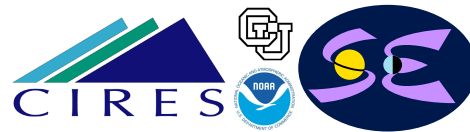


POLARIMETRIC AND GEOMETRIC LOCALIZATION: SPACE WEATHER TOOLS TO CALCULATE CME VELOCITY IN 3D SPACE

Curt A. de Koning and V.J. Pizzo

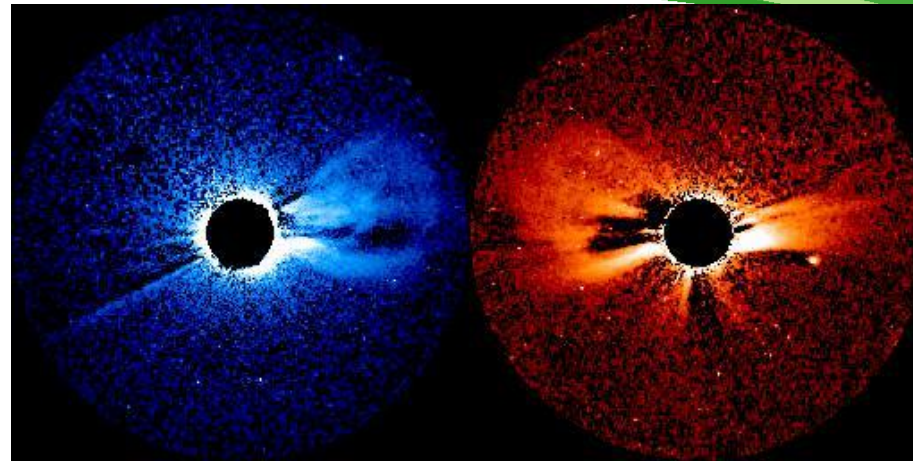


STEREO SWG XXI

DUBLIN IRELAND MMX MAR XXI

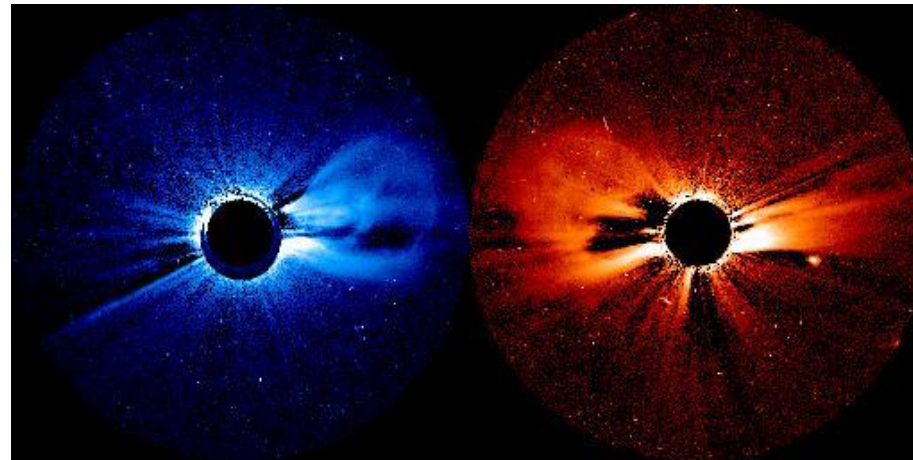
The STEREO Space Weather Beacon provides highly compressed and binned image data in near-real-time. This data provides a sufficient signal-to-noise ratio for space weather forecasting.

Beacon: 256×256

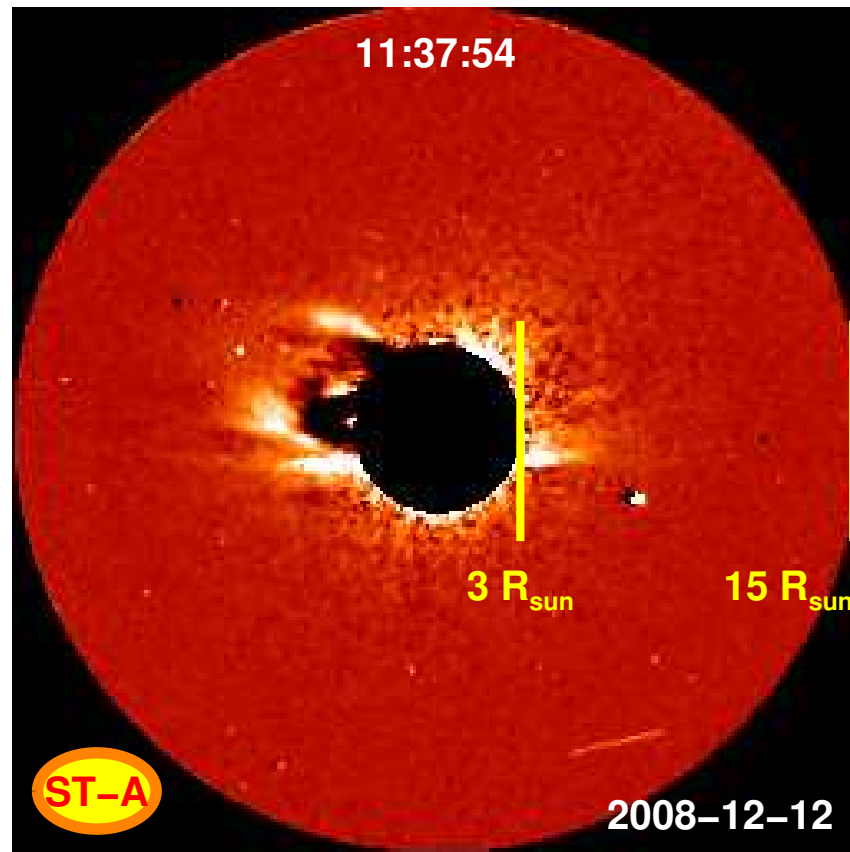


2008-12-12 1422 UT

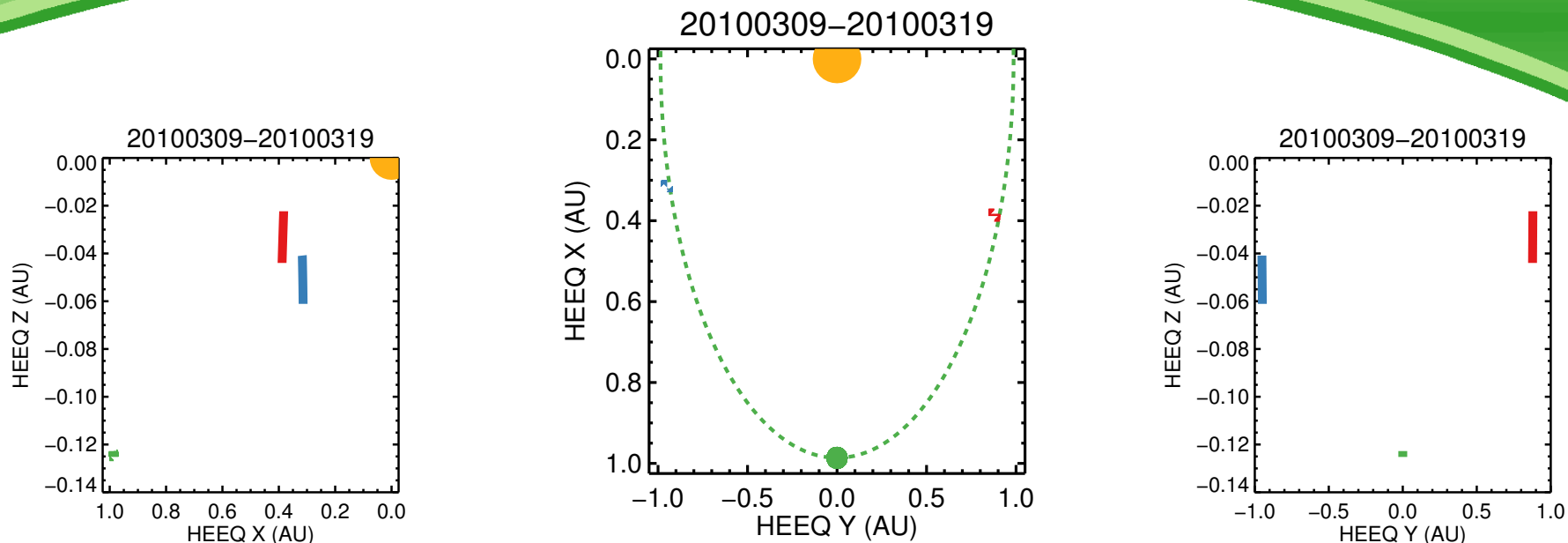
Science: 2048×2048



The COR2 instrument provides early warning of an approaching CME. Its field-of-view is sufficiently large that we can observe the temporal development of a CME, even for very fast CMEs.



