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

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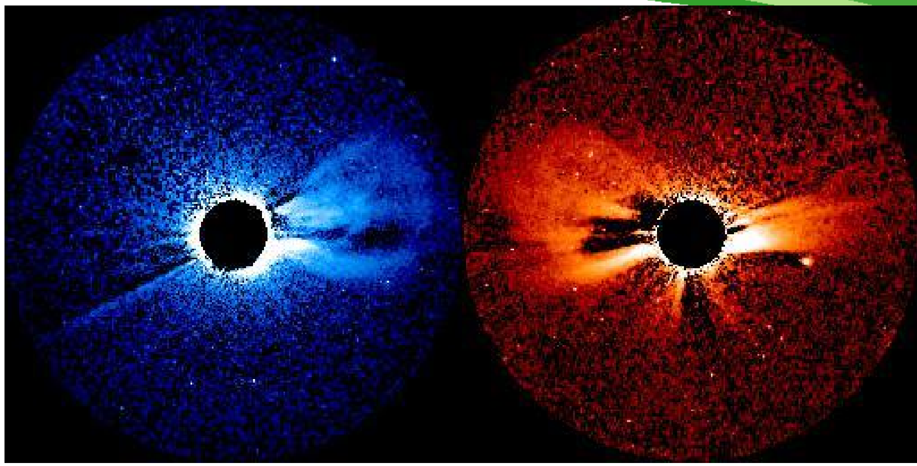
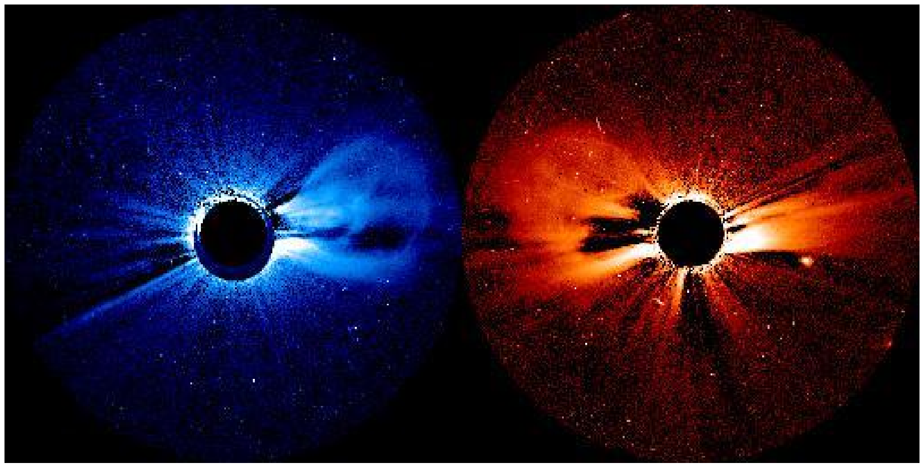
The STEREO Space Weather Beacon provides highly compressed and binned image data in near-real-time. This data provides a sufficient signal-to-noise ratio for space weather forecasting.

Beacon: 256×256

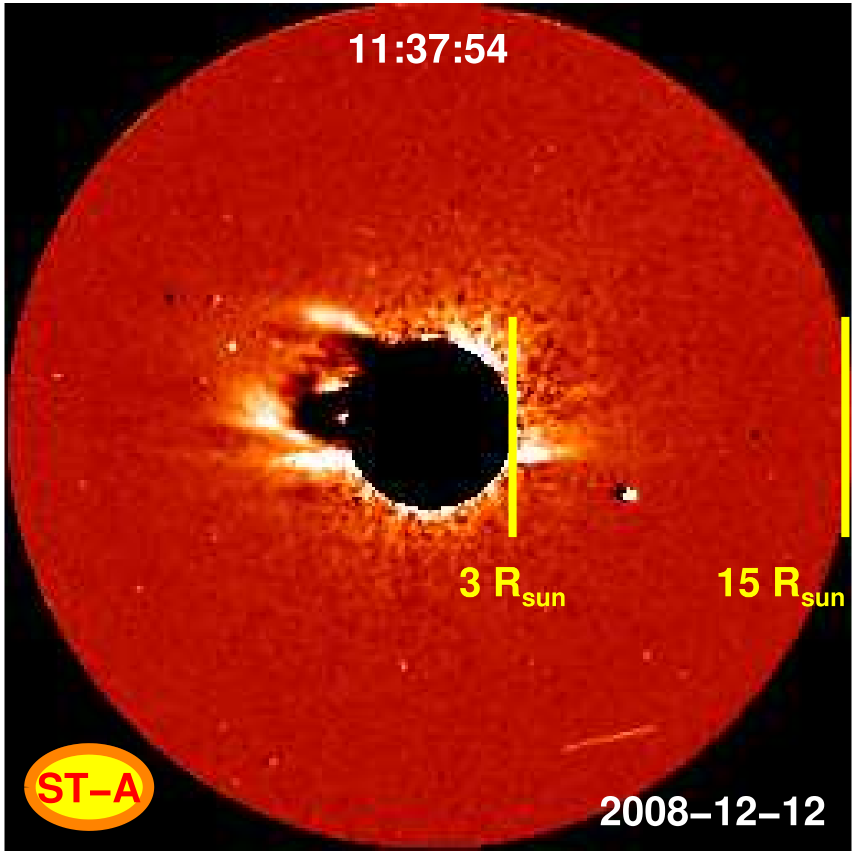


2008-12-12 1422 UT

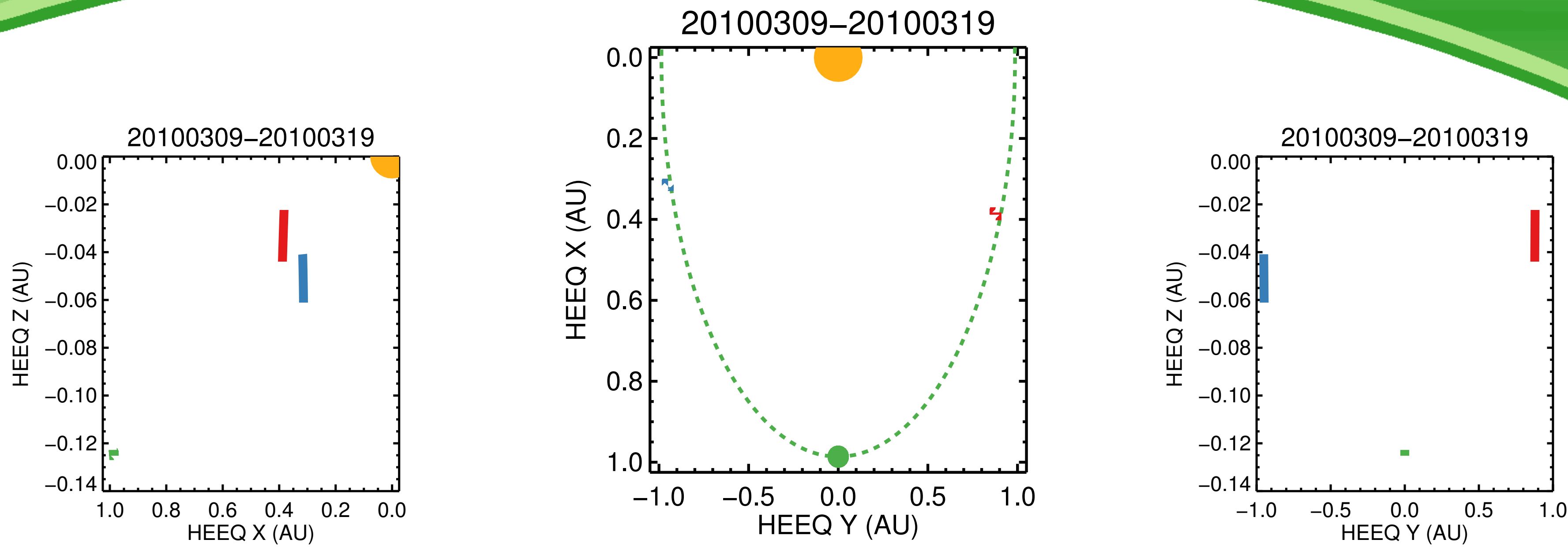


Science: 2048×2048

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.



