Numerical Simulations of STEREO ICMEs

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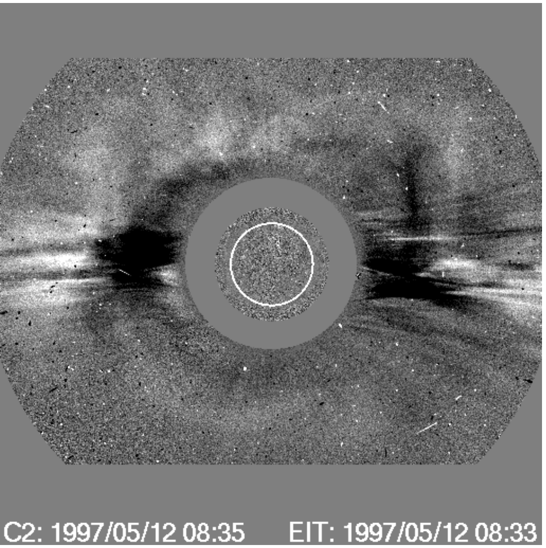
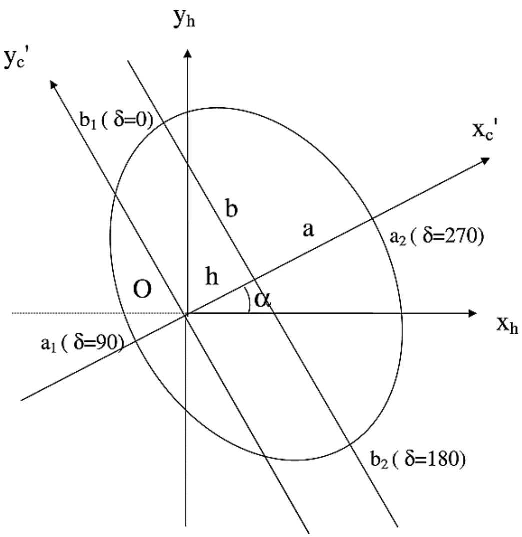
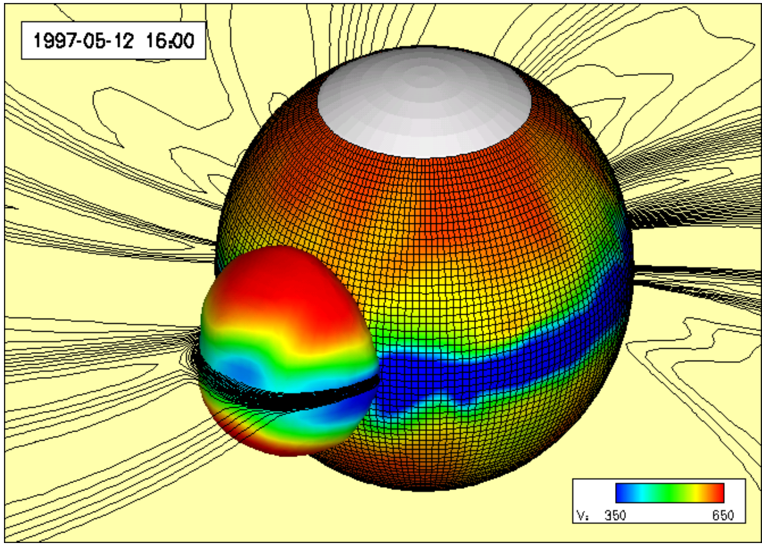
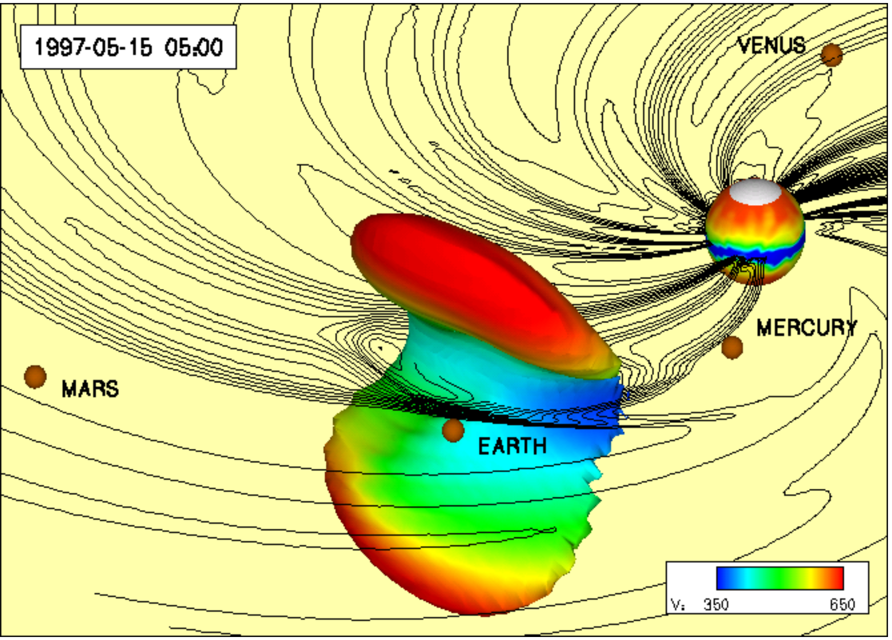
STEREO-SWG Workshop, Pasadena, CA, February 3-5, 2009

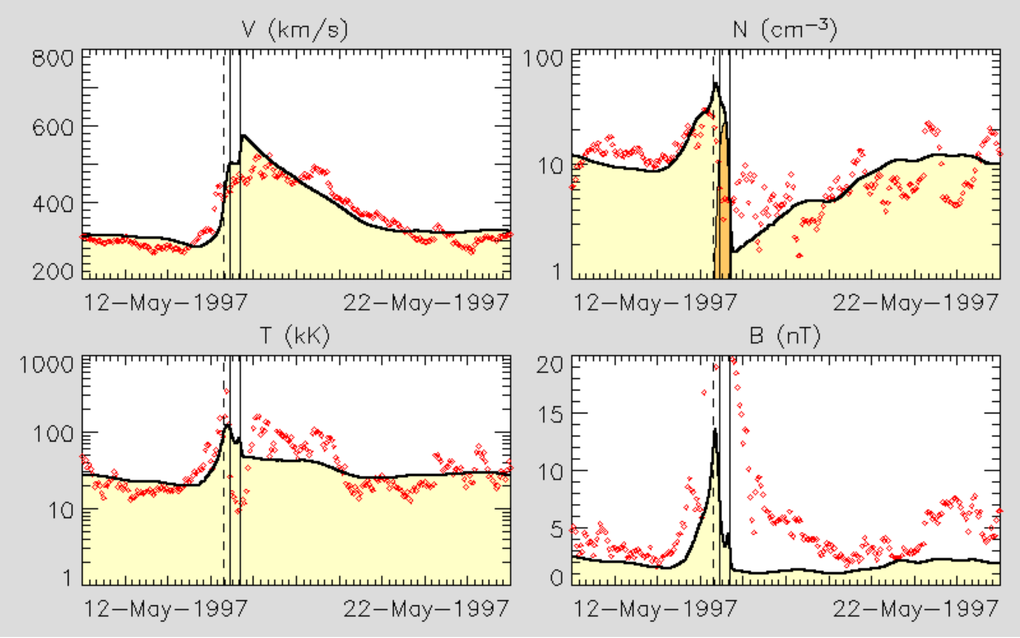
Simulation of Heliospheric Disturbances – Cone Model



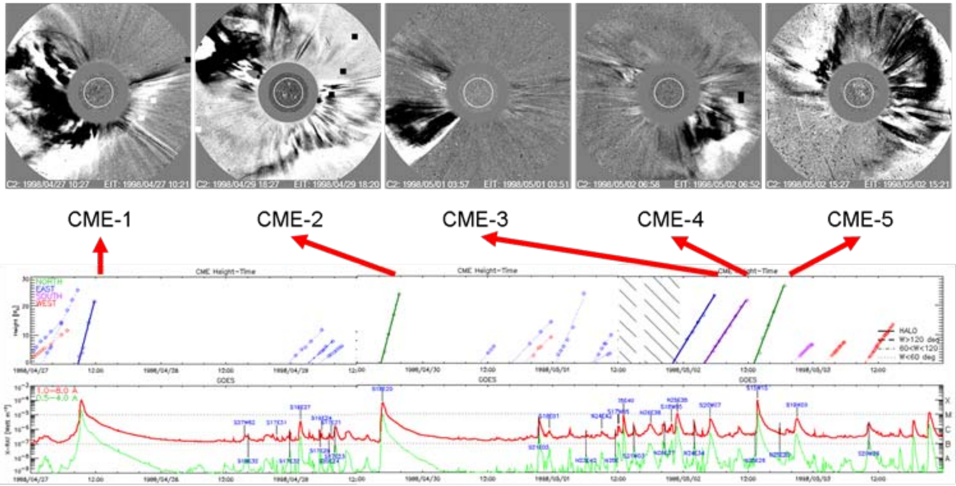


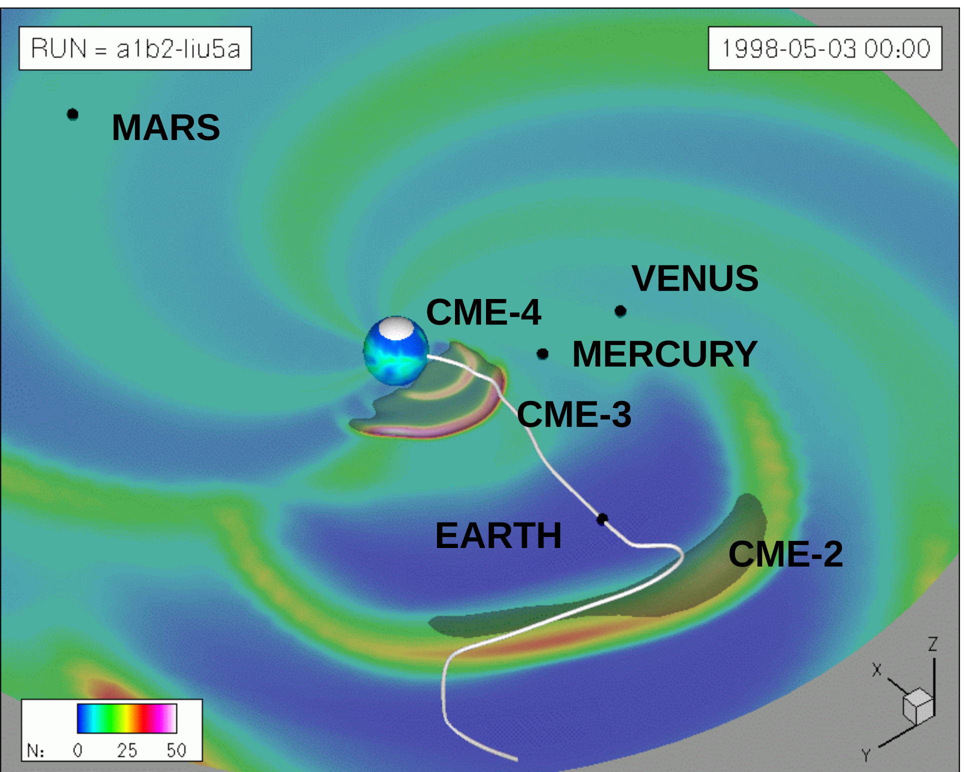






April/May, 1998 CME Events





Using Cone Models

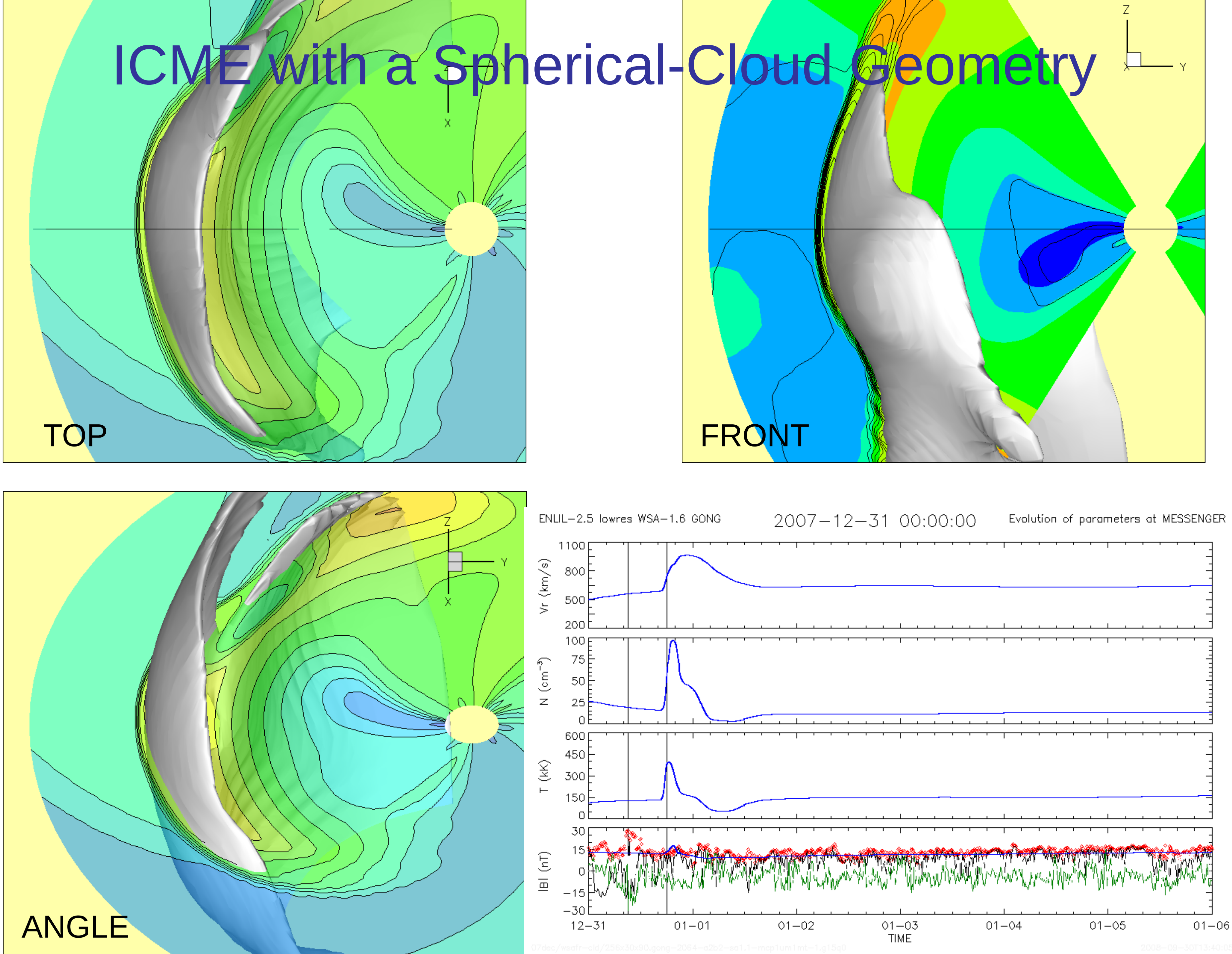
PLUS

- observationally based
- simple specification
- numerically robust
- more accurate than empirical formulae
- global context for transient and background structures
- interplanetary shocks and IMF line connectivity

MINUS

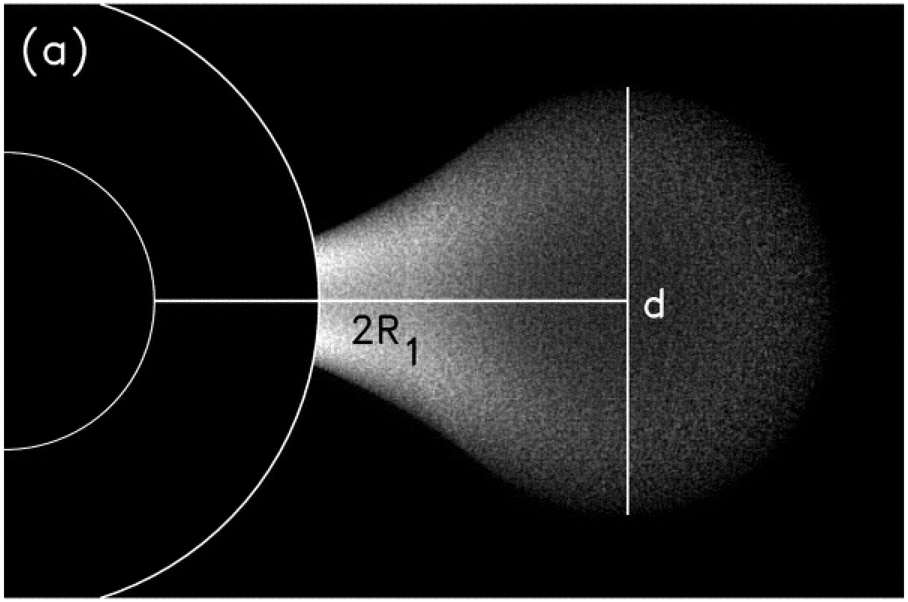
- absence of internal magnetic structure
- initial effect on surrounding solar wind
- reverse shock
- shock stand-off distance

ICME with a Spherical-Cloud Geometry

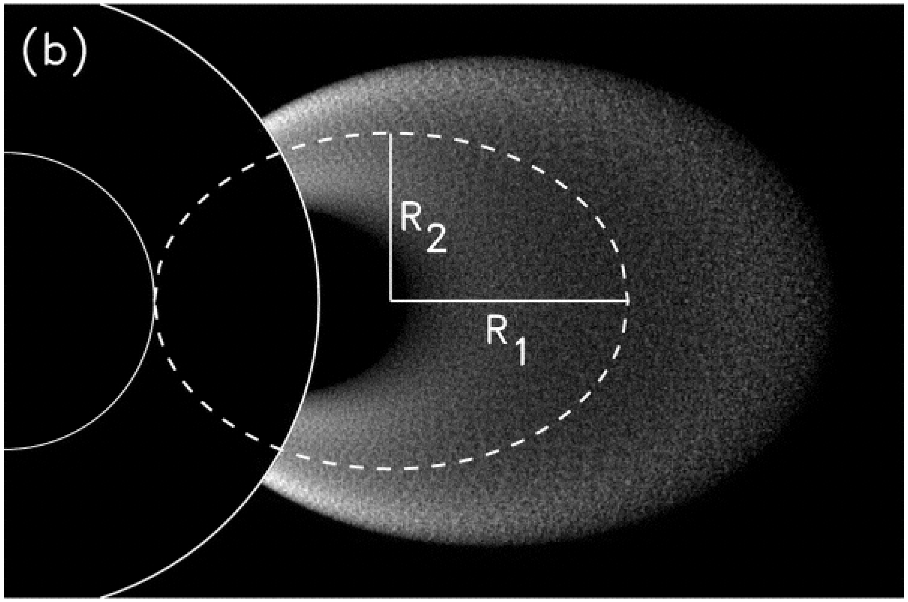


Eruptive Flux Rope (EFR) Model

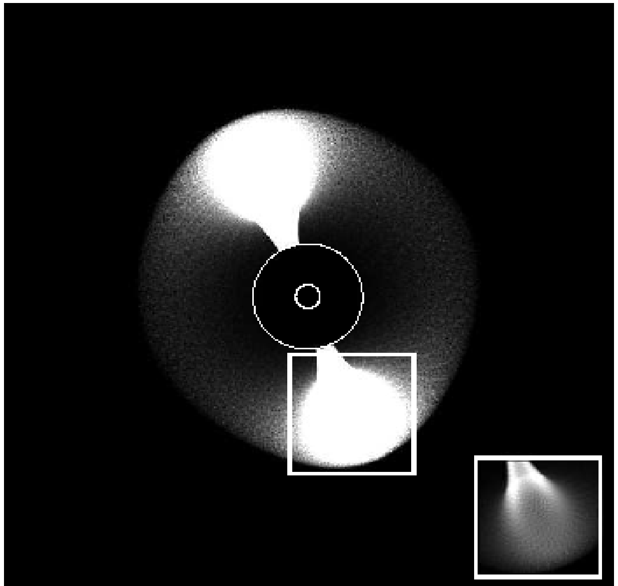
Axial view



Broadside view

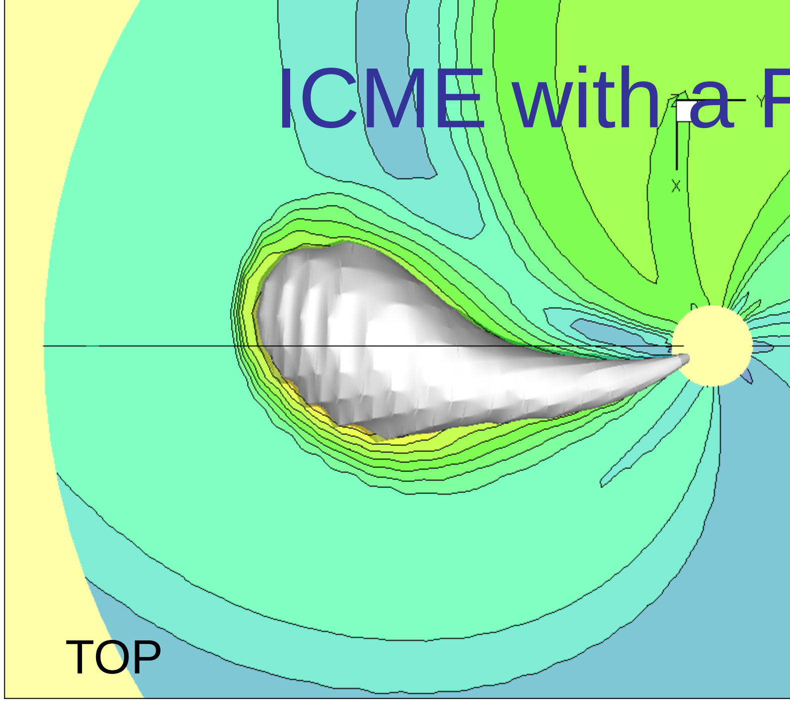


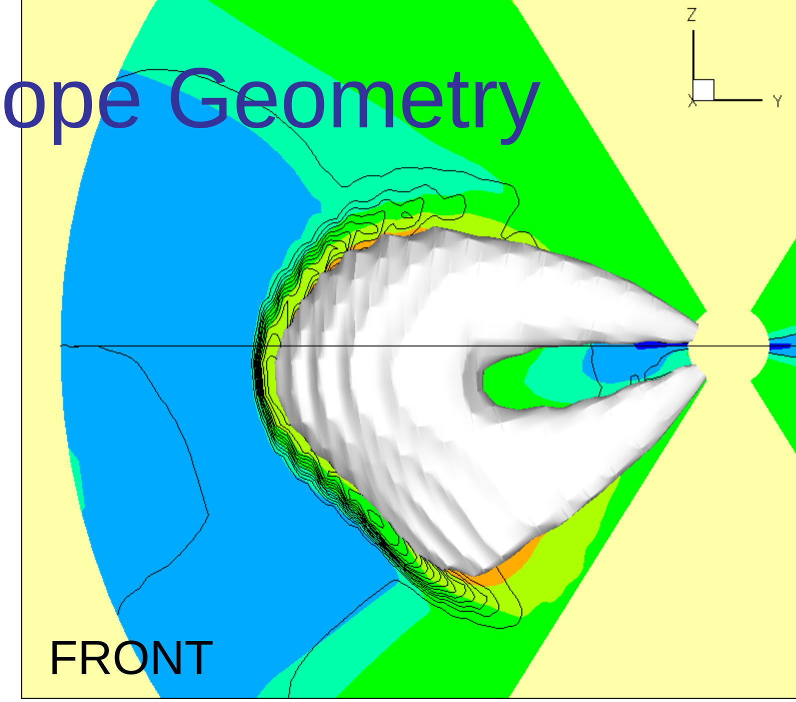
Front view

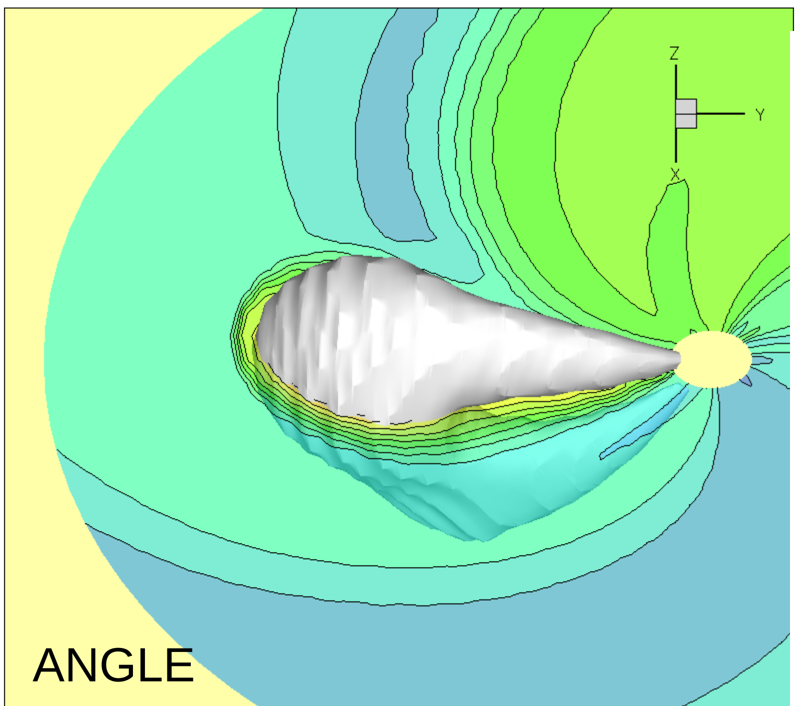


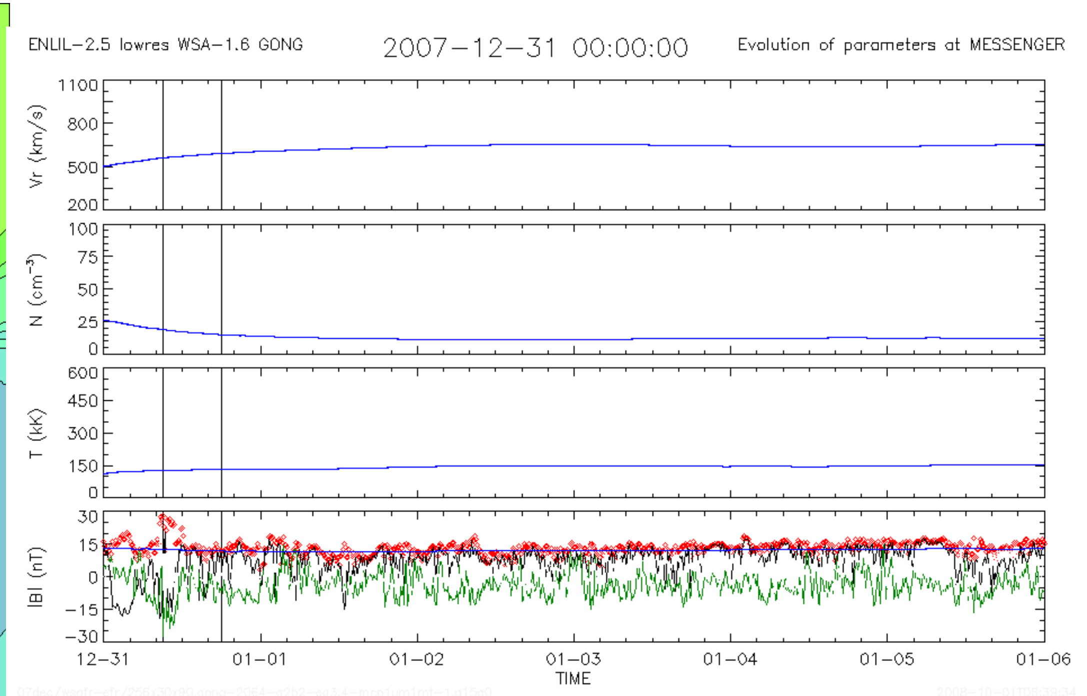
Chen, 1996;
Krall et al., 2000;
Krall and Chen, 2004;
Xie et al., 2008