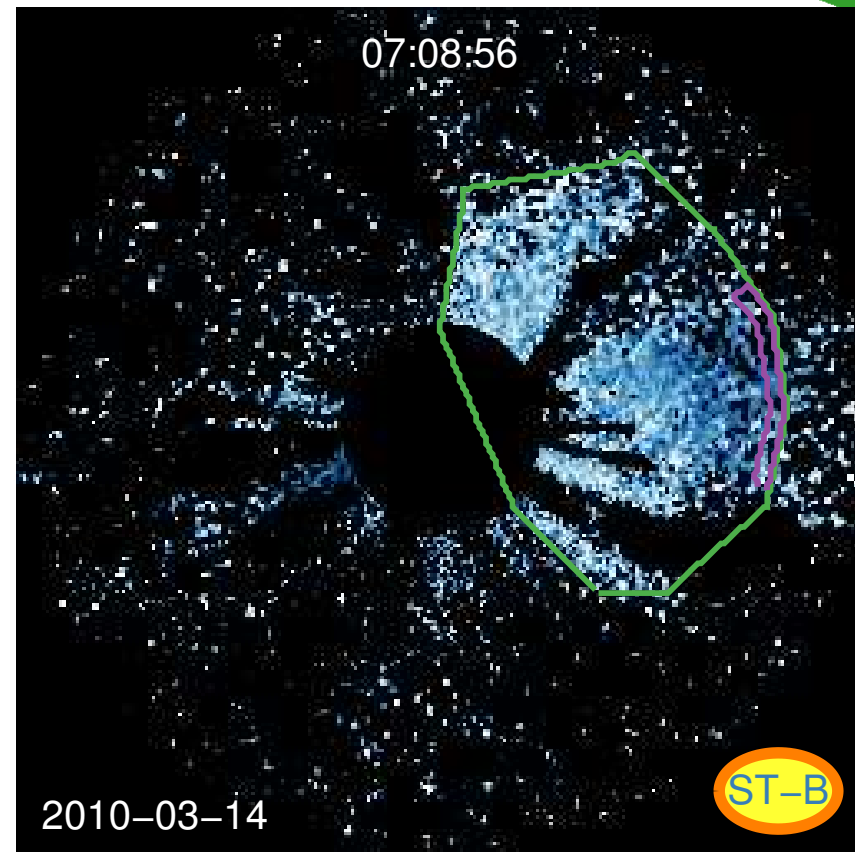
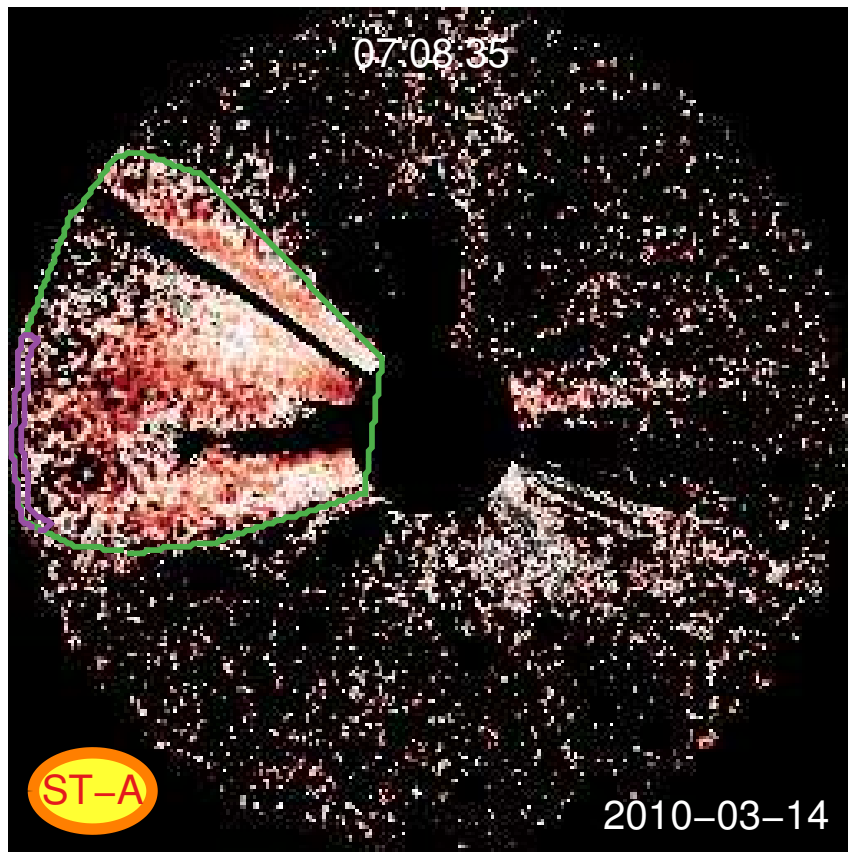
Position of **STEREO-A**, **STEREO-B**, and **Earth** around 2010 March 14.



	A	E	B
Heliocentric radius (AU)	0.9597	0.9941	1.003
Heliographic (HEEQ) longitude	66.285	0.000	-71.660
Heliographic (HEEQ) latitude	-1.985	-7.182	-2.923
Separation angle with Earth	66.226		71.447
Separation angle A with B		137.668	

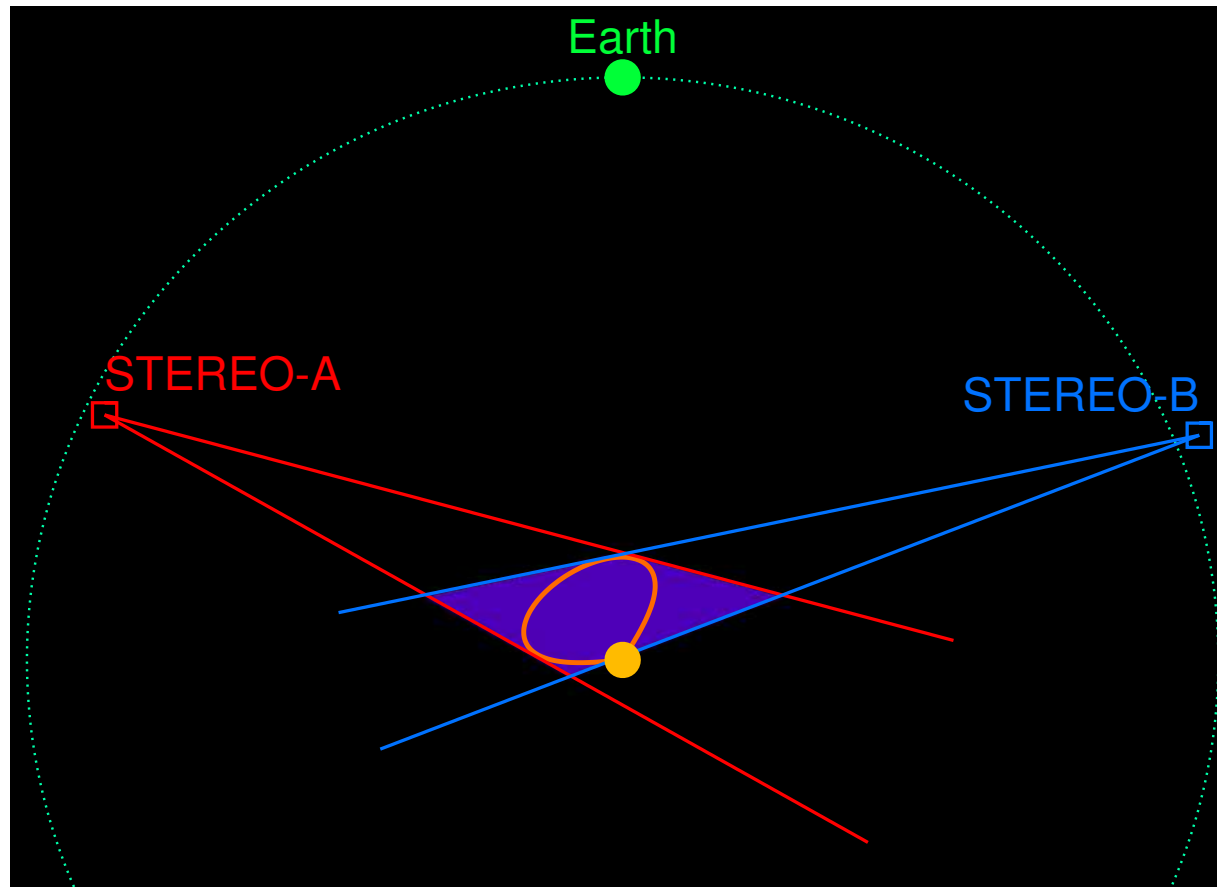
Geometric and Polarimetric Localization

Example taken from CME observed on 2010 March 14 at 0708 UT; manually selected CME and leading-edge boundaries are superimposed on COR2 beacon image.



