Real-Time Modelling of CMEs Using the WSA-ENLIL+Cone Model

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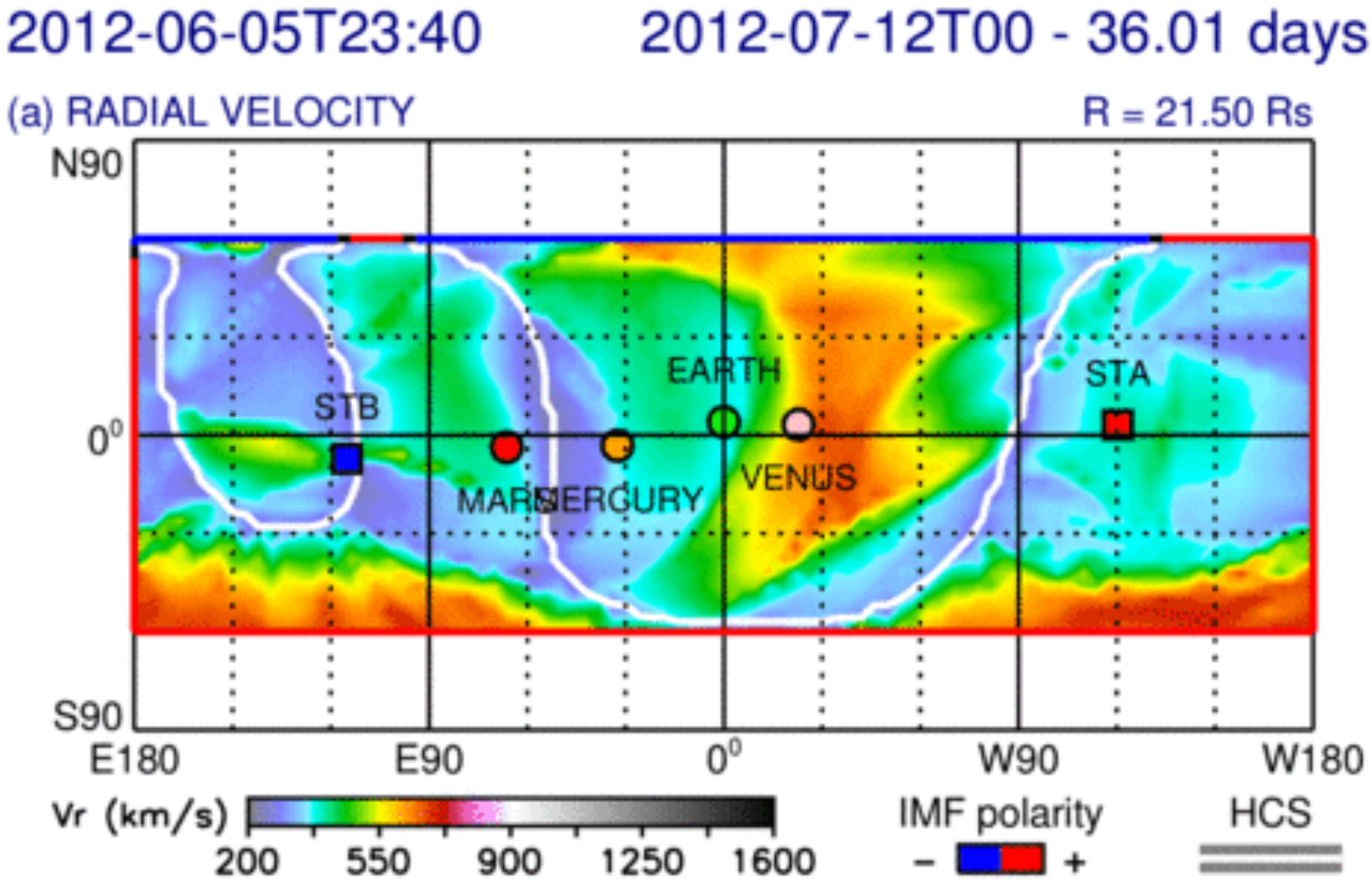
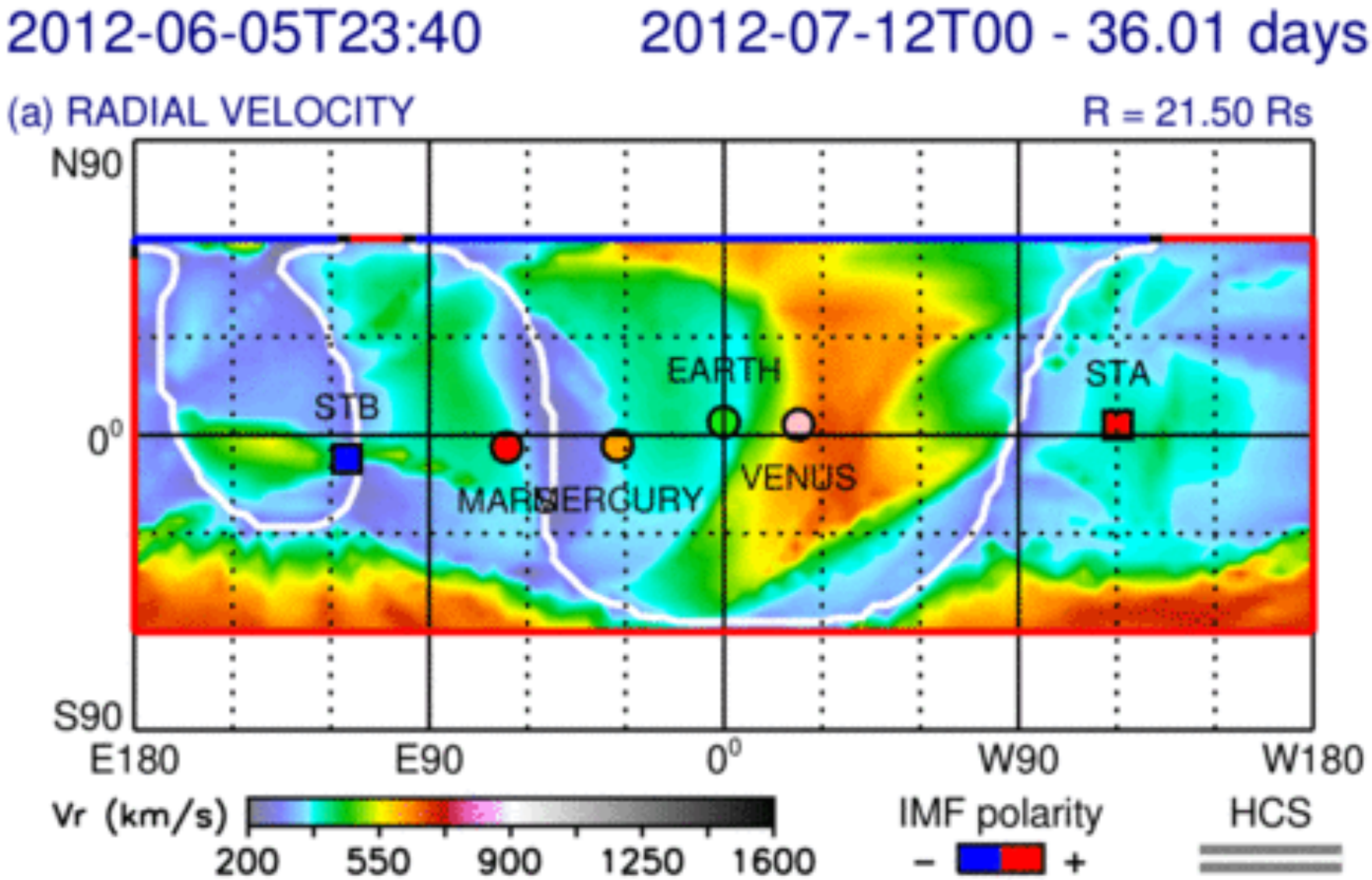
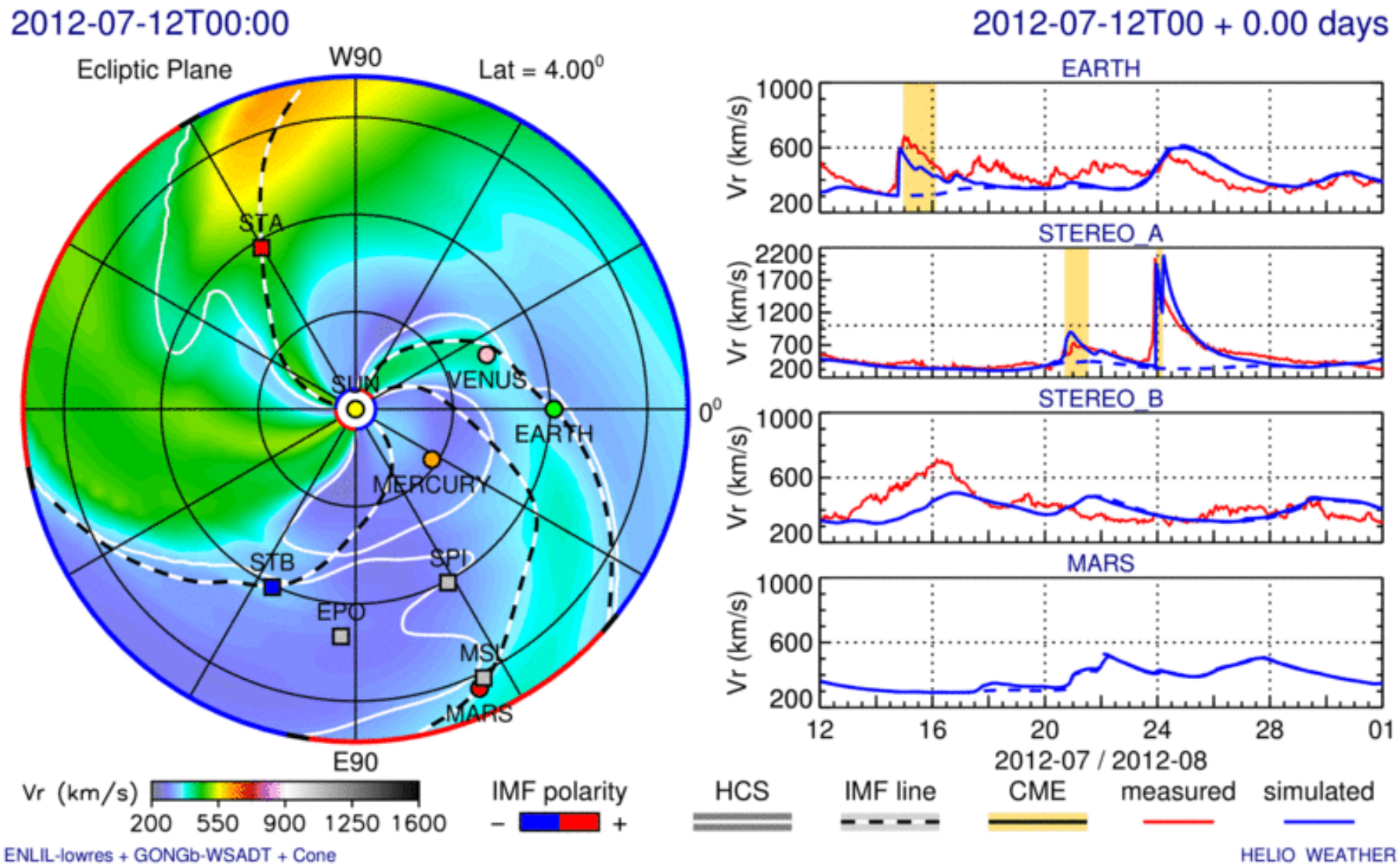
CCMC at NASA GSFC