ICME with a Flux-Rope Geometry

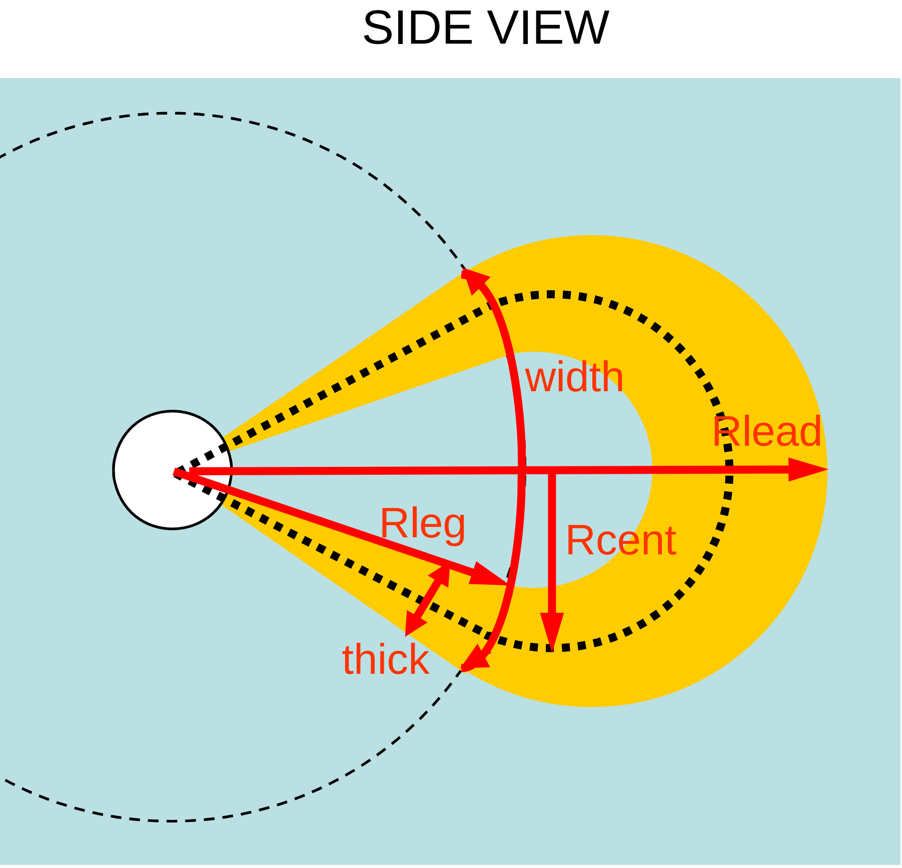


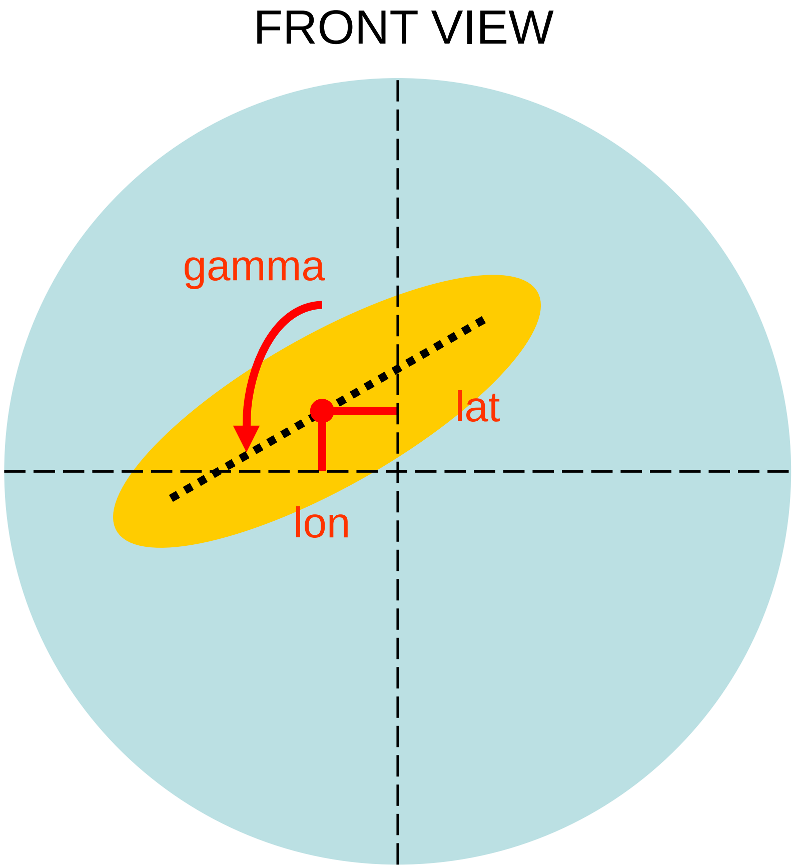






ICME – Hydrodynamic Rope Model

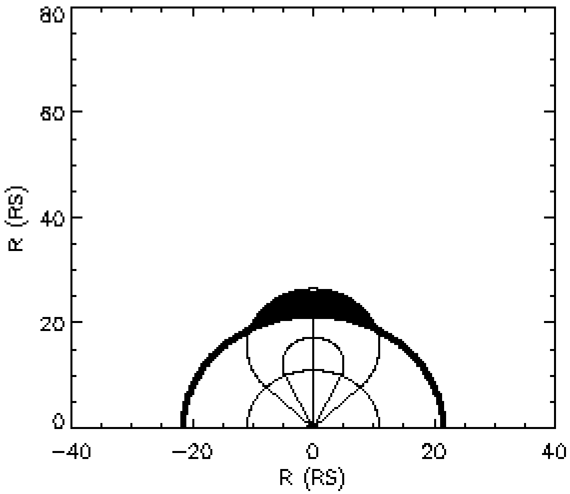




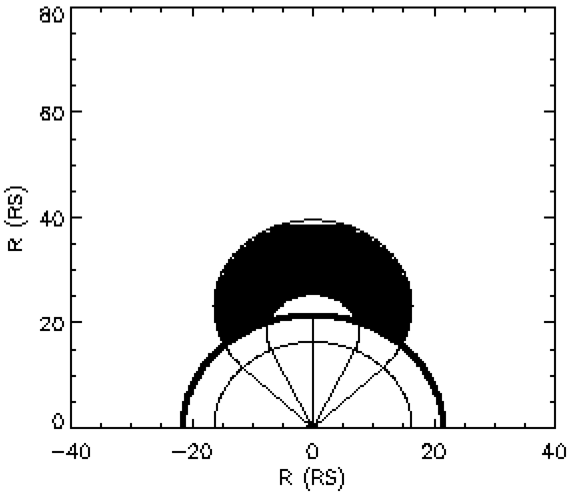
- Thernisien et al. (2008) – fitting STEREO coronagraph observations
- Spatial structure → time dependent boundary conditions

Launching the Hydrodynamic Rope Model

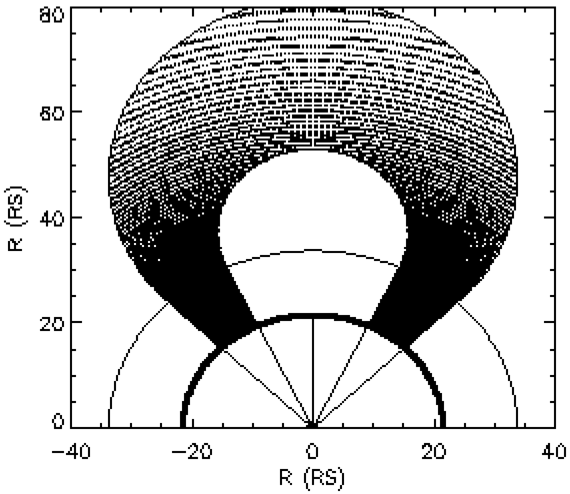
Emerging cap



Emerging main body



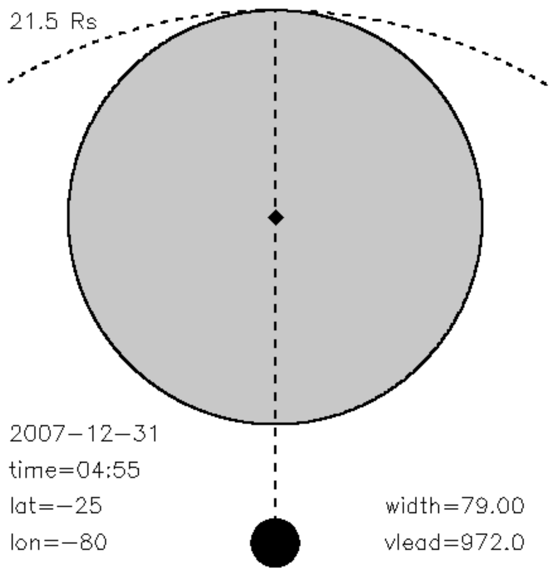
Emerging legs



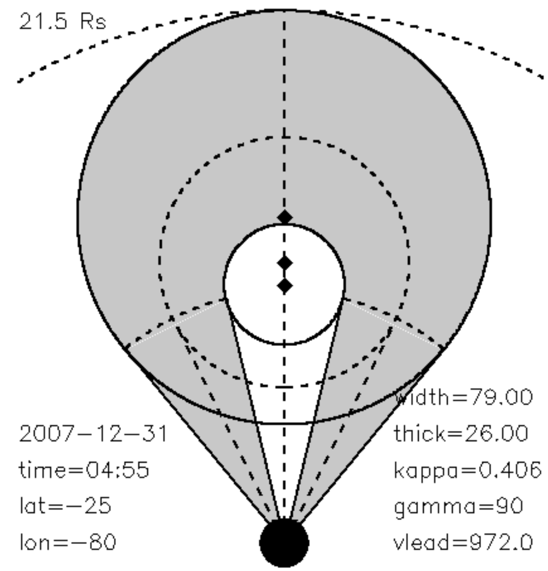
- Self-similarity achieved by linear decrease of the speed
- Leg-structures may last few days