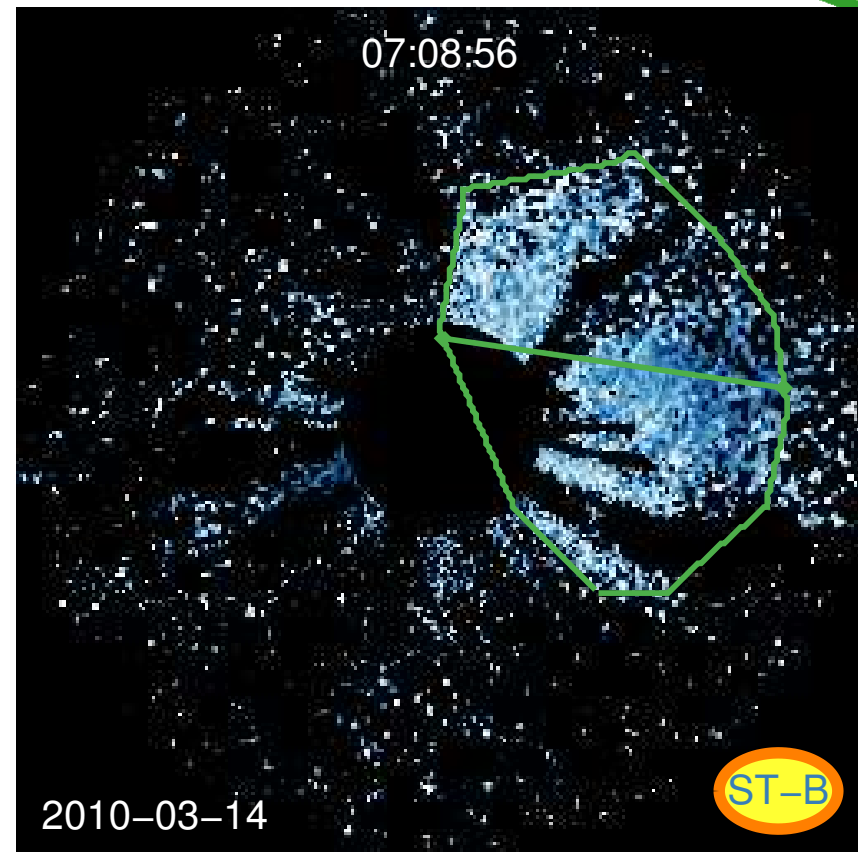
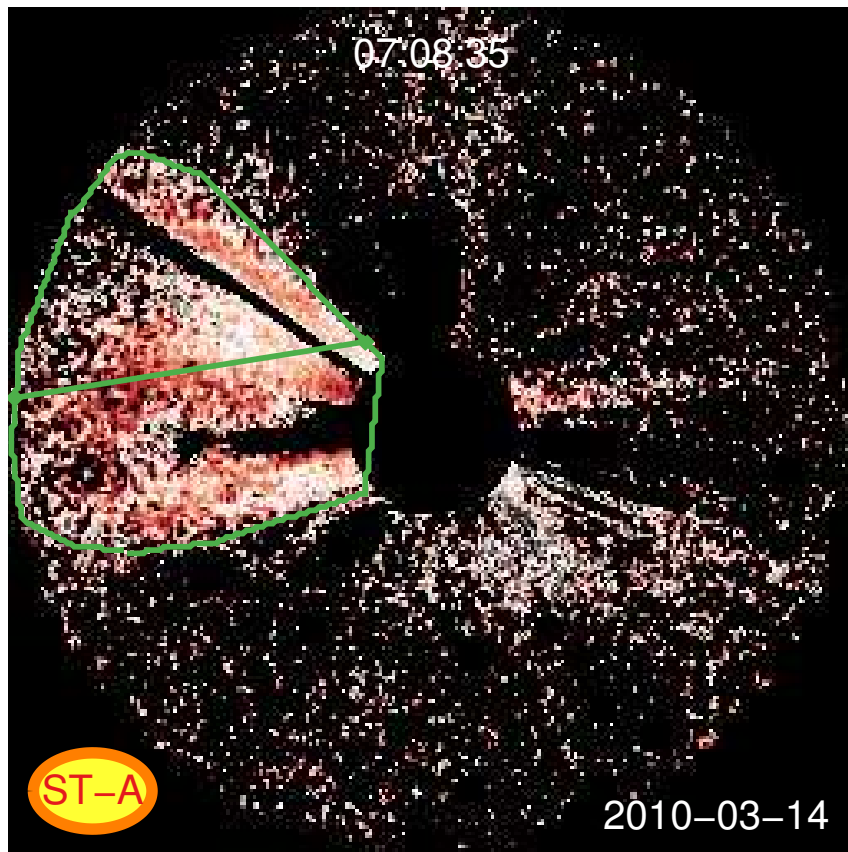
Geometric Localization [Pizzo and Biesecker, 2004]

The locator algorithm should quickly determine CME location and velocity and run in nearly automated mode; therefore, it must be simple, robust, and easy to use.