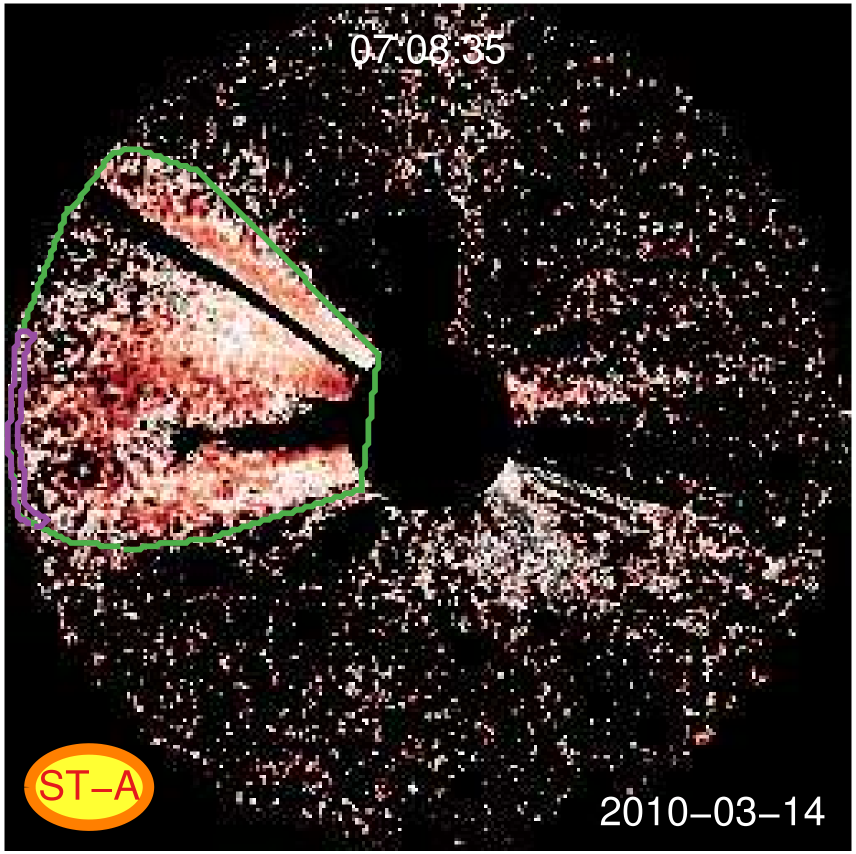
Position of STEREO-A, STEREO-B, and Earth around 2010 March 14.

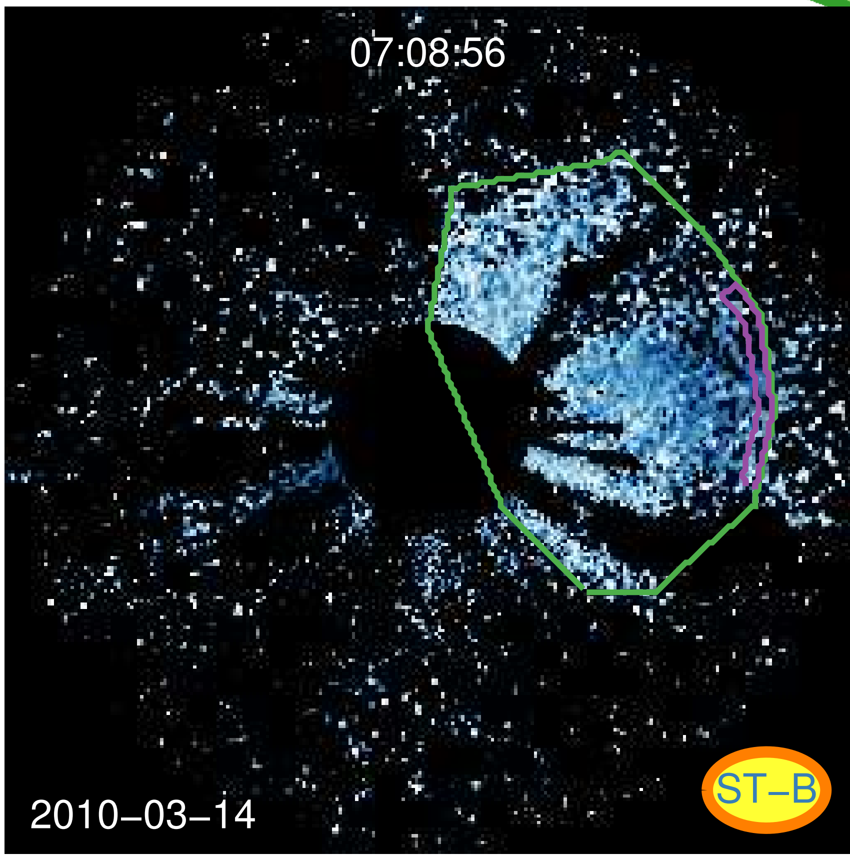


	A	E	B
Heliocentric radius (AU)	0.9597	0.9941	1.003
Heliographic (HEEQ) longitude	66.285	0.000	-71.660
Heliographic (HEEQ) latitude	-1.985	-7.182	-2.923
Separation angle with Earth	66.226		71.447
Separation angle A with B		137.668	

Geometric and Polarimetric Localization

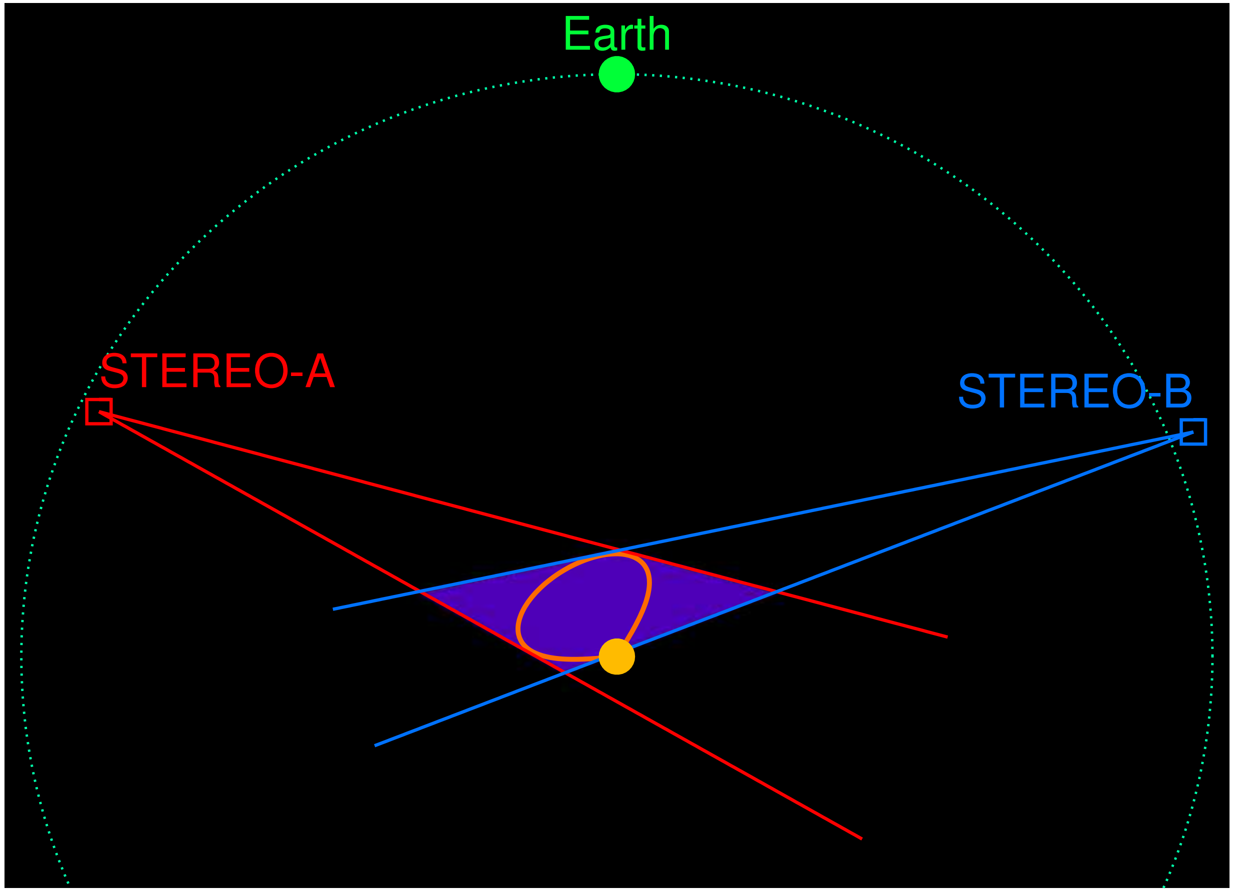
Example taken from CME observed on 2010 March 14 at 0708 UT; manually selected CME and leading-edge boundaries are superimposed on COR2 beacon image.