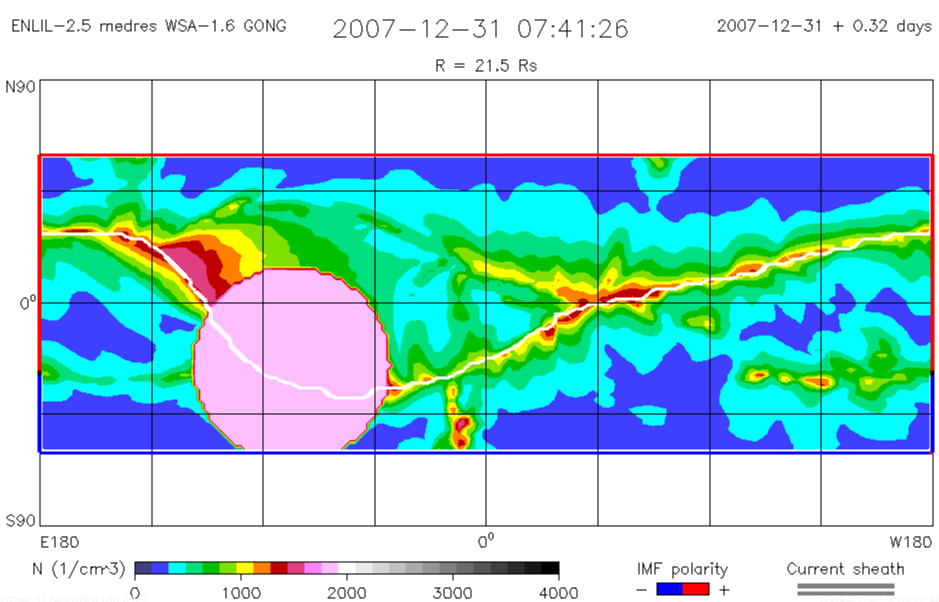
2007 December 31 CME

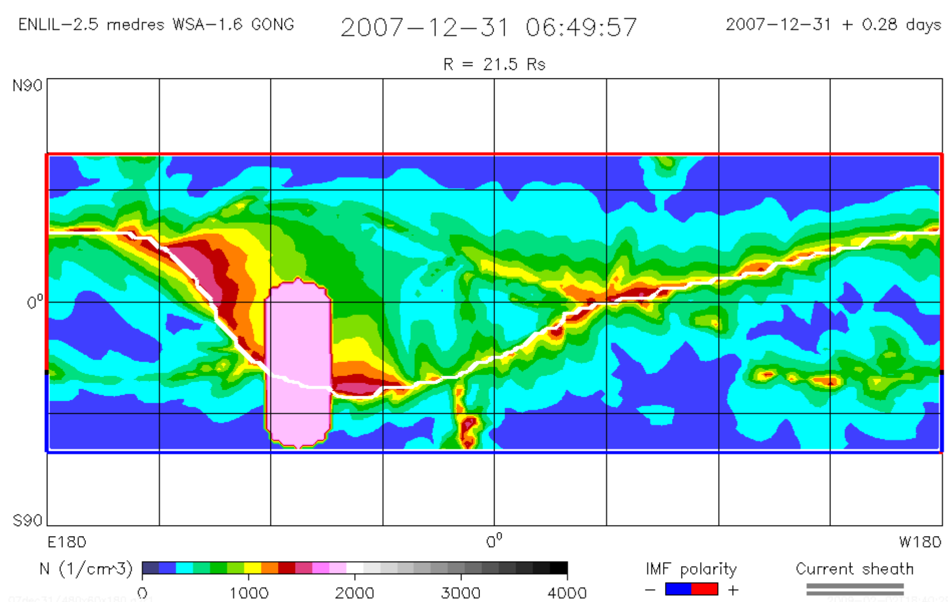
Cone Model



Rope Model

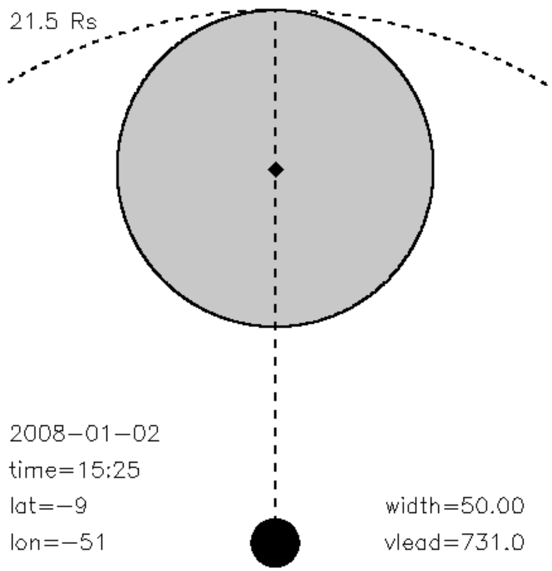




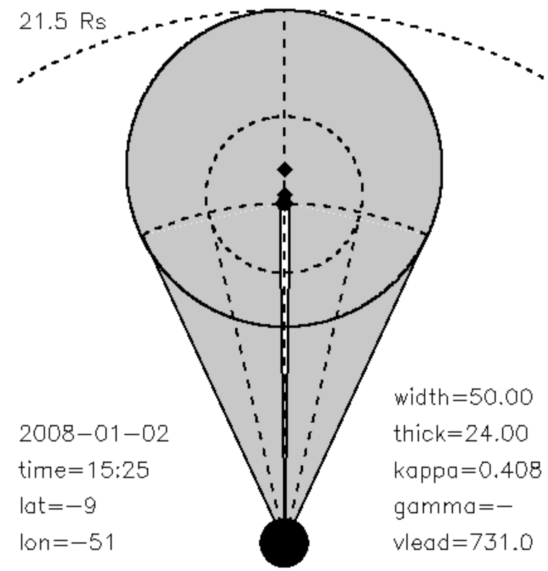


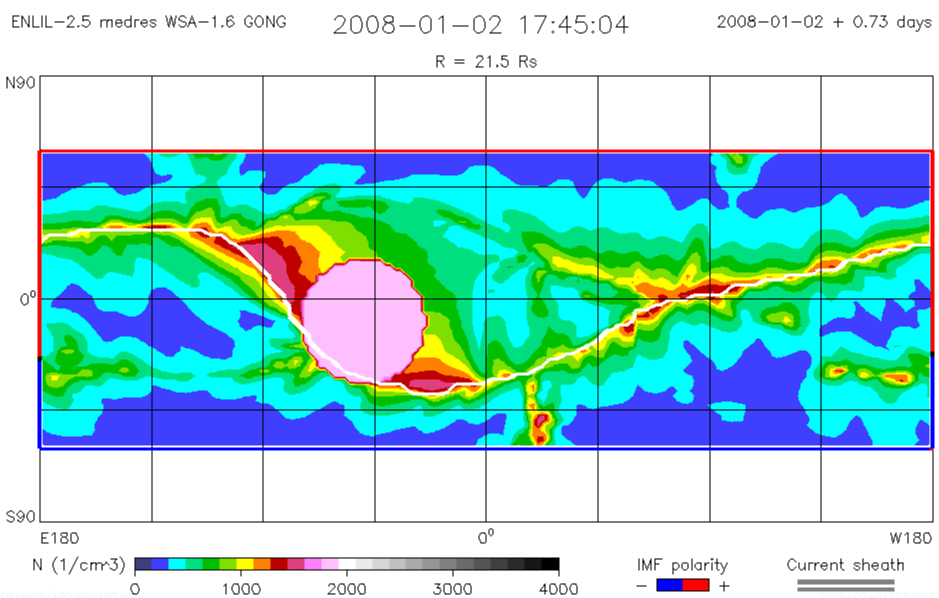
2008 January 2 CME

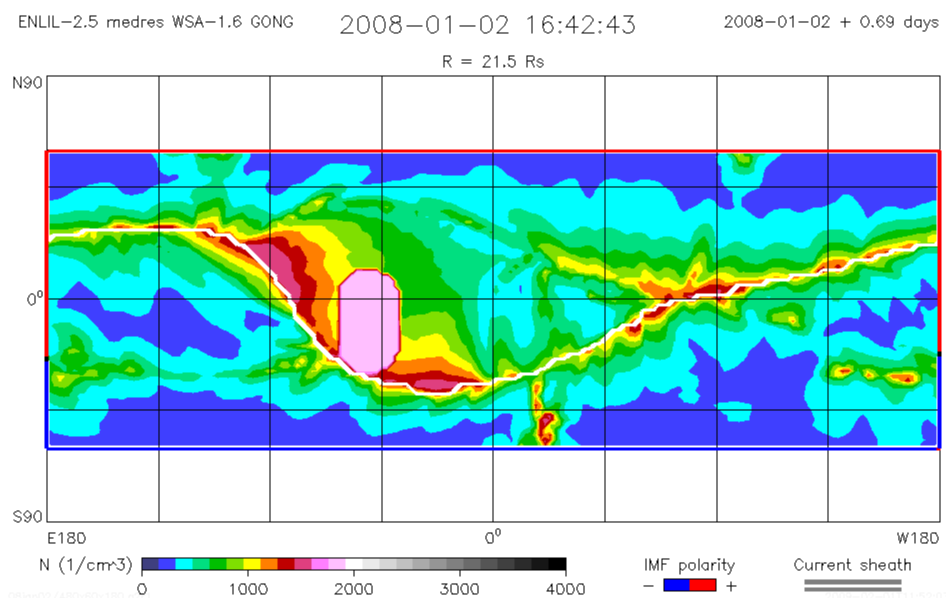
Cone Model



Rope Model

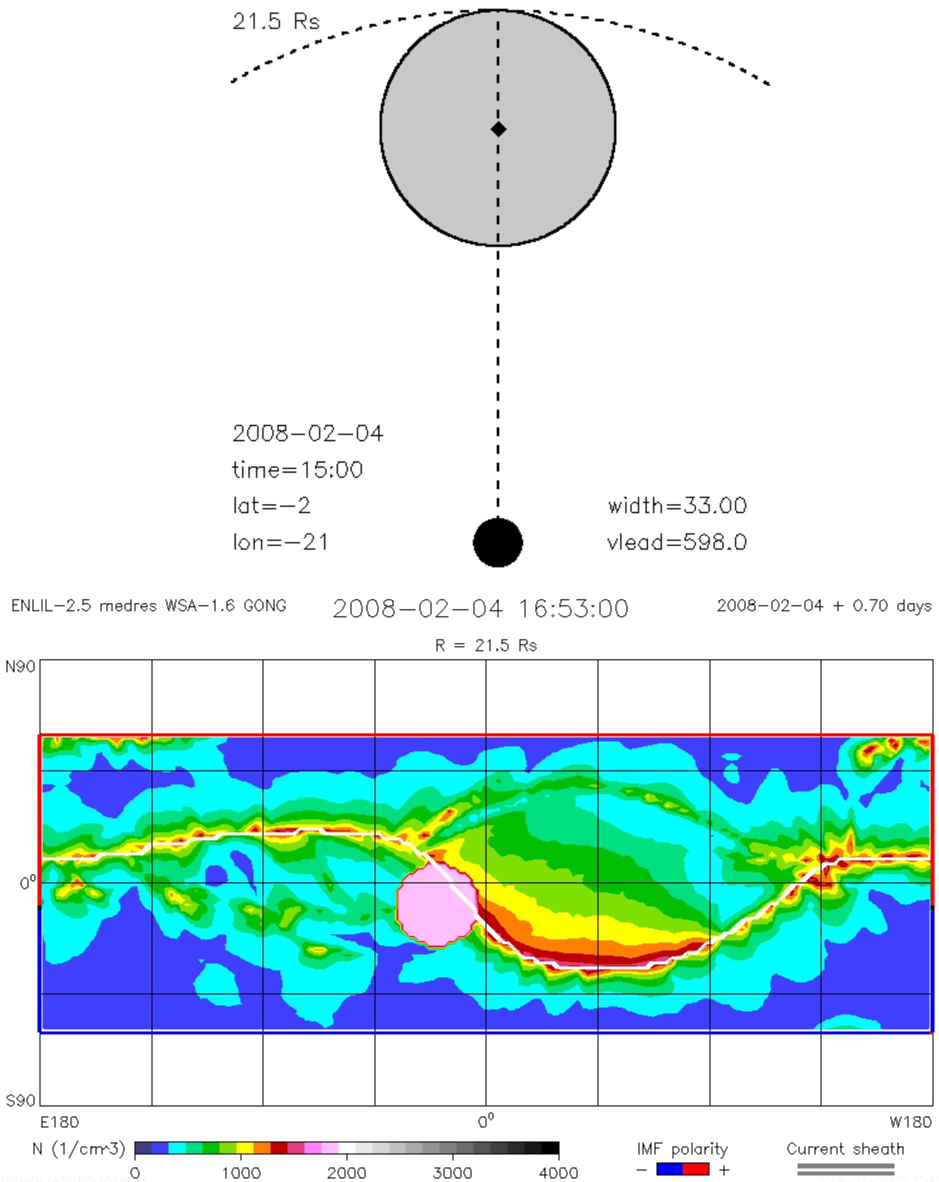




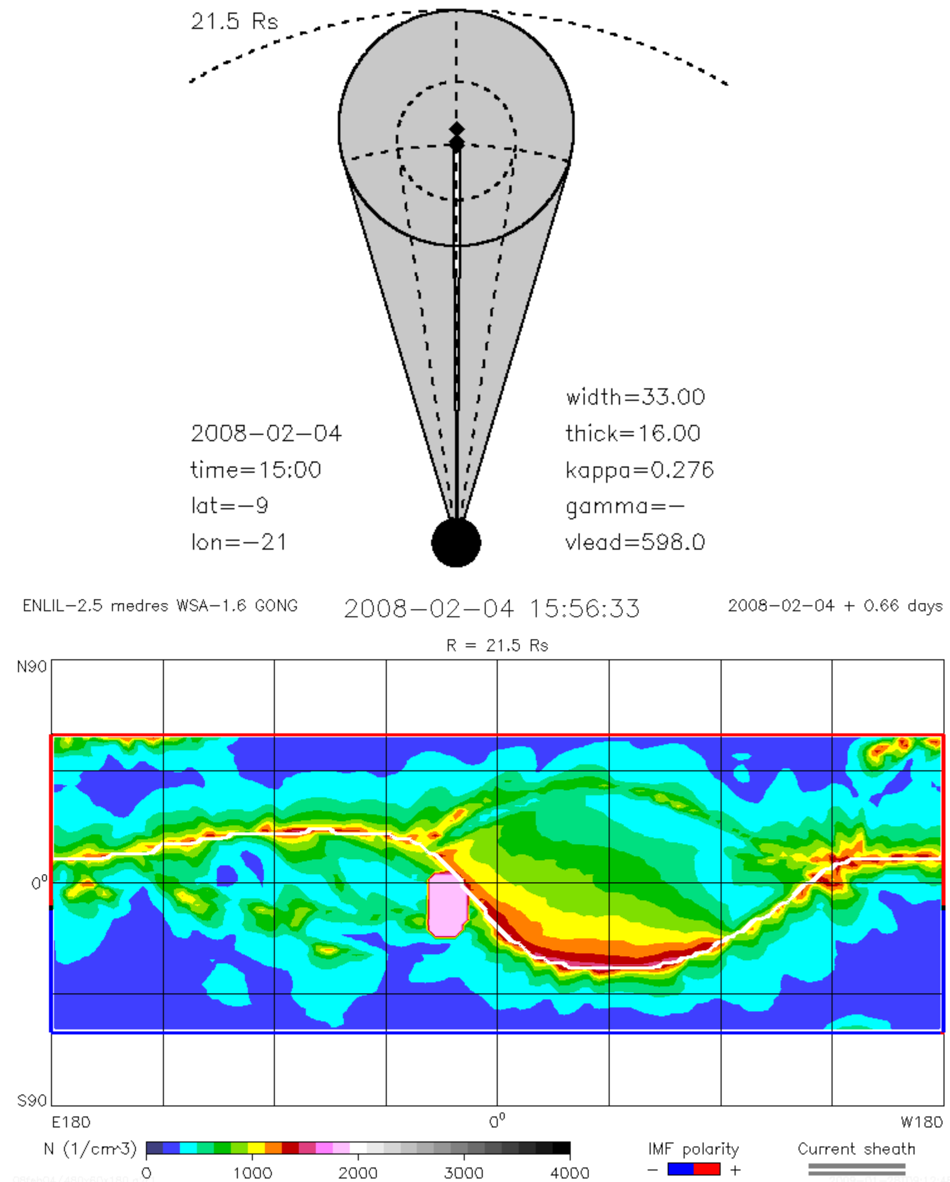


2008 February 4 CME

Cone Model

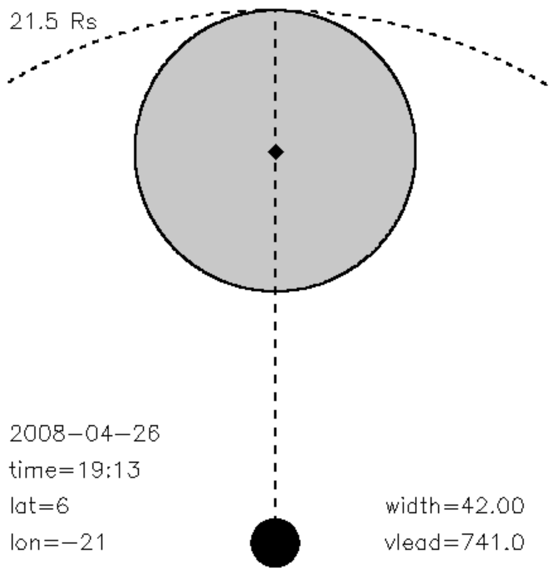


Rope Model

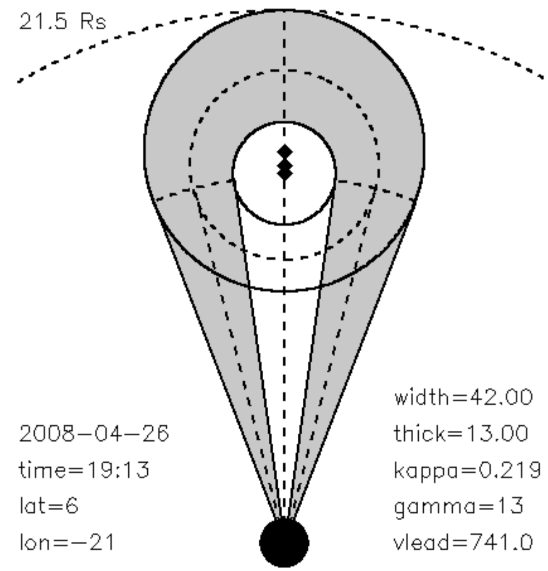


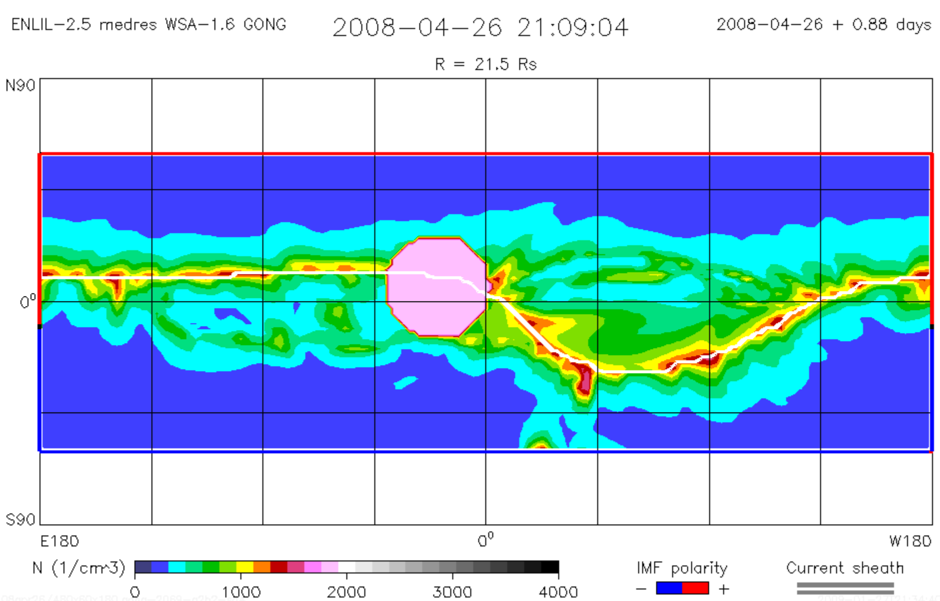
2008 April 26 CME

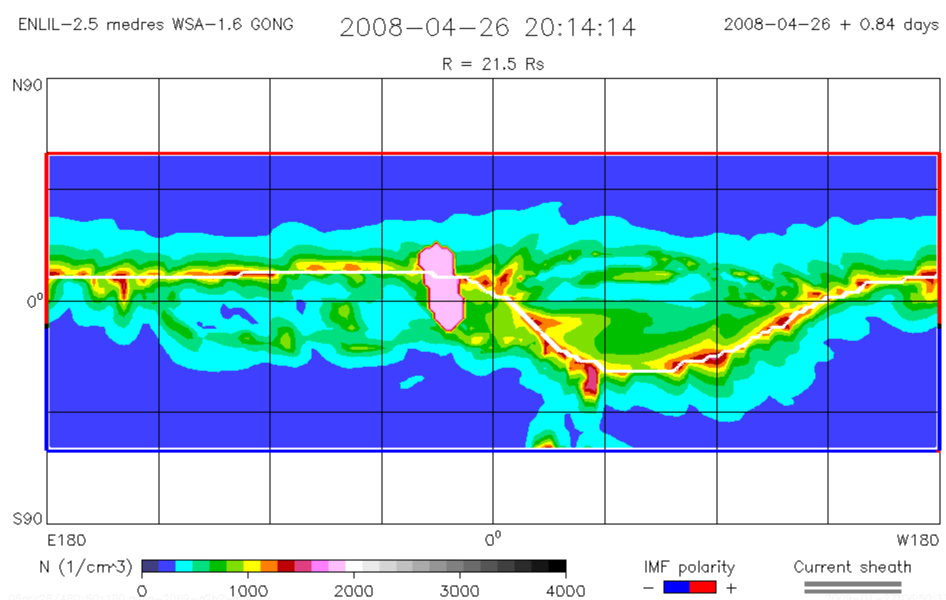
Cone Model



Rope Model

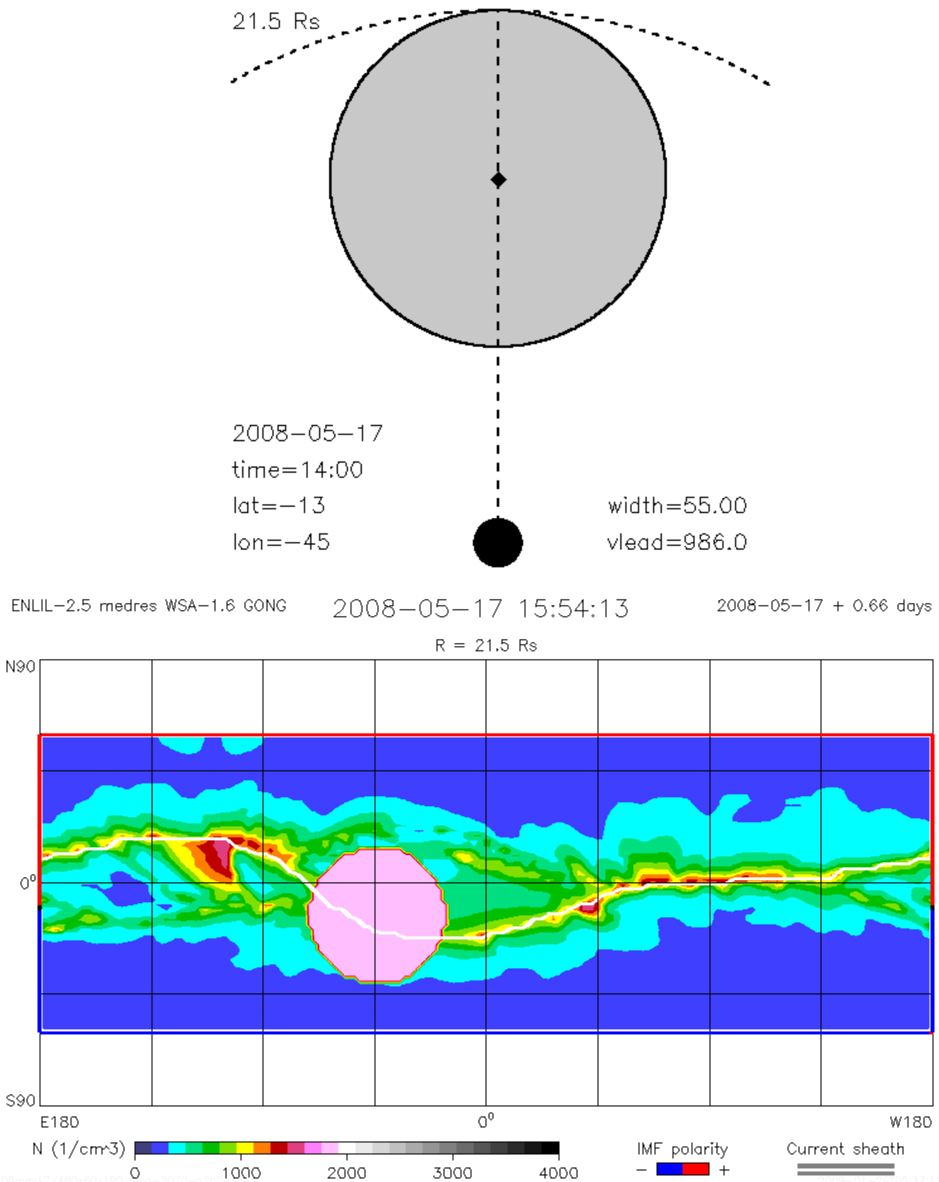




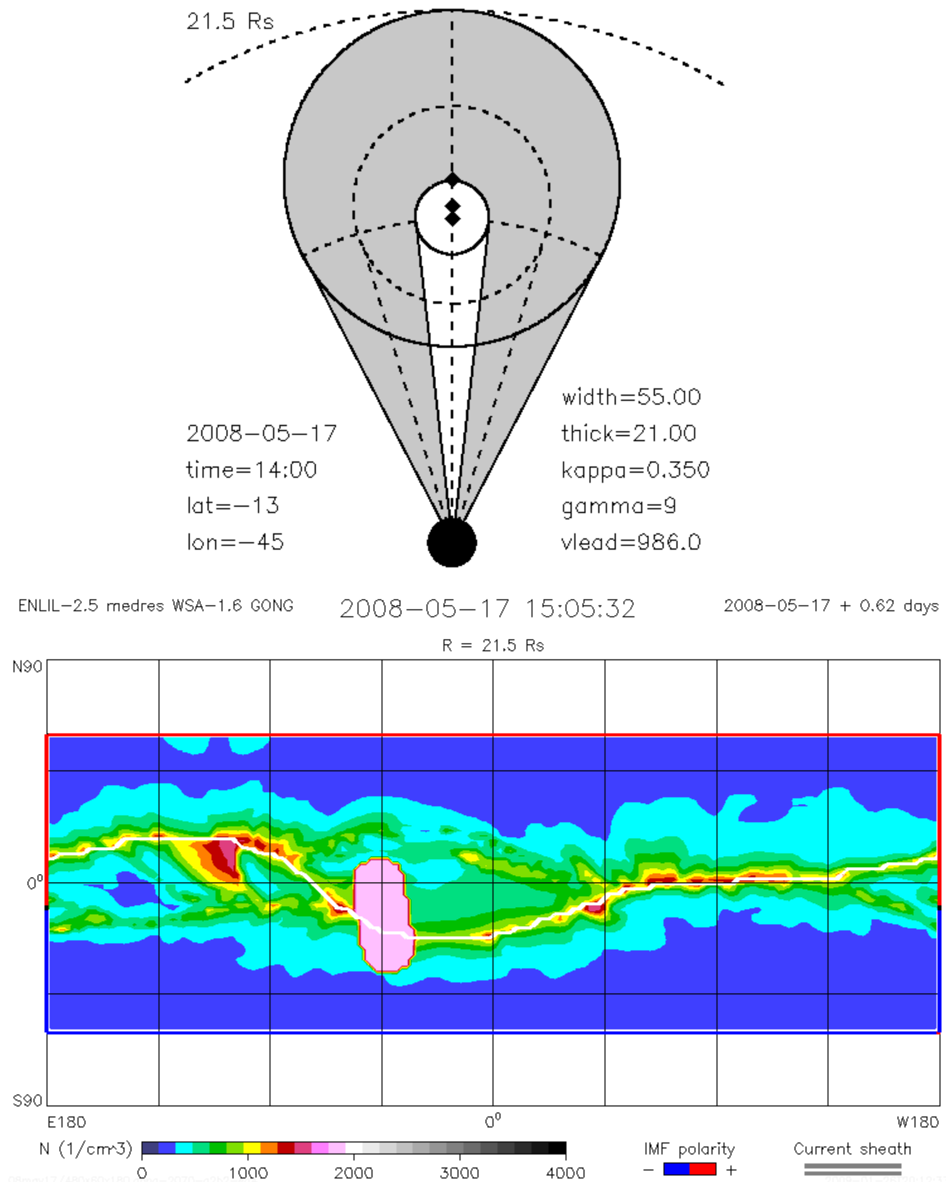


2008 May 17 CME

Cone Model

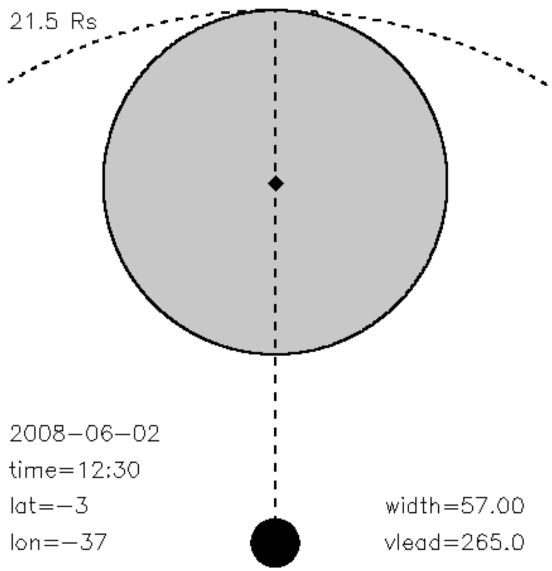


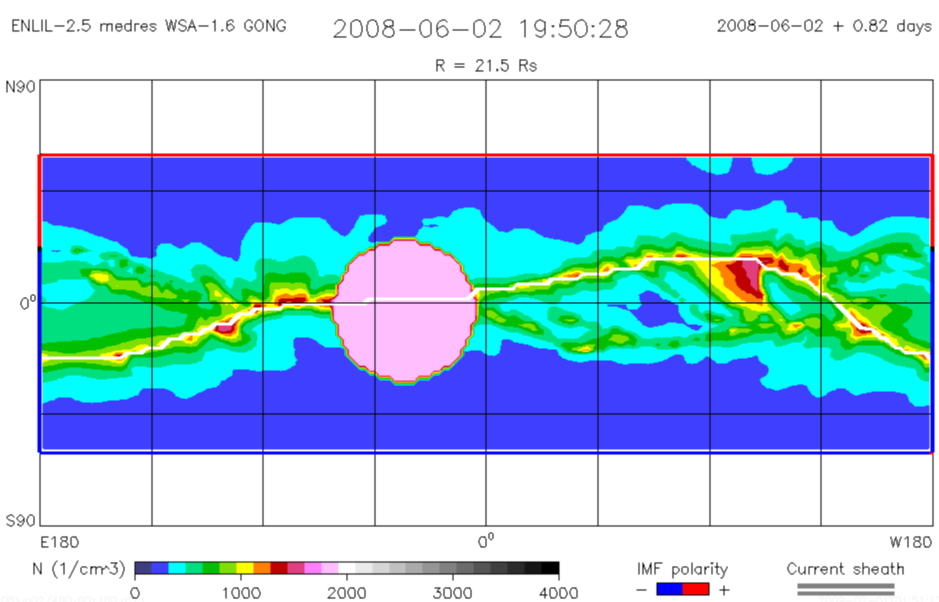
Rope Model



2008 June 2 CME

Cone Model





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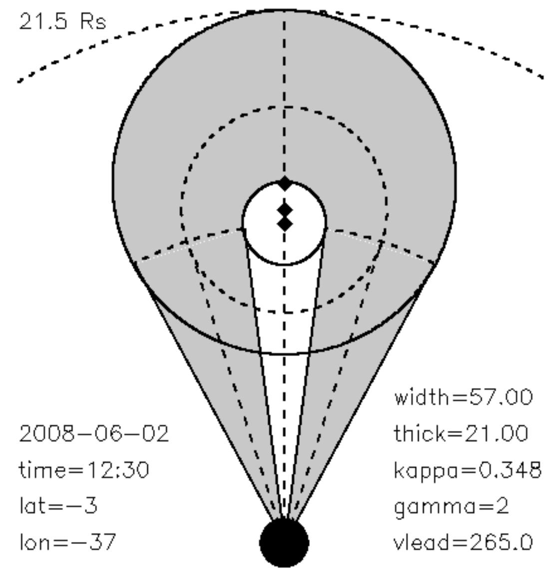
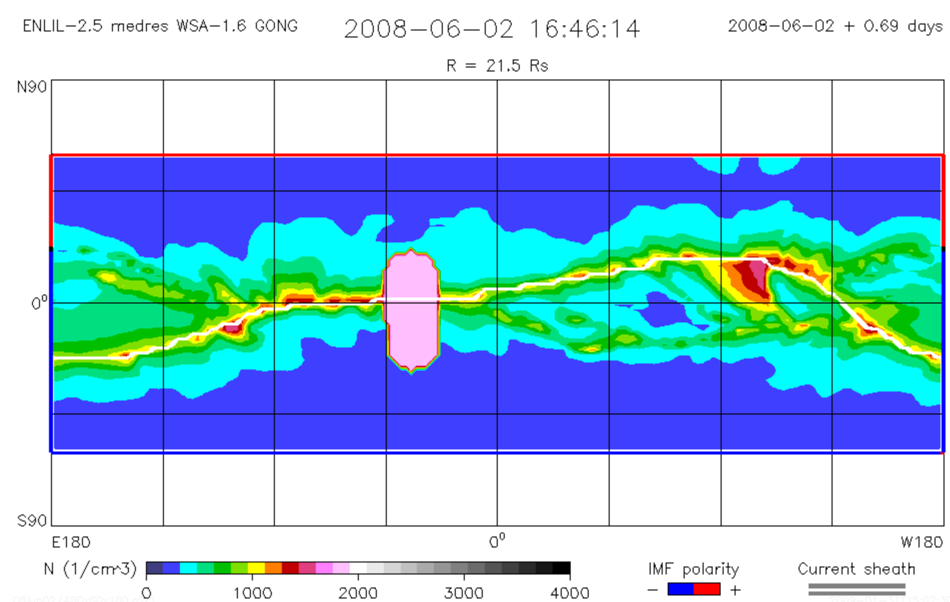
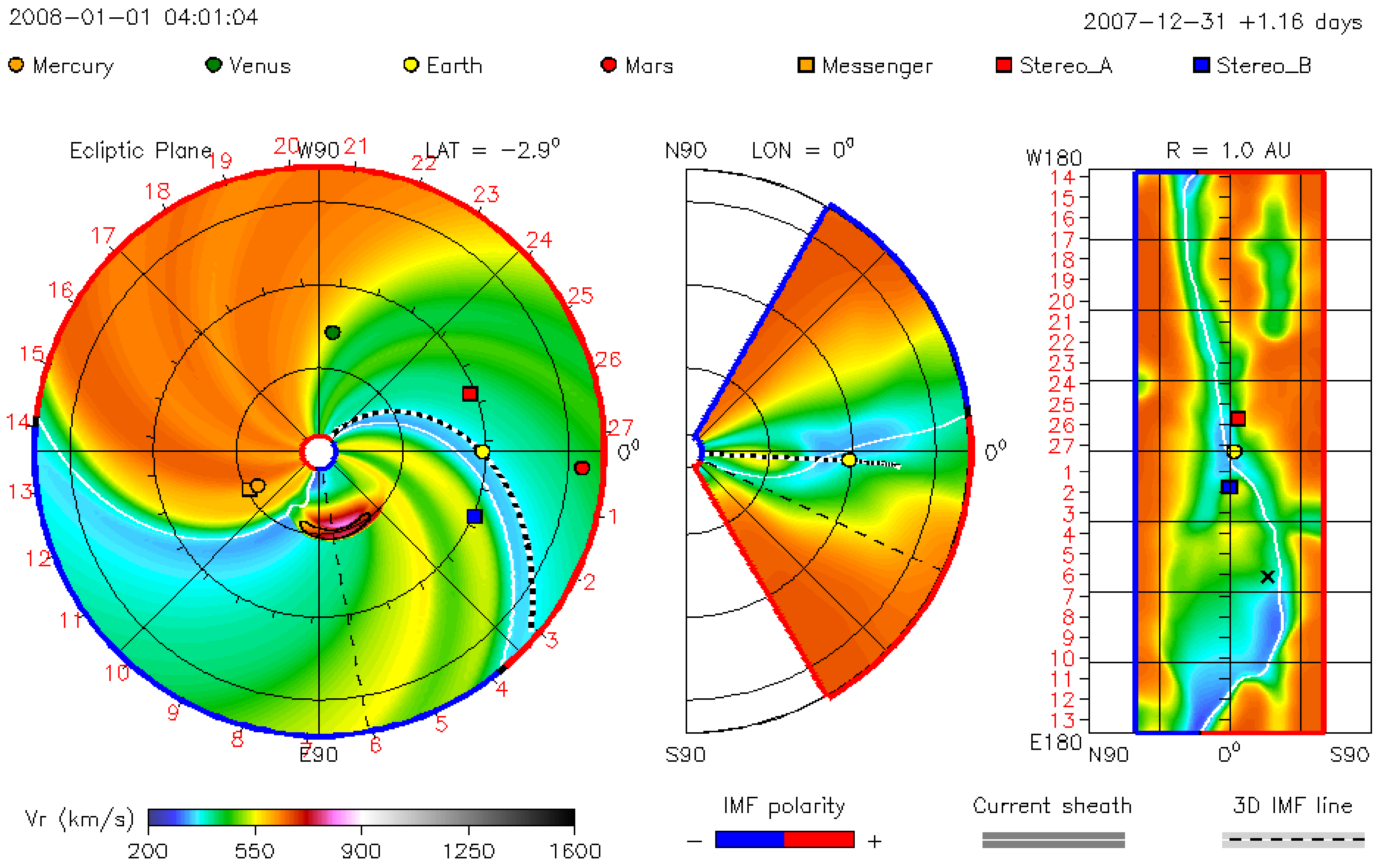
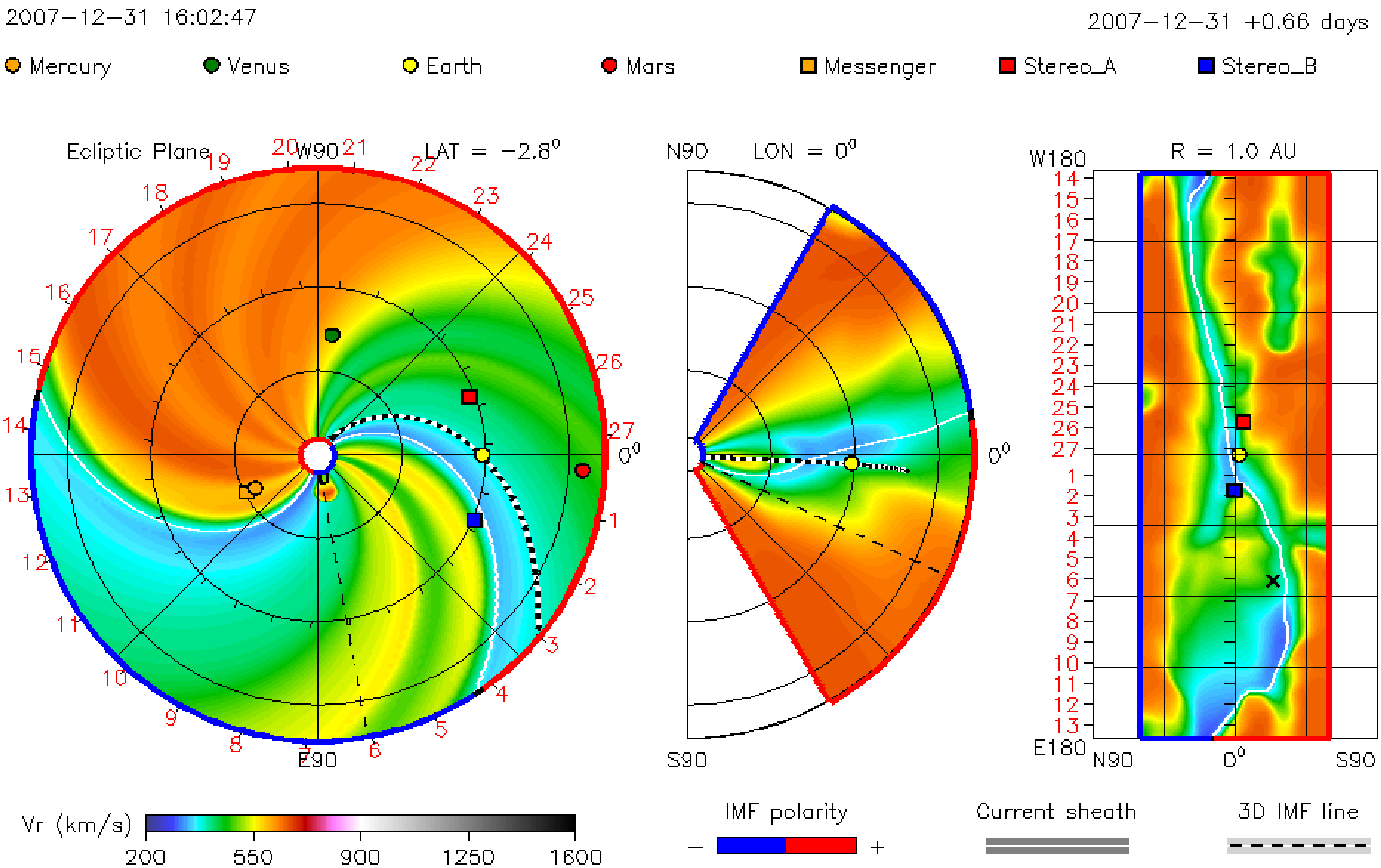