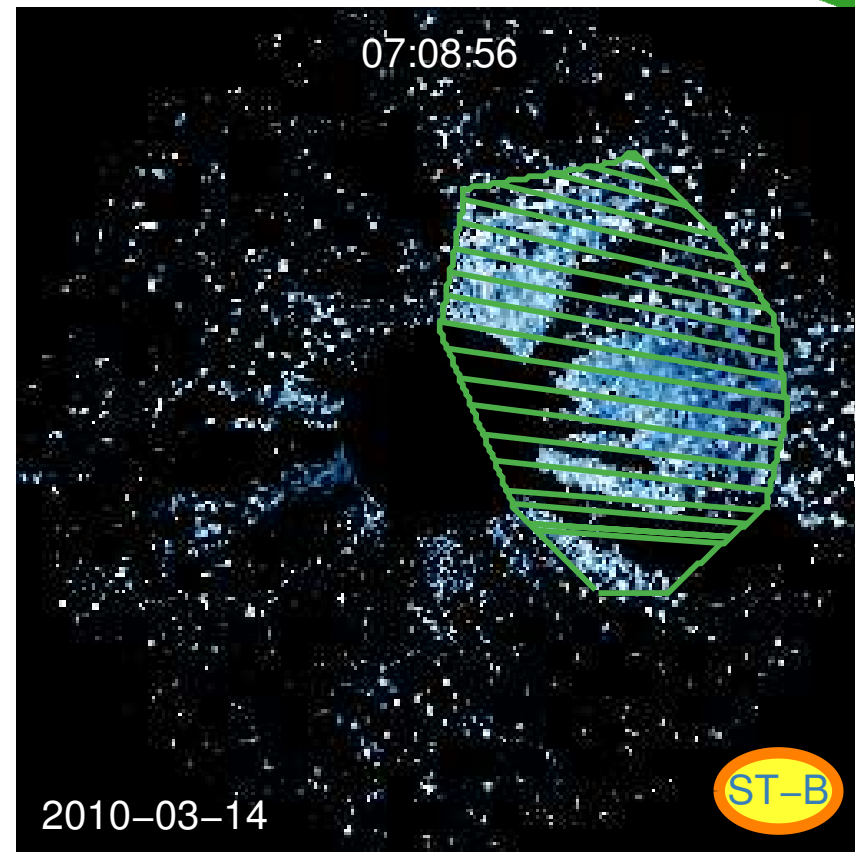
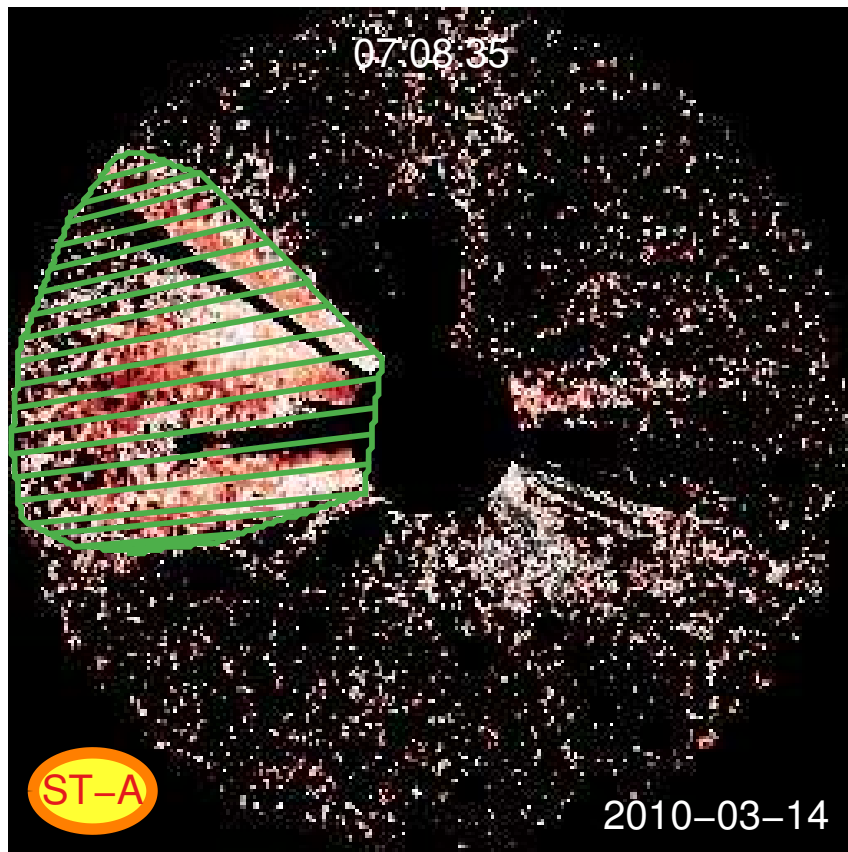
Geometric Localization

The program automatically chooses a plane that contains the spacecraft and cuts through the two images of the CME.



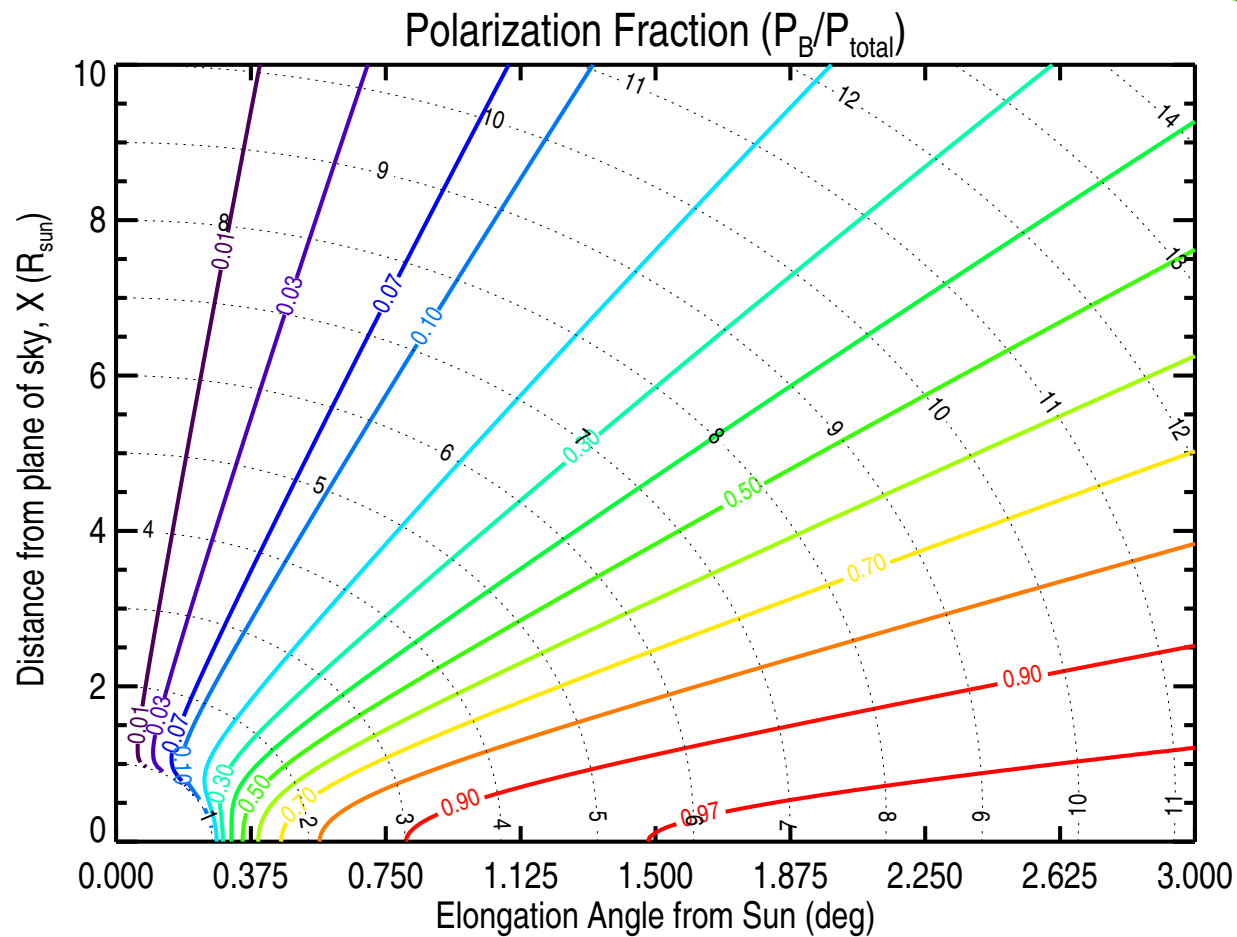
Geometric Localization

By applying geometric localization to a stack of planes, we can delineate the region of 3D space wherein the CME is contained.