Modeling CMEs with WSA-ENLIL+Cone



Modeling CMEs with WSA-ENLIL+Cone



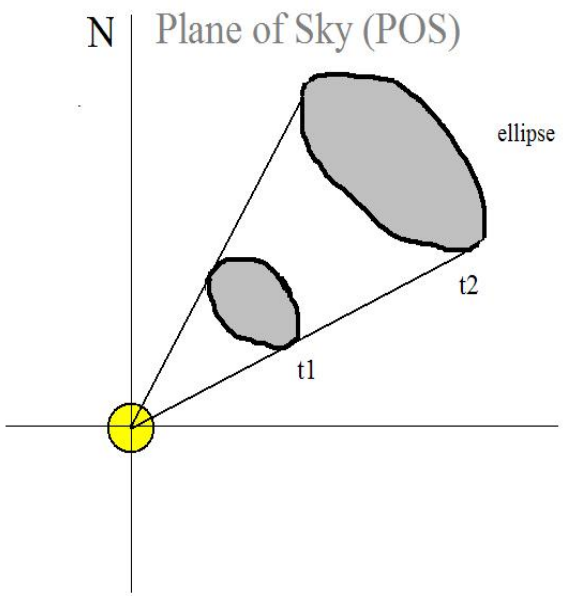

2012-07-12T00:00
Ecliptic Plane
W90
Lat = 4.00°
STA
SUN
VENUS
EARTH
MERCURY
STB
SPI
EPO
MSL
MARS
E90
0°
2012-07-12T00 + 0.00 days
EARTH
STEREO_A
STEREO_B
MARS
Vr (km/s)
1000
600
200
2200
1700
1200
700
12
16
20
24
28
01
2012-07 / 2012-08
Vr (km/s)
200 550 900 1250 1600
IMF polarity
–
+
HCS
IMF line
CME
measured
simulated
ENLIL-lowres + GONGb-WSADT + Cone
HELIO WEATHER

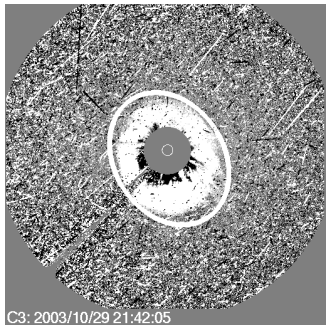
Cone Model for CMEs

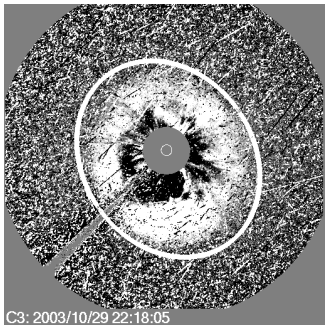
CME measuring technique that assumes:

- CME propagates with nearly constant angular width in a radial direction
- CME bulk velocity is radial and the expansion is isotropic

Zhao et al, 2002, Cone Model:

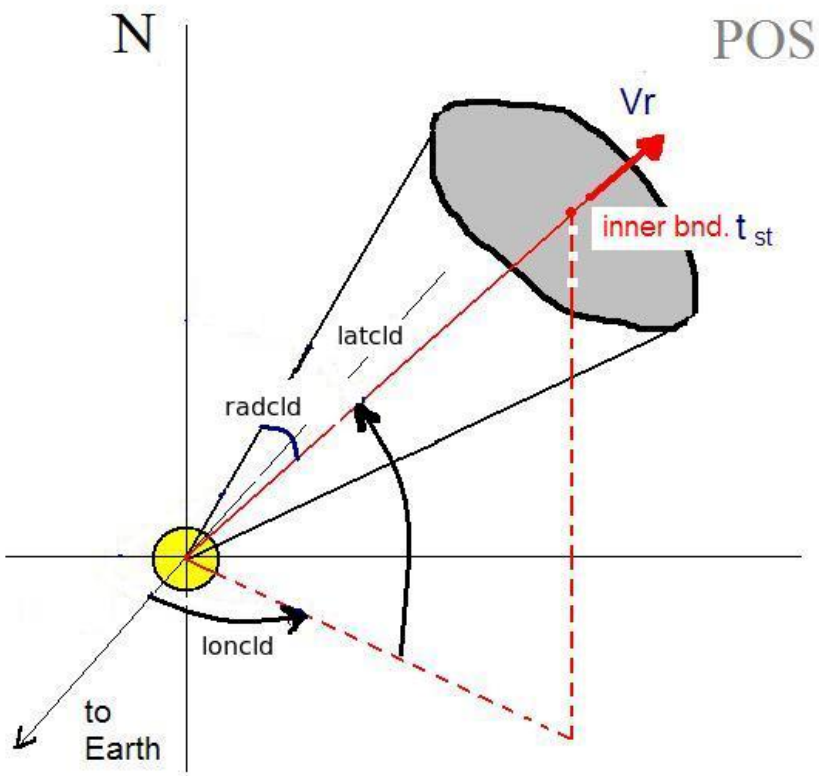






The projection of the cone on the coronagraph image is an ellipse

Cone model parameters

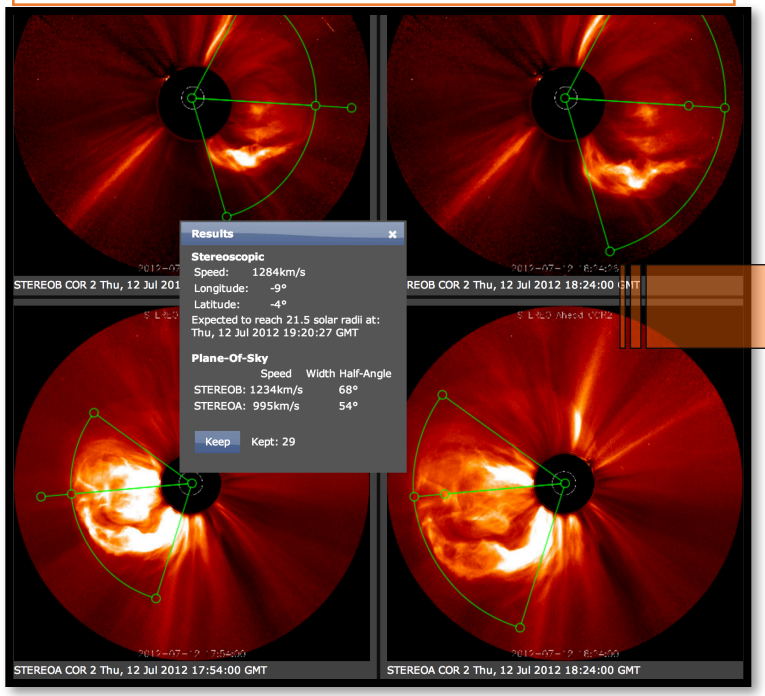


Input to ENLIL cone model run

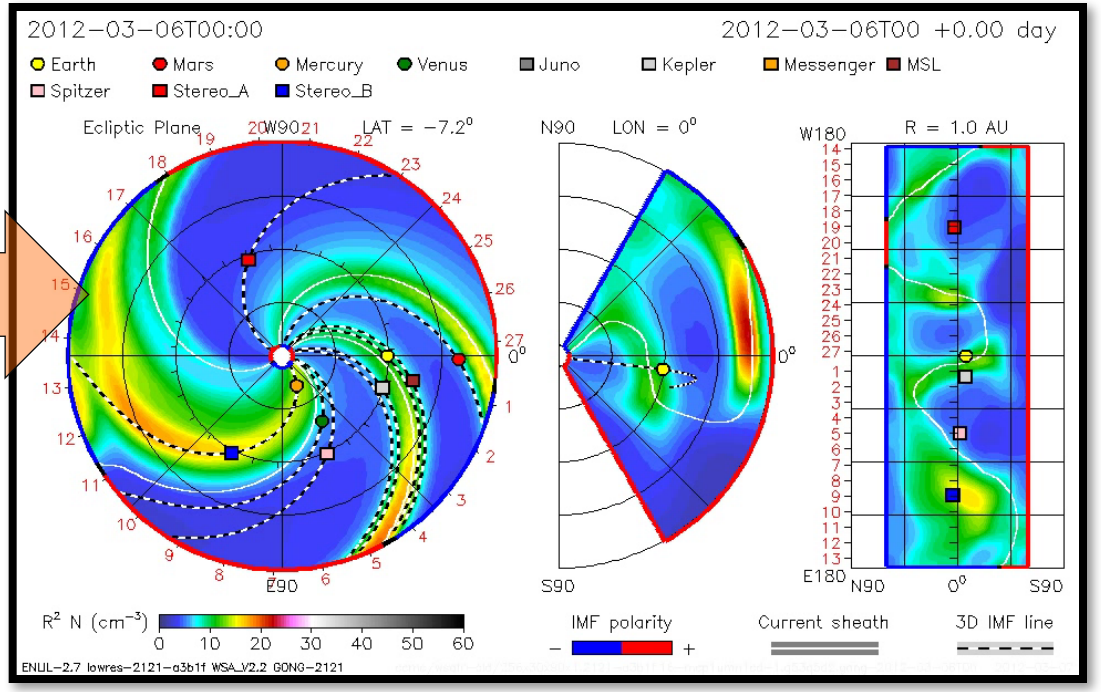
- time the CME reaches the inner boundary of 21.5 Solar Radii
- Latitude (in HEEQ coordinates)
- Longitude (in HEEQ coordinates)
- Half-width (deg)
- Radial velocity (km/s)

WSA-ENLIL Cone Model

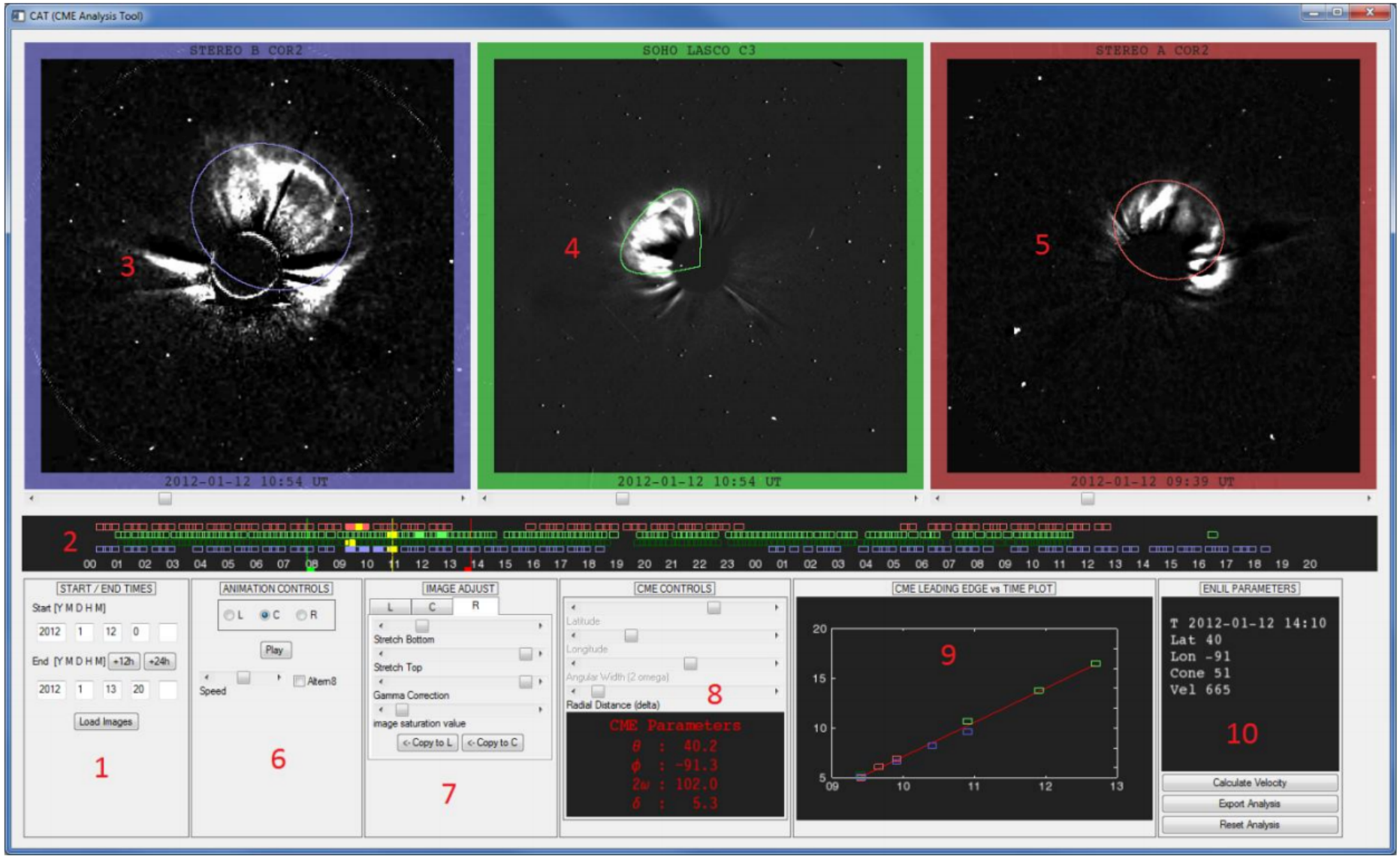
Parameters Defined with CCMC CME Triangulation Tool: StereoCAT



CME Parameters: Input To WSA-ENLIL Cone Model



SWPC CME Analysis Tool (SWPC_CAT)



Navigate to the quiz webpage:
http://www.quizzoodle.com/session/join/

Quiz admin session link.