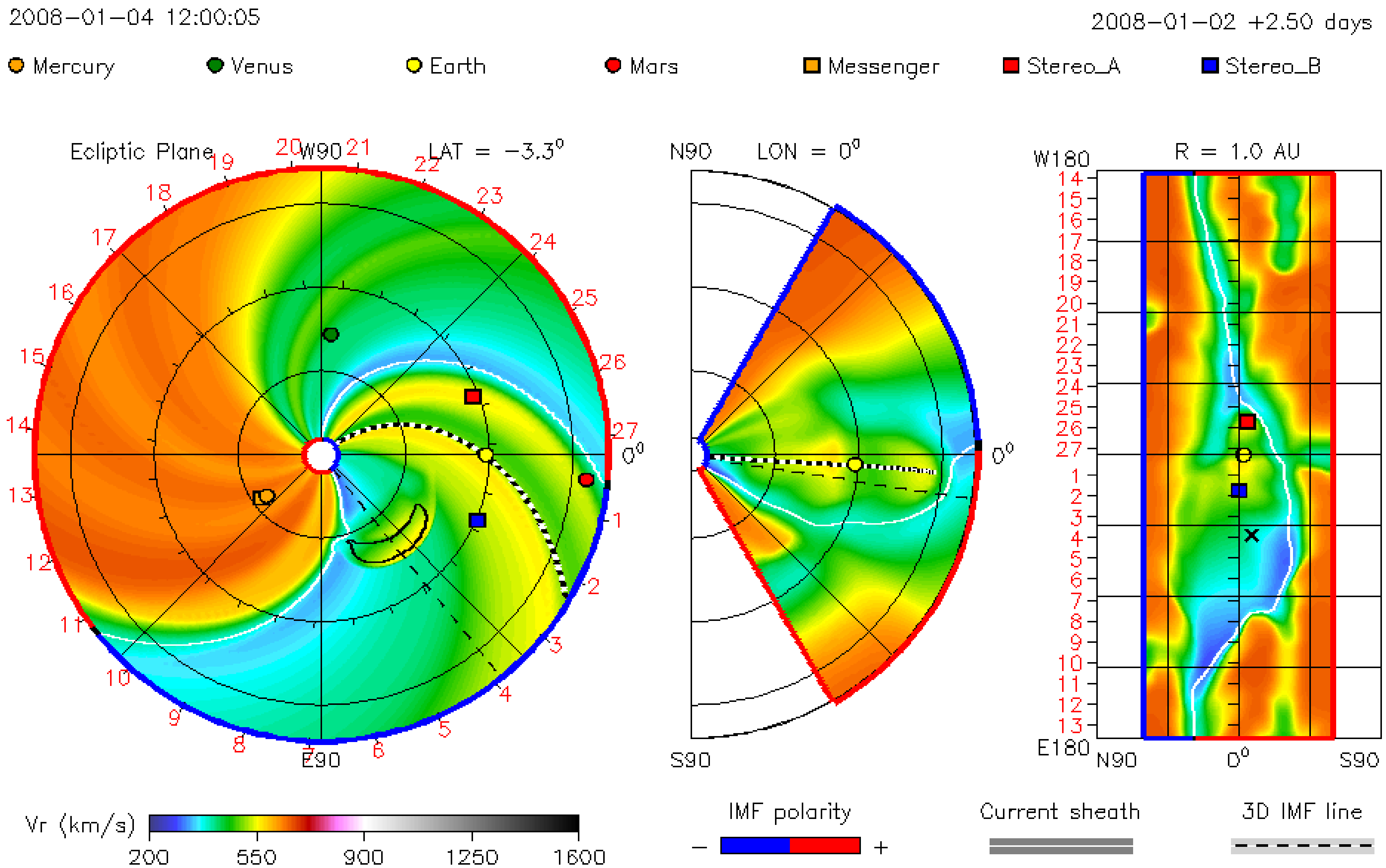
2007 December 31 CME – Cone Model



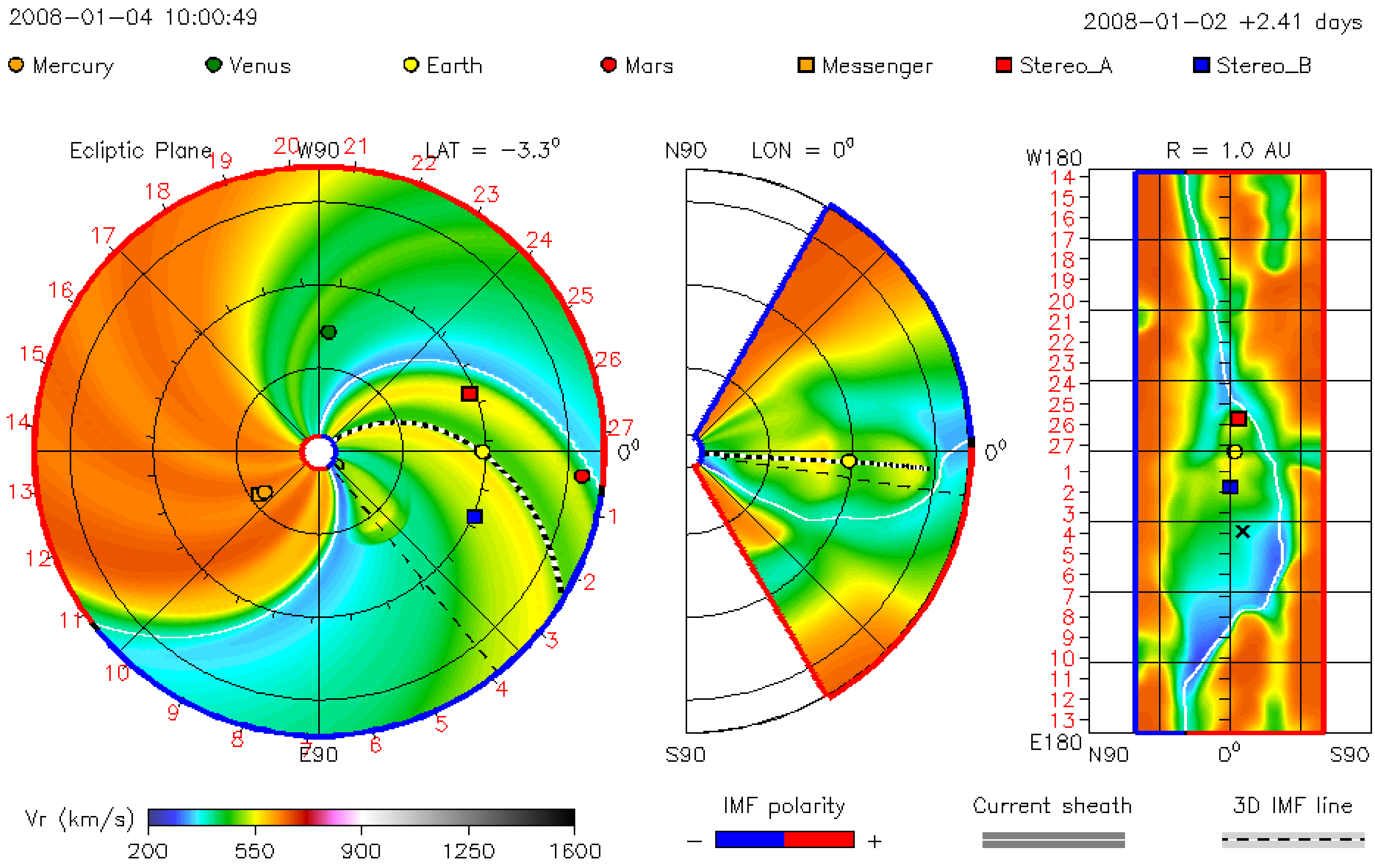
2007 December 31 CME – Rope Model



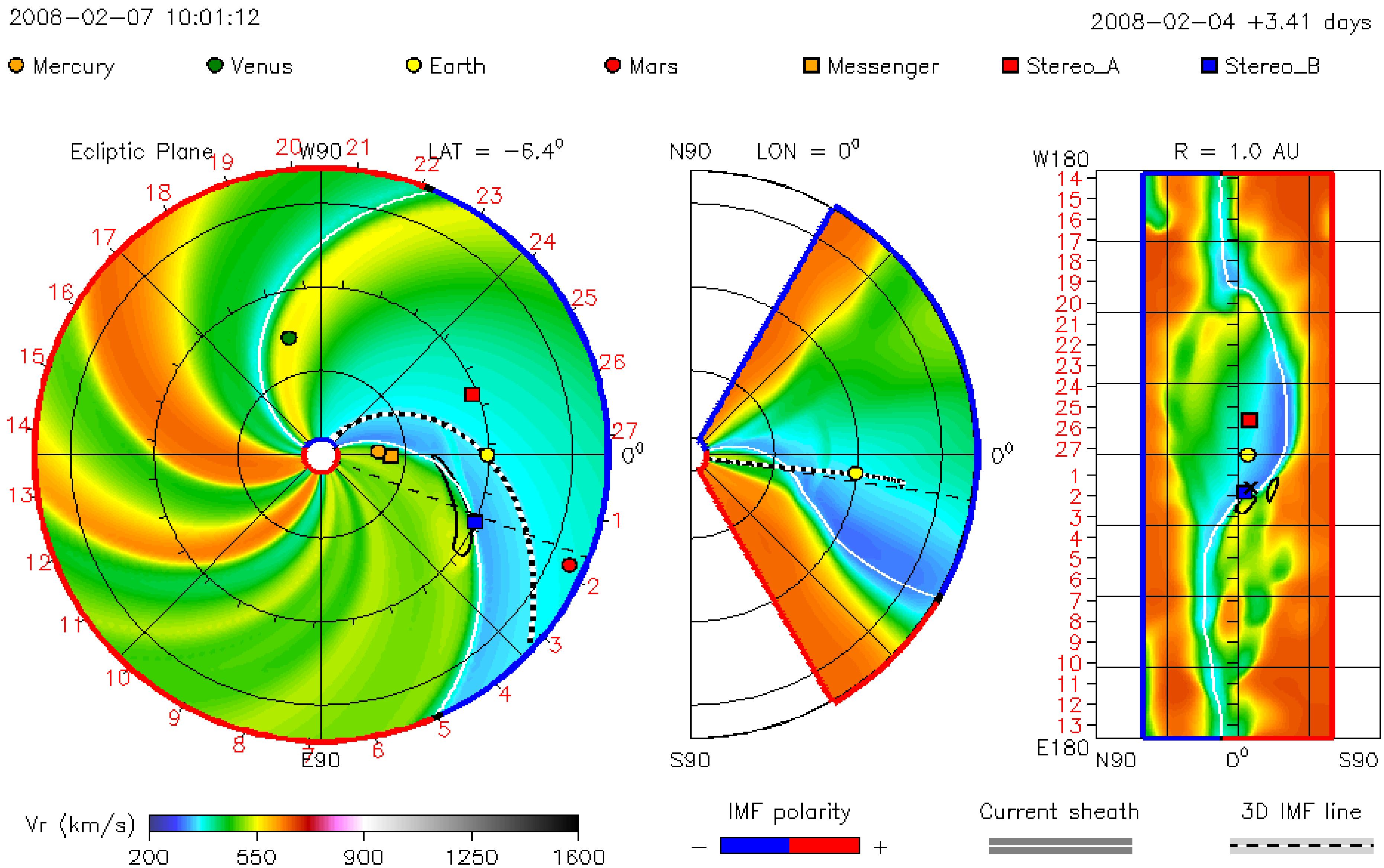
2008 January 2 CME – Cone Model



2008 January 2 CME – Rope Model



2008 February 4 CME – Cone Model



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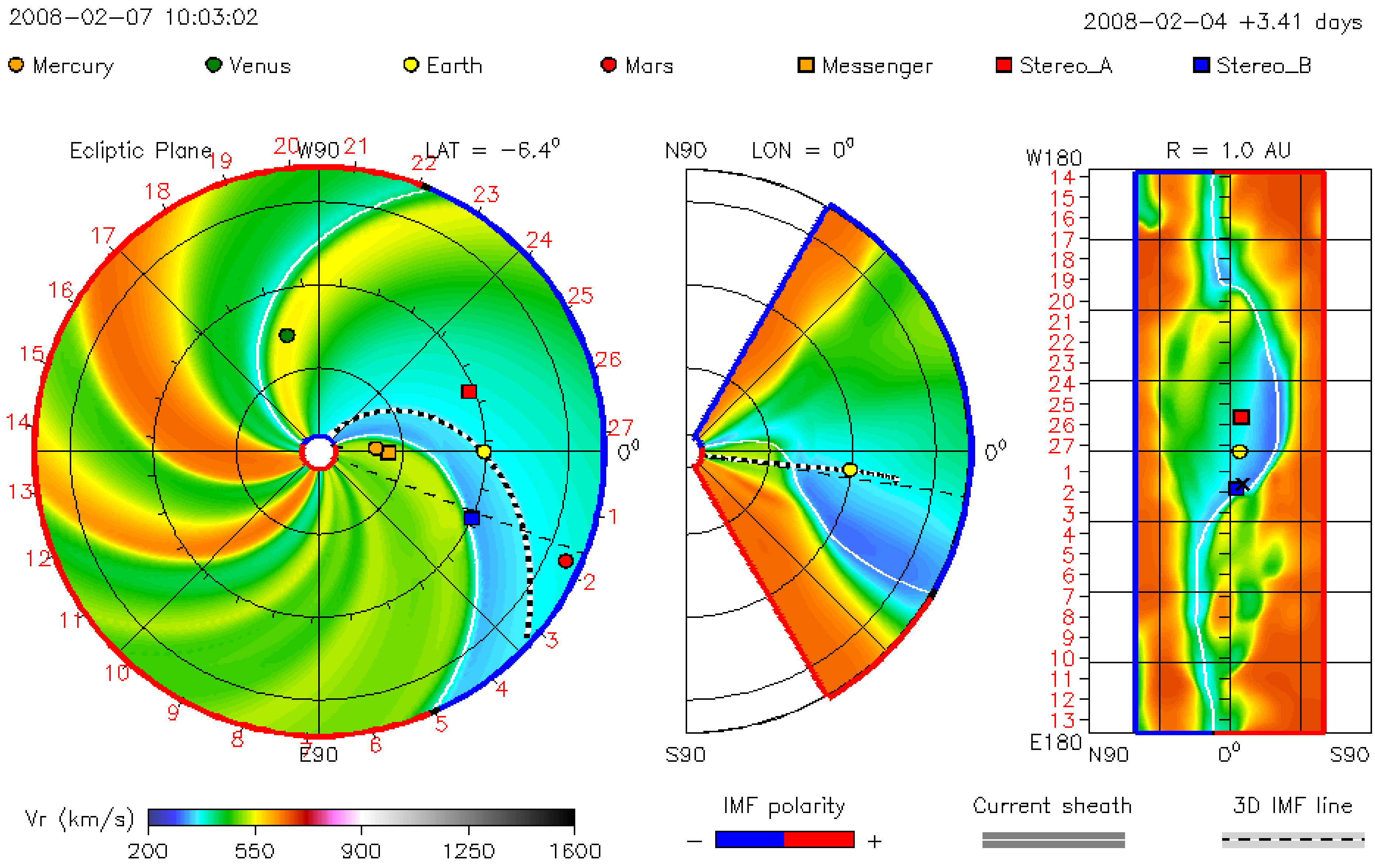
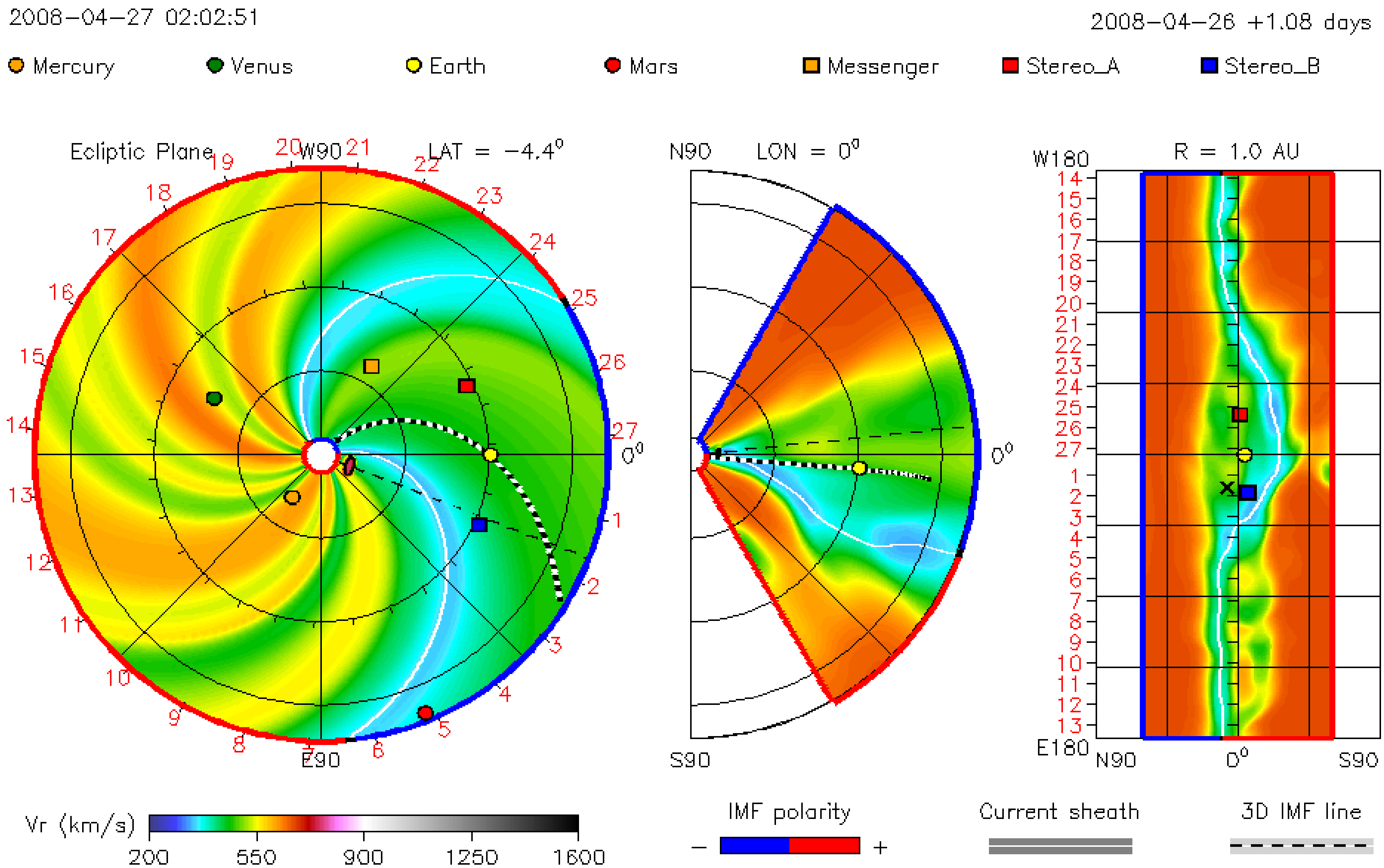


2008 April 26 CME – Cone Model



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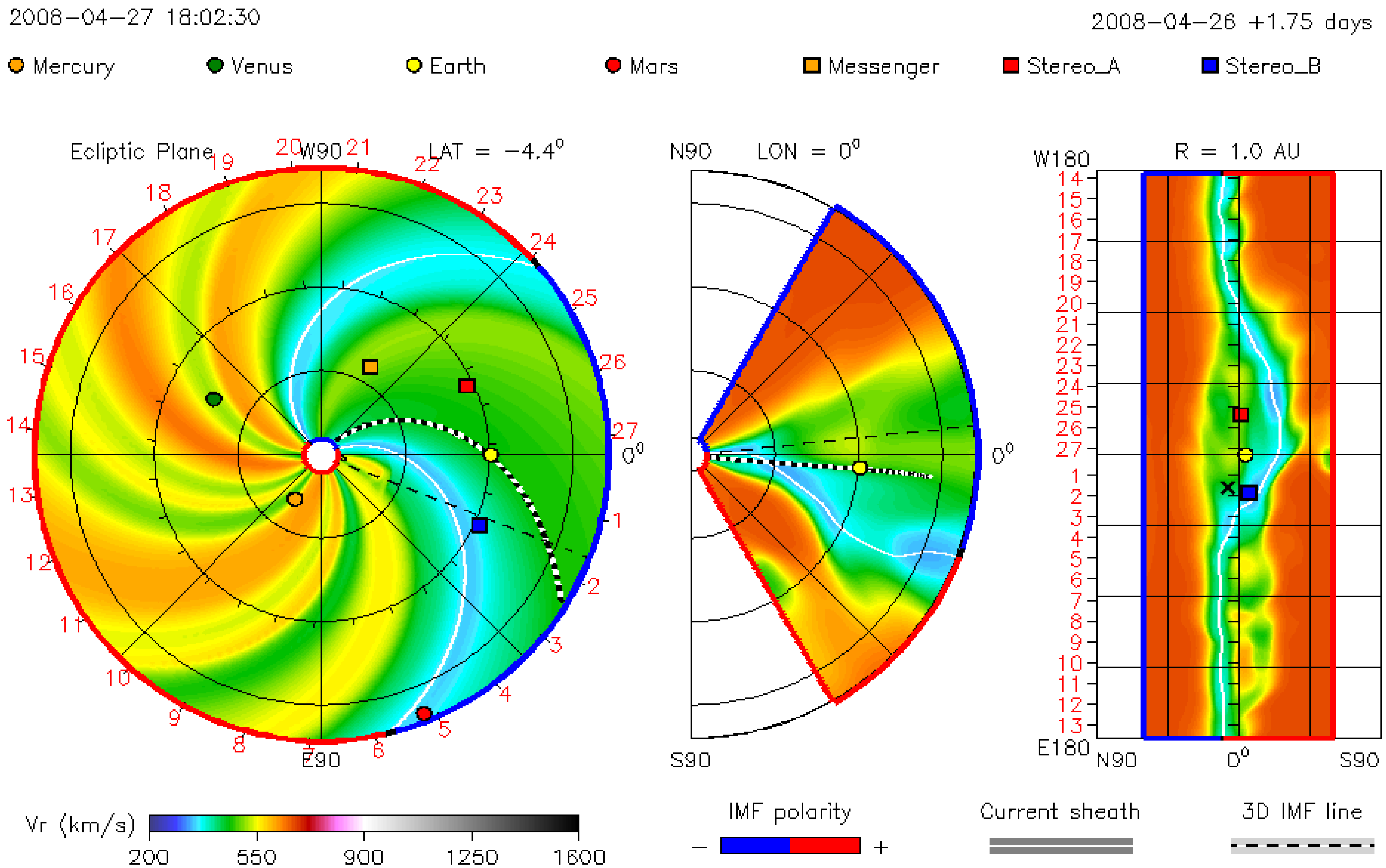
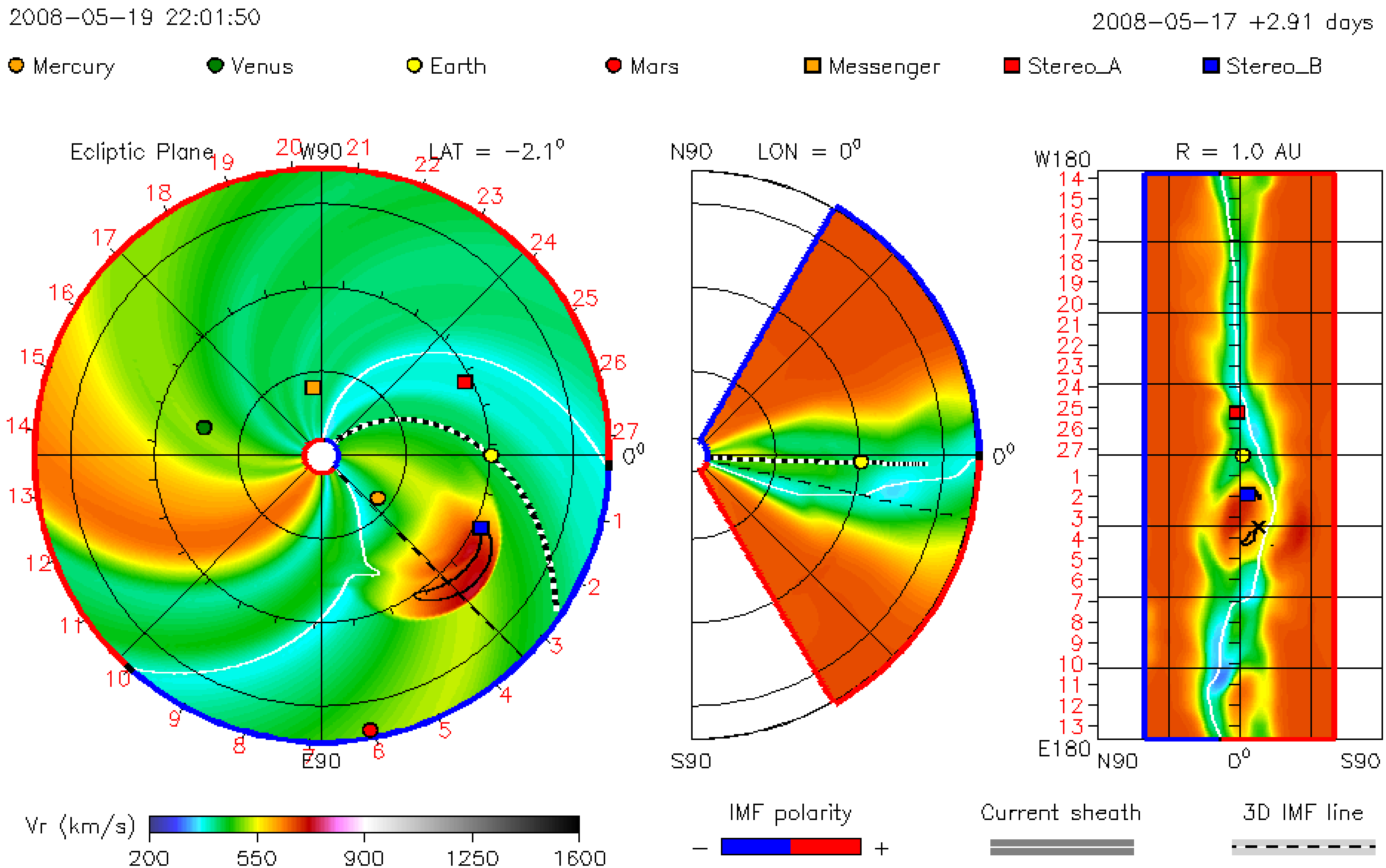