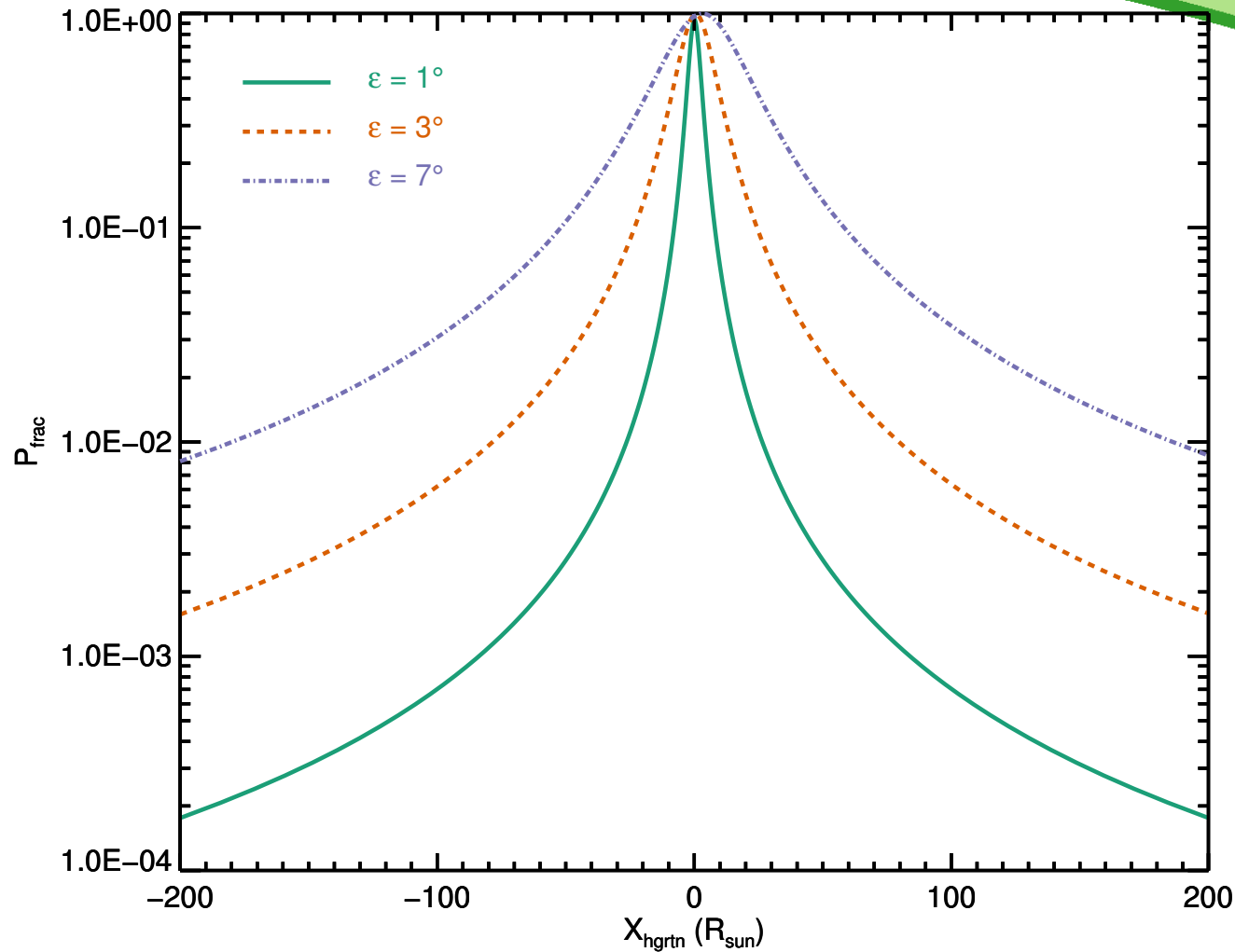
Polarimetric Localization

CME polarization is measured using three polarizers. The measured polarization fraction within a CME can be related to the source location relative to the plane of the sky [Moran and Davila, 2004].



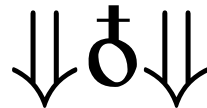
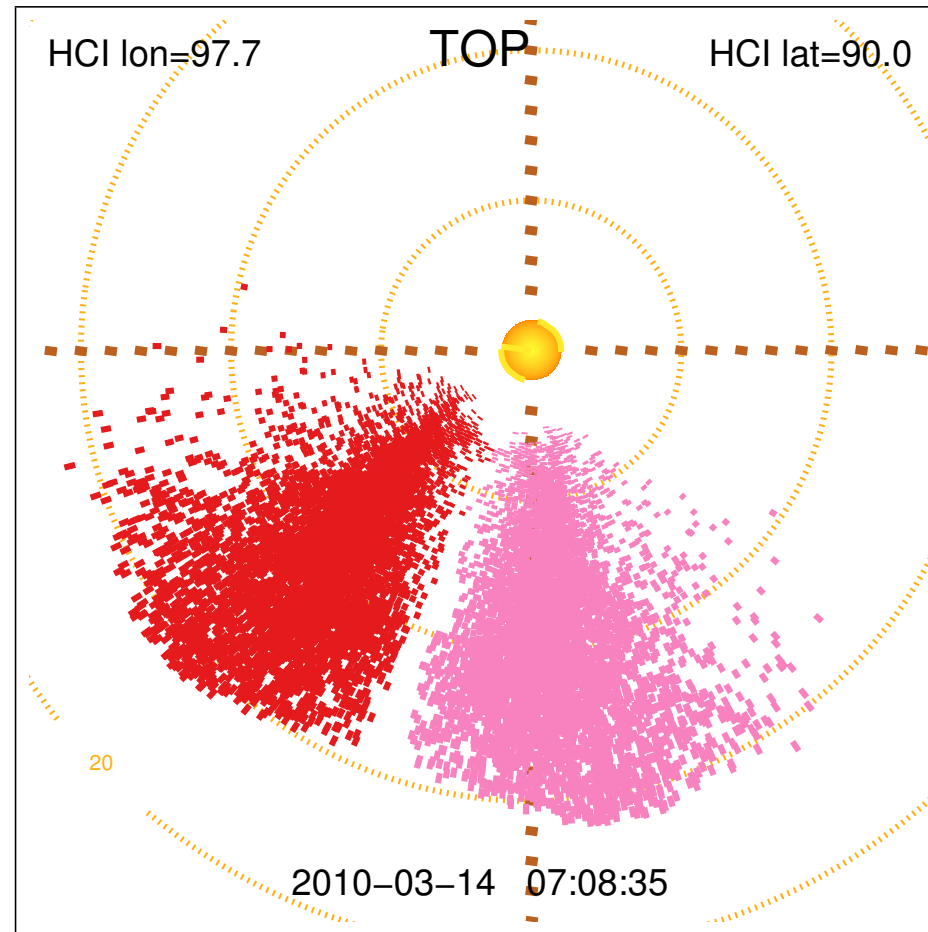
Polarimetric Localization

This technique yields only the distance from the plane of the sky, $|X|$. In other words, for a fixed elongation angle, an object in front of or behind the plane of the sky can have the same P_{frac} .



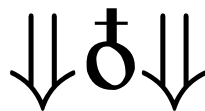
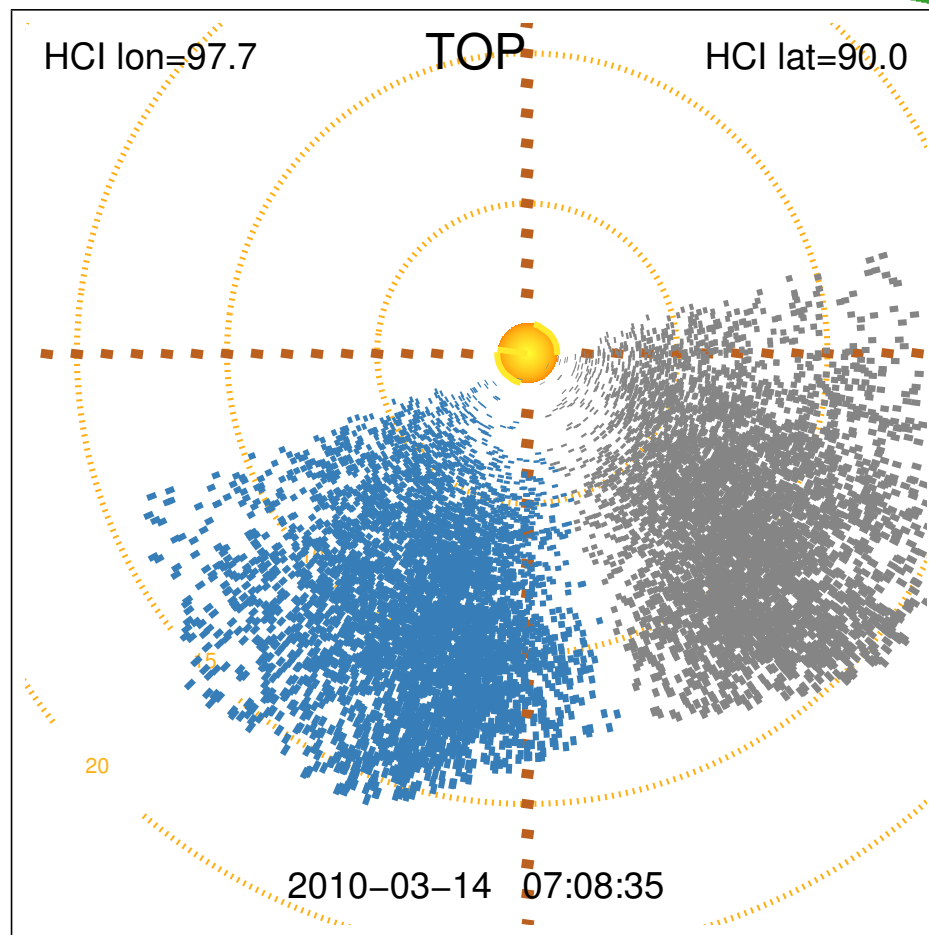
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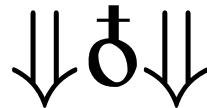
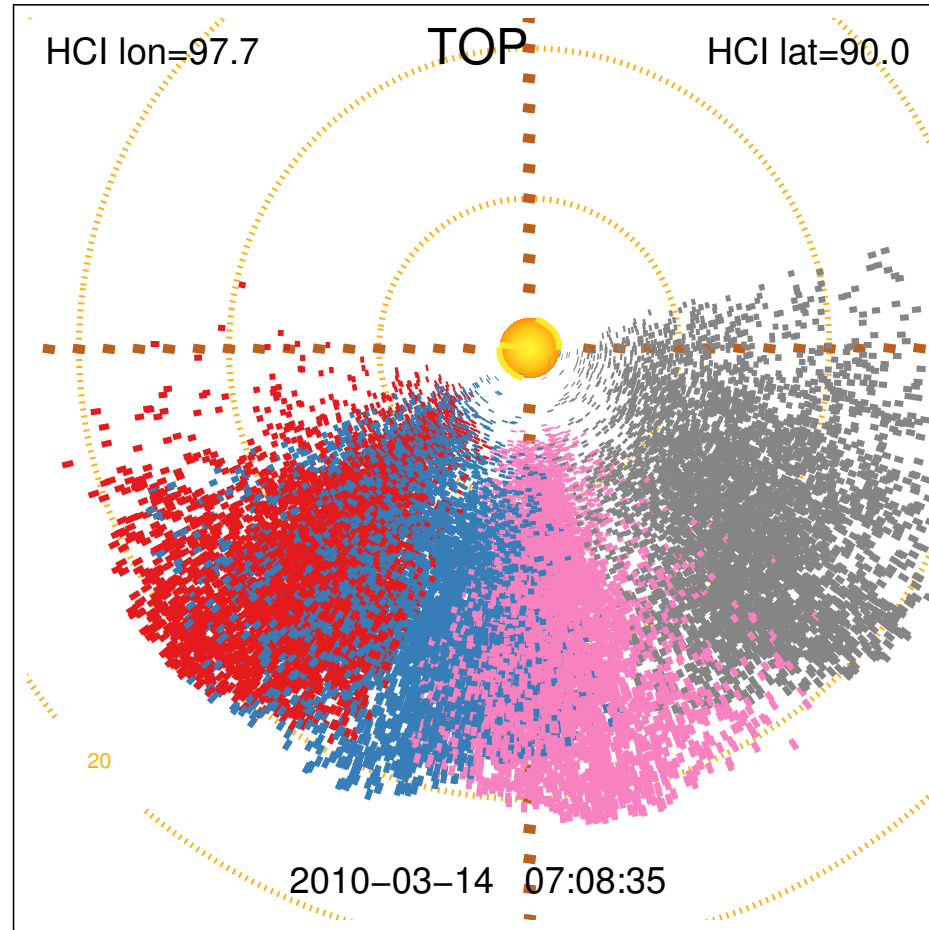
Polarimetric Localization

