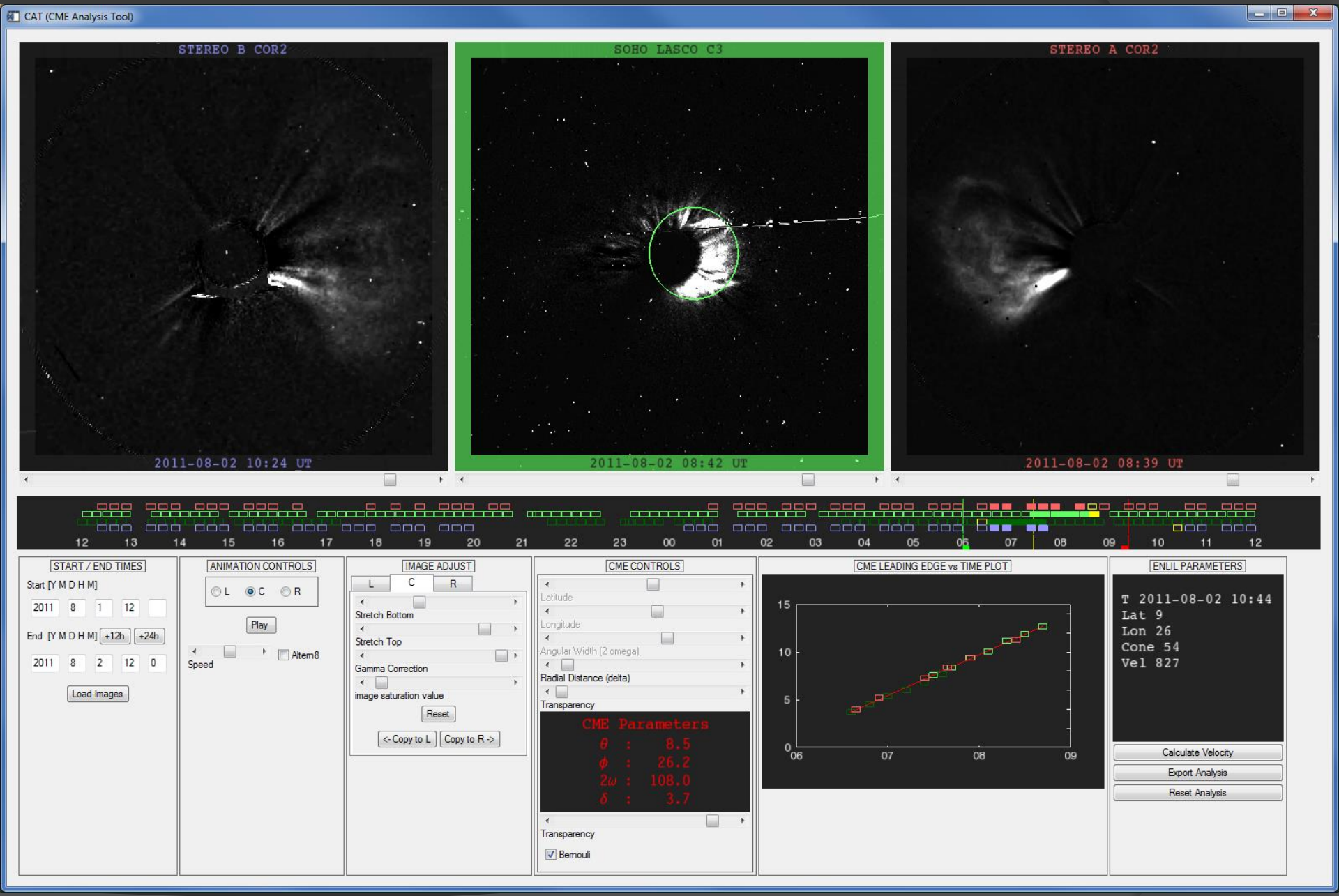
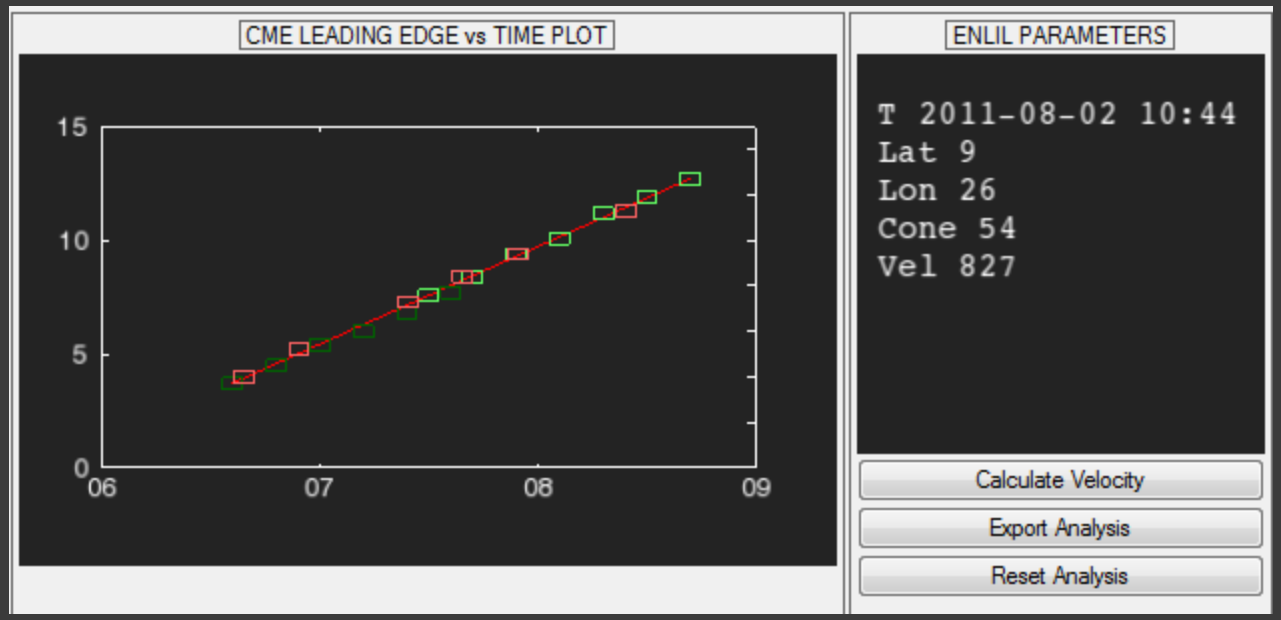


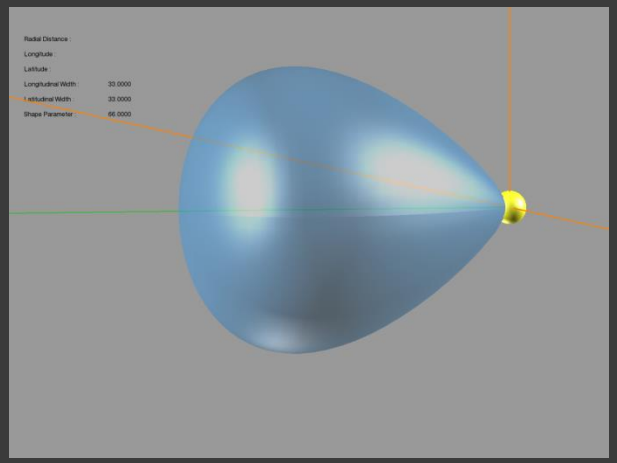
CME Analysis Tool (CAT)