2008 May 17 CME – Cone Model



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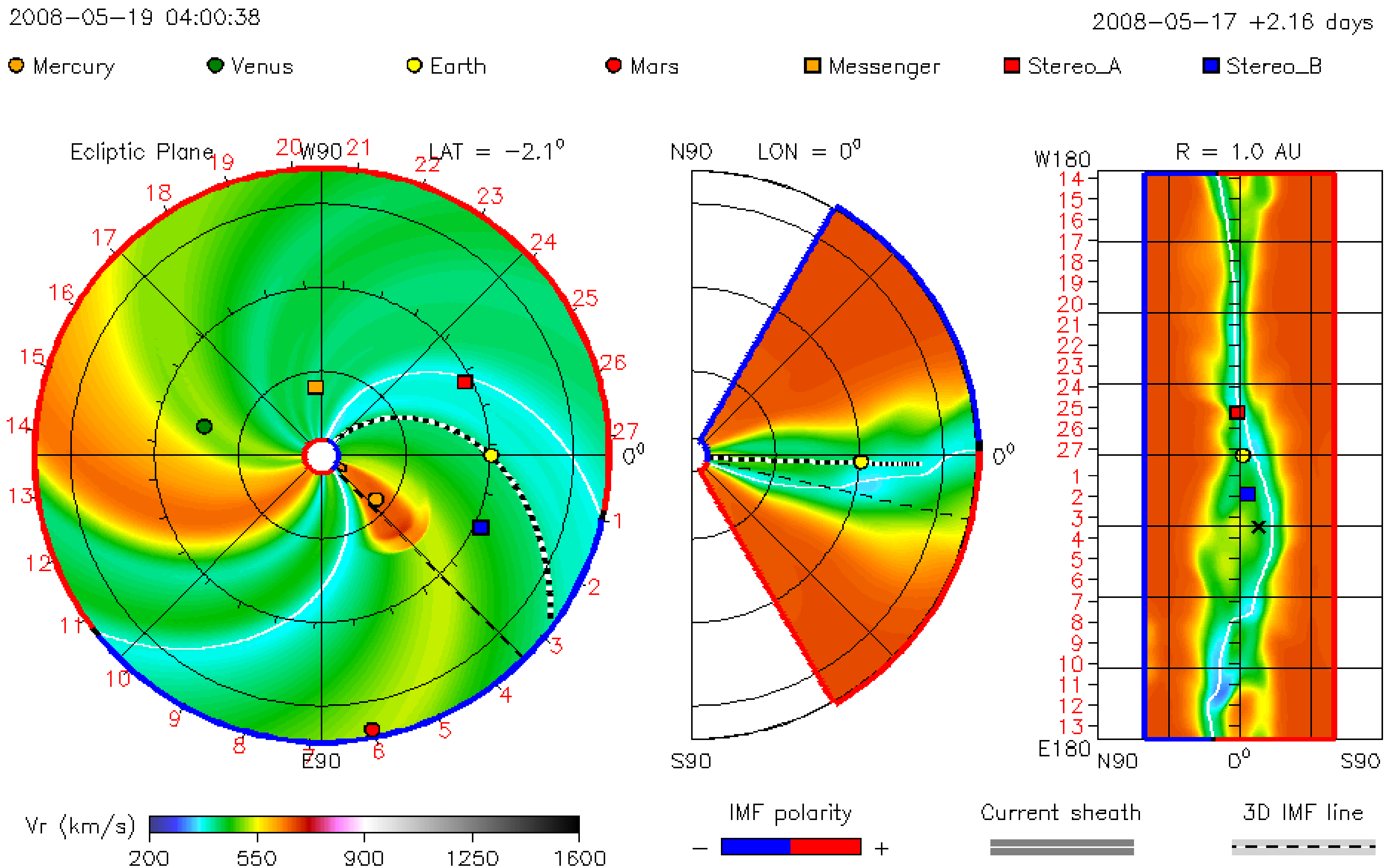
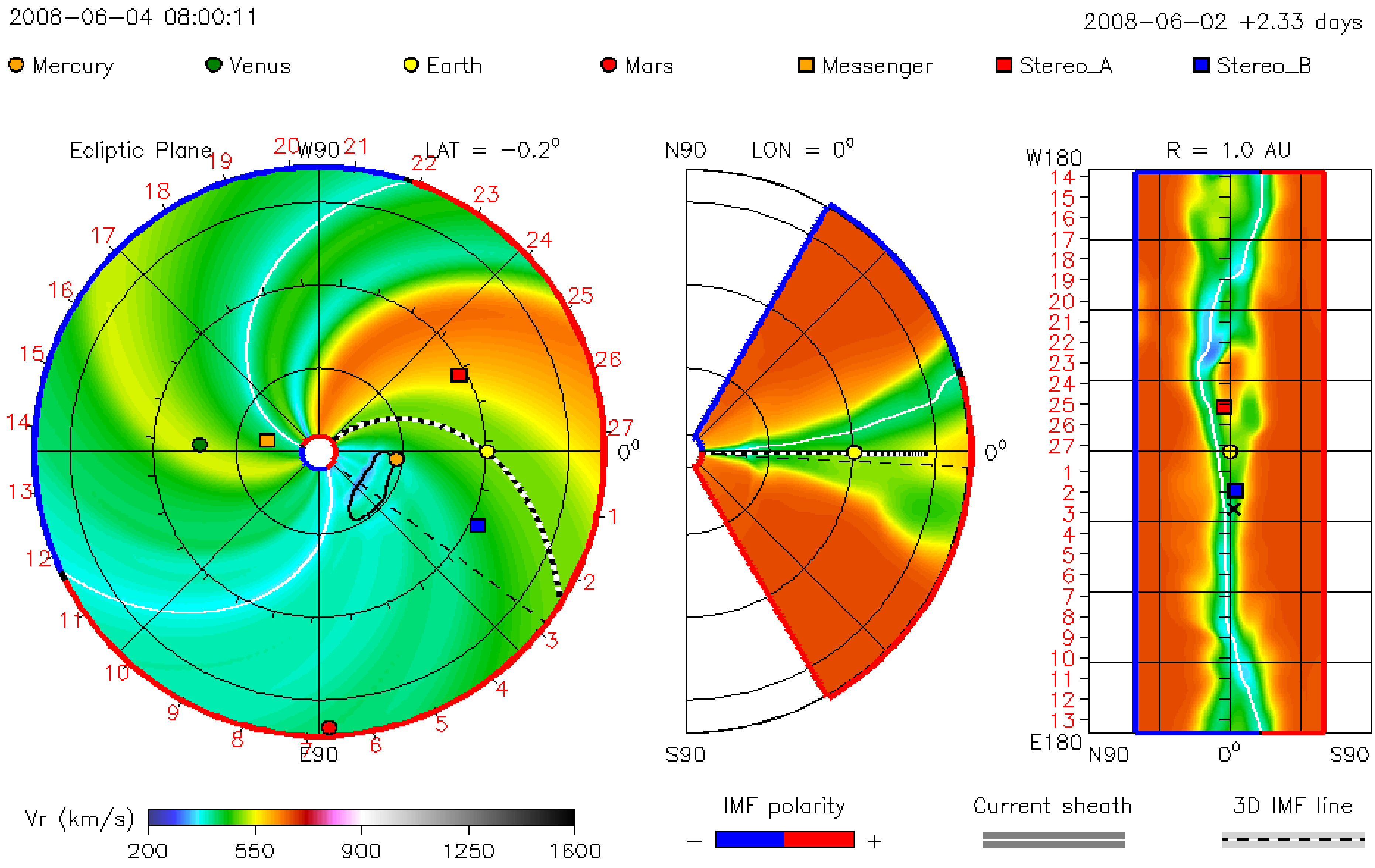


2008 June 2 CME – Cone Model



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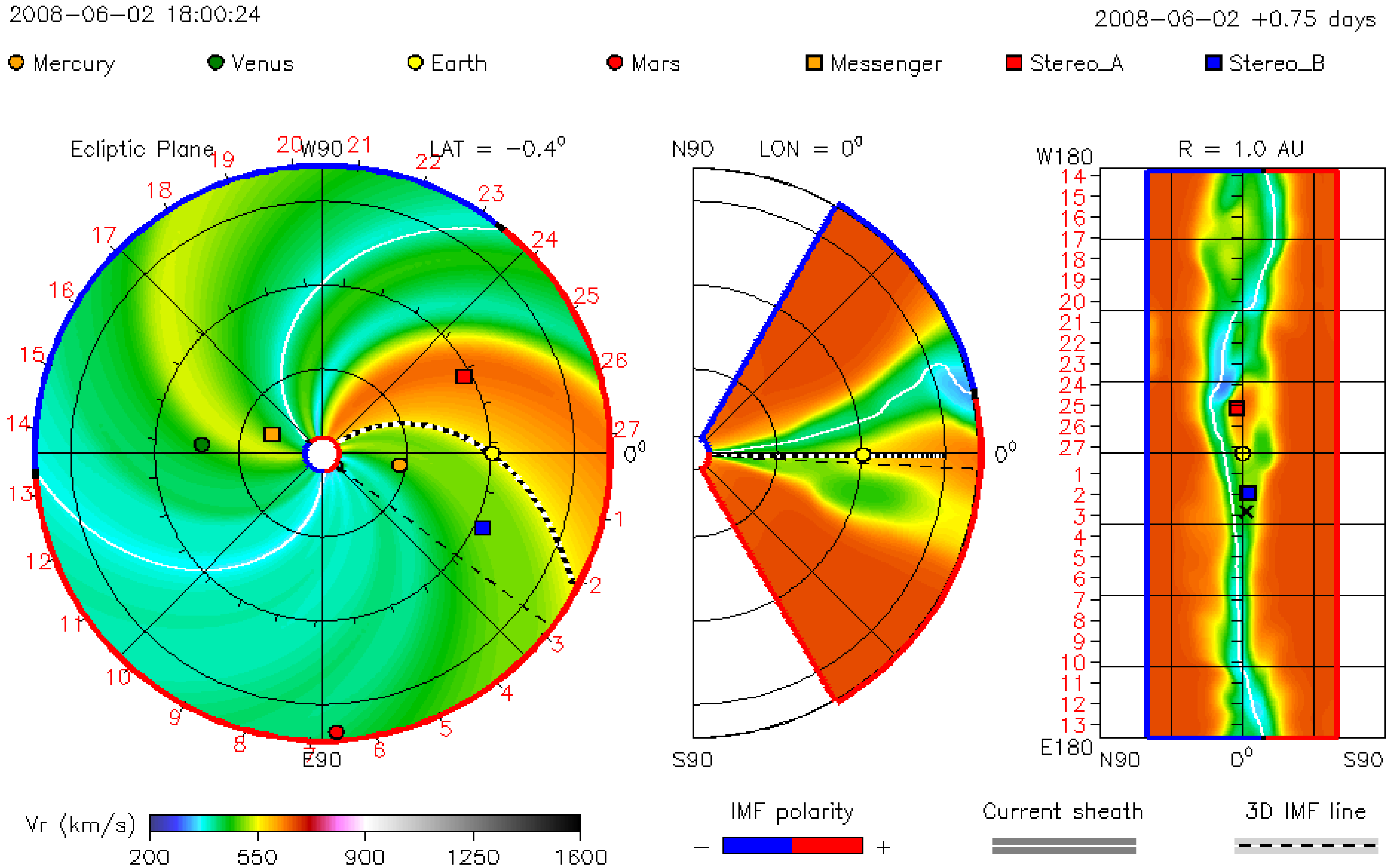
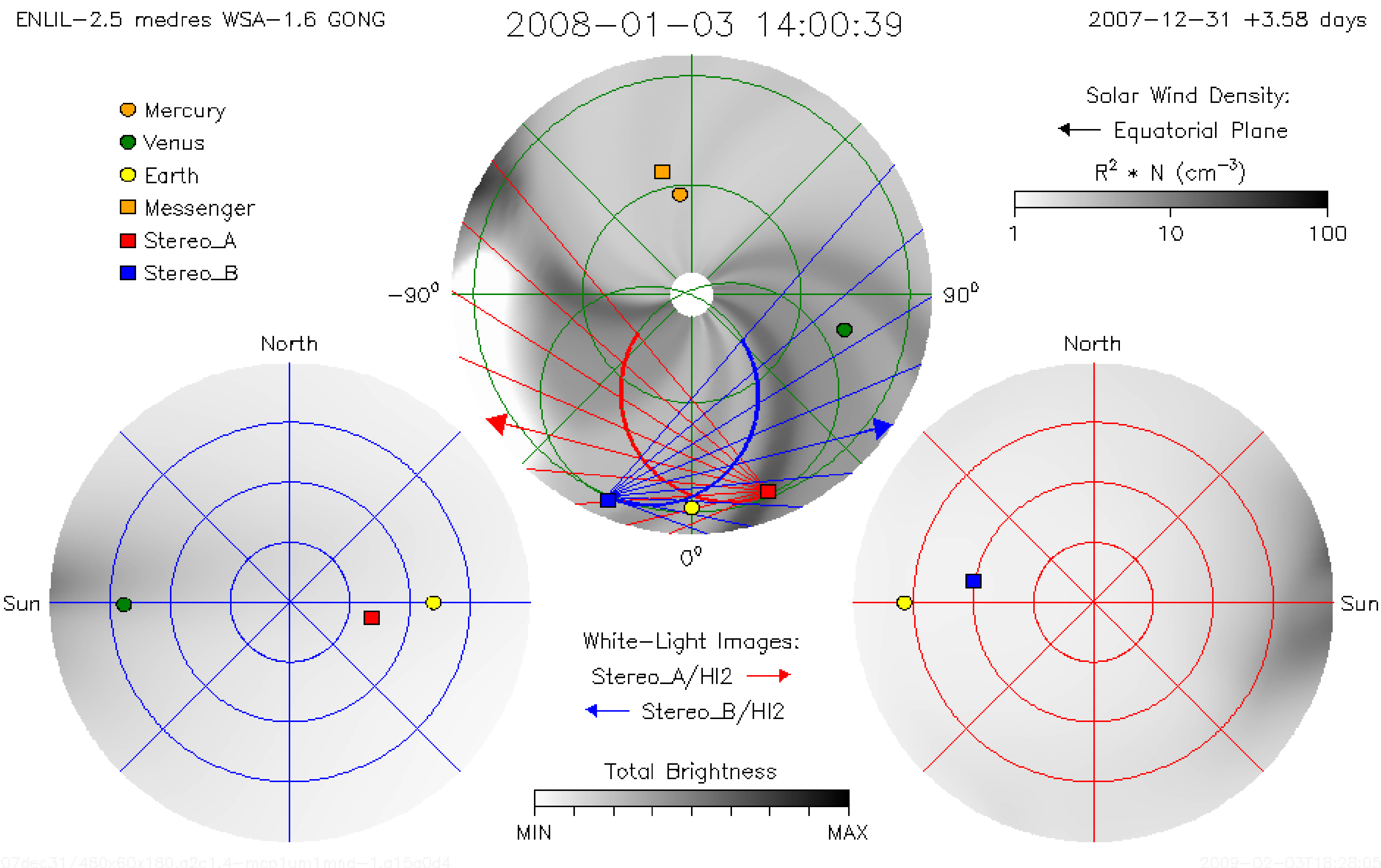


2007 December 31 CME – Cone Model



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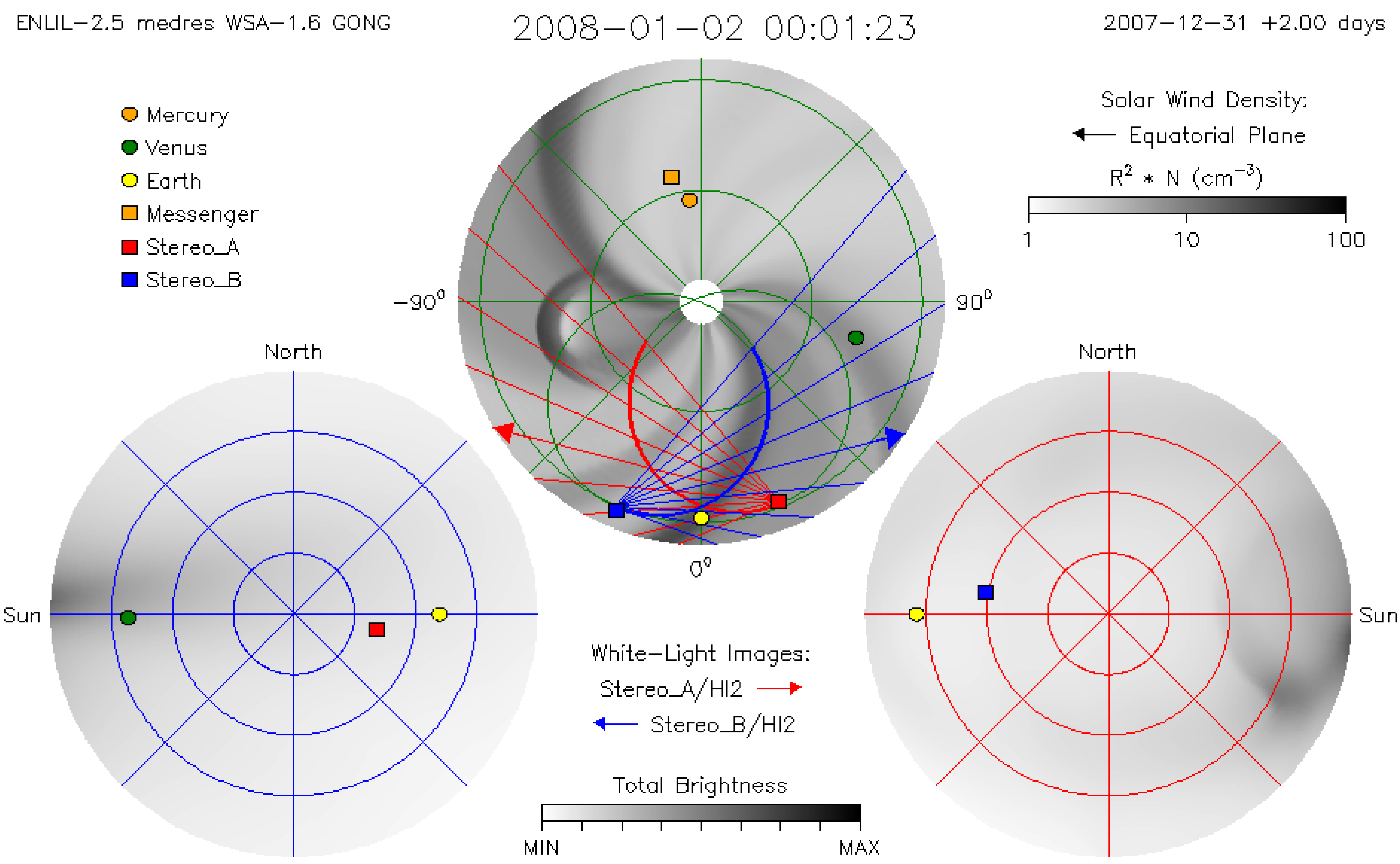

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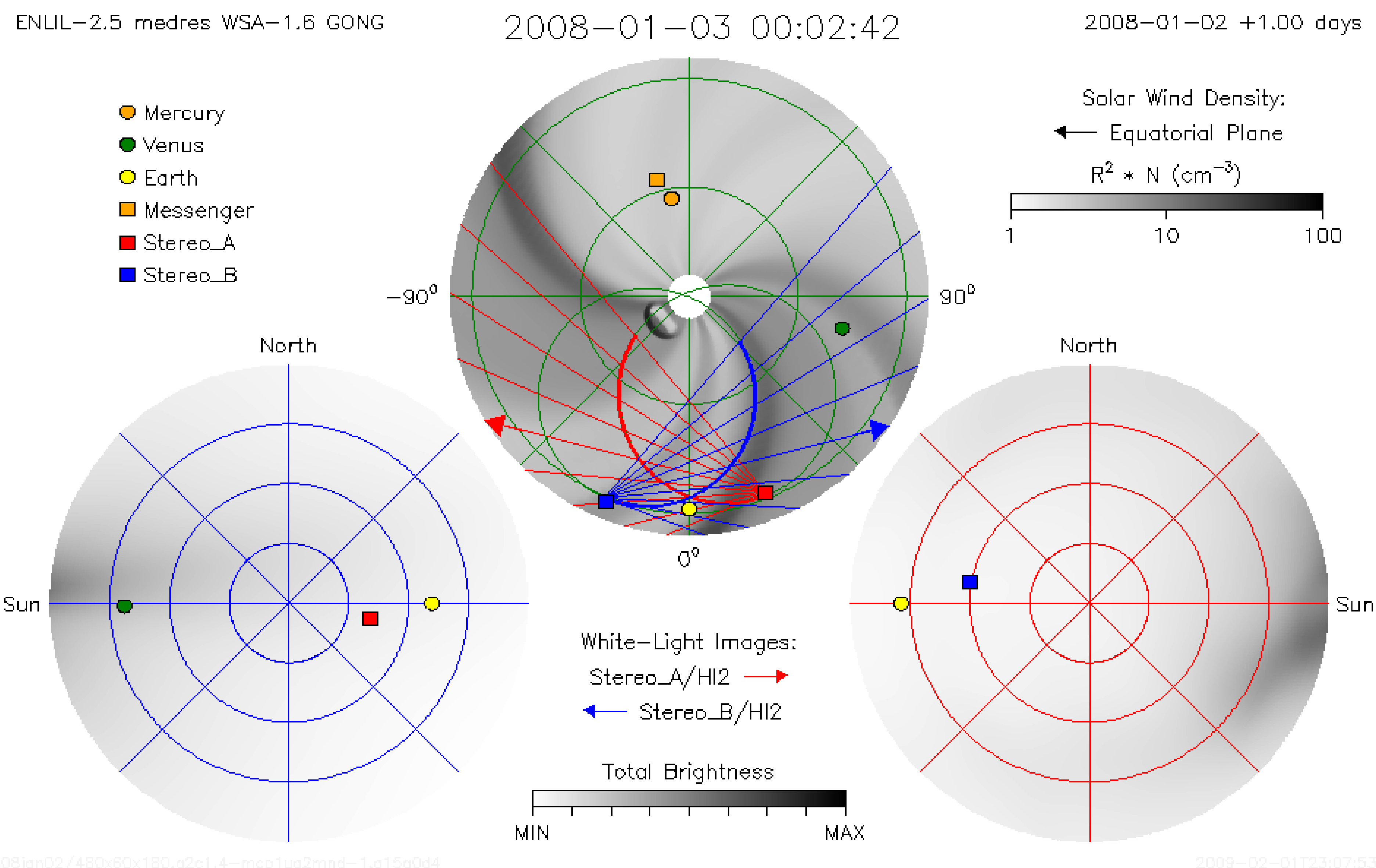