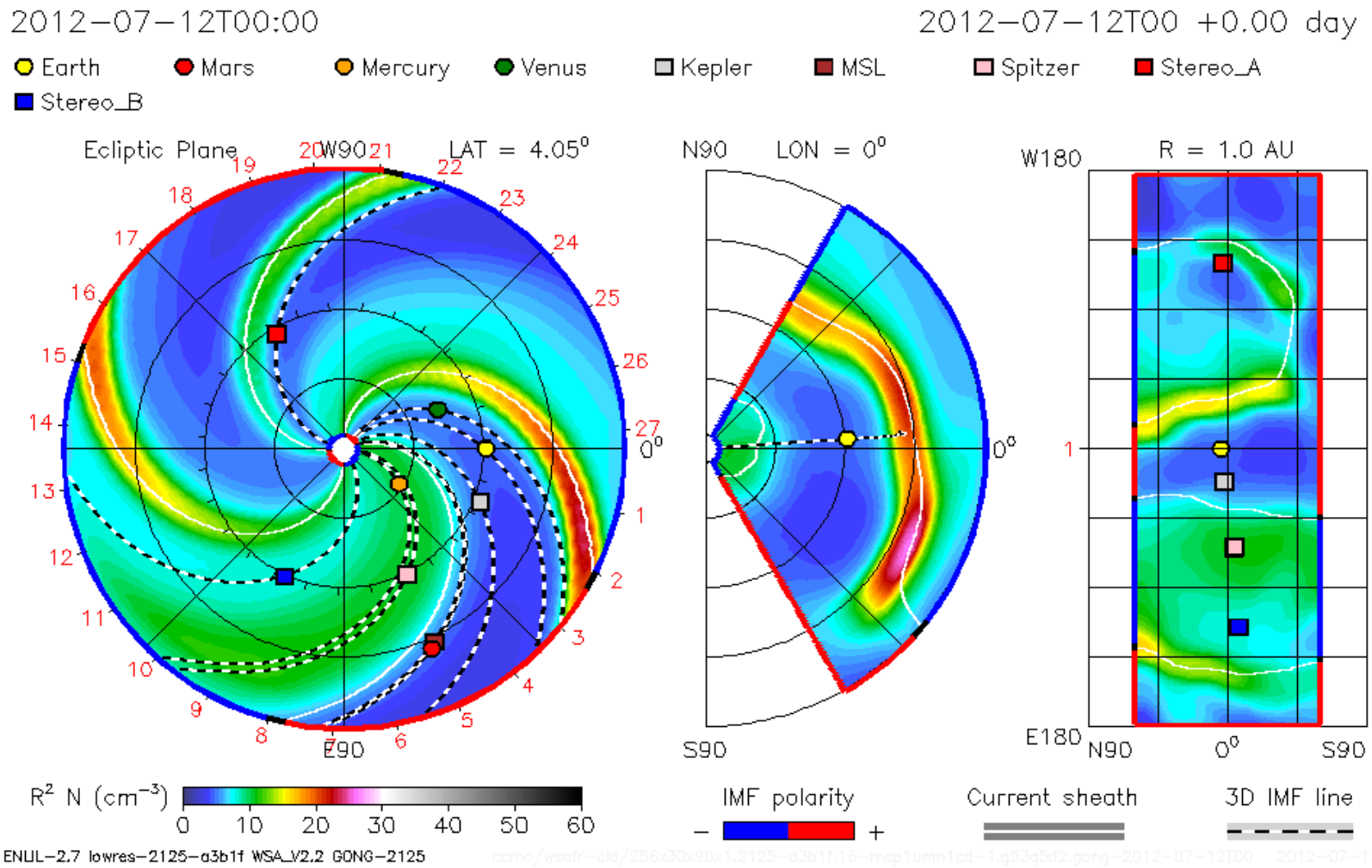
What CME speed is used as input to the model?