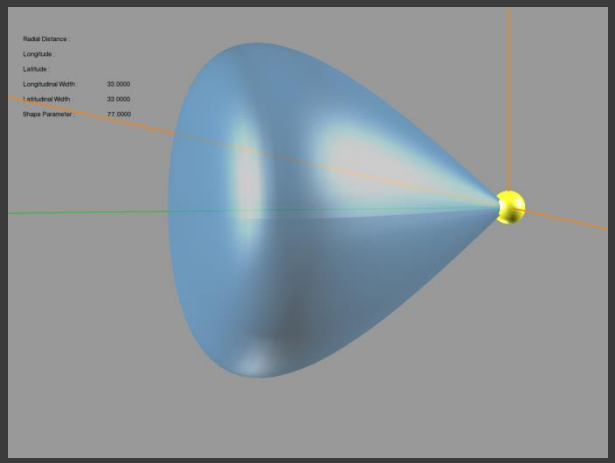


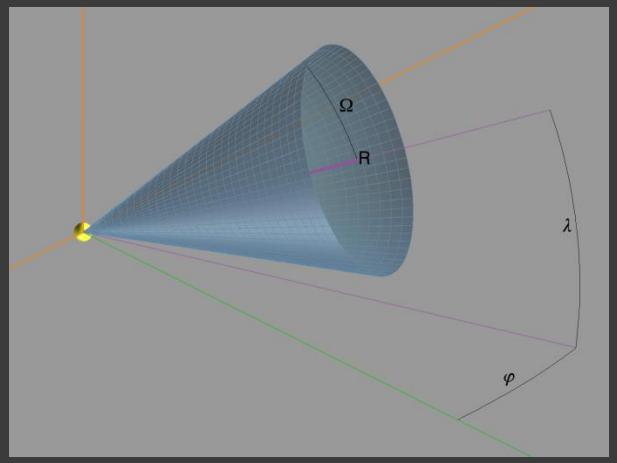
The result: CME parameters for Enlil

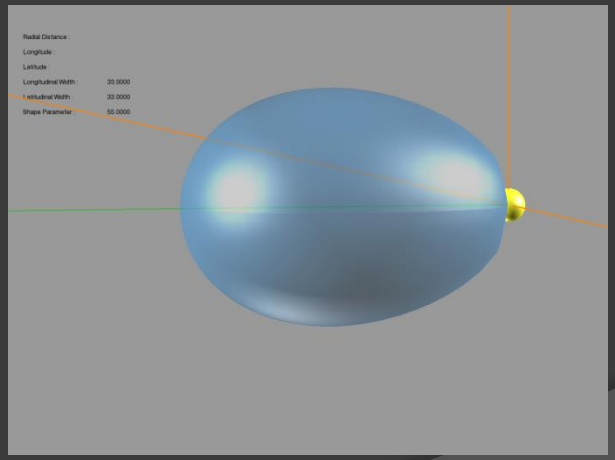


Researching different CME objects (Curt de Koning)

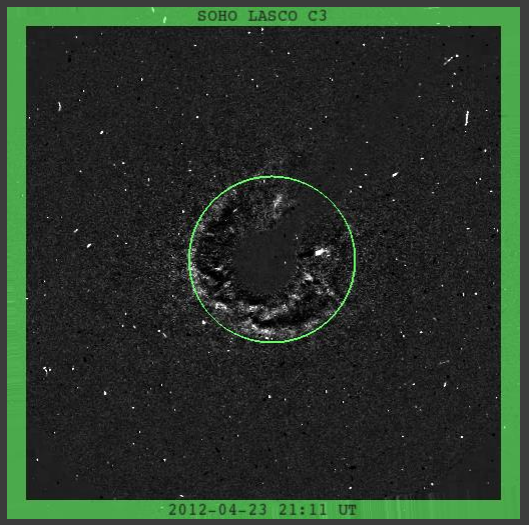




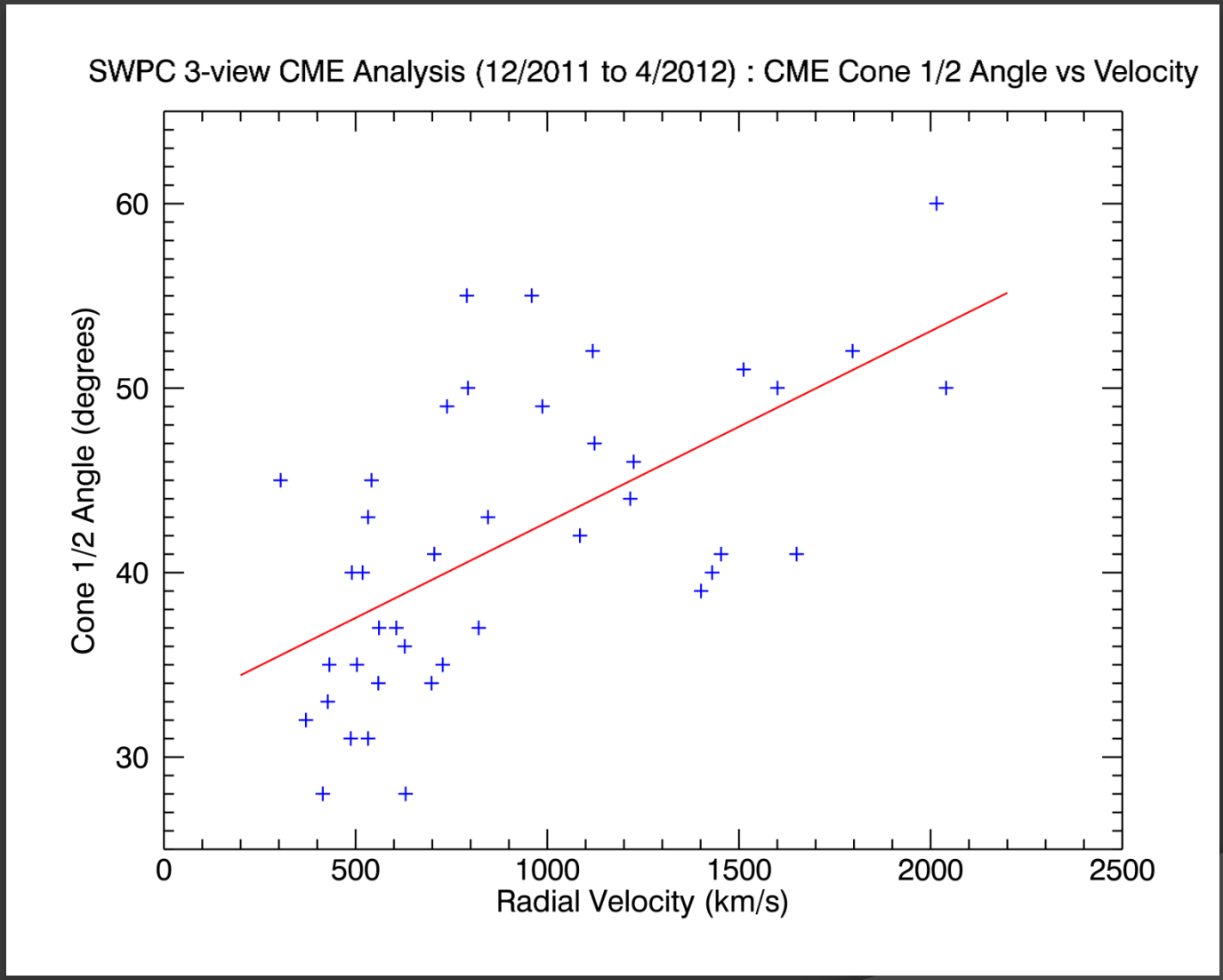




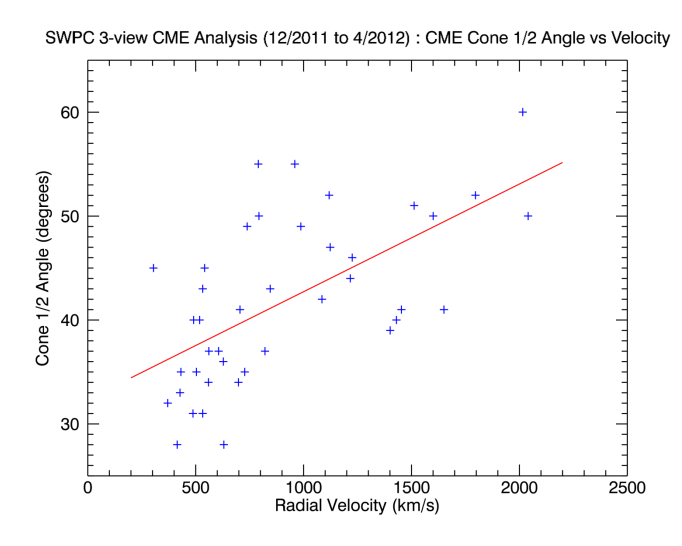
What if we only have one Coronagraph ?