Note that polarimetric localization biases the CME location toward the spacecraft plane of sky.



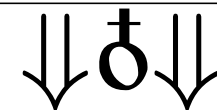
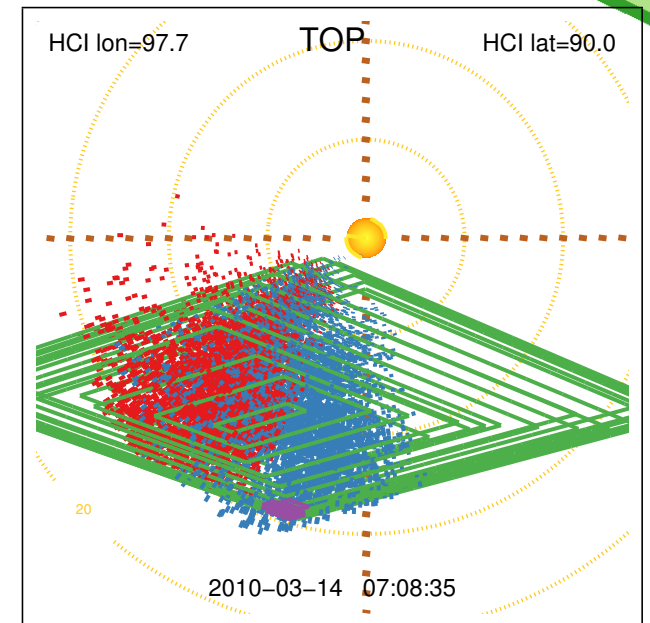
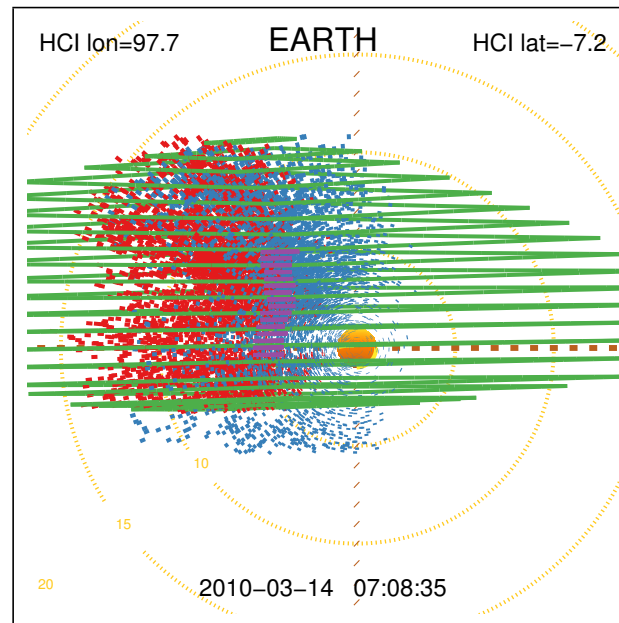
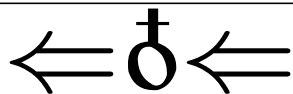
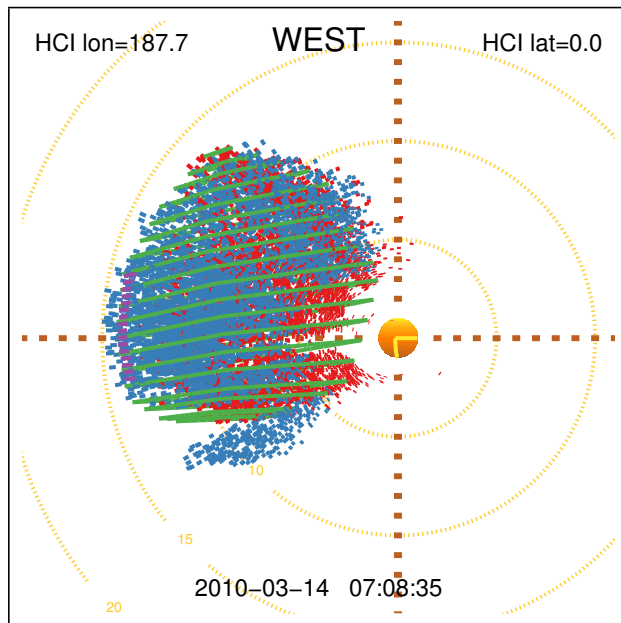
Polarimetric Localization

Using polarization data from two spacecraft will remove the ahead-of/behind plane-of-sky ambiguity.



Localization Results

Location of CME within 3D space on 2010 March 14 at 0708 UT.