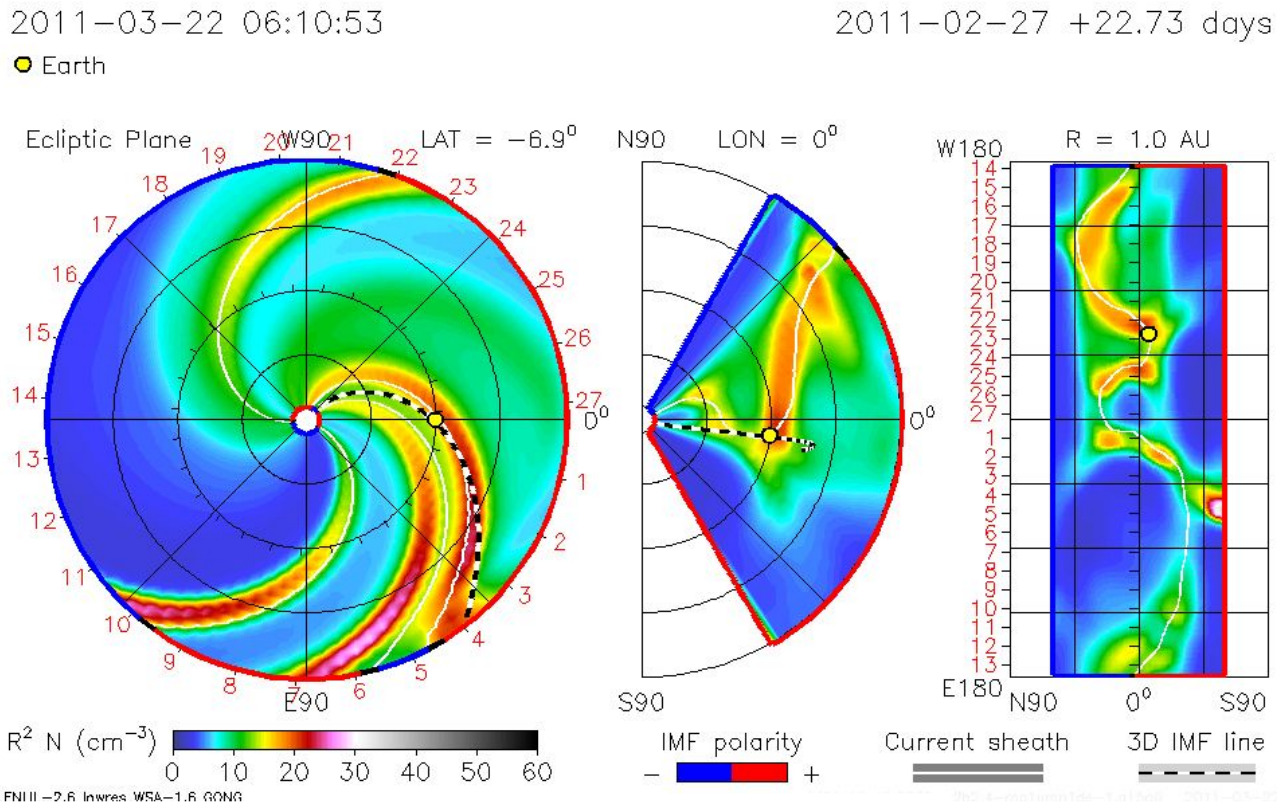
a) The CME speed near the solar surface

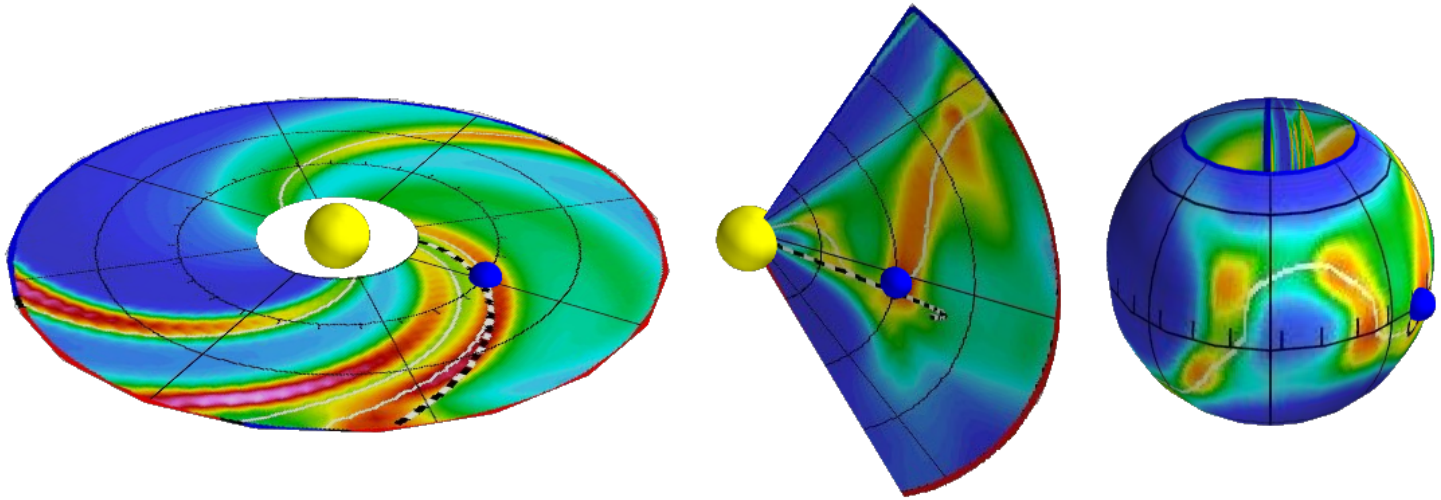
b) The CME speed at the measured height

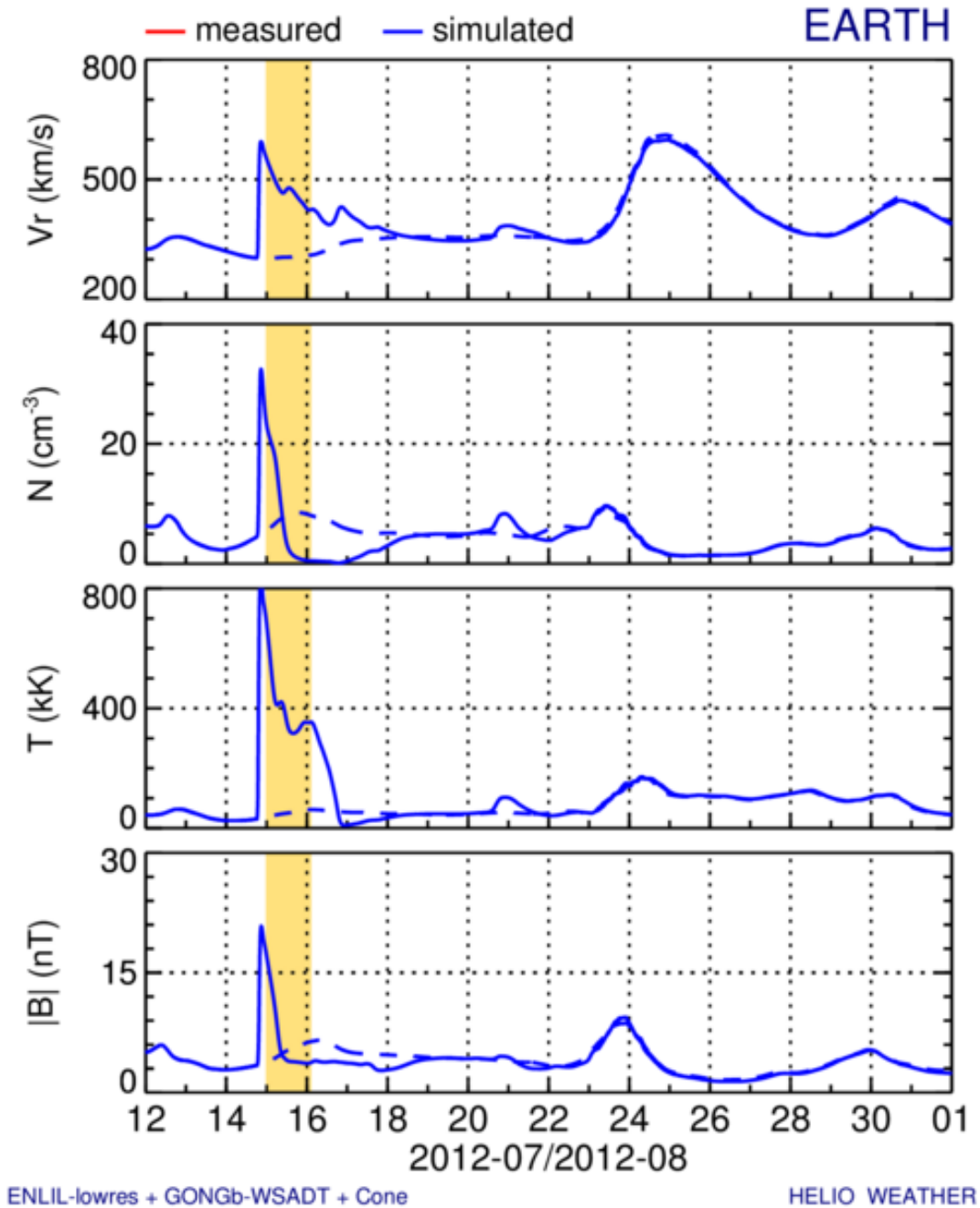
c) The CME speed extrapolated at 21.5 solar radii, the model inner boundary

d) The fastest CME speed measured at any height

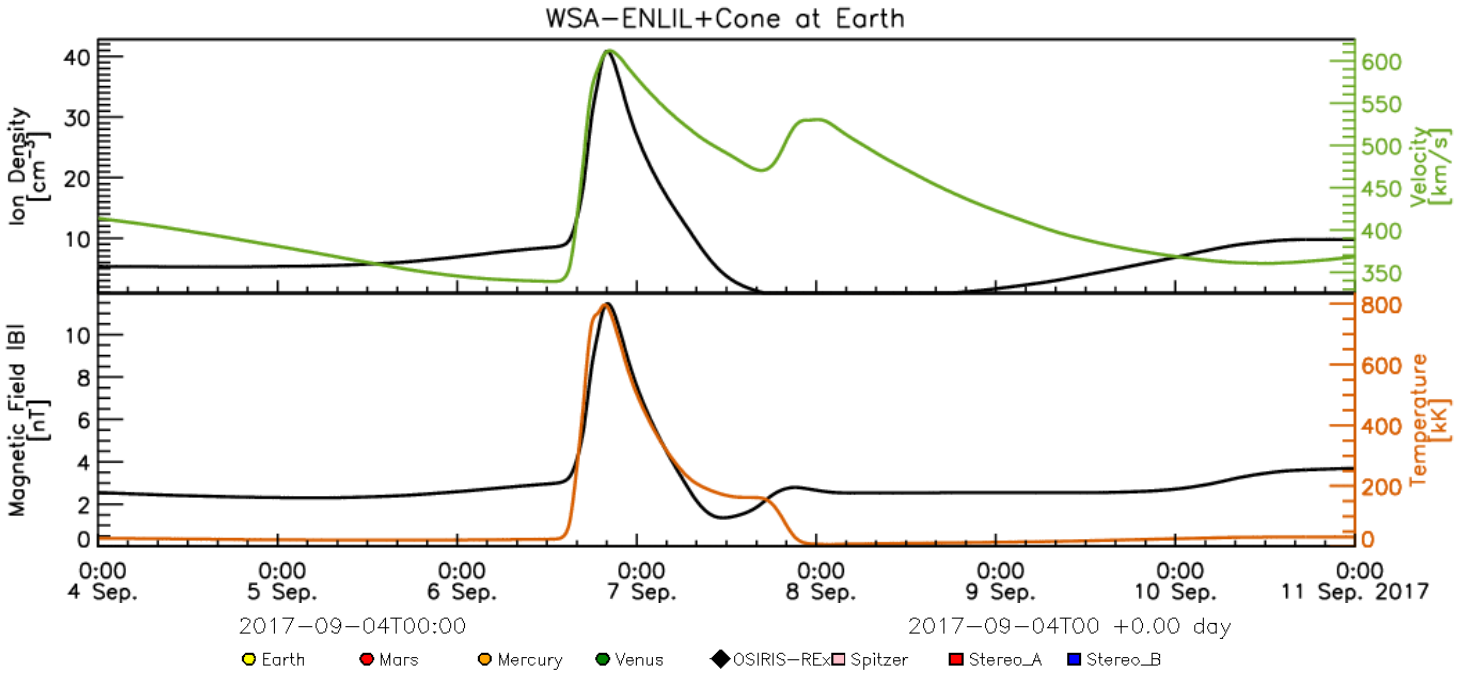

2012–07–12T00:00
2012–07–12T00 +0.00 day
Earth
Mars
Mercury
Venus
Kepler
MSL
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
LAT = 4.05°
W90
E90
N90
S90
LON = 0°
W180
E180
R = 1.0 AU
R² N (cm⁻³)
0 10 20 30 40 50 60
IMF polarity
Current sheath
3D IMF line
ENUL–2.7 lowres–2125–a3b1f WSA_V2.2 GONG–2125