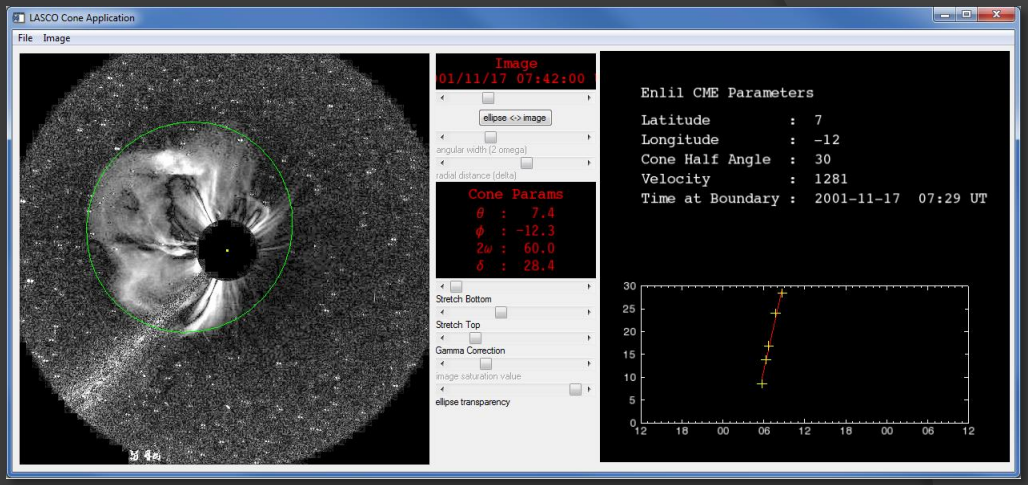


What if we only have one Coronagraph ?



What if we only have one Coronagraph ?





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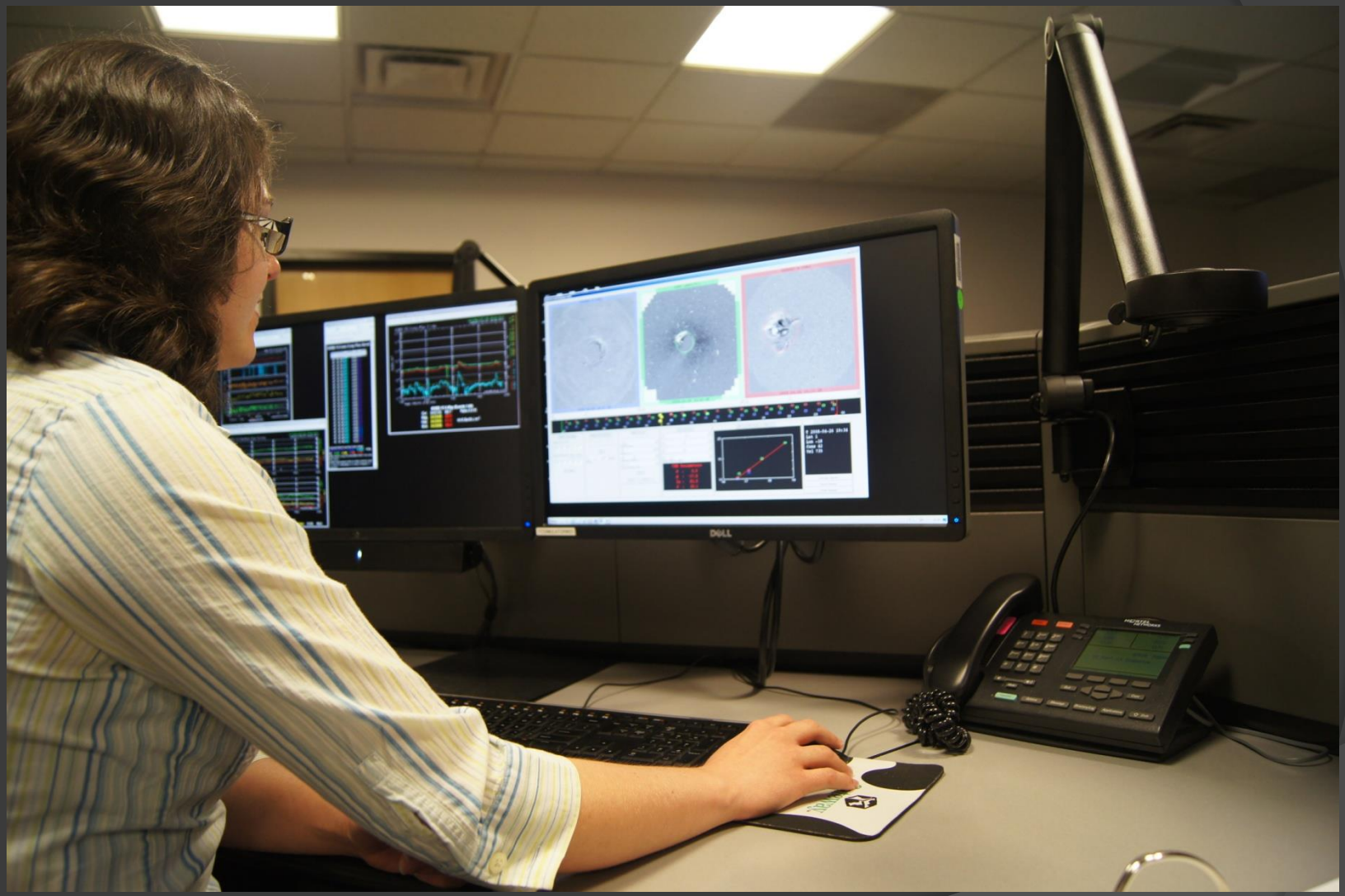
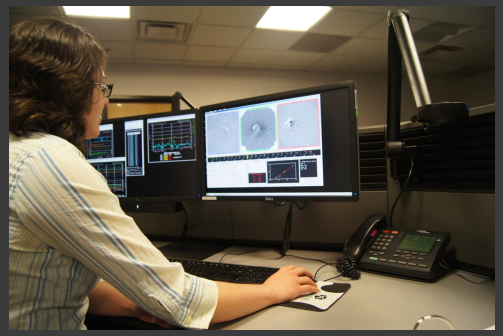
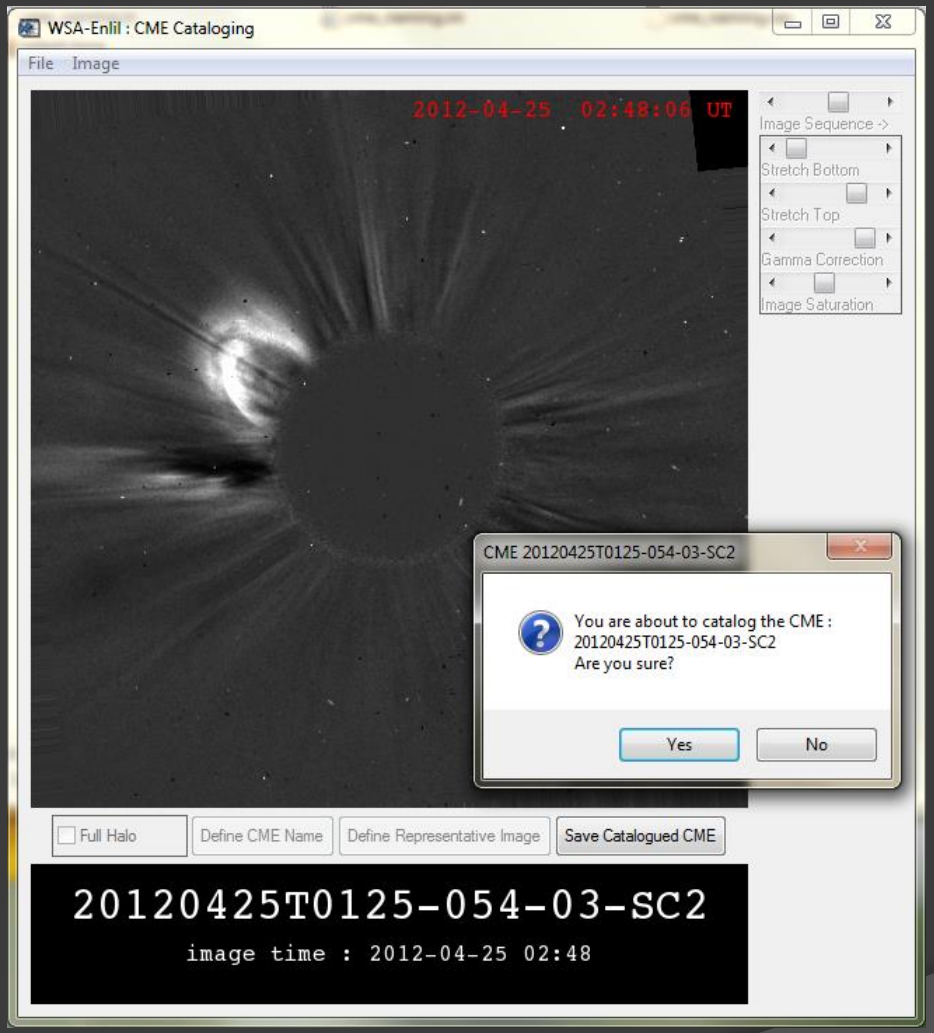
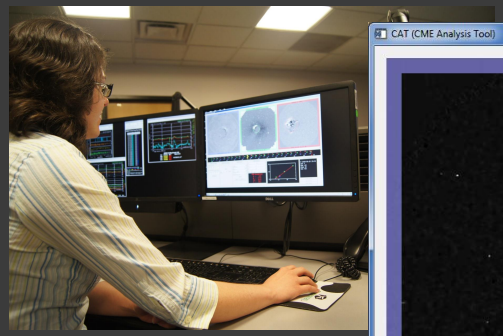