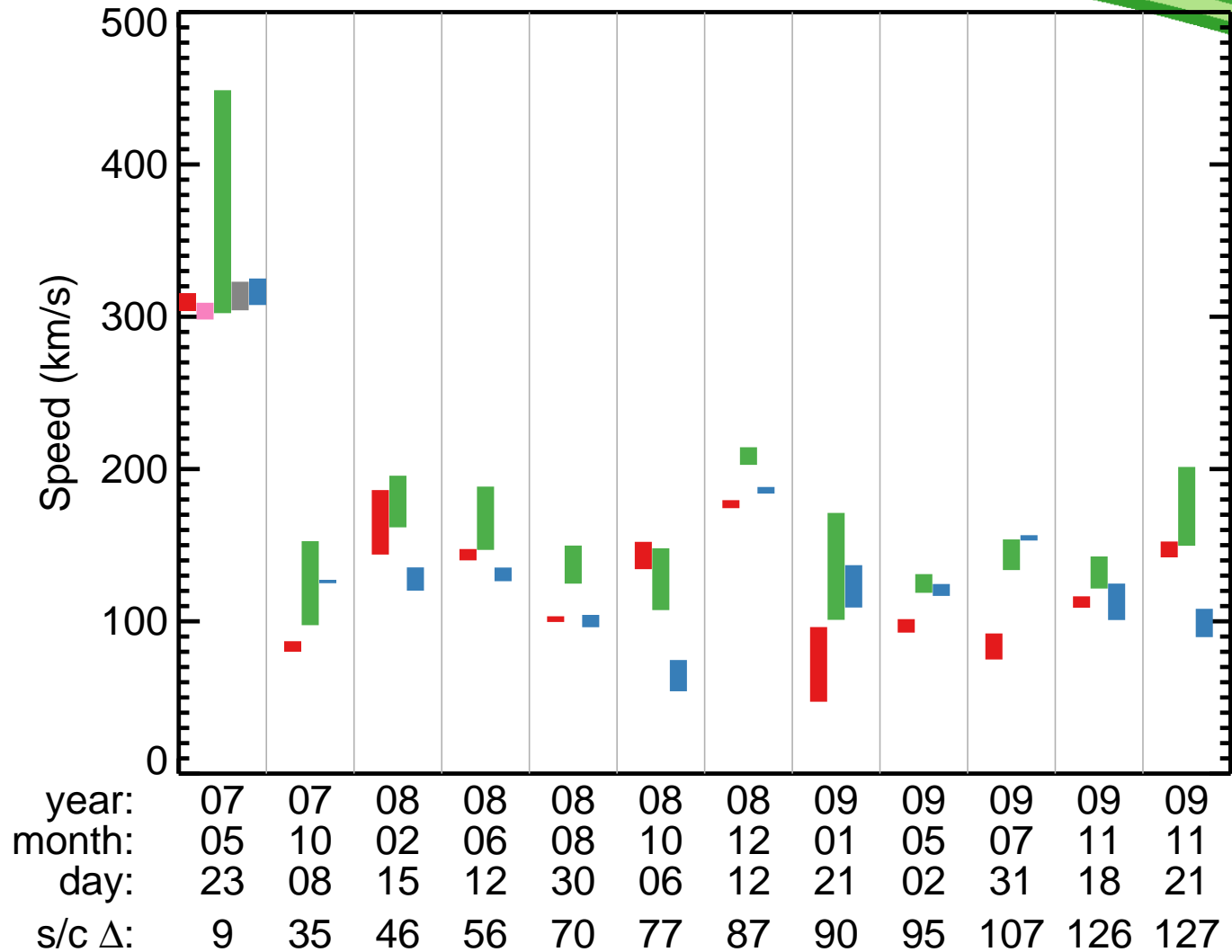


Velocity summary for CME of 2010 March 14.

	Speed (km·s ⁻¹)	Latitude (° N)	Longitude (° W)
.....			
cent (PL-A)	153 ± 9	21 ± 2	-48 ± 4
cent (PL-B)	149 ± 7	22 ± 3	-40 ± 3
cent (GL)	195 ± 42	21 ± 8	-55 ± 11
.....			
cent (PL-A)	278 ± 57	-8 ± 5	-64 ± 7
cent (PL-B)	232 ± 30	4 ± 10	-20 ± 5
LE (GL)	247 ± 39	5 ± 3	-39 ± 10

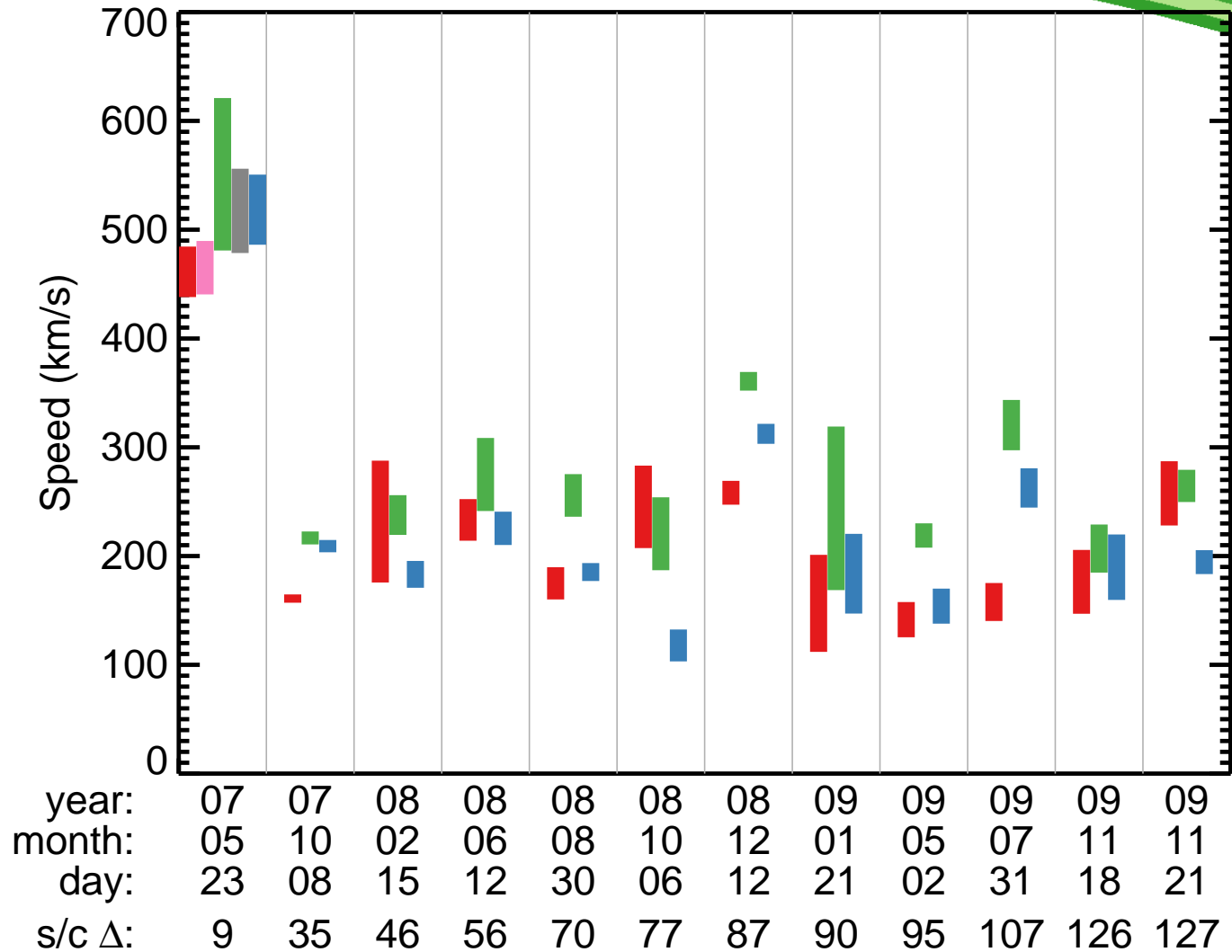
Velocity Summary

Centroid speed for 12 CMEs.