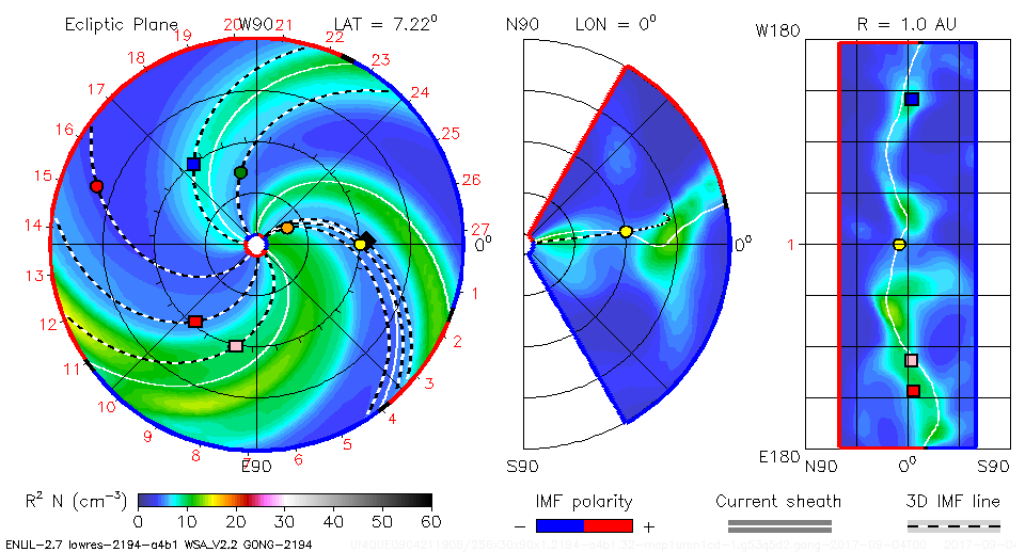

2011−03−22 06:10:53
2011−02−27 +22.73 days
Earth
Ecliptic Plane
W90
LAT = −6.9°
N90
LON = 0°
W180
R = 1.0 AU
E90
S90
E180
N90
0°
S90
R^2 N (cm^{-3})
0 10 20 30 40 50 60
IMF polarity
−
+
Current sheath
3D IMF line



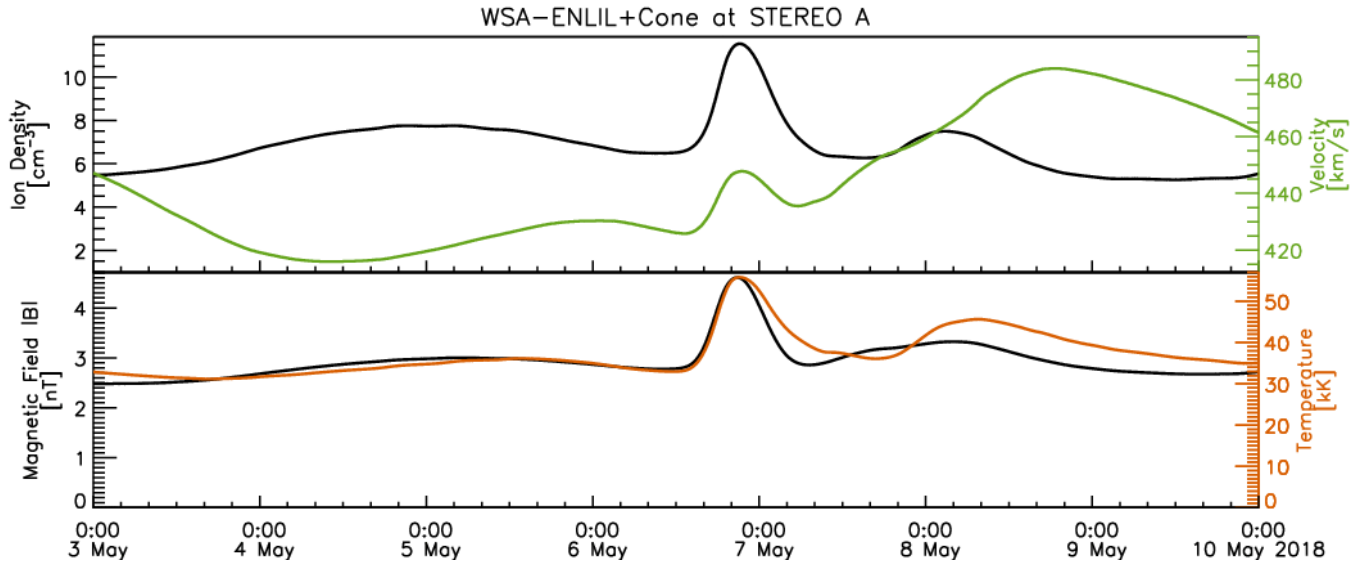

measured
simulated
EARTH
Vr (km/s)
800
500
200
N (cm-3)
40
20
0
T (kK)
800
400
0
|B| (nT)
30
15
0
12
14
16
18
20
22
24
26
28
30
01
2012-07/2012-08
ENLIL-lowres + GONGb-WSADT + Cone
HELIO WEATHER