DELL

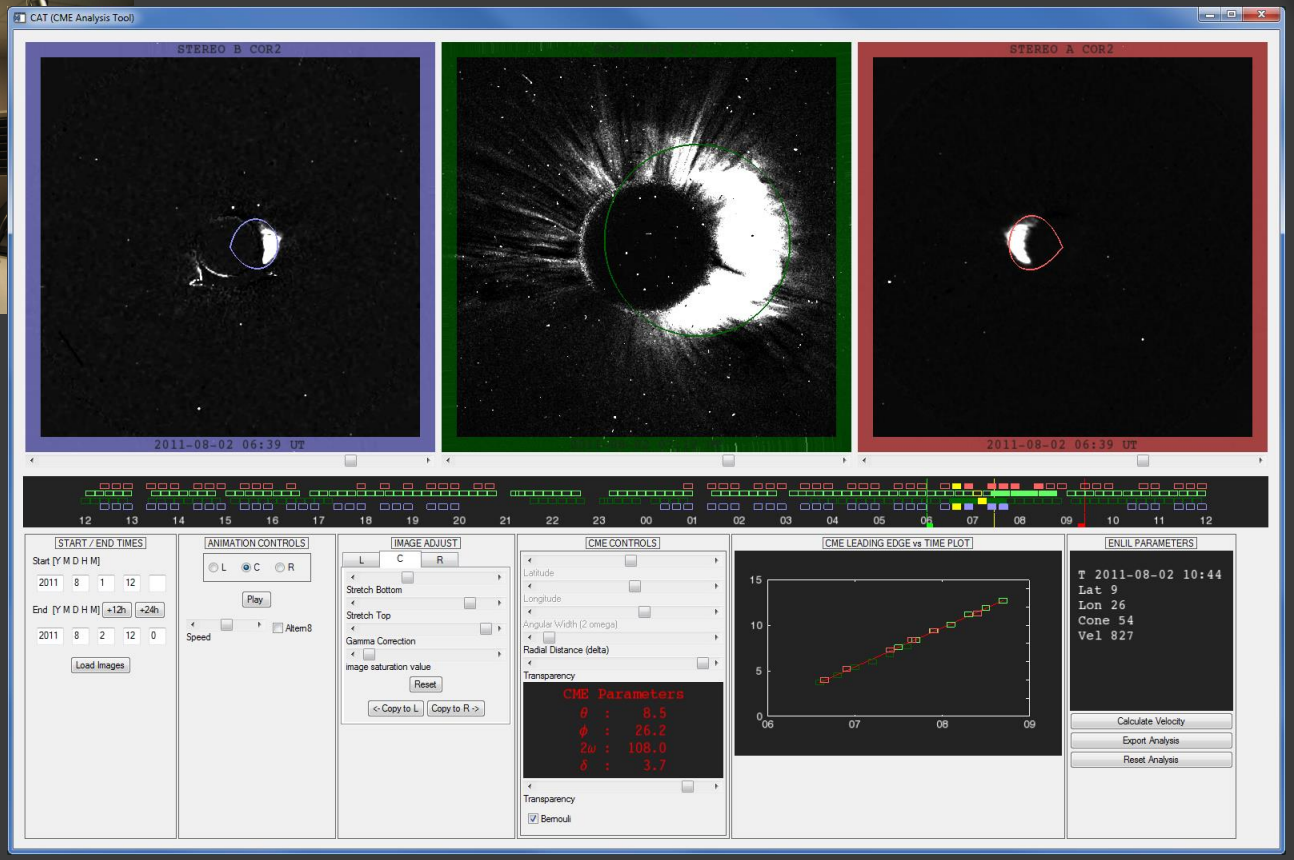
CME Naming / Cataloging



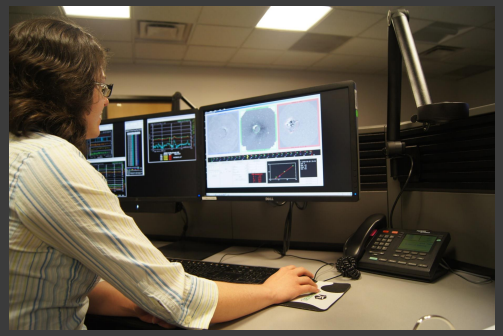


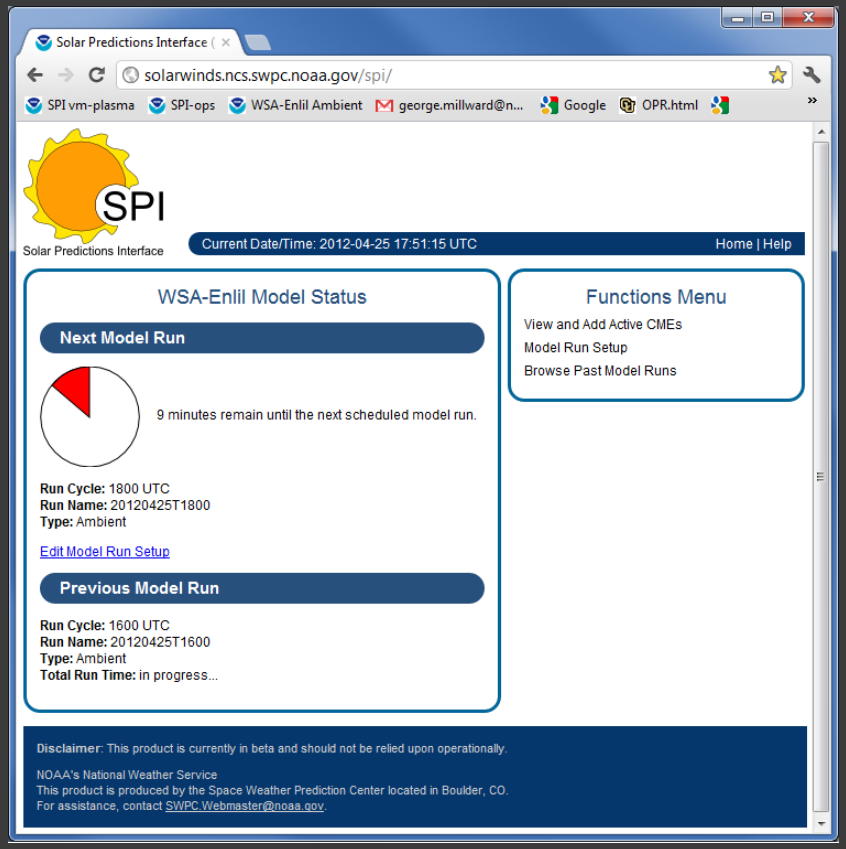
CME Analysis



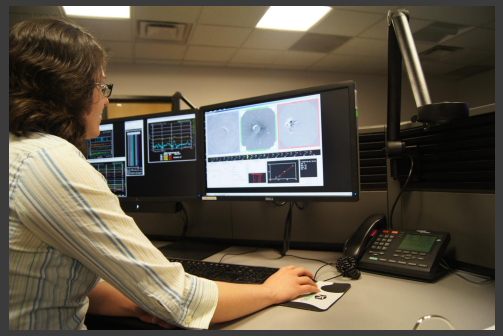


Solar Predictions Interface (SPI)



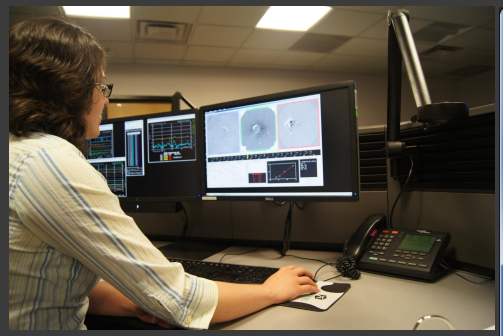