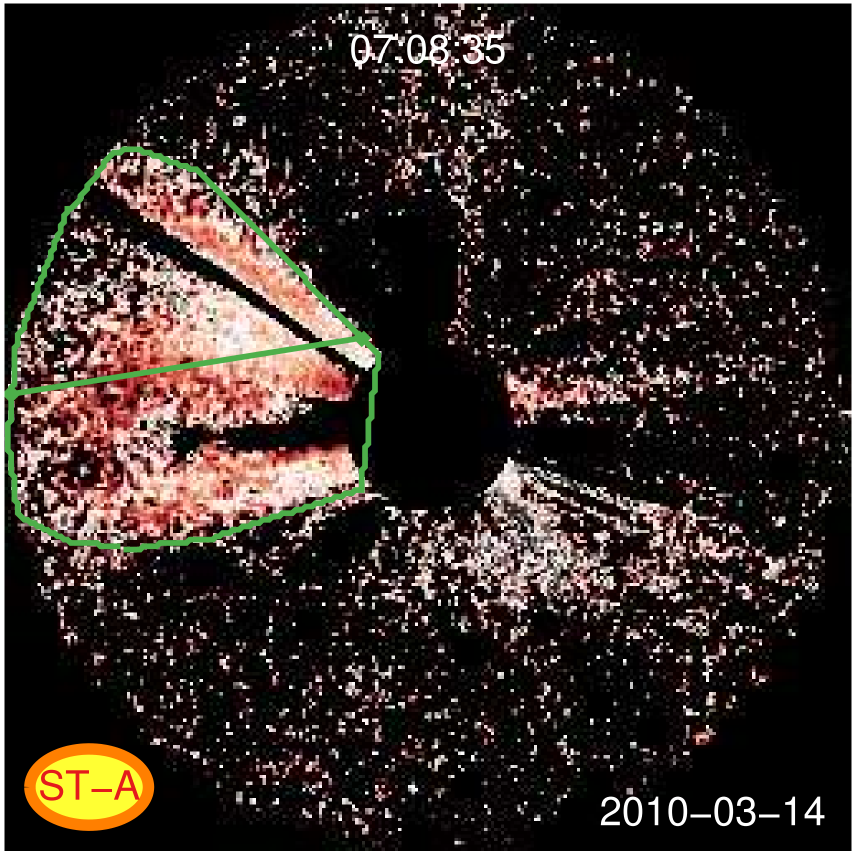
Geometric Localization [Pizzo and Biesecker, 2004]

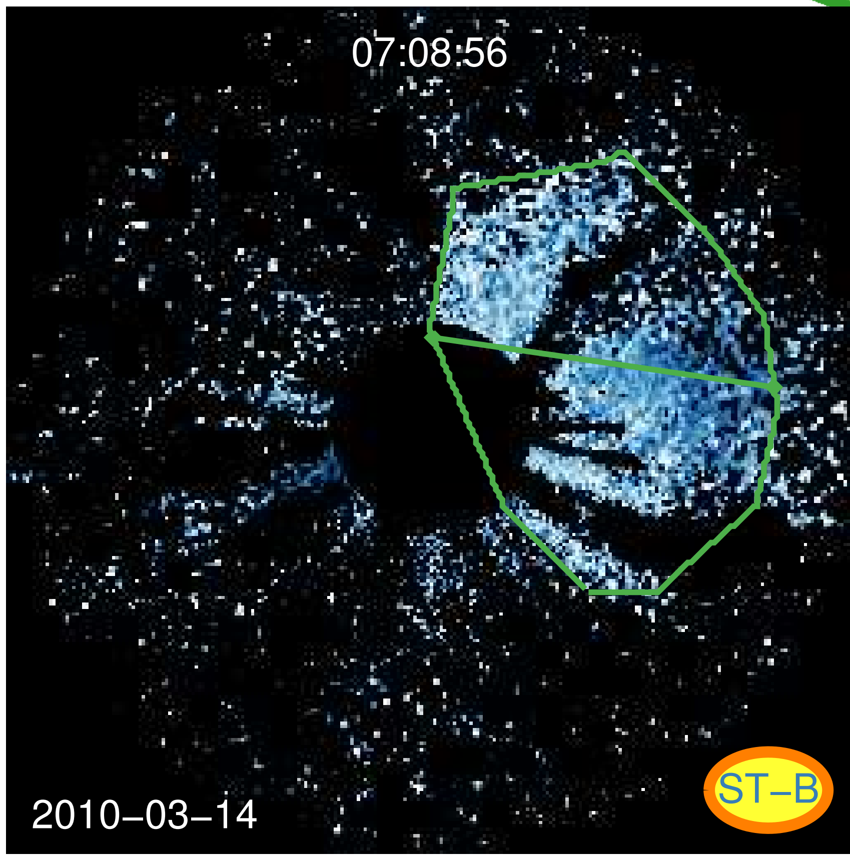
The locater algorithm should quickly determine CME location and velocity and run in nearly automated mode; therefore, it must be simple, robust, and easy to use.