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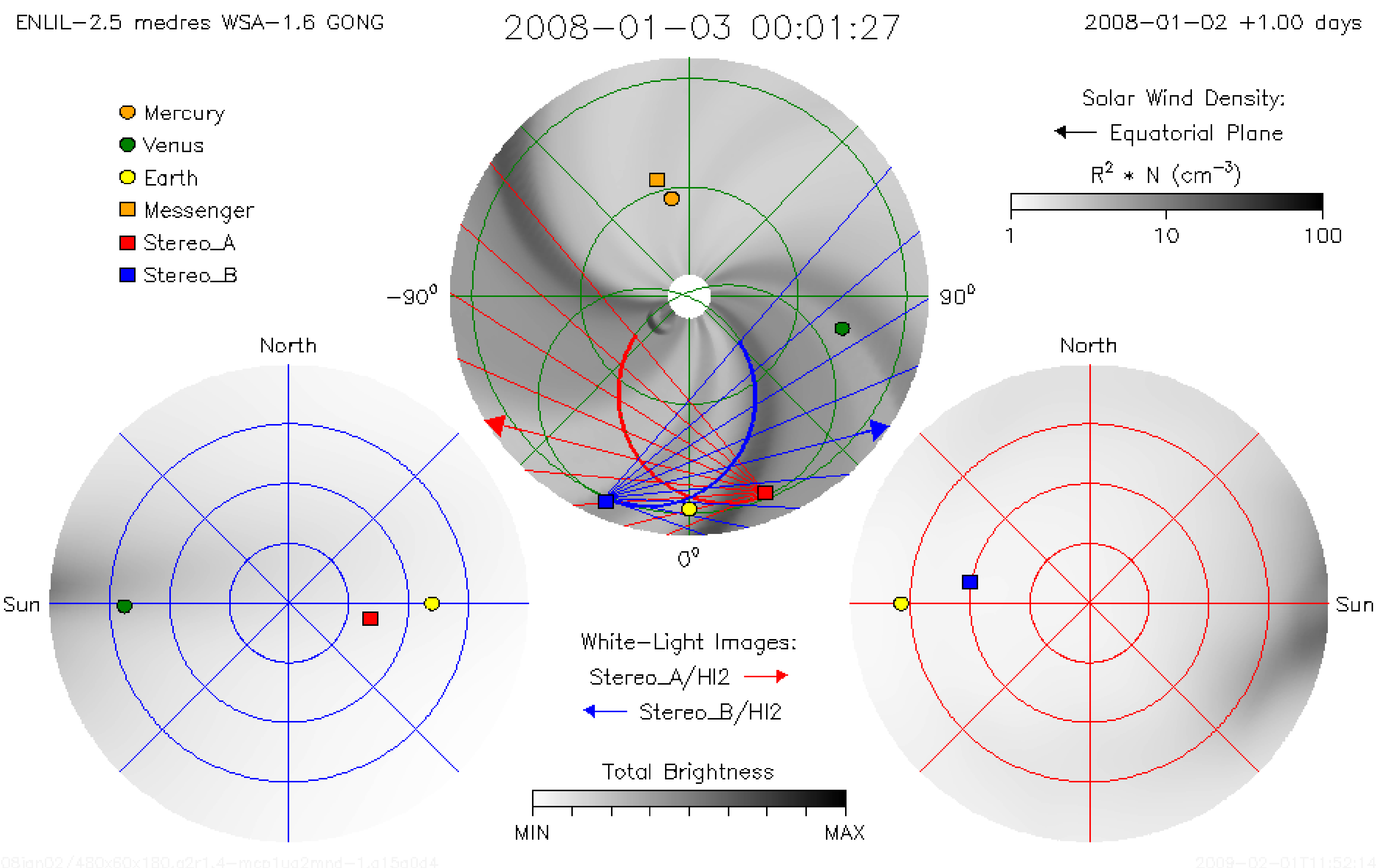

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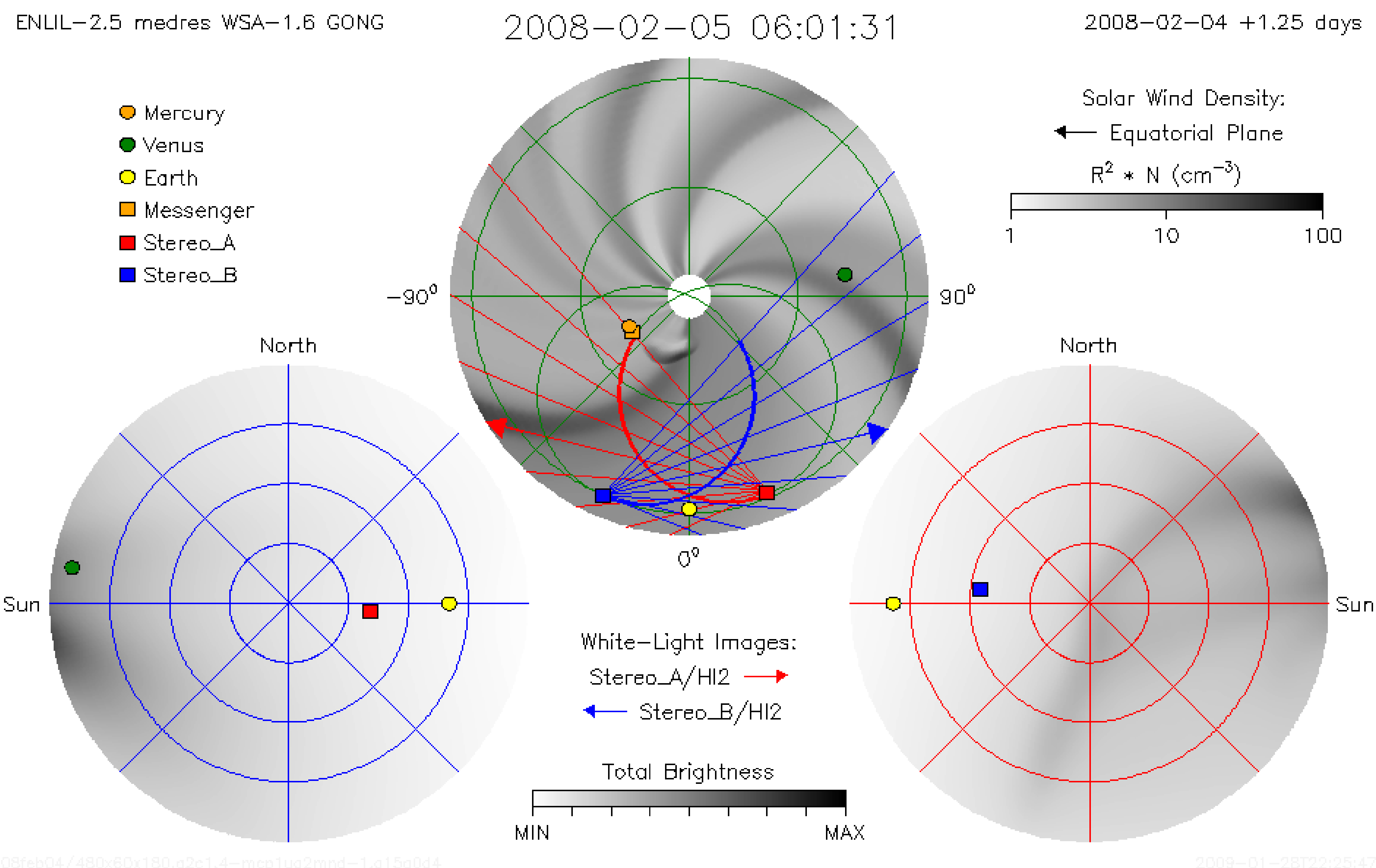

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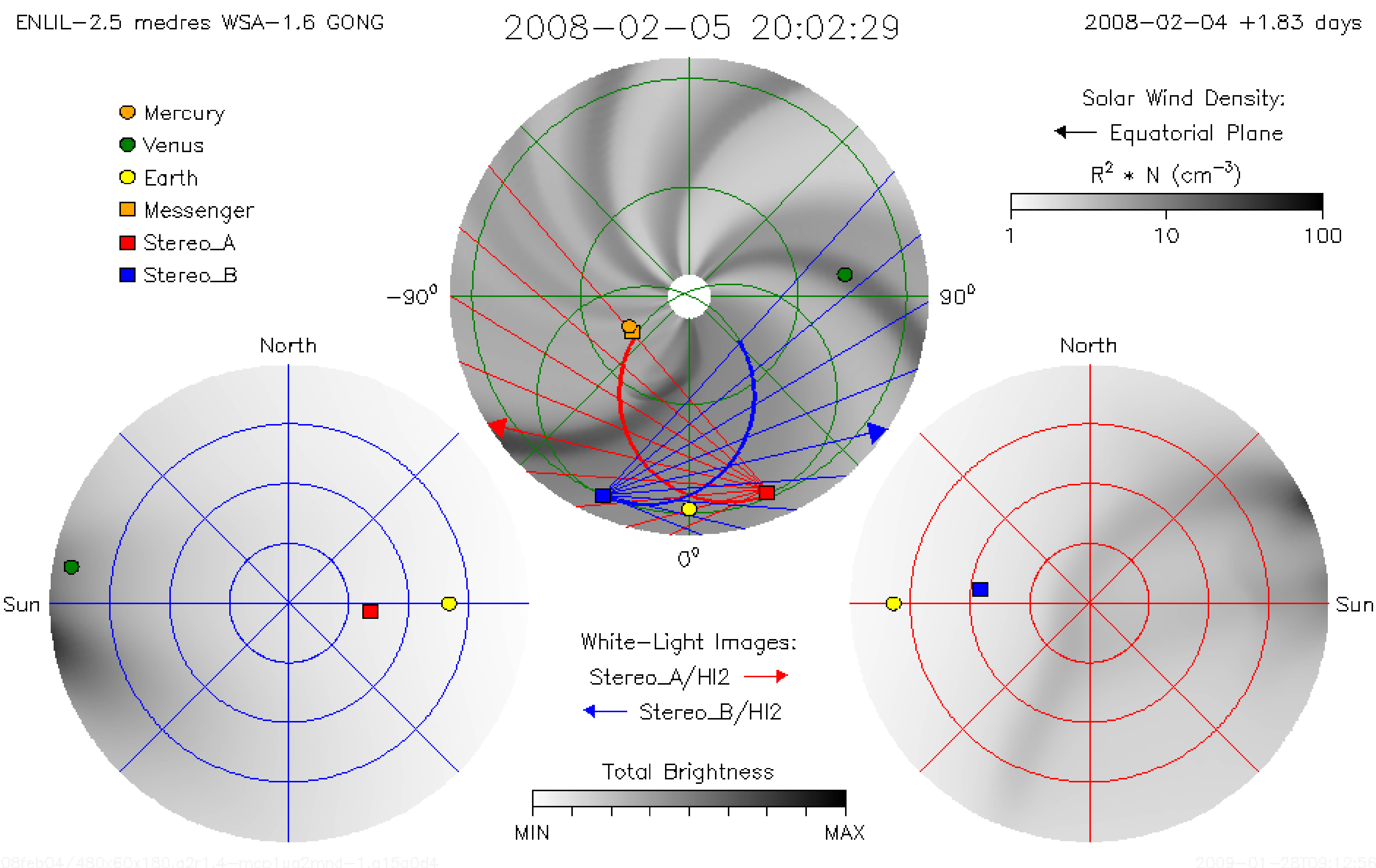
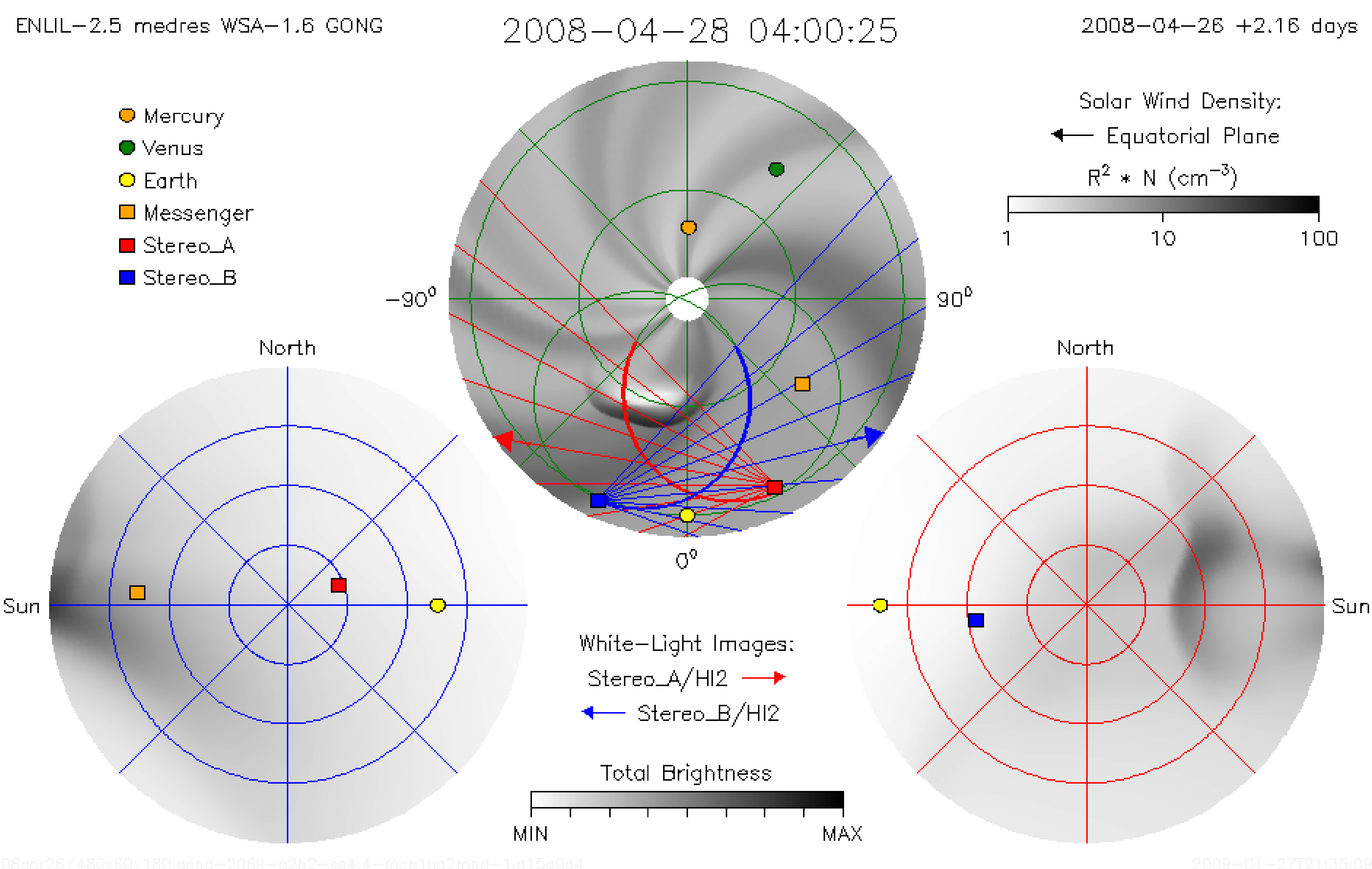


2008 April 26 CME – Cone Model



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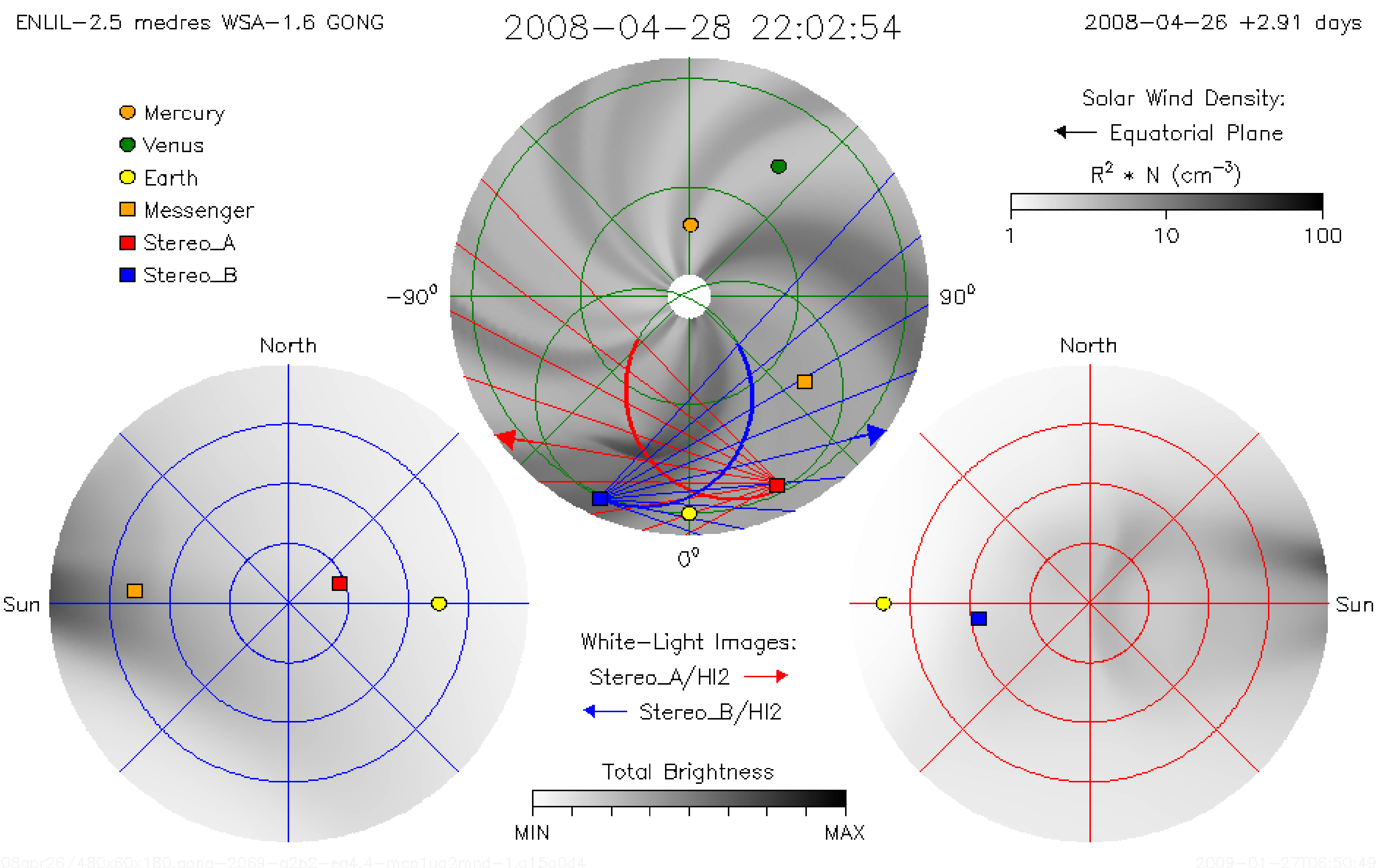
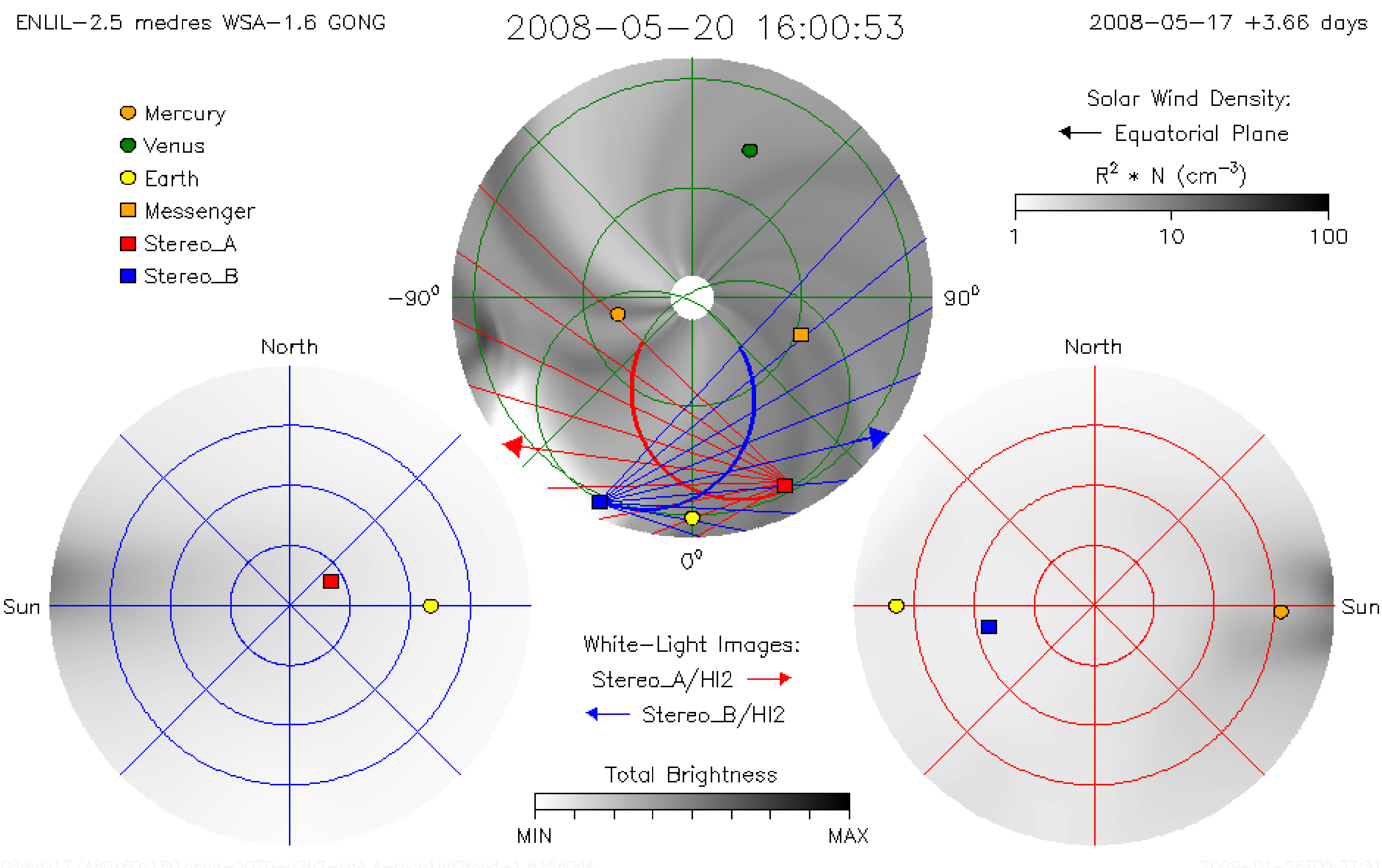