Solar Predictions Interface (SPI)



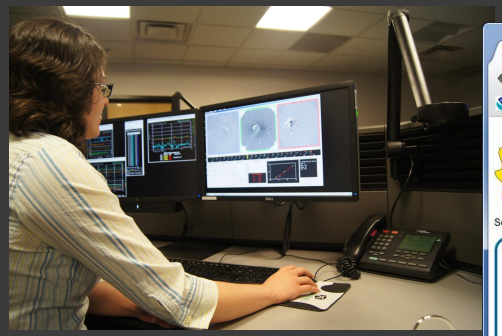
View catalogued CMEs: (available for CME analysis)

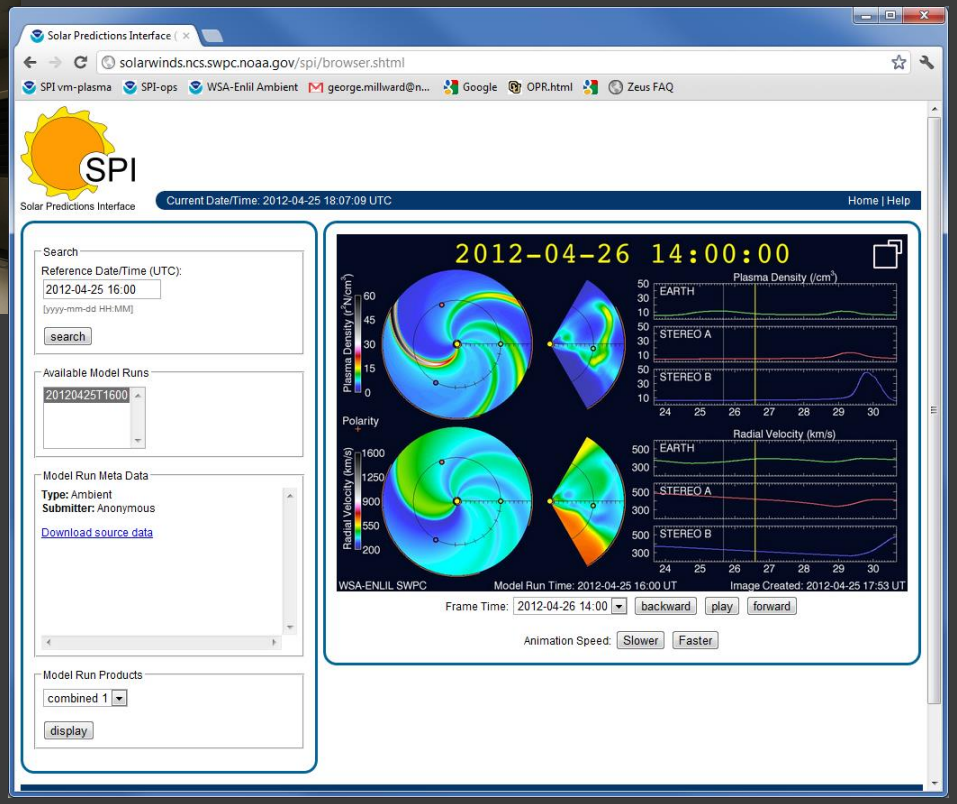
Solar Predictions Interface (SPI)



Add analyzed CME data to next model run

Solar Predictions Interface (SPI)