Geometric Localization

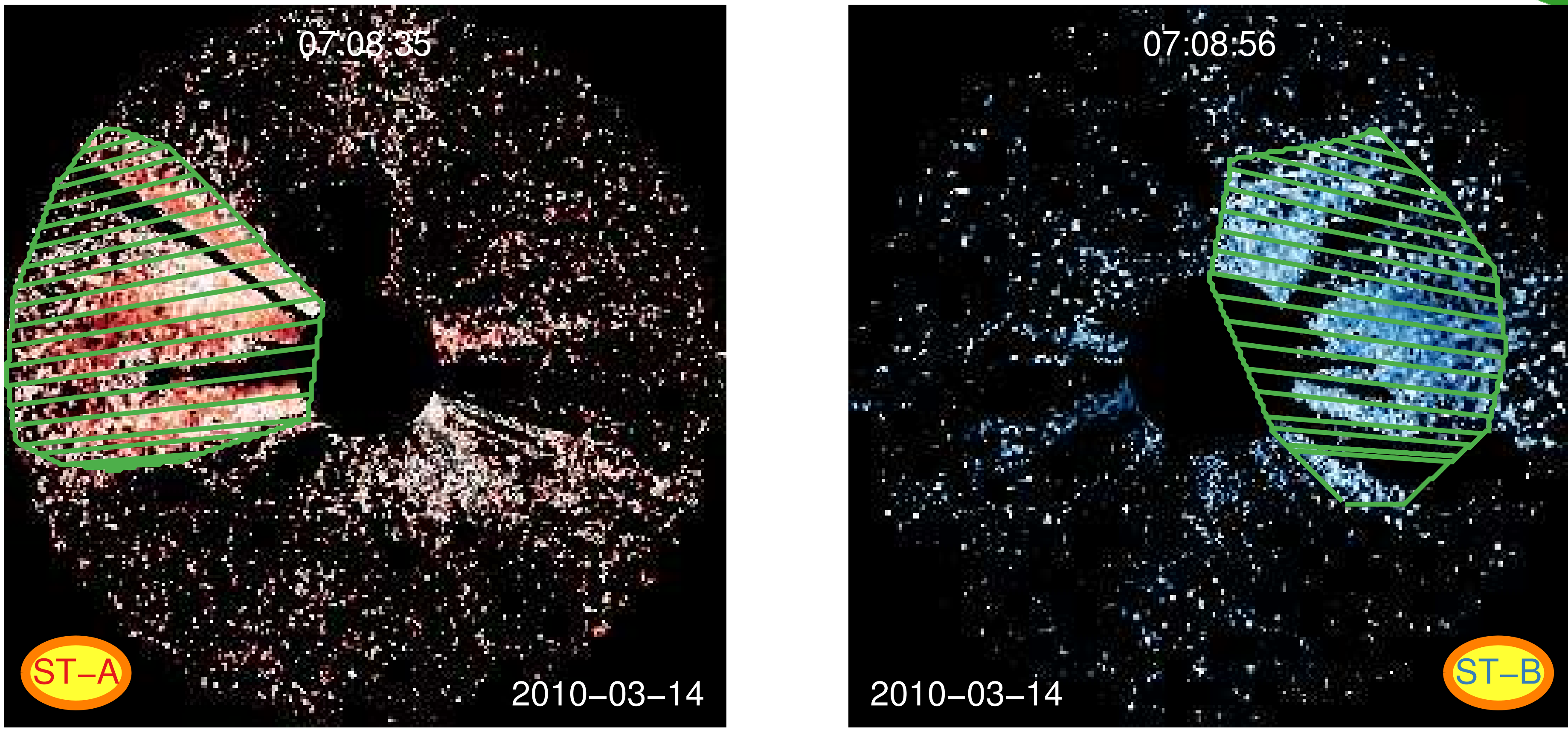
The program automatically chooses a plane that contains the spacecraft and cuts through the two images of the CME.