2008 May 17 CME – Cone Model



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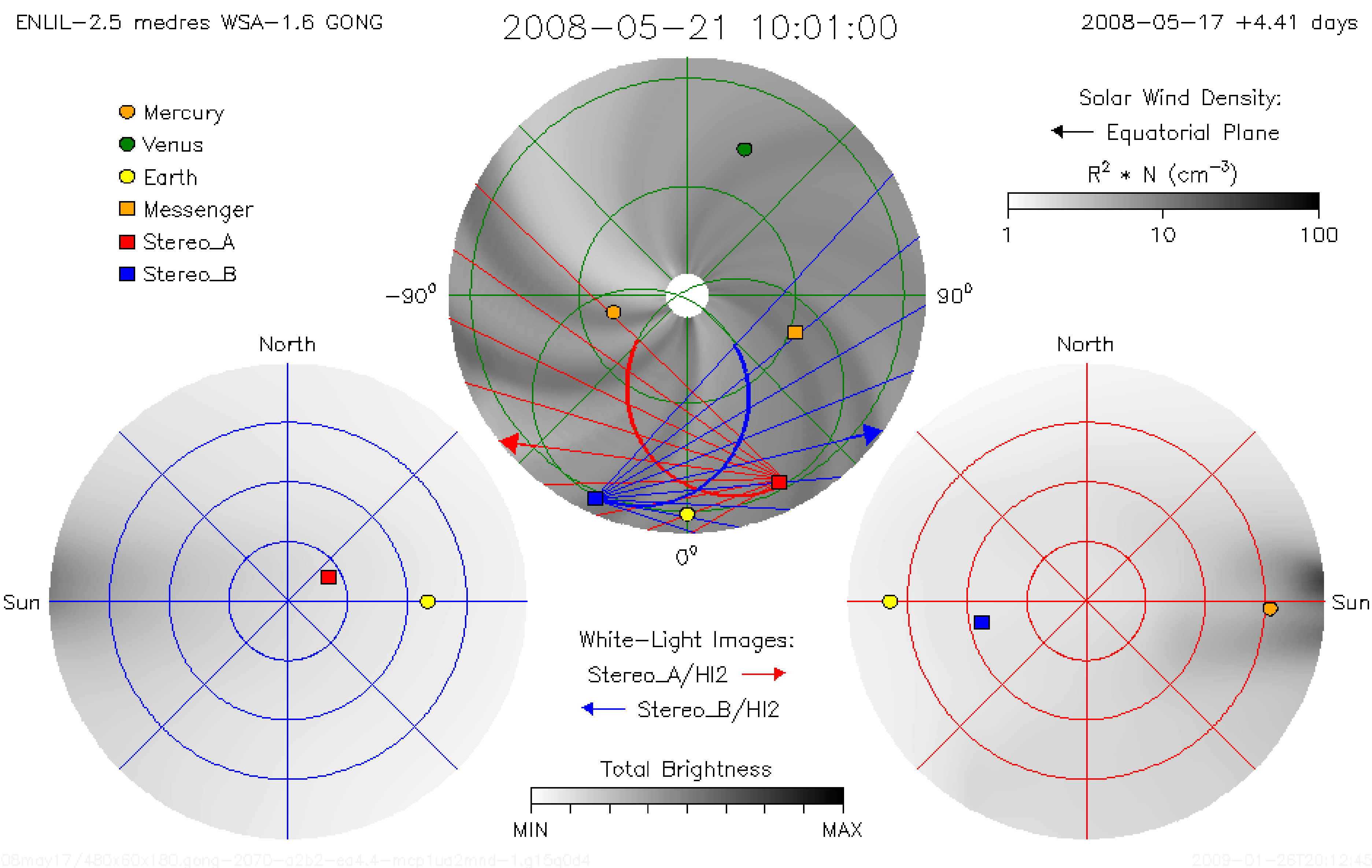
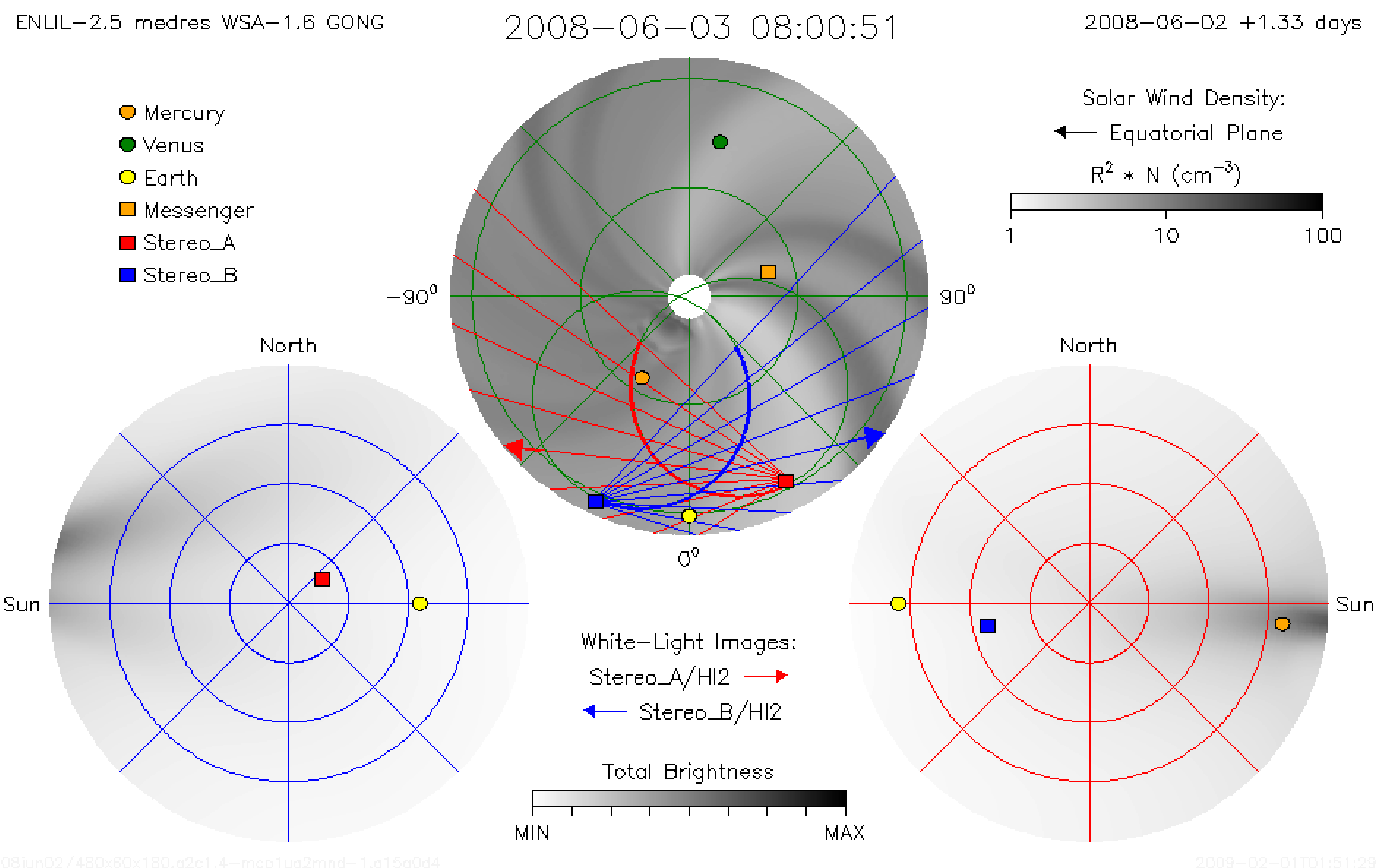
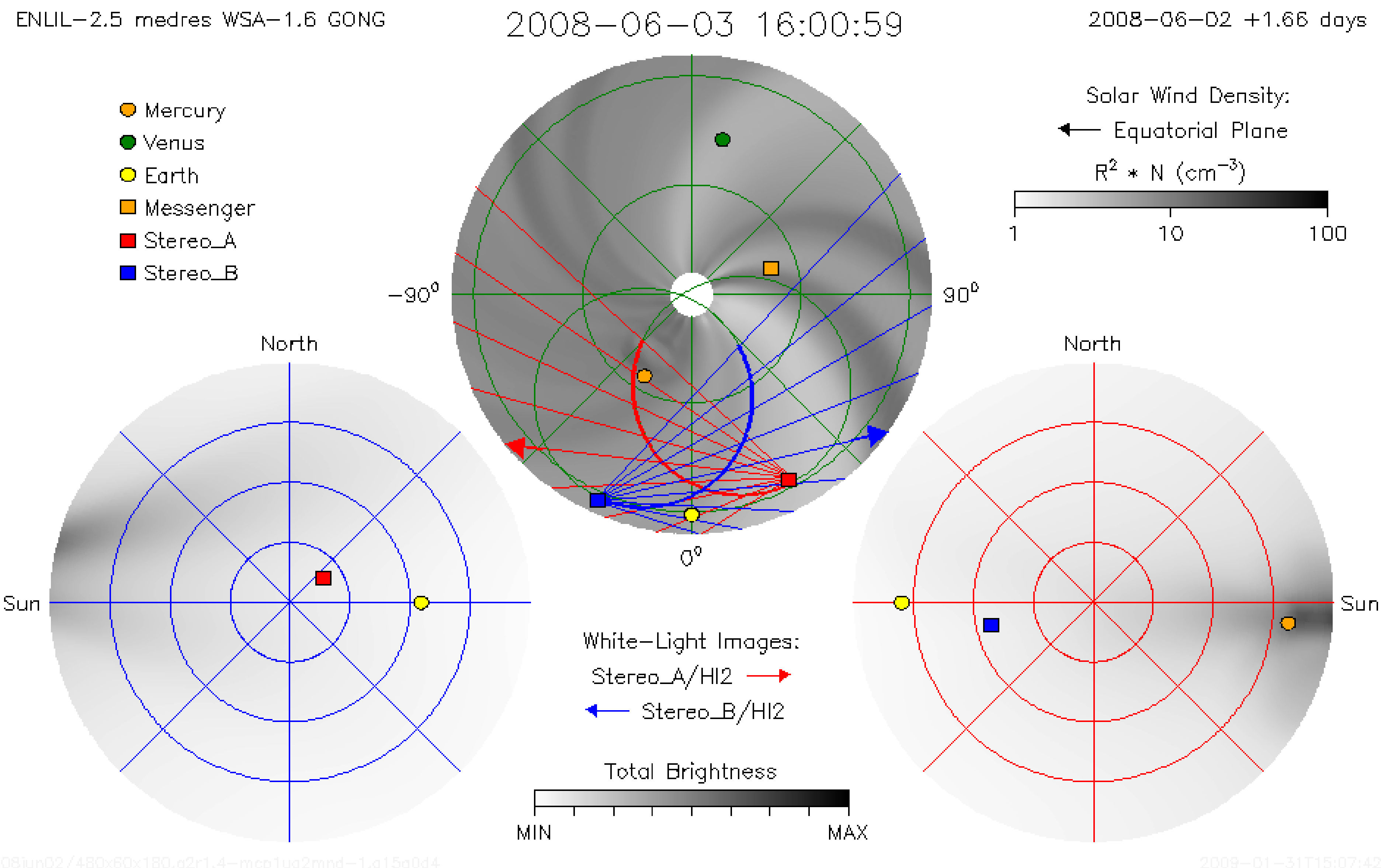


2008 June 2 CME – Cone Model



2008 June 2 CME – Rope Model



In-Situ Observations and Predictions

(work in progress)

CME	STEREO-B			ACE			STEREO-A		
event	obs	cone	rope	obs	cone	rope	obs	cone	rope
2007-12-31	0	0	0	0	0	0	0	0	0
2008-01-02	0	S+e	0	0	0	0	0	0	0
2008-02-04	?	S+E	S+e	0	S	0	0	0	0
2008-04-26	S+E	S+E	S+E	0	S+e	0	0	0	0
2008-05-17	0	S+E	S	0	s	0	?	0	0
2008-06-02	S+E	E	E	0	e	0	0	0	0

<u>Disk space requirements:</u>

- 15 GBytes/event – 6-day period, 2-hour cadence
- 8 Mbytes/event – animations & temporal profiles

Conclusions

- Interpretation of multi-spacecraft heliospheric observations and 3D reconstruction of structures observed by STEREO heliospheric imagers is challenging:
  - the same white-light intensity can be produced by different CME parts;
  - the same CME parts can be observed with different white-light intensities.

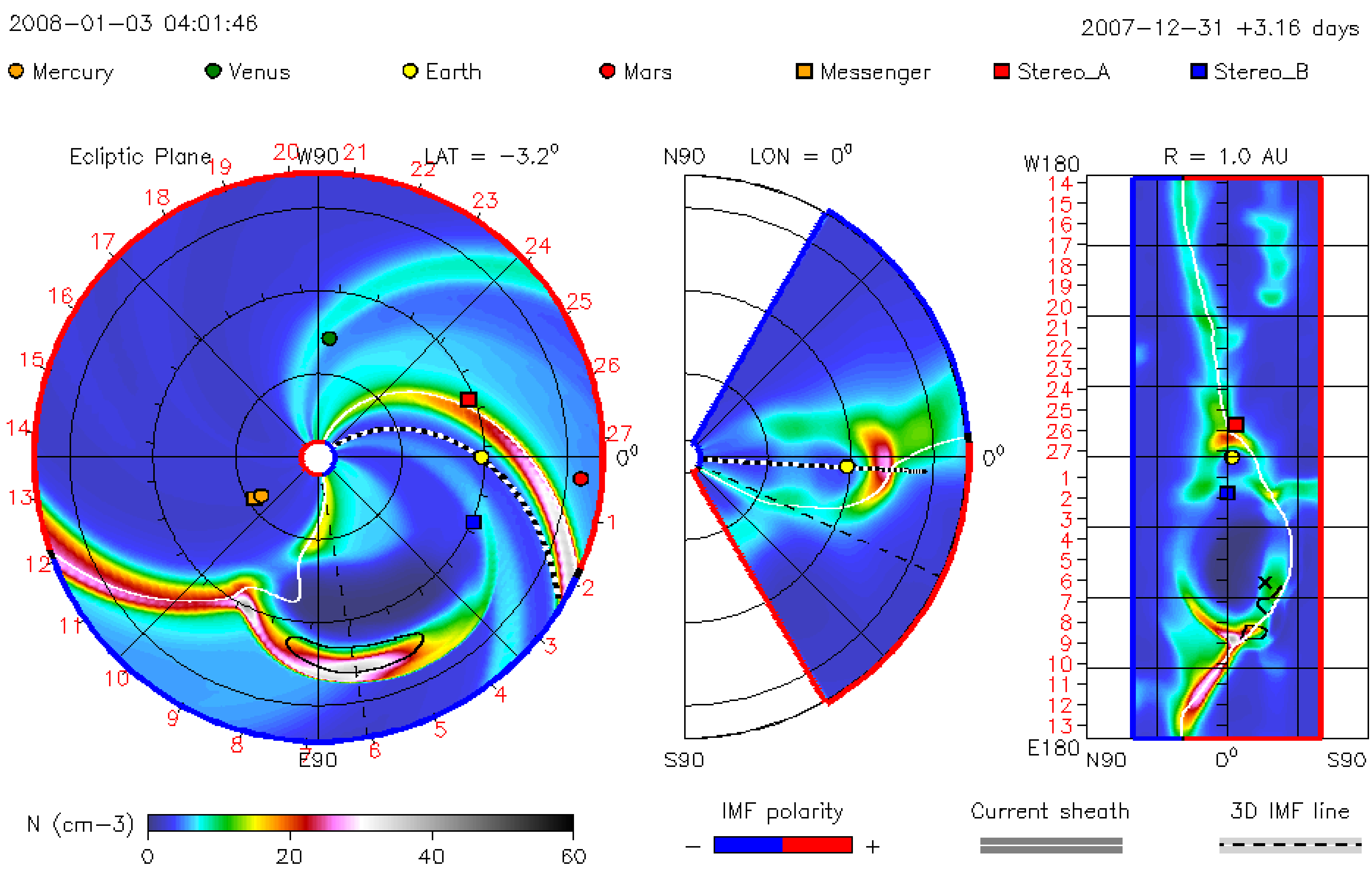
- Numerical simulations can provide:
  - provide global context and hints what can and cannot be observed;
  - missing quantities to interpret observations;
  - predict arrival of disturbances to different locations.

- We have developed a hybrid modeling system for simulation of co-rotating and transient heliospheric disturbances. This system can serve as a practical and efficient solution until better near-Sun observations and more sophisticated CME models become available. The main advantage of our approach is robust, fast, event-by-event simulation.

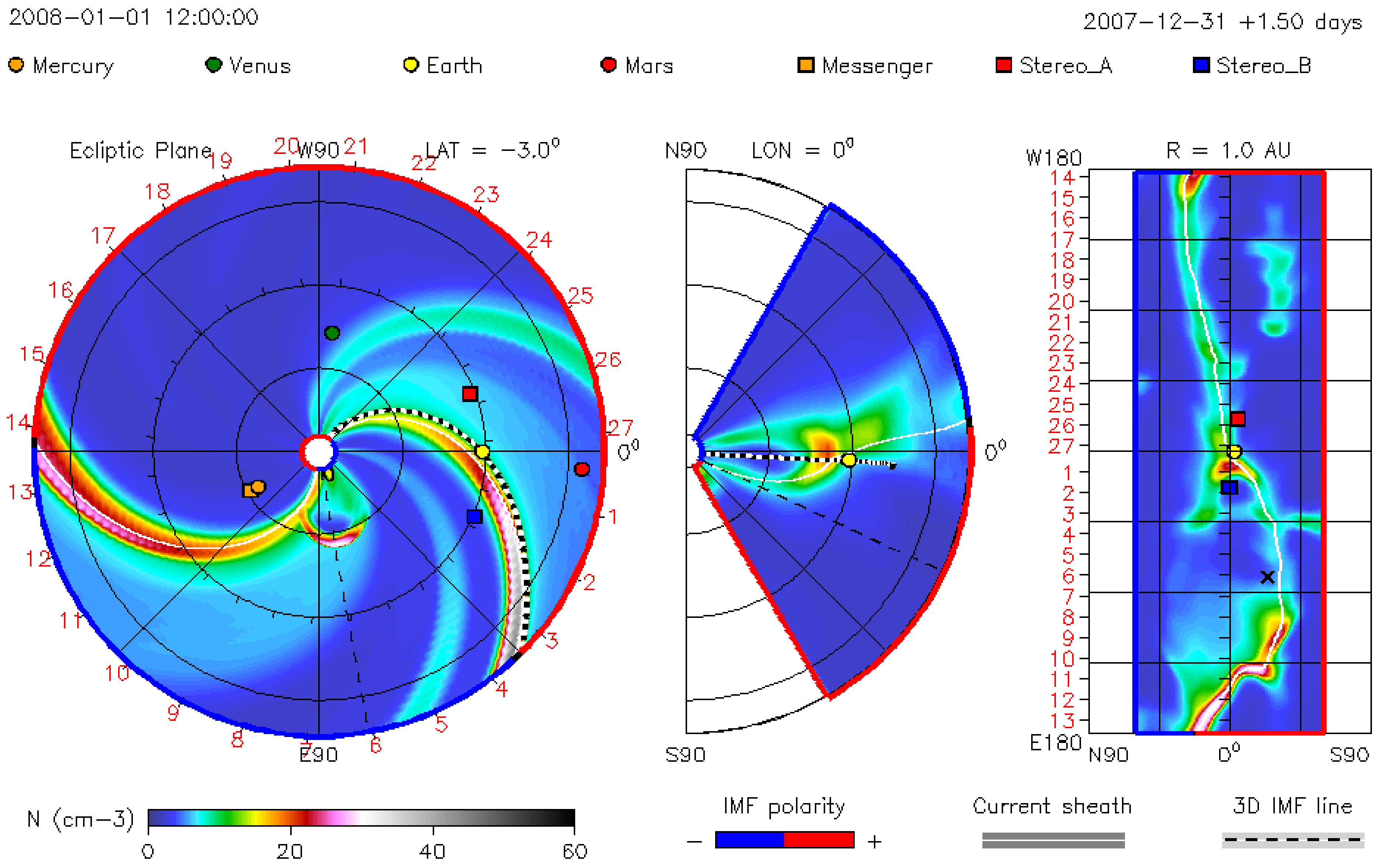
- Results from ICMEs simulated so far suggest that the rope model provides much better match with remote and in-situ observations than the cone model does with a circular cross section.