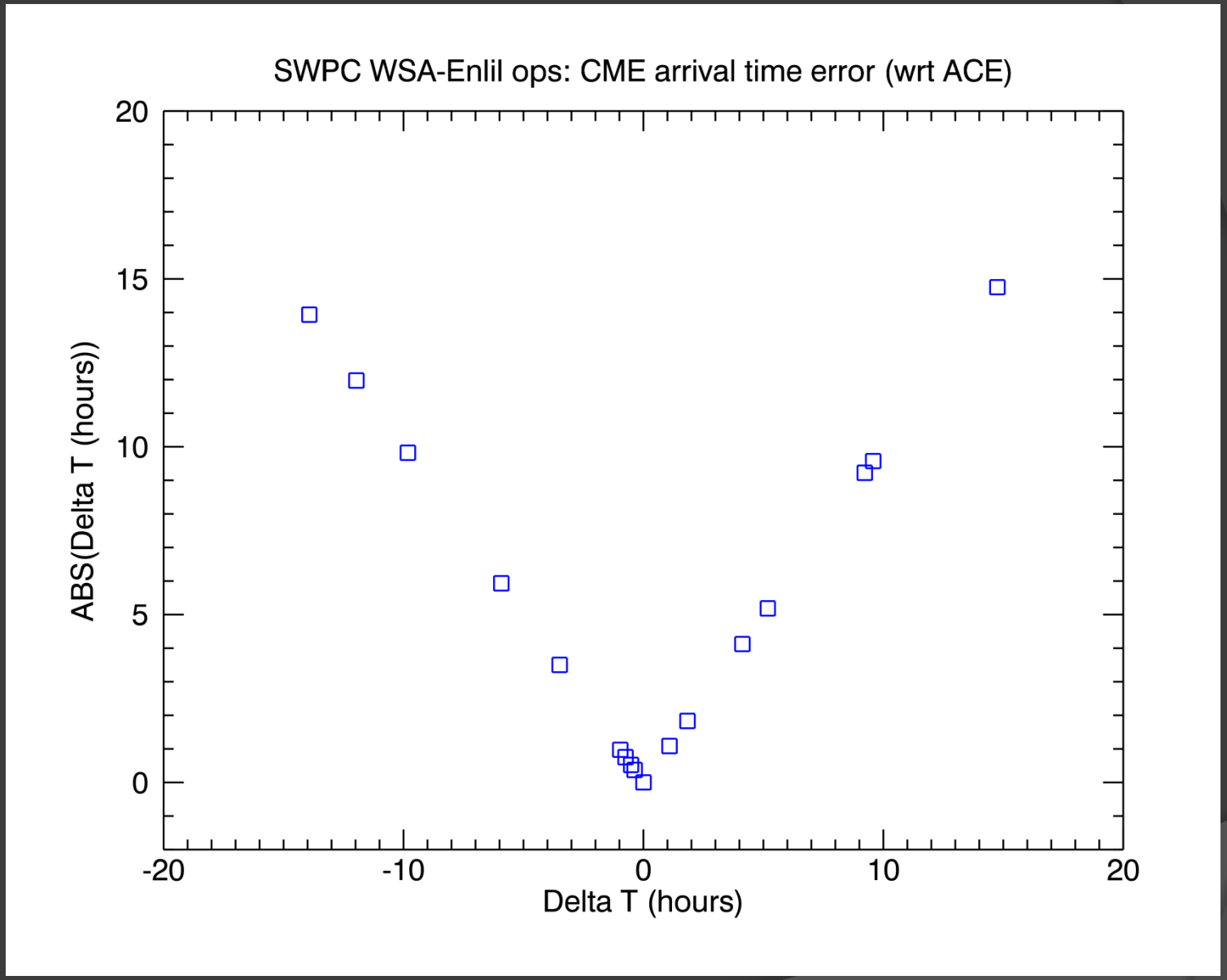


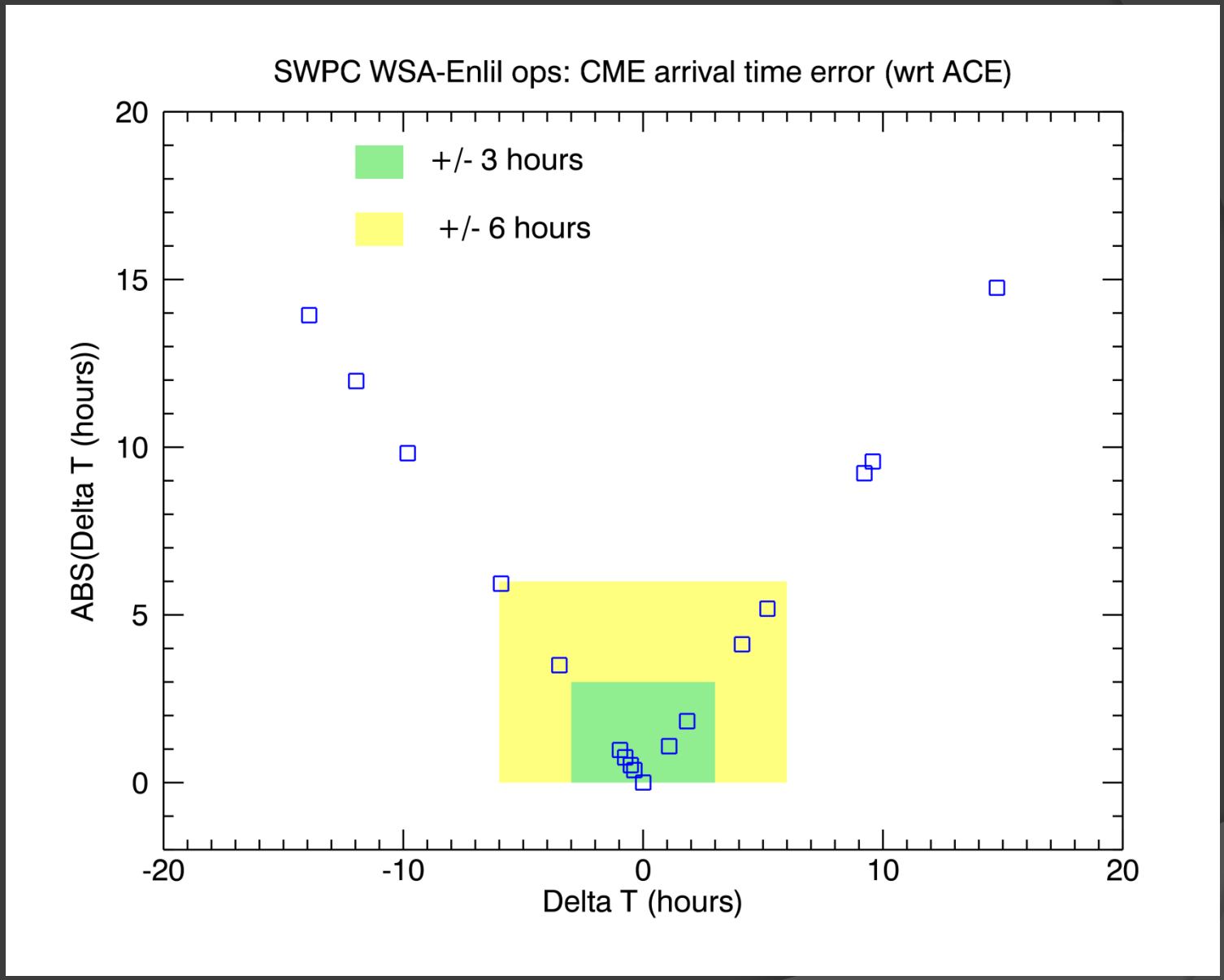


Browse model runs

Select a model run for dissemination on the public webpage

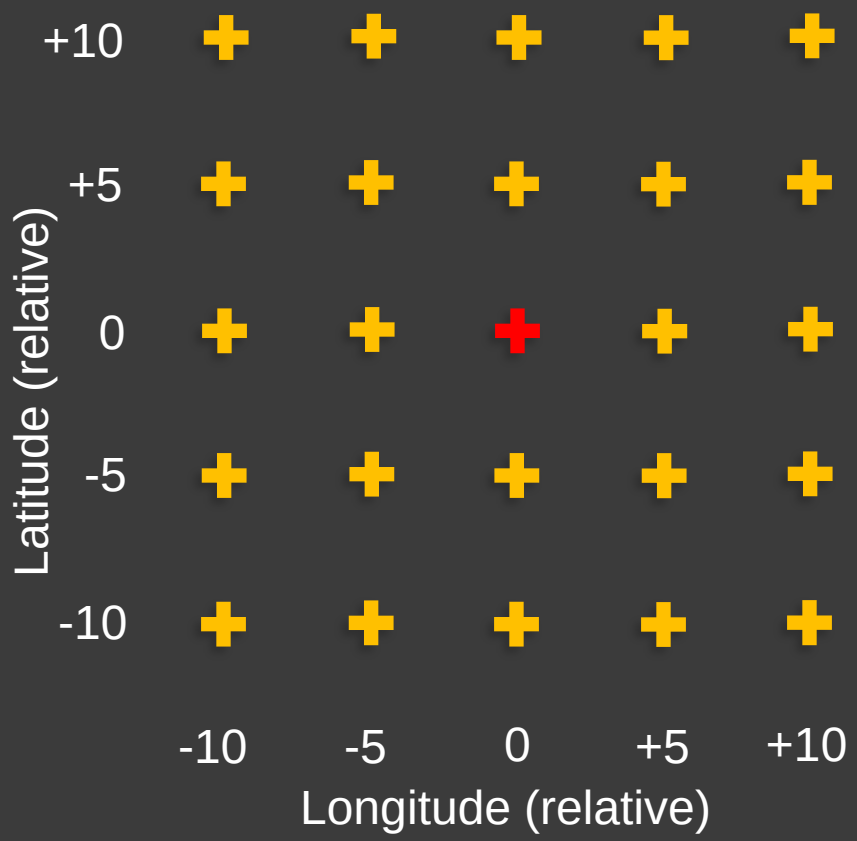
Inform SWFO forecast

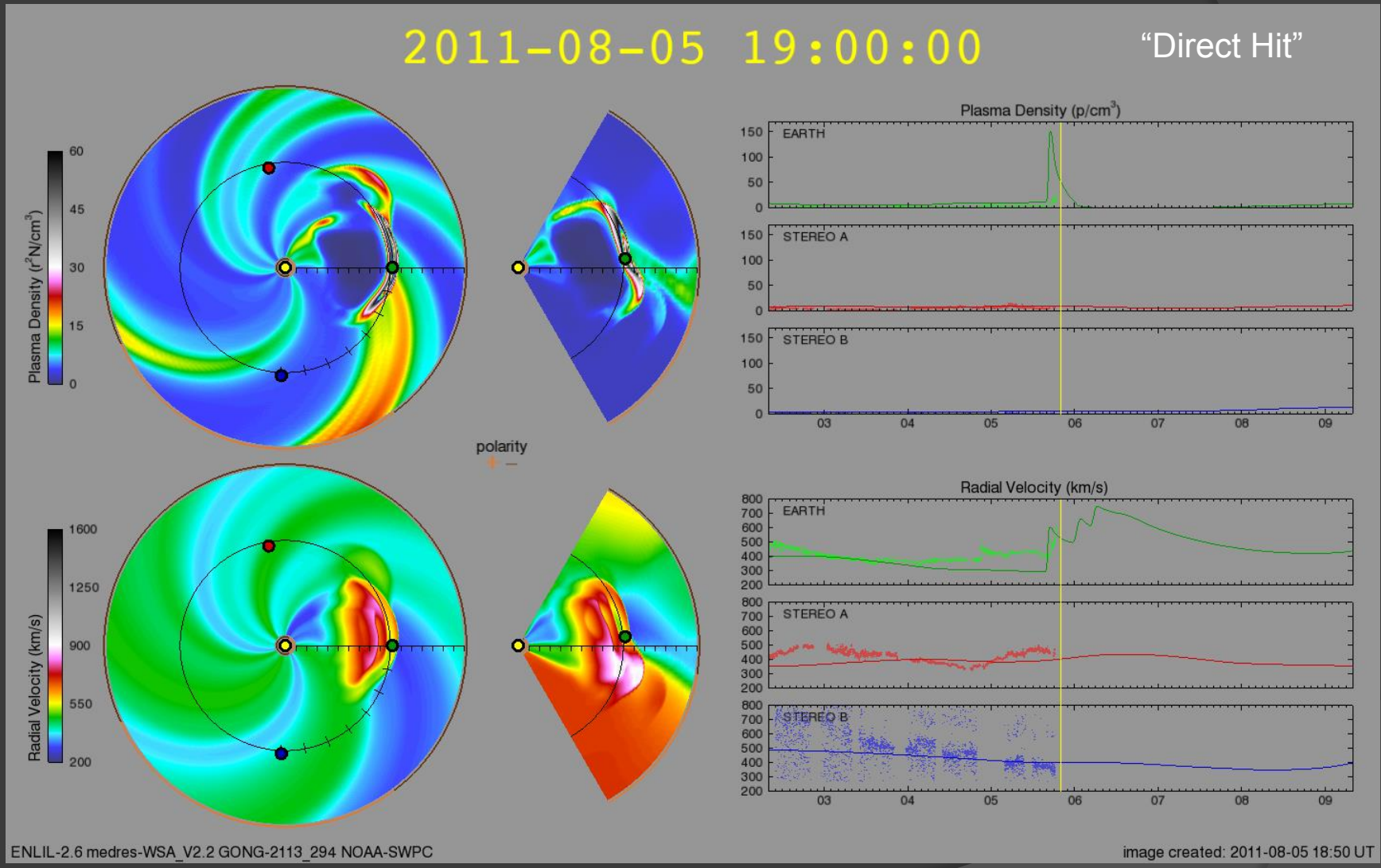

SWPC WSA-Enlil ops: CME arrival time error (wrt ACE)
ABS(Delta T (hours))