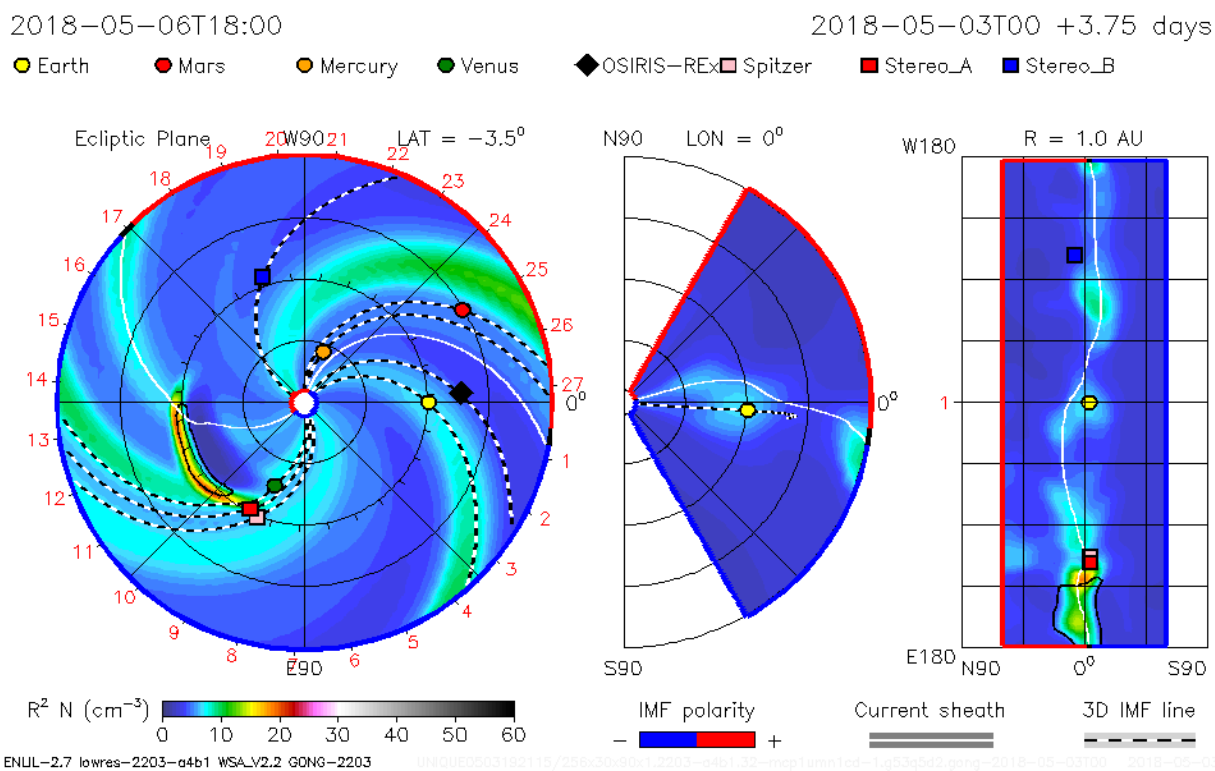
Determining CME Arrival Time



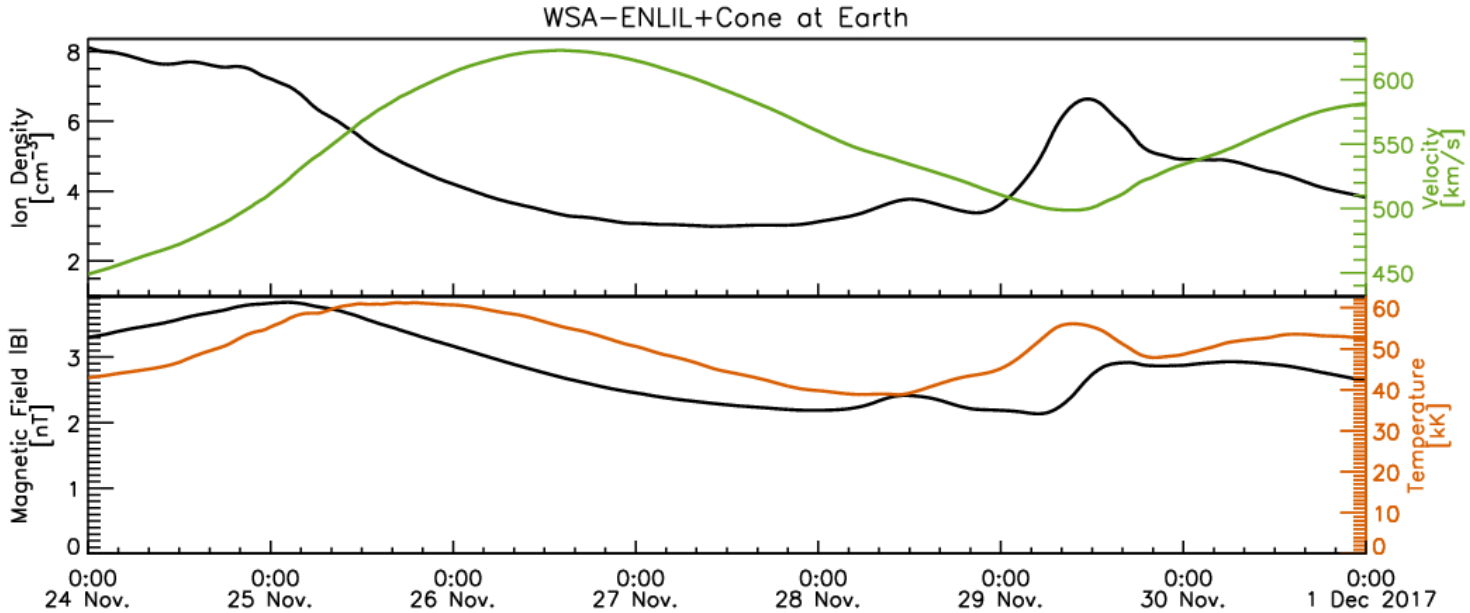


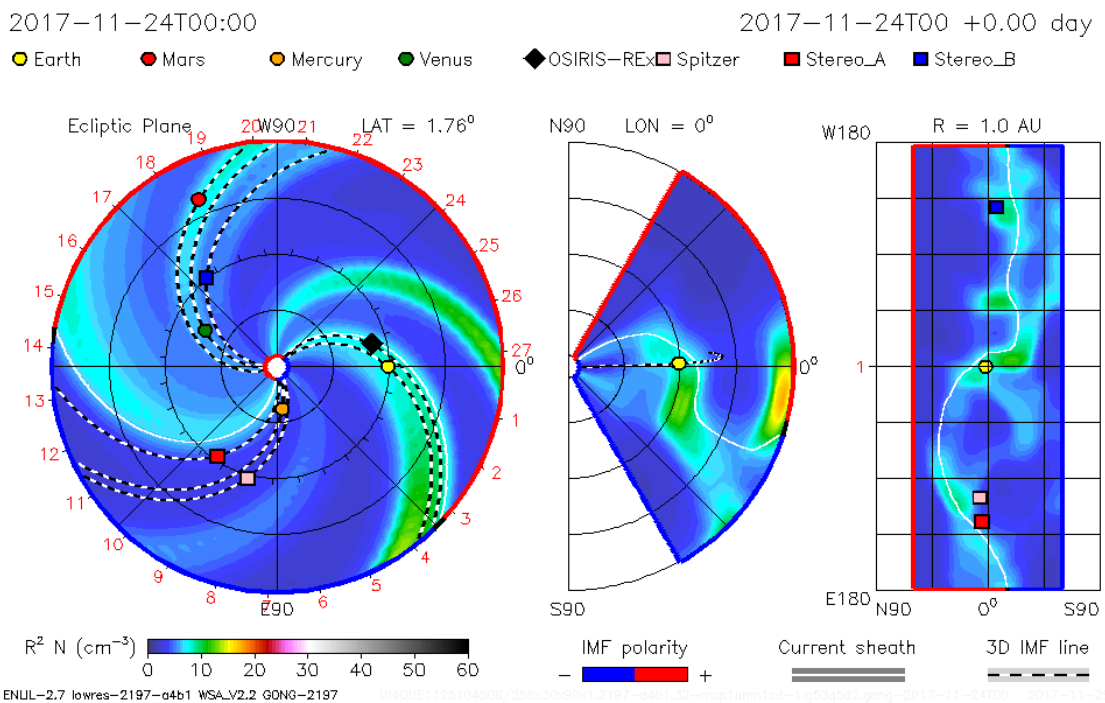
“direct” arrival





“flank” arrival


WSA−ENLIL+Cone at Earth
Ion Density [cm⁻³]
Velocity [km/s]
Magnetic Field |B| [nT]
Temperature [kK]
0:00 24 Nov.
0:00 25 Nov.
0:00 26 Nov.
0:00 27 Nov.
0:00 28 Nov.
0:00 29 Nov.
0:00 30 Nov.
0:00 1 Dec 2017


2017−11−24T00:00
2017−11−24T00 +0.00 day
Earth
Mars
Mercury
Venus
OSIRIS−REx
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
LAT = 1.76°
W90
E90
N90
S90
LON = 0°
W180
E180
R = 1.0 AU
R² N (cm⁻³)
IMF polarity
Current sheath
3D IMF line
ENLIL−2.7 lowres−2197−a4b1 WSA_V2.2 GONG−2197

glancing

What are the main CME parameters that determine if it will have a direct impact, or a glancing blow?

a) speed, latitude, longitude

b) speed, longitude, half-width

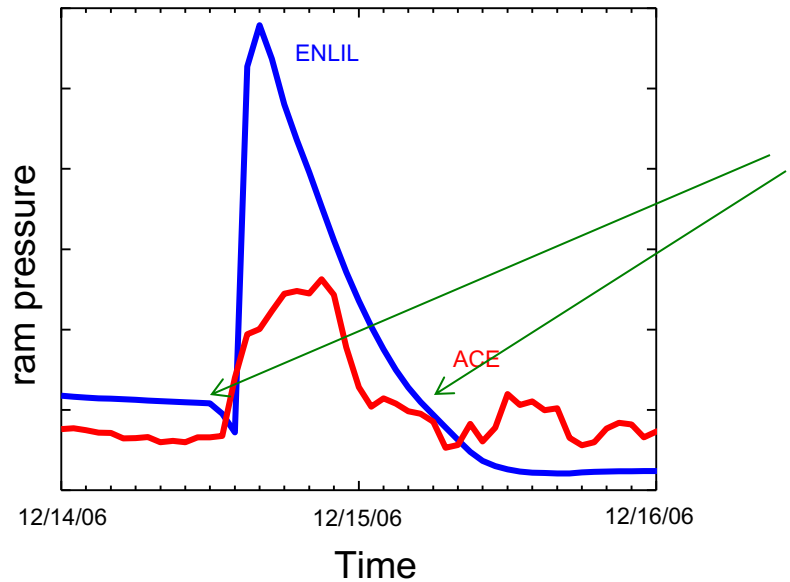
c) latitude, longitude, half-width

d) half-width, speed, latitude

CME Impact: Arrival time, duration of passage, magnetopause standoff distance

CME shock arrival – a sharp jump in the dynamic pressure

$$nm_pV^2$$



Duration of the disturbance – duration of the dynamic pressure hump

Magnetic field required to stop SW

$$\frac{B_{stop}^2}{2\mu_0} = Knm_pV^2$$

→

Magnetopause standoff distance

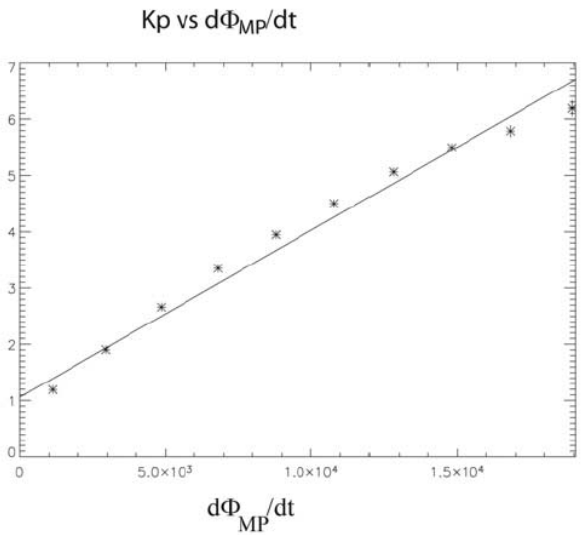
$$\frac{r_{mp}}{R_e} = \left(\frac{B_0}{B_{stop}}\right)^{1/3}$$