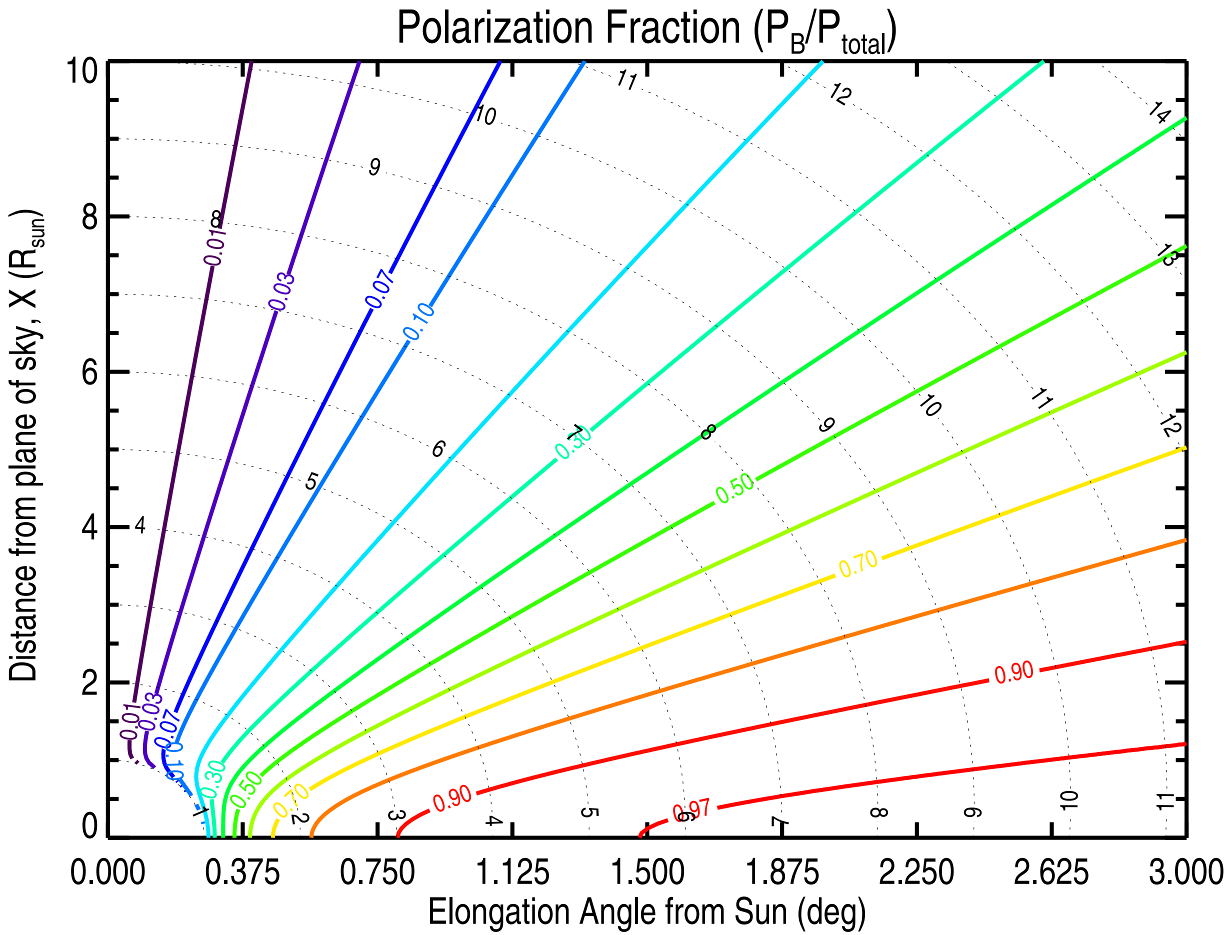
Geometric Localization

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



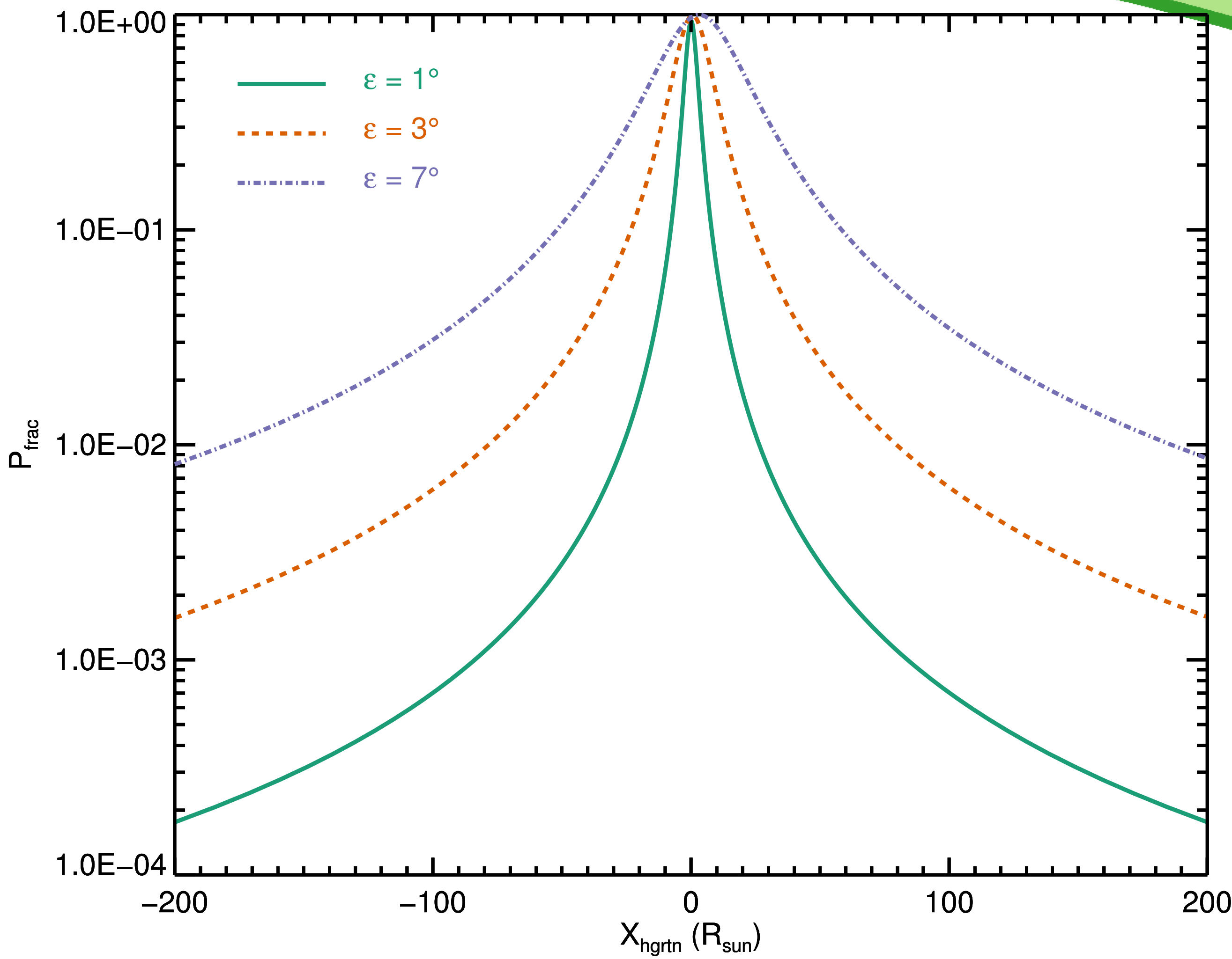
Polarimetric Localization

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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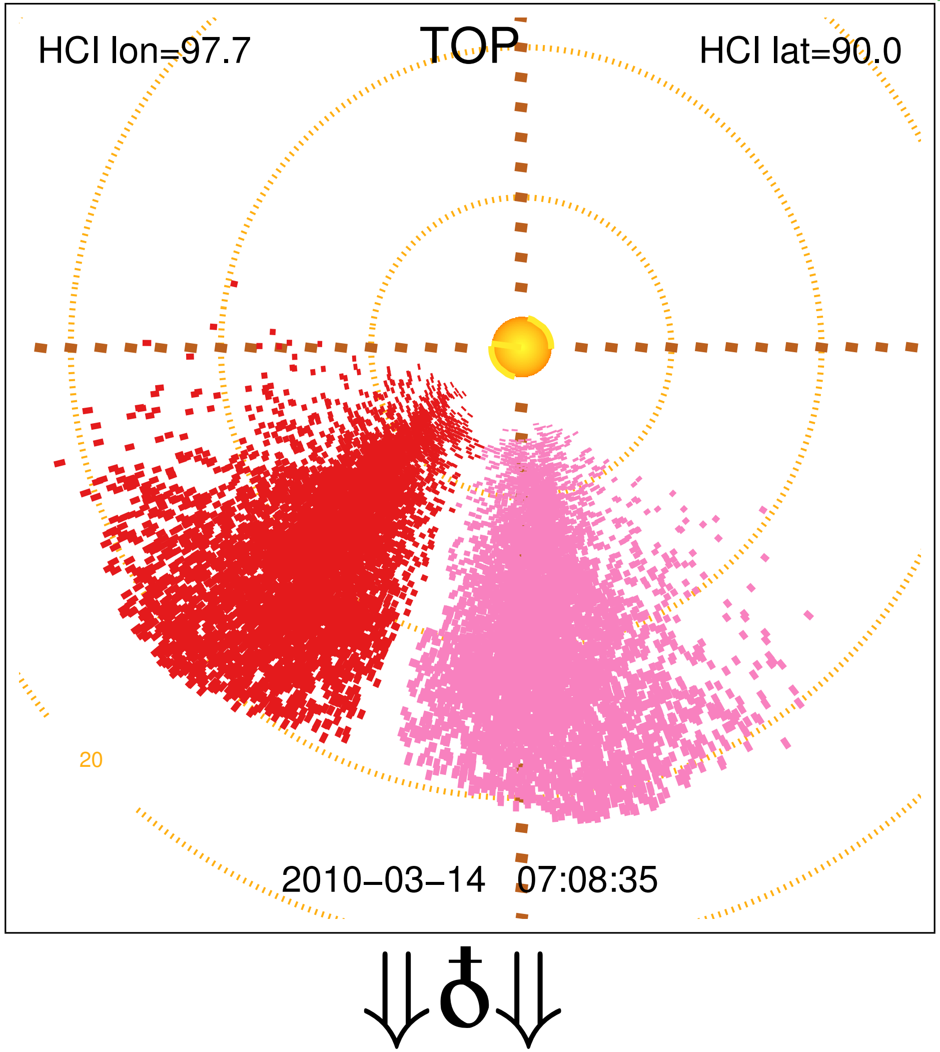
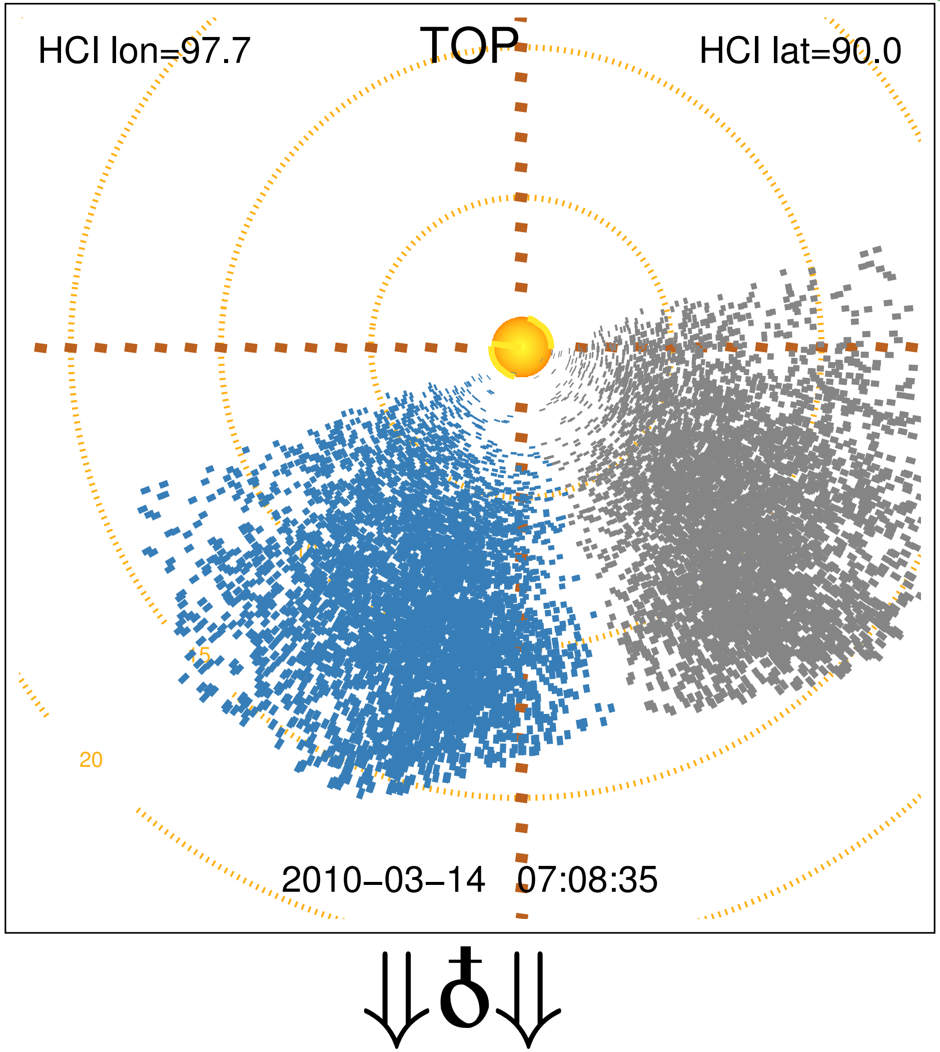