BACKUP

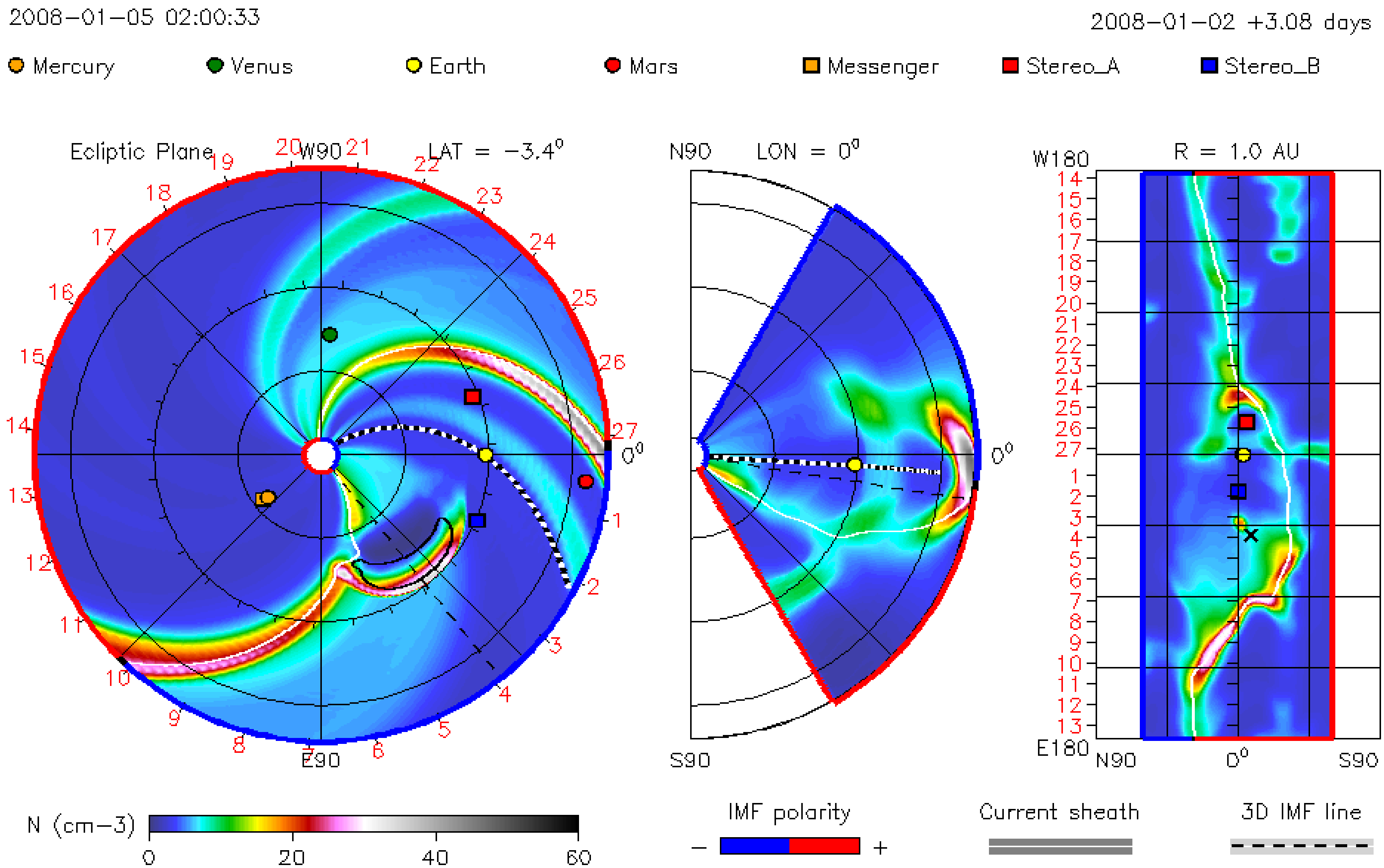
2007 December 31 CME – Cone Model



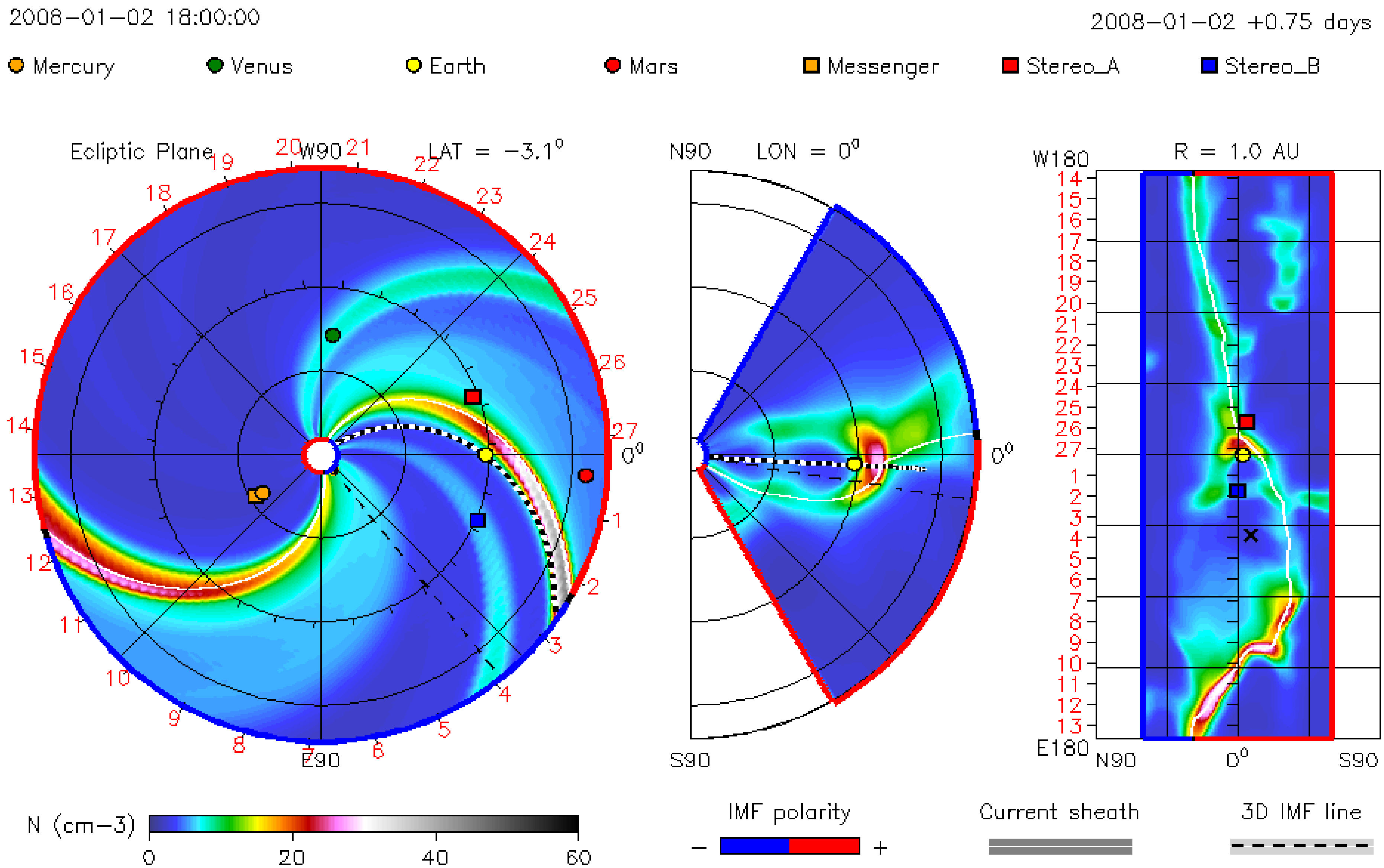
2007 December 31 CME – Rope Model



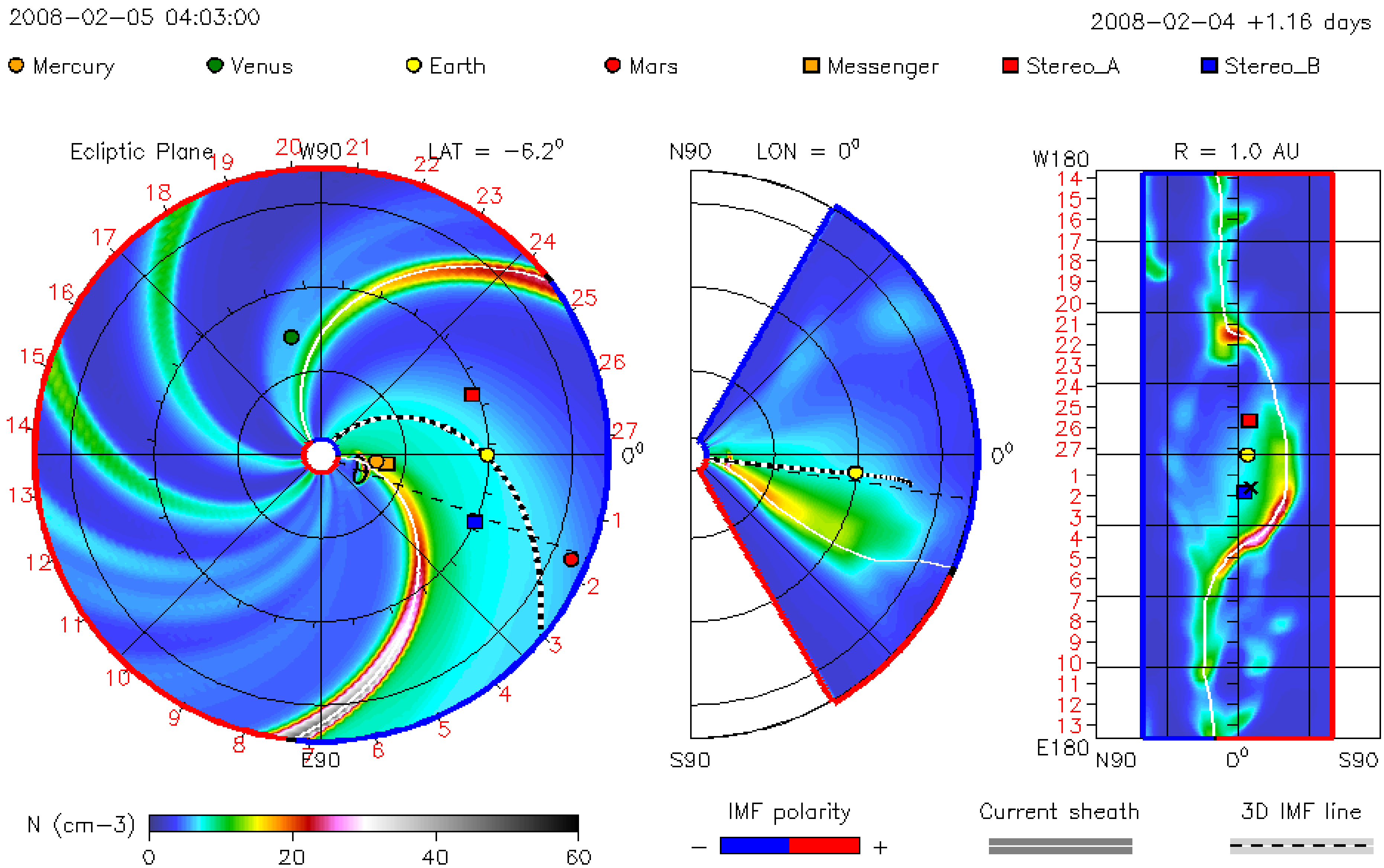
2008 January 2 CME – Cone Model



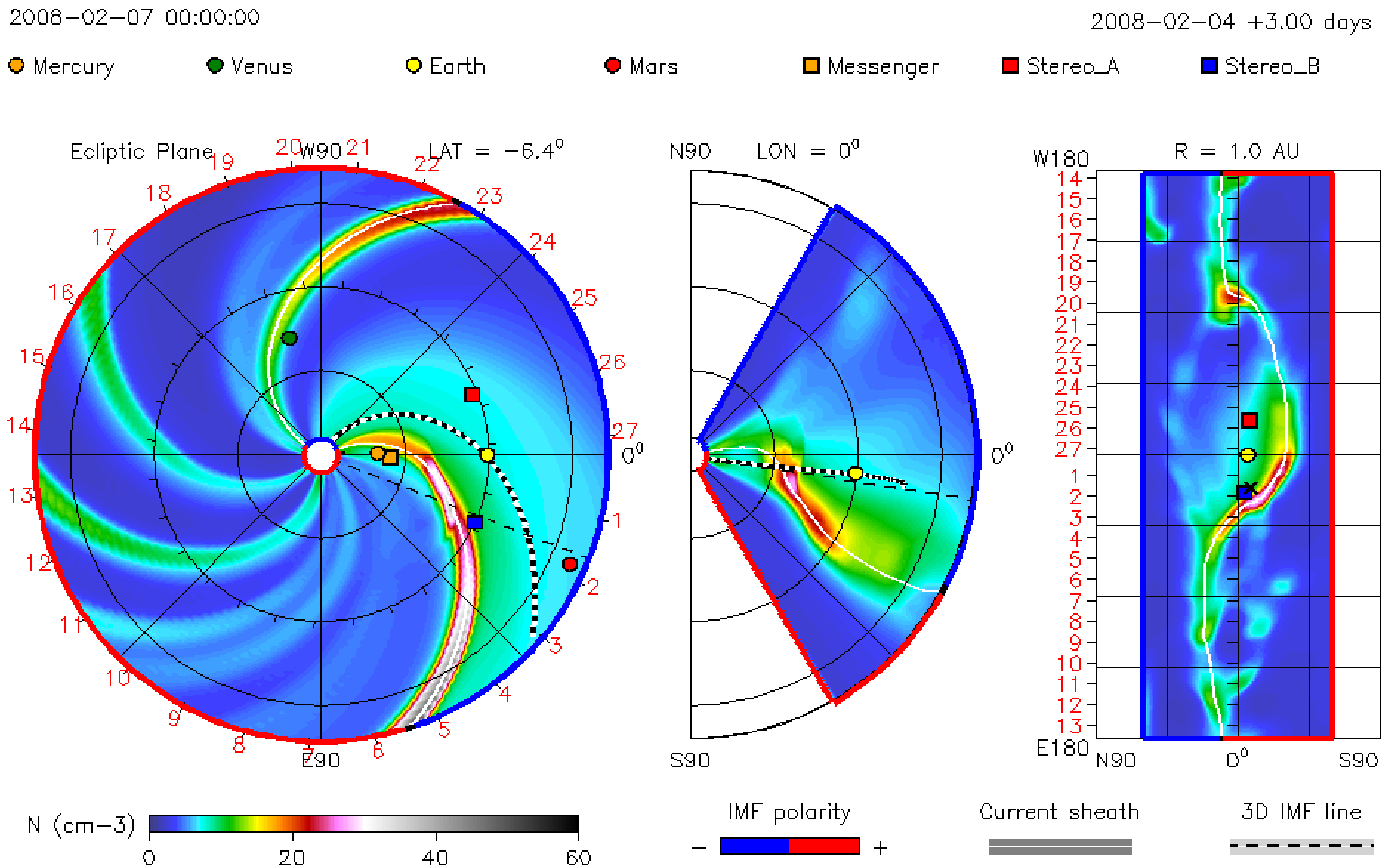
2008 January 2 CME – Rope Model



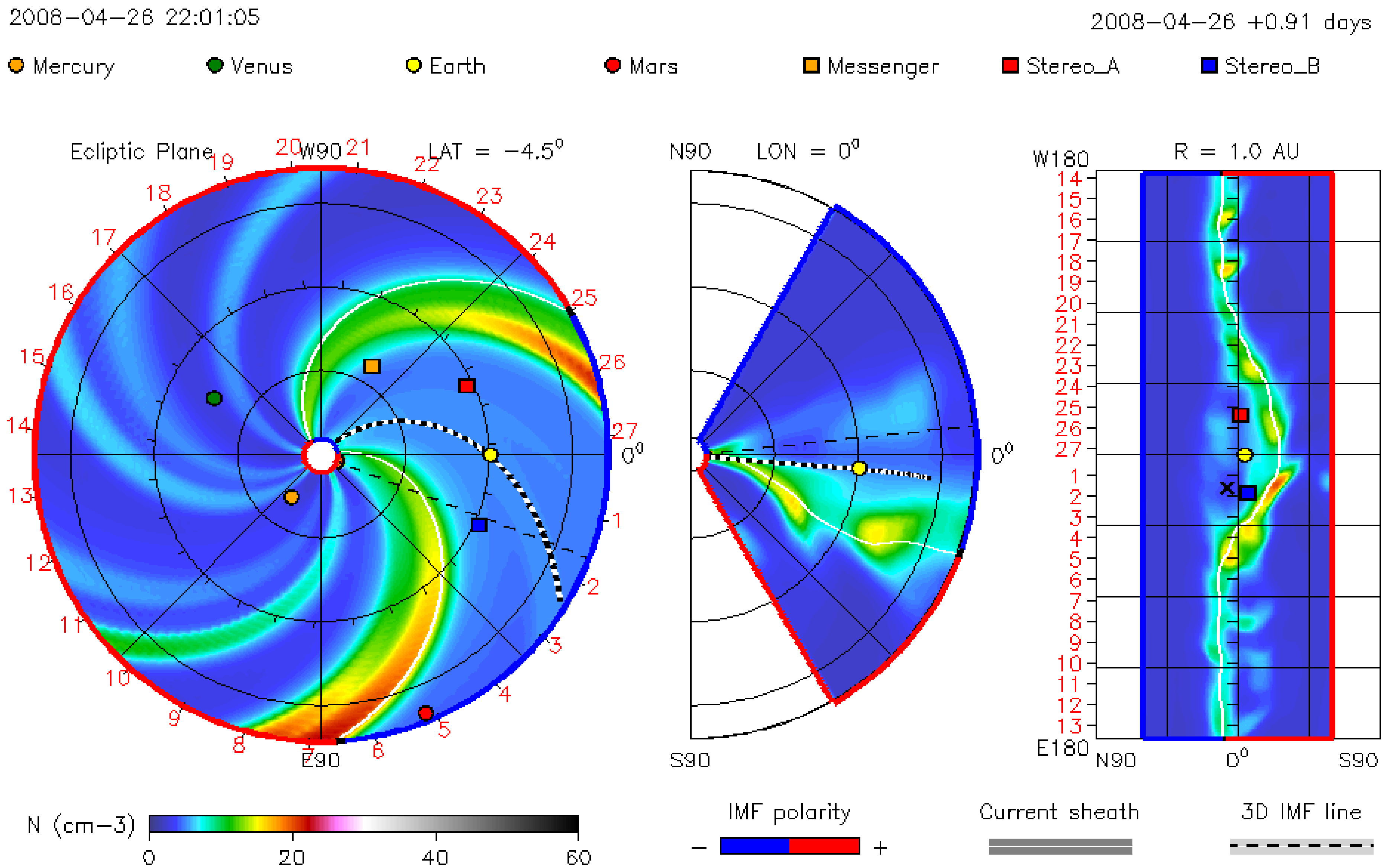
2008 February 4 CME – Cone Model



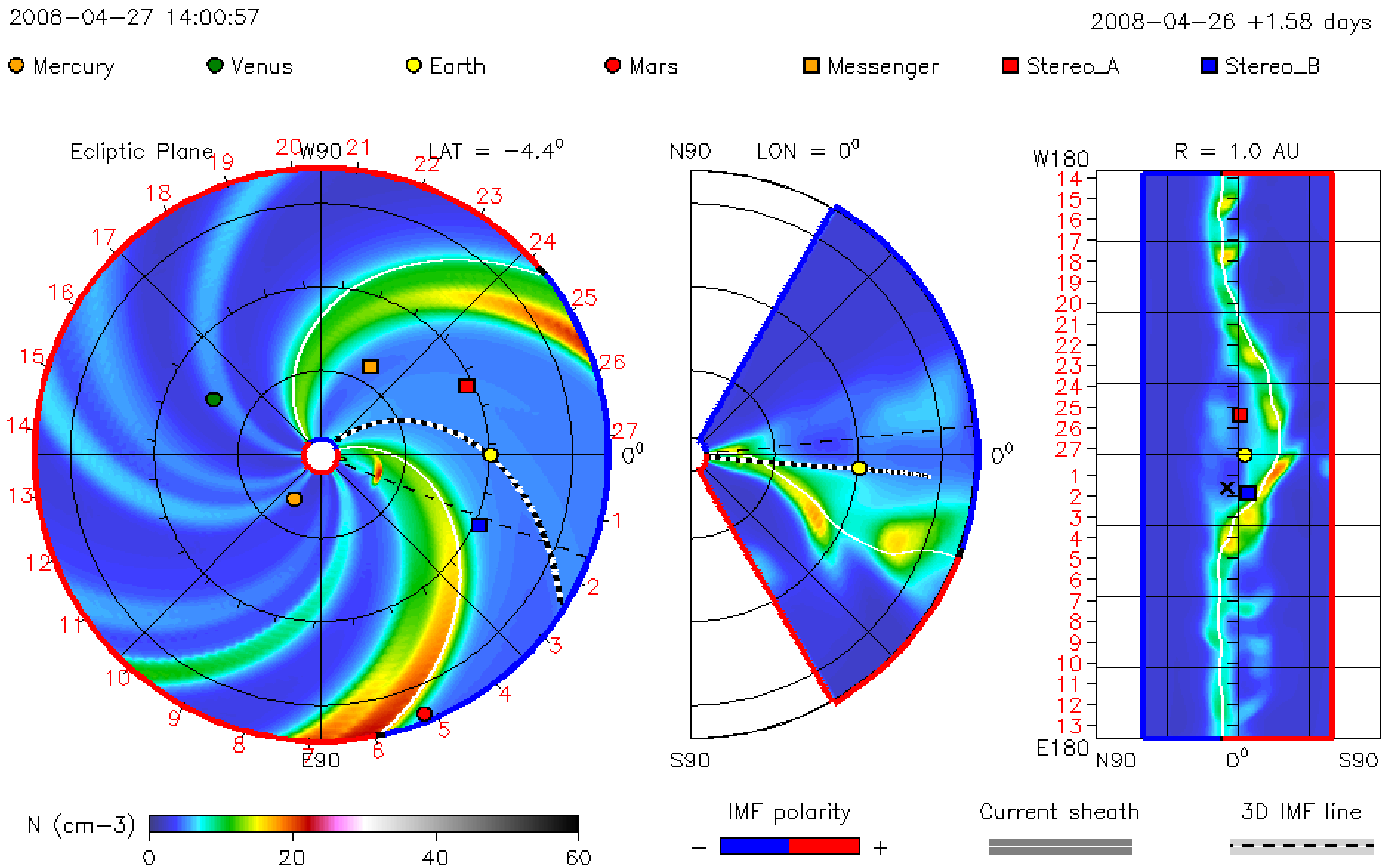
2008 February 4 CME – Rope Model



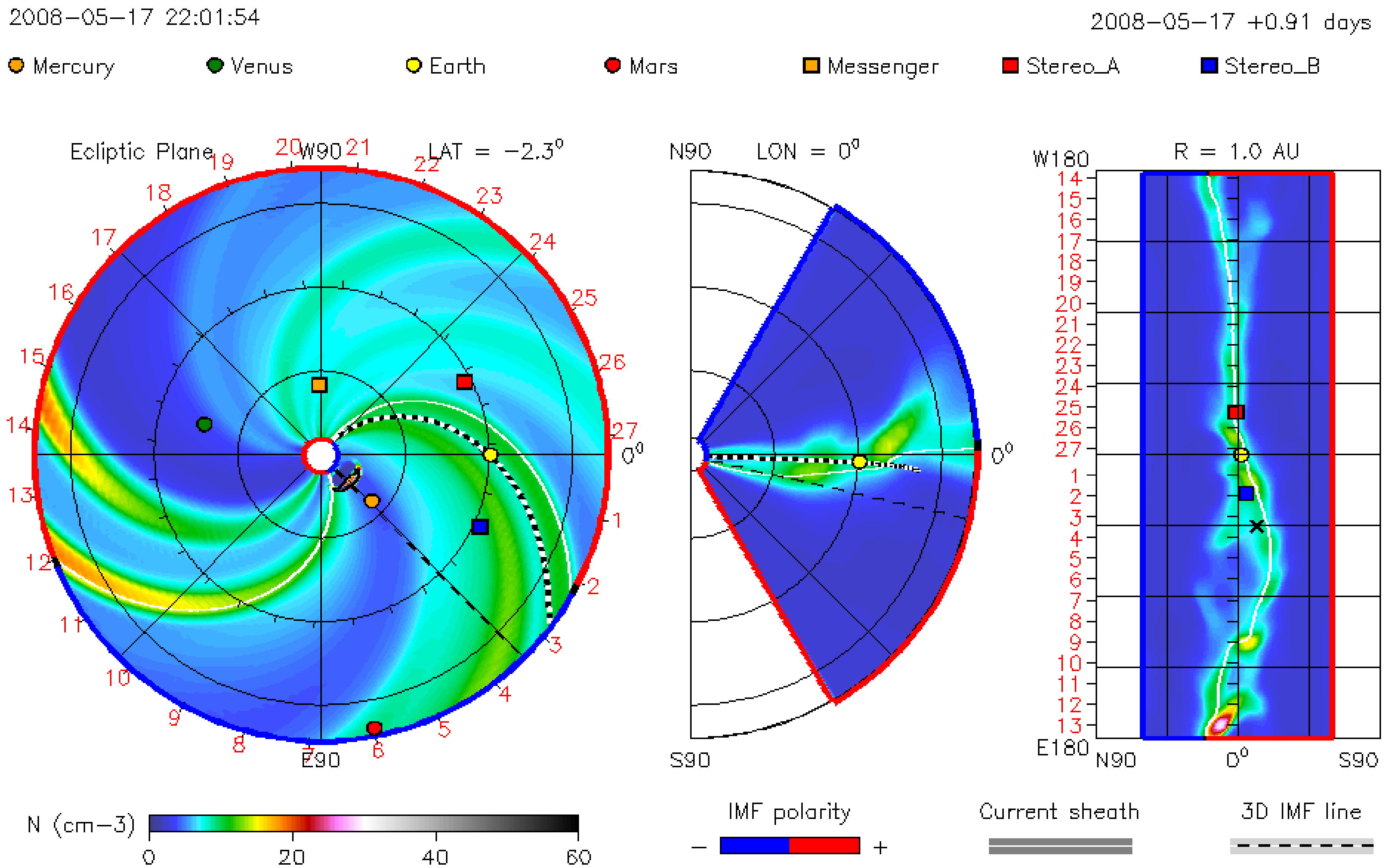
2008 April 26 CME – Cone Model



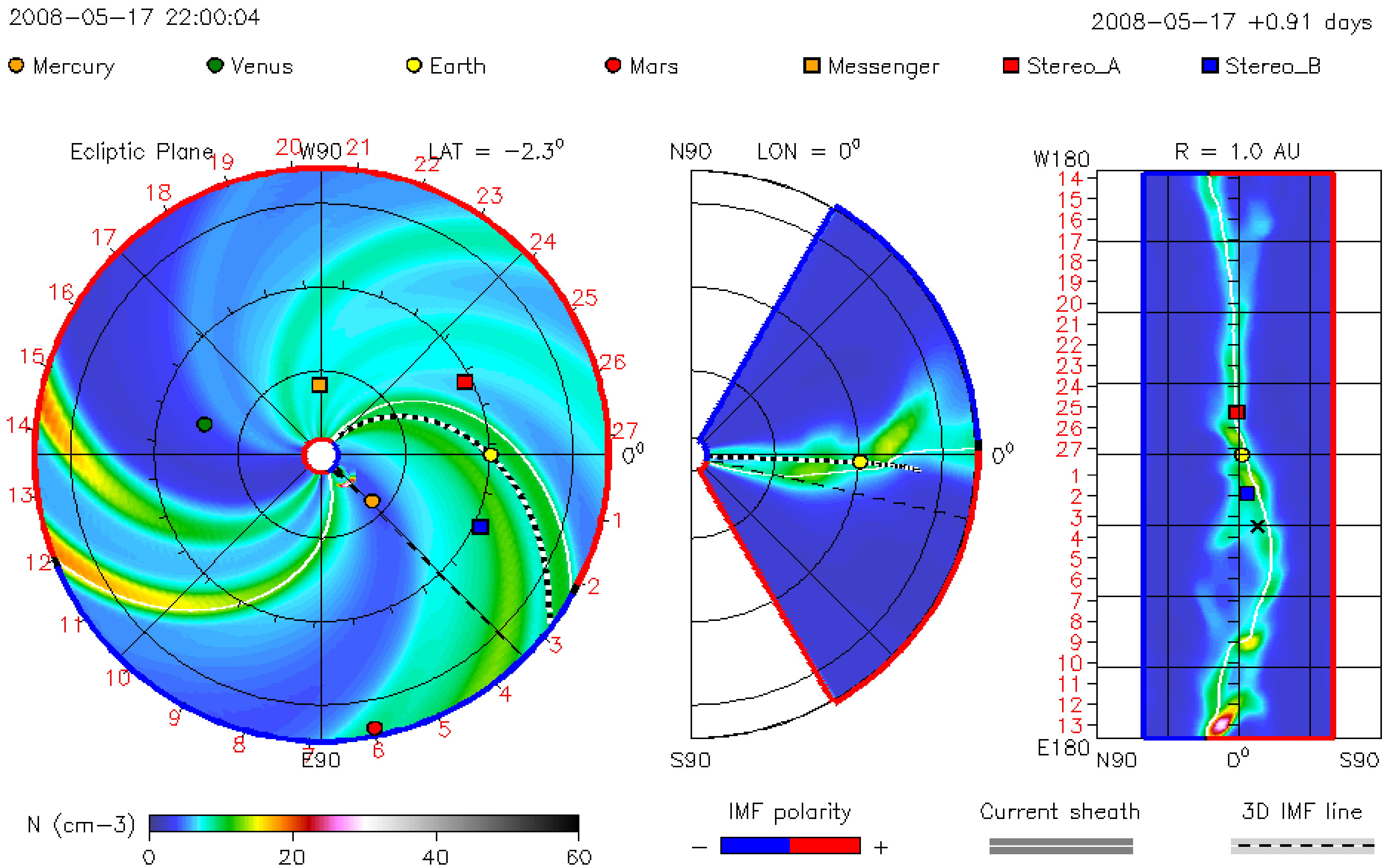
2008 April 26 CME – Rope Model



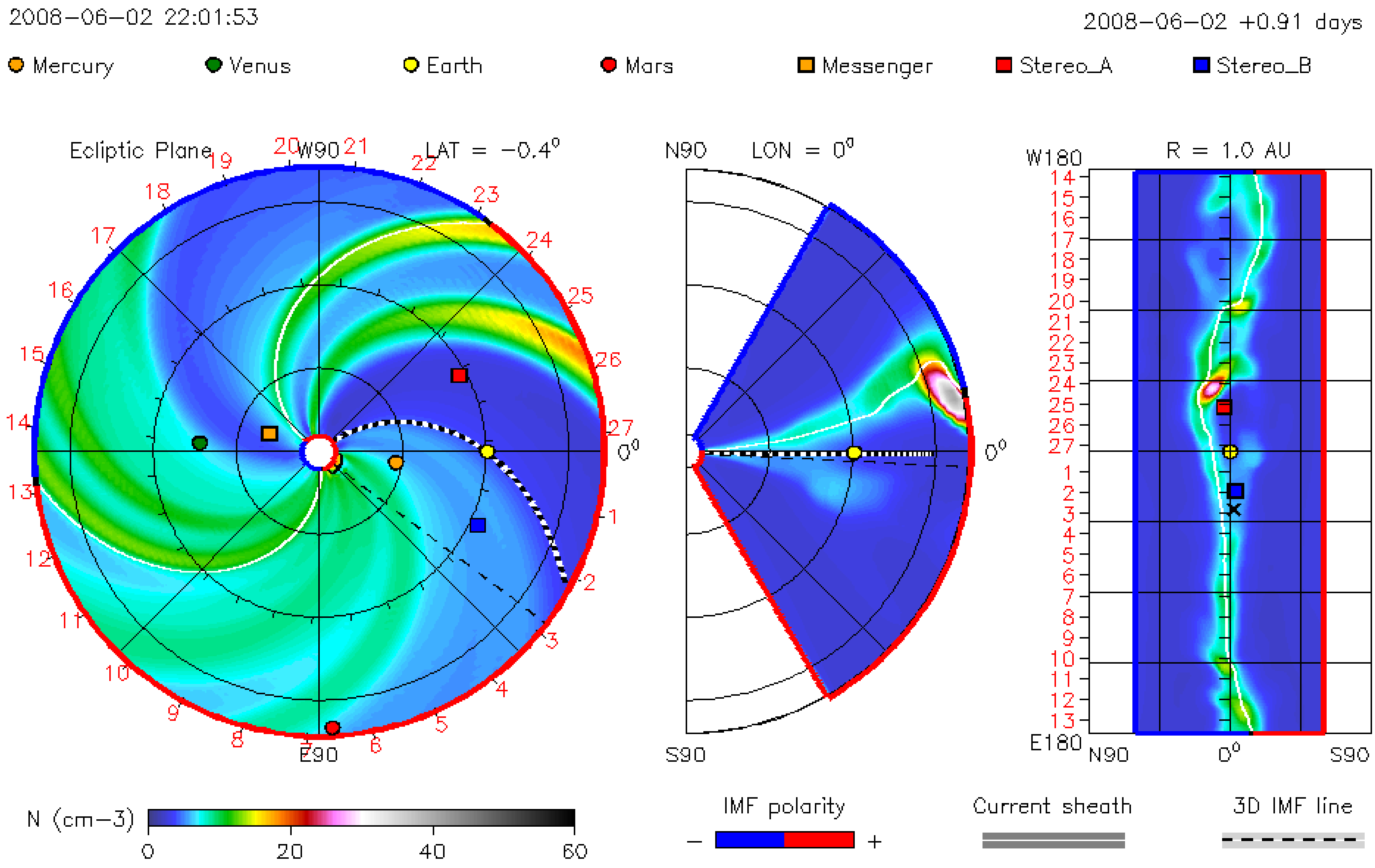
2008 May 17 CME – Cone Model



2008 May 17 CME – Rope Model



2008 June 2 CME – Cone Model



2008 June 2 CME – Rope Model