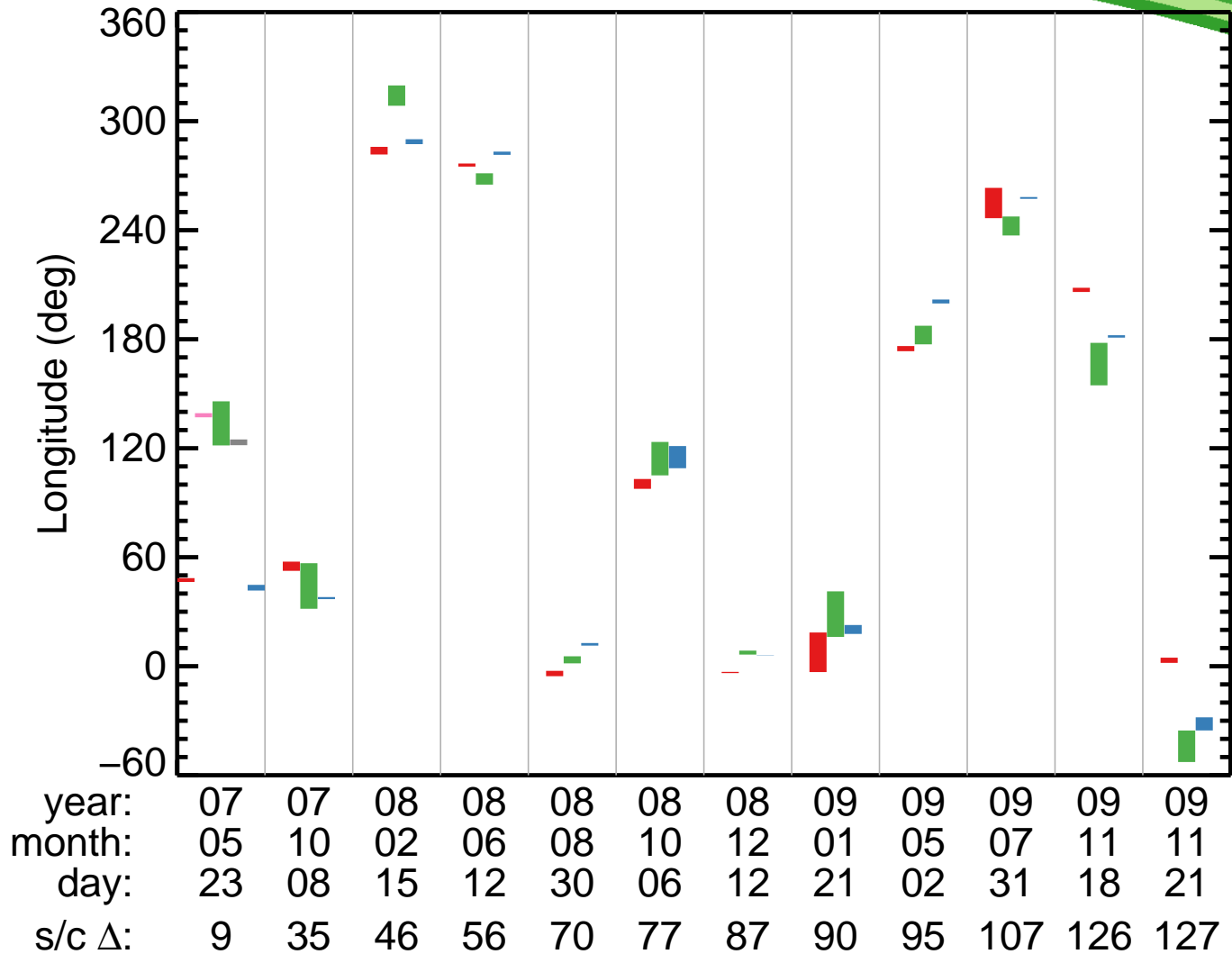
Velocity Summary

Leading-edge speed for 12 CMEs.



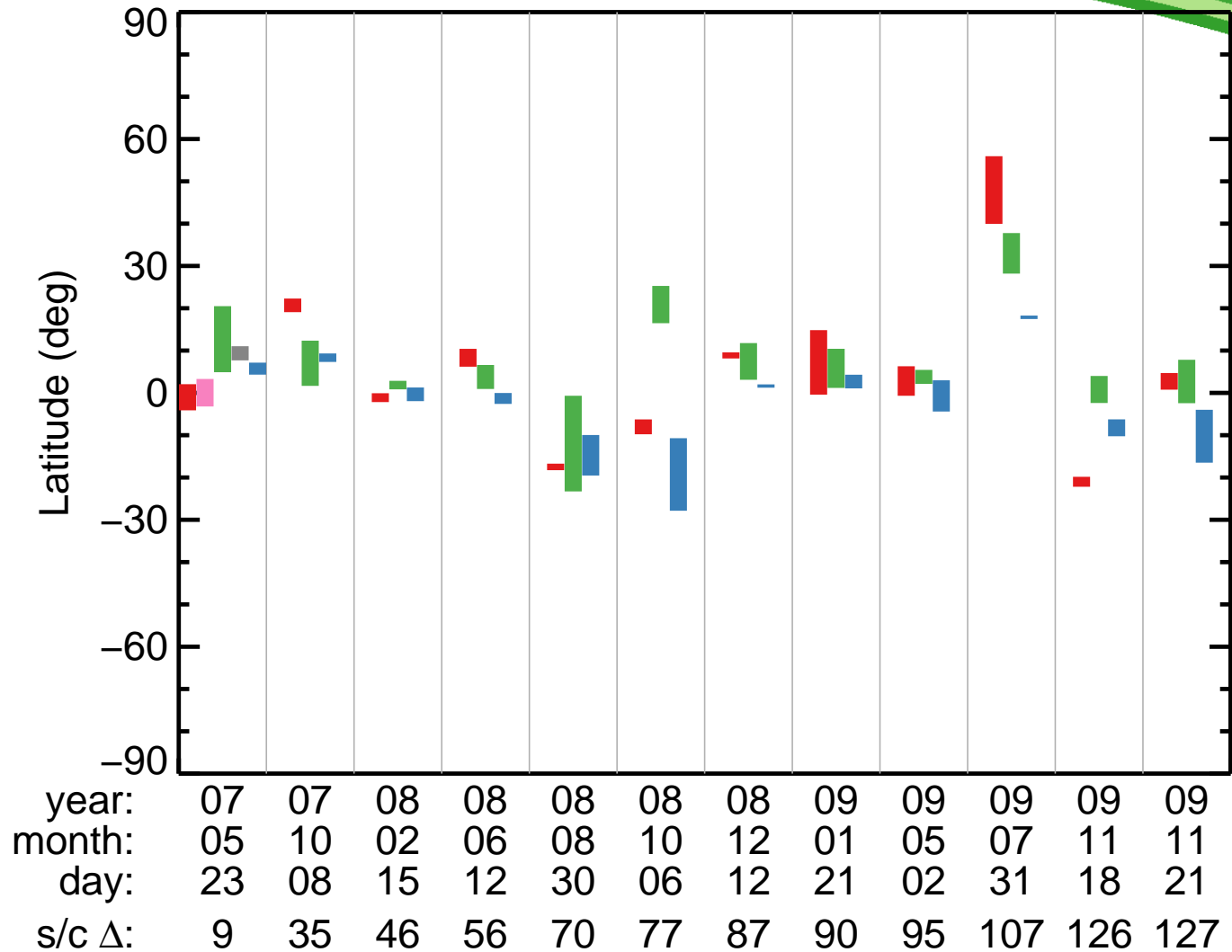
Velocity Summary

Direction of propagation (longitude) for 12 CMEs.



Velocity Summary

Direction of propagation (latitude) for 12 CMEs.



CONCLUSIONS

Both localization techniques are ...

- ▶ straightforward to apply,
- ▶ usable in near-real time—A temporal sequence of COR2 beacon images for a single CME can be analyzed in less than 10 minutes.

The random error in the computed CME velocity ...

- ▶ does not appear to depend on spacecraft separation;
- ▶ is frequently less than 10%.

From such analyses we can readily compute the centroid, leading-edge, and expansion velocities for the CME.

CONCLUSIONS

Geometric localization . . .

- ▶ requires two spacecraft;
- ▶ is totally geometric in nature, that is, it makes zero assumptions about CME shape.

CONCLUSIONS

Polarimetric localization . . .

- ▶ requires only one spacecraft;
- ▶ requires well-known equations of Billings [1966];
- ▶ is biased to the plane of sky.

CONCLUSIONS

Polarimetric localization . . .

- ▶ requires only one spacecraft;
- ▶ requires well-known equations of Billings [1966];
- ▶ is biased to the plane of sky.

Both localization techniques promise a substantial improvement in our capability to locate and characterize CMEs for forecasting.

FINAL THOUGHTS

Geometric and polarimetric localization will shortly be undergoing a limited amount of verification and validation. By October 2011 they will be “tools” within NOAA/SWPC. In that context, these techniques will provide ...

- ▶ initial forecasts of CME velocity;
- ▶ supplemental inputs, alongside a standard cone model based on SOHO data, to WSA/Enlil.

FINAL THOUGHTS

Space weather forecasting takes place in real time! Therefore ...

- ▶ forecasting techniques must work with real-time data. Real-time data ...
 - is heavily compressed and binned;
 - frequently has significant gaps in coverage.
- ▶ science data and after-the-fact beacon data may be useful for slow CMEs; however, for worst-case CMEs, such data will not be available until after the CME has impacted Earth.
- ▶ forecasting techniques must be simple. Forecasters do not have the time to do several trial and error runs in order to find the best ellipse to a fuzzy halo observed by SOHO.

2012 Dec 21 X-400 CME