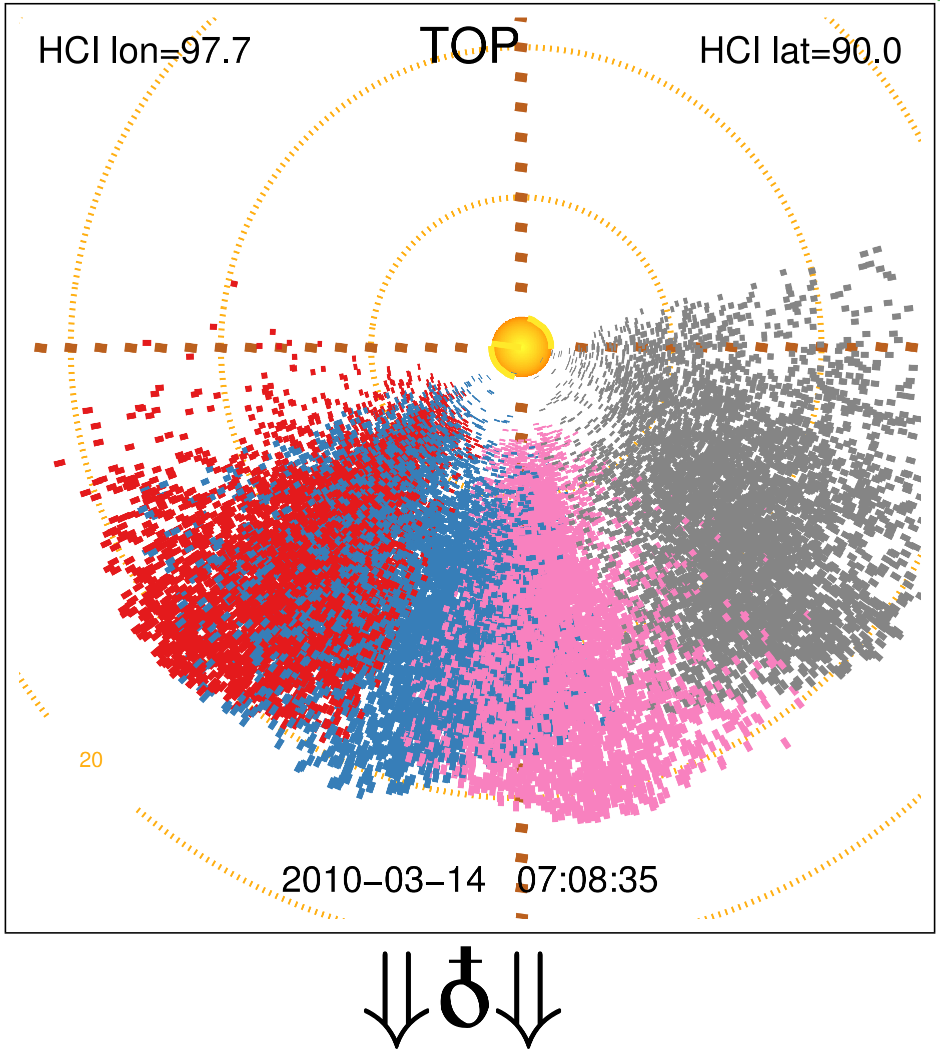
Polarimetric Localization

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



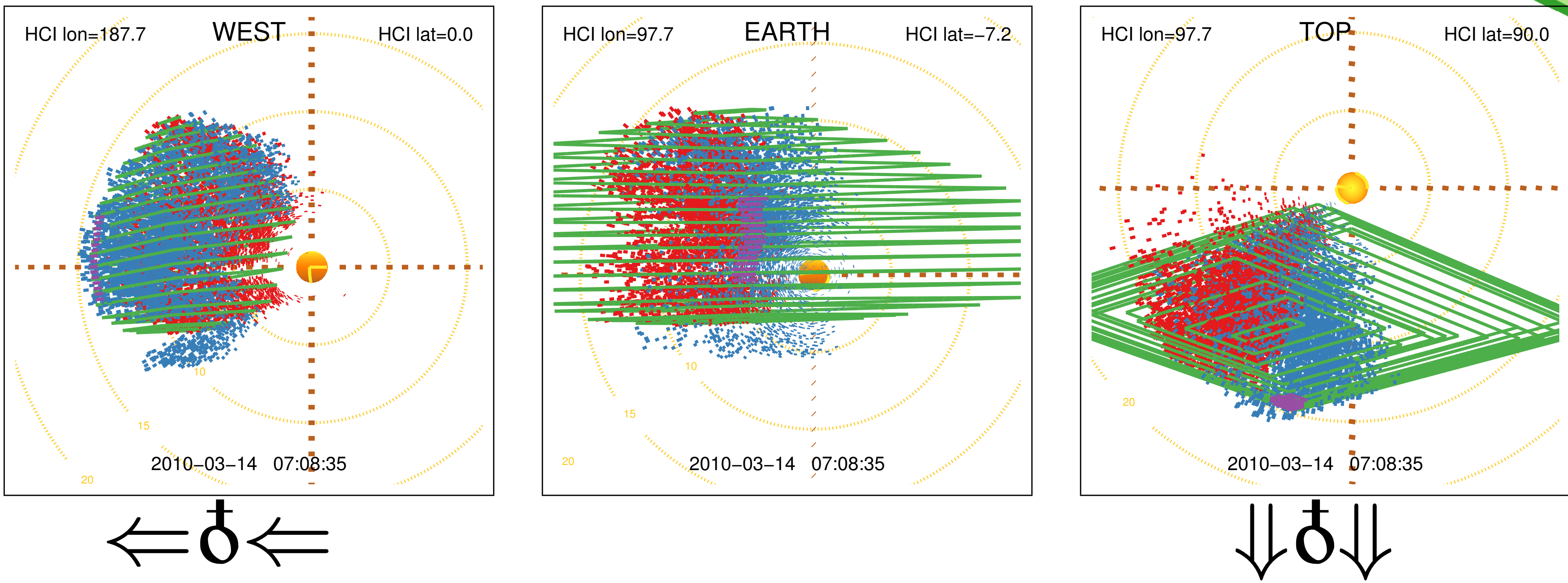
Polarimetric Localization

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.