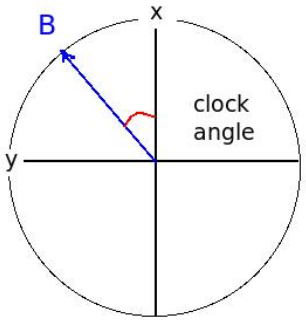
Kp Index Prediction– Newell Coupling Function

Kp is predicted using a relationship between the solar wind speed, magnetic field, and magnetic field clock angle. (Θ_C=90°, 135°, and 180°)

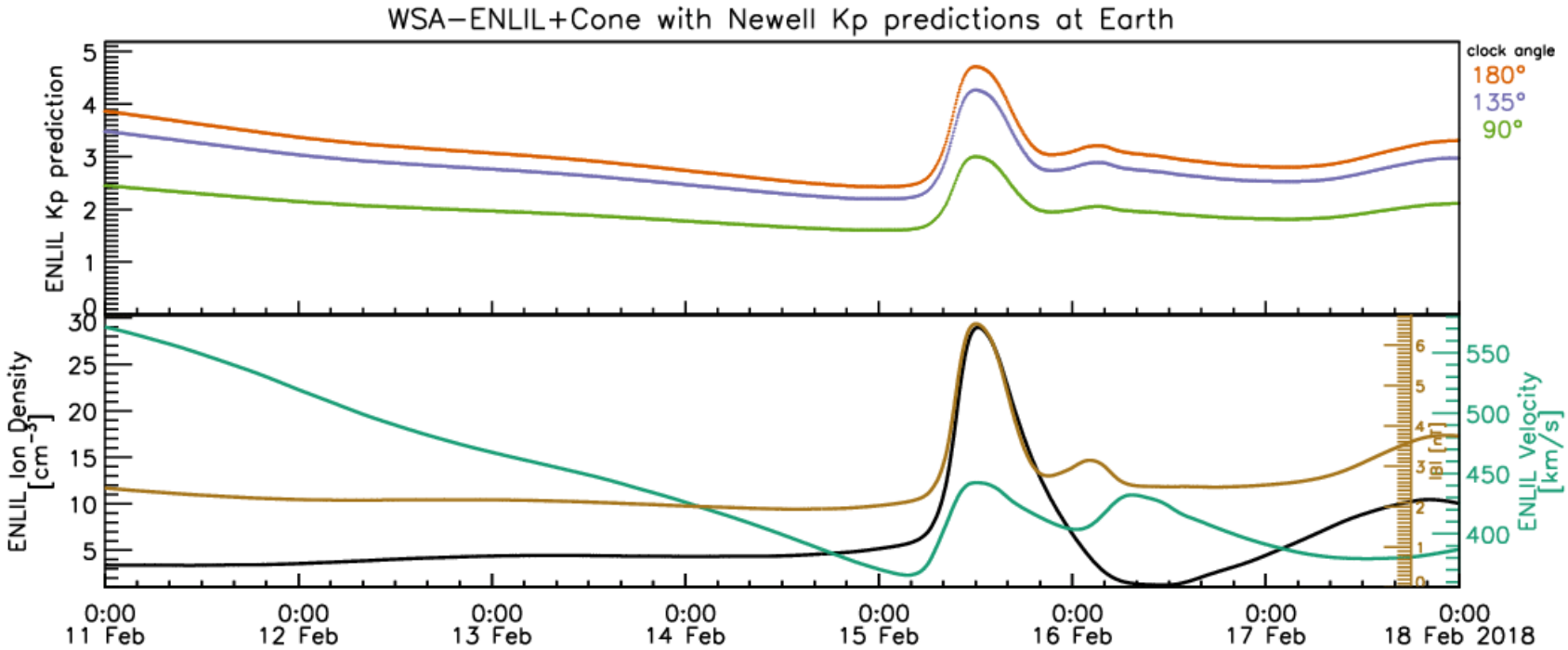
Magnetic flux opening rate at the magnetopause

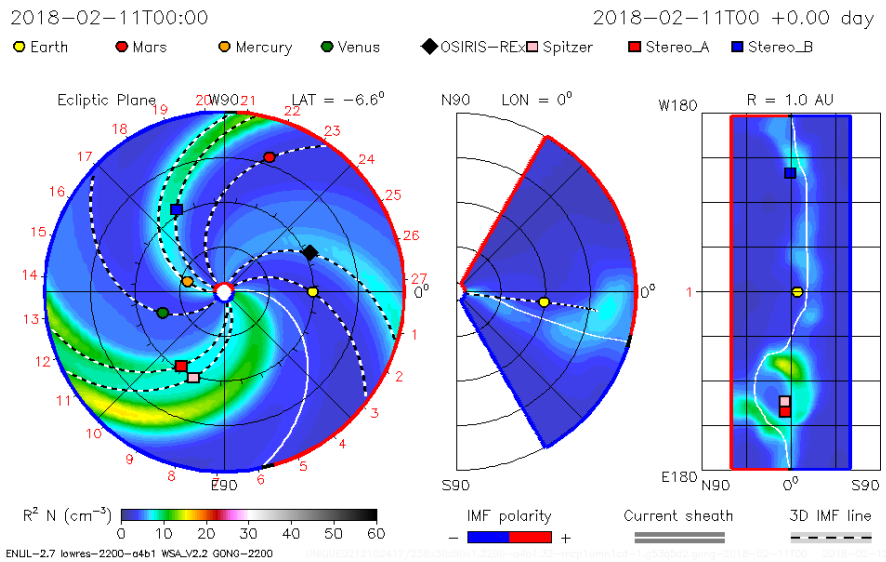
$$d\Phi_{MP}/dt = v^{4/3} B_T^{2/3} \sin^{8/3}(\theta_c/2)$$





$$Kp = 9.5 - \exp\left(2.17676 - 0.000052001\frac{d\Phi_{MP}}{dt}\right)$$


WSA−ENLIL+Cone with Newell Kp predictions at Earth
ENLIL Kp prediction
clock angle
180°
135°
90°
ENLIL Ion Density [cm⁻³]
|B| [nT]
ENLIL Velocity [km/s]
0:00 11 Feb
0:00 12 Feb
0:00 13 Feb
0:00 14 Feb
0:00 15 Feb
0:00 16 Feb
0:00 17 Feb
0:00 18 Feb 2018


2018−02−11T00:00
2018−02−11T00 +0.00 day
Earth
Mars
Mercury
Venus
OSIRIS−REx
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
LAT = −6.6°
W90
E90
N90
LON = 0°
S90
W180
E180
R = 1.0 AU
R² N (cm⁻³)
0 10 20 30 40 50 60
IMF polarity
Current sheath
3D IMF line
ENLIL−2.7 lowres−2200−a4b1 WSA_V2.2 GONG−2200

E-mail/text file with CME impact estimate at Earth

Arrival time(year/month/day, hr:min UT) =2012-07-31T15:02Z
(confidence level +-7 hours)

Duration of the disturbance (hr) = 10.3
(confidence level +-8 hours)

Minimum magnetopause standoff distance: Rmin(Re)=5.6
(under quiet conditions: Rmin(Re)=10;
R_geosynchr(Re)=6.6)

Kp index for three possible IMF clock angles
(angle 180 gives the maximum possible estimated Kp):
(Kp)_90=4
(Kp)_135=6
(Kp)_180=7

****

Here are the links to the movies of the modeled event

http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-pdyn.gif

Inner Planets
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den-Stereo_B.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel-Stereo_B.gif

Timelines
http://iswa2.ccmc.gsfc.nasa.gov/downloads/20120729_014700_ENLIL_CONE_timeline.gif
http://iswa2.ccmc.gsfc.nasa.gov/downloads/20120729_014700_ENLIL_CONE_Kp_timeline.gif

Impact estimate at NASA mission locations

Mars
****

CME did not hit the Mars.
or
CME impact is very weak.

****

Stereo A
****

CME did not hit the StereoA.
or
CME impact is very weak.

****

Stereo B
****
CME did not hit the StereoB.
or
CME impact is very weak.

****

Spitzer
****

Arrival time(year/month/day, hr:min UT) =2015-05-11T20:49Z

Inner Planets
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den-Stereo_B.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel-Stereo_B.gif

Inner Planet Timelines
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Mars_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_STA_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_STB_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Spitz_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Merc_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Venus_timeline.gif