Delta T (hours)
20
15
10
5
0
-20
-10
0
10
20

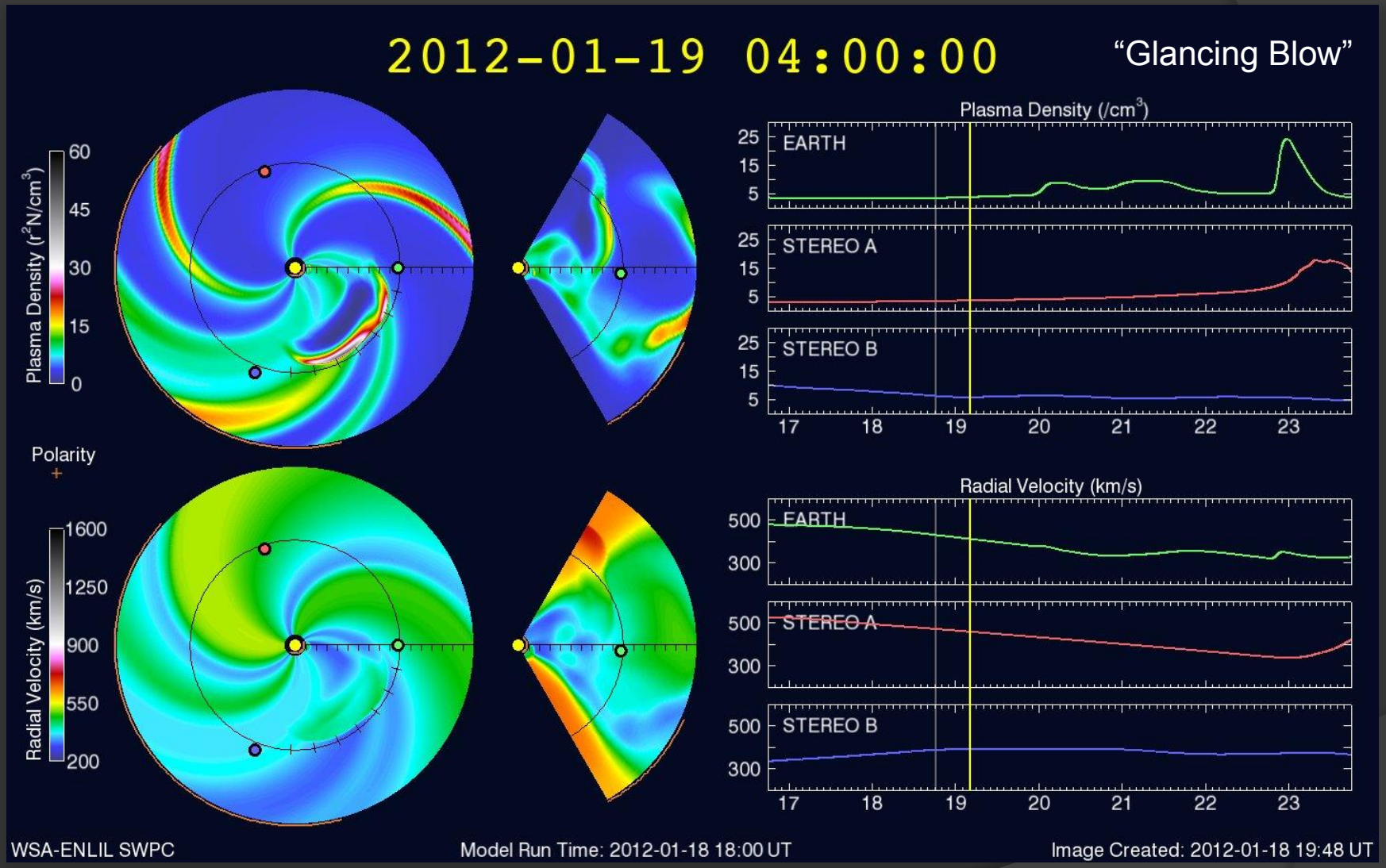

SWPC WSA-Enlil ops: CME arrival time error (wrt ACE)
+/- 3 hours
+/- 6 hours
ABS(Delta T (hours))
Delta T (hours)
20
15
10
5
0
-20
-10
0
10
20

Ensemble of 25 WSA-Enlil model runs – varying the latitude / longitude of CME propagation direction.