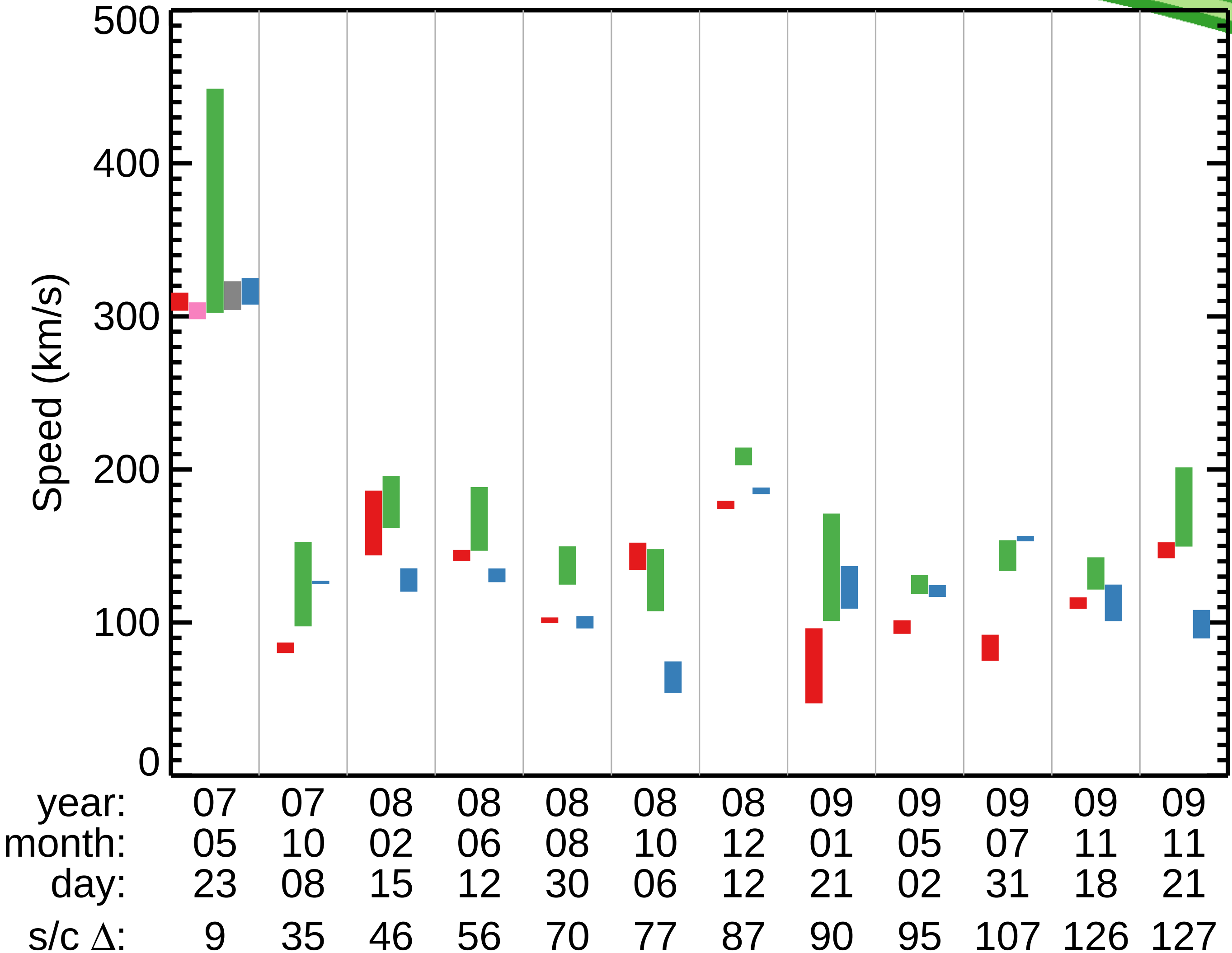


Velocity summary for CME of 2010 March 14.

	Speed ($km \cdot s^{-1}$)	Latitude ($^\circ$ N)	Longitude ($^\circ$ 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

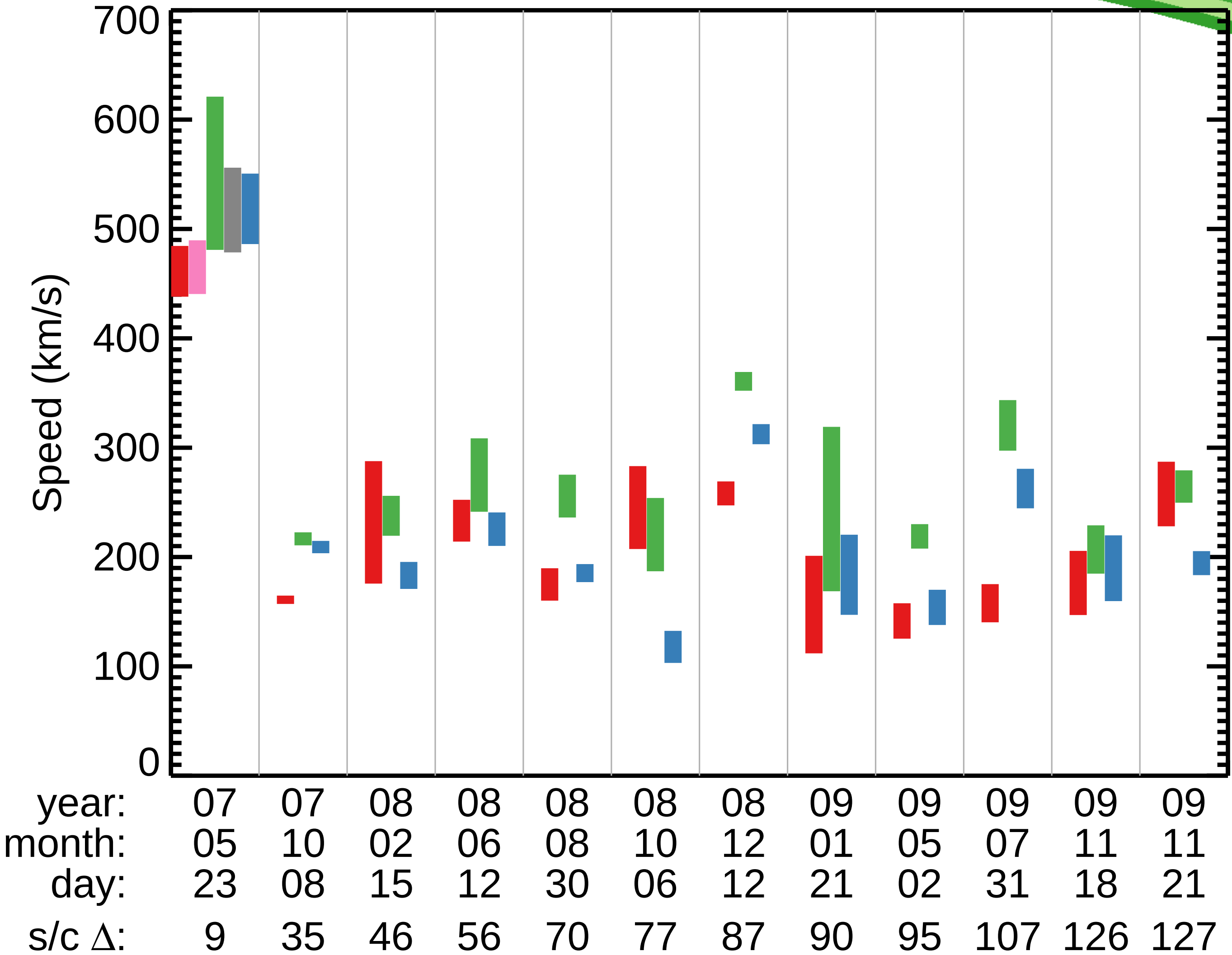
Velocity Summary

Centroid speed for 12 CMEs.