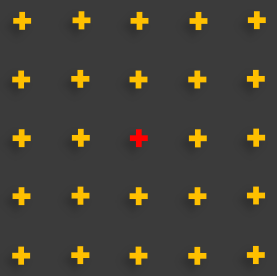
(CME velocity and cone angle kept constant)

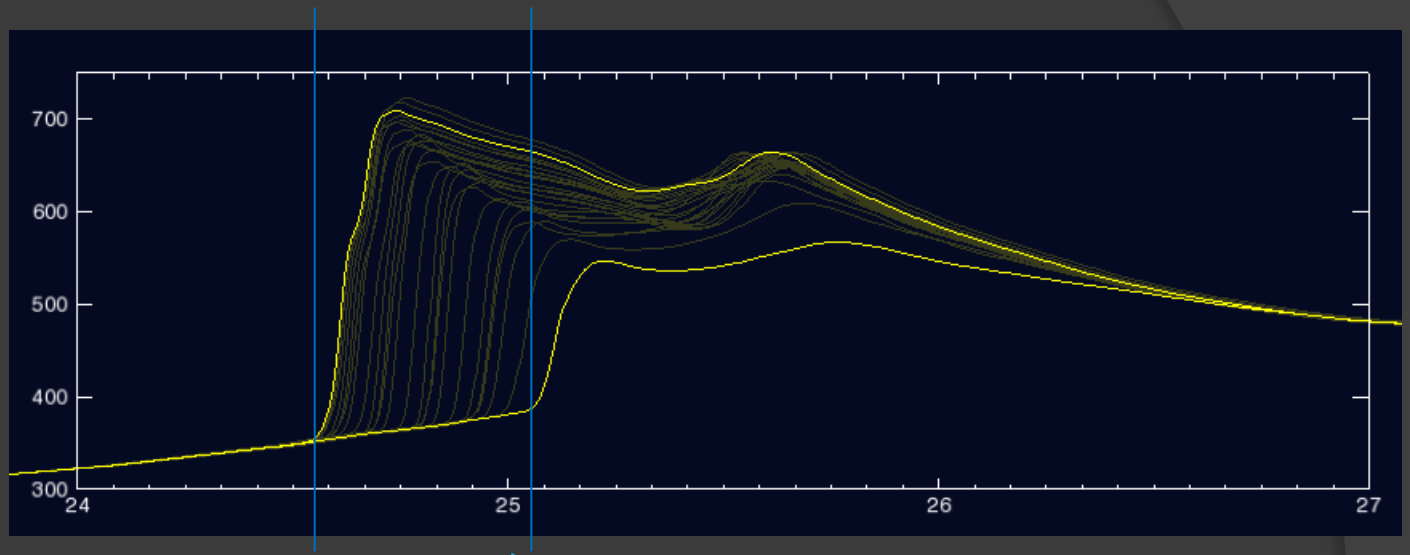



2011-08-05 19:00:00
"Direct Hit"
Plasma Density (p/cm^3)
EARTH
STEREO A
STEREO B
Plasma Density (r^{2}N/cm^3)
polarity
Radial Velocity (km/s)
EARTH
STEREO A
STEREO B
Radial Velocity (km/s)
ENLIL-2.6 medres-WSA_V2.2 GONG-2113_294 NOAA-SWPC
image created: 2011-08-05 18:50 UT


2012-01-19 04:00:00
"Glancing Blow"
Plasma Density (r²N/cm³)
60
45
30
15
0
Polarity
+
Radial Velocity (km/s)
1600
1250
900
550
200
Plasma Density (/cm³)
EARTH
STEREO A
STEREO B
25
15
5
17
18
19
20
21
22
23
Radial Velocity (km/s)
EARTH
STEREO A
STEREO B
500
300
WSA-ENLIL SWPC
Model Run Time: 2012-01-18 18:00 UT
Image Created: 2012-01-18 19:48 UT

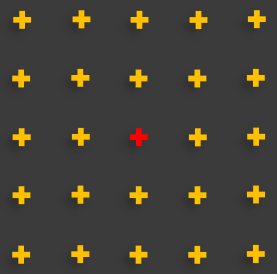
“Direct Hit” ensemble

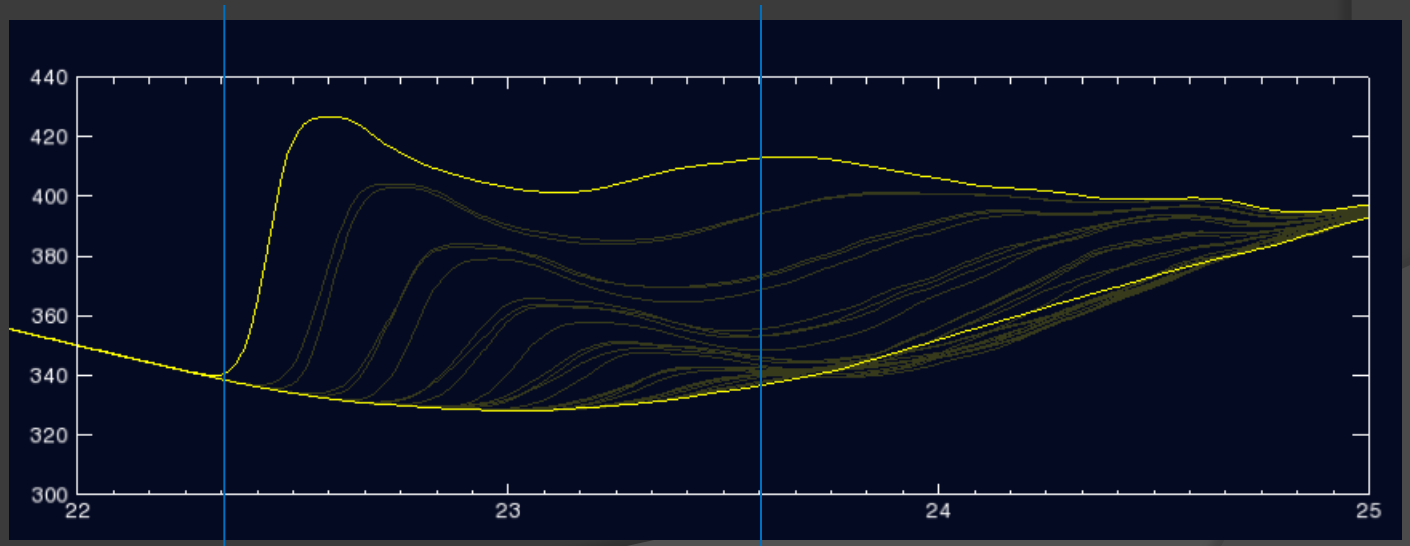




12 hours (+/- 6)

“Glancing Blow” ensemble





30 hours (+/- 15)

The Future (2013)

- Continued validation/verification/performance tracking
- System developments
- Transition ADAPT (AFRL) : SWPT activity
- Enlil developments – real time updating : SWPT activity

valley-death.jpg 810×616 pixels

http://4.bp.blogspot.com/-sJIjm6hMMKs/TocqKJq0LDI/AAAAA

Google

Steinberg forum | Co-op bank | WSA-Enlil Ambient | ACE 6hour | ACE 3day | ACE 7day | Kp | Guardian | SOS