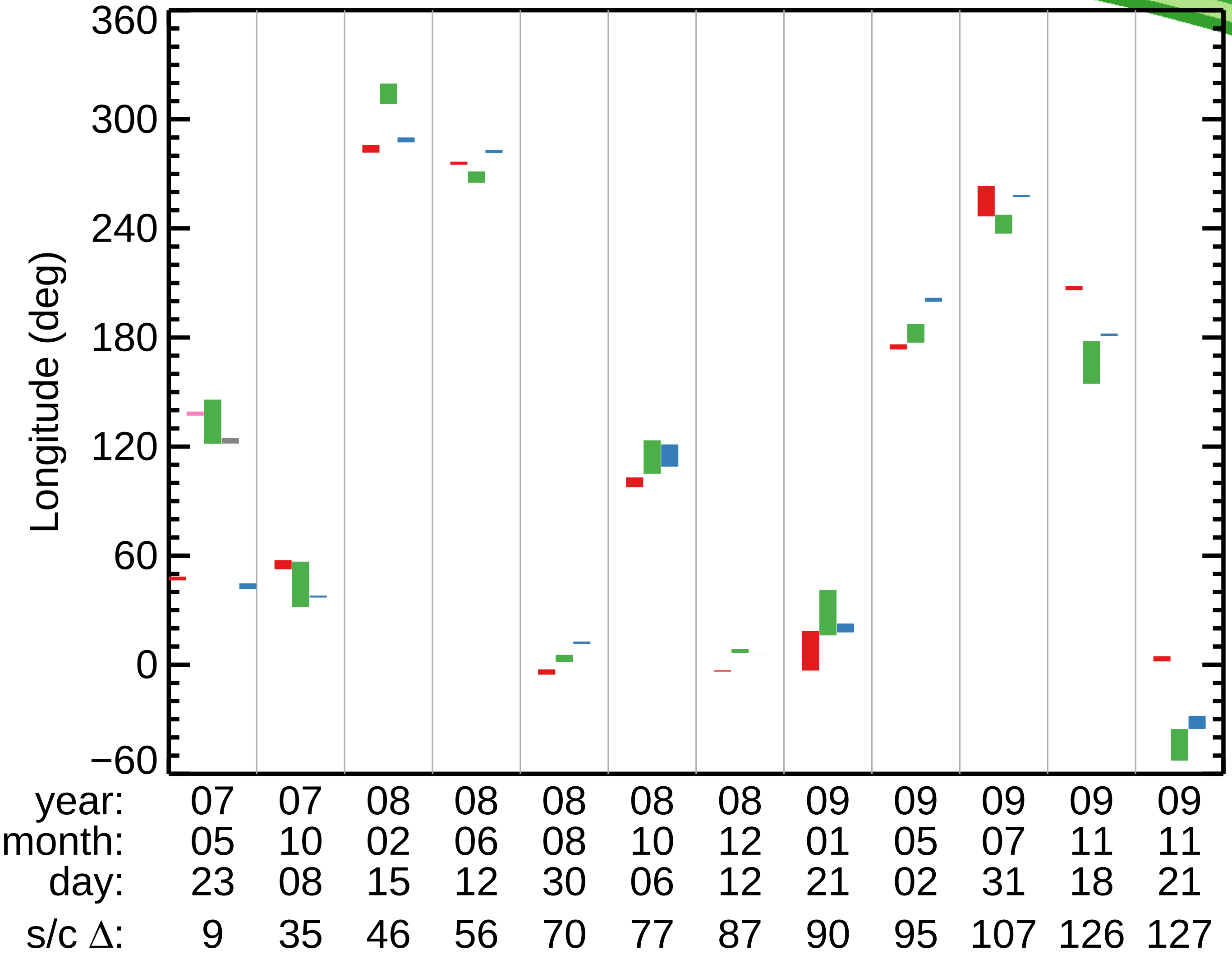
Velocity Summary

Leading-edge speed for 12 CMEs.



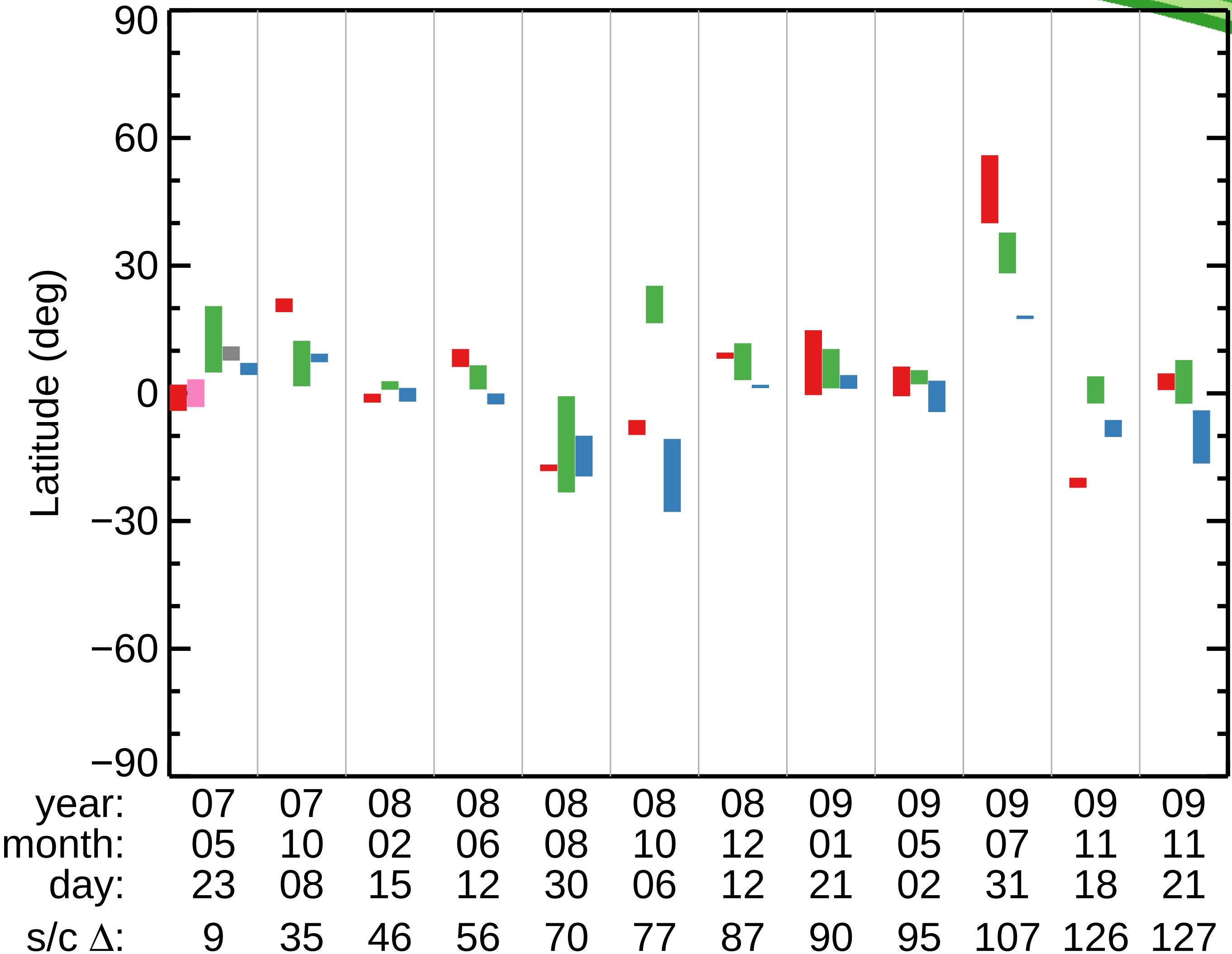
Velocity Summary

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.

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Polarimetric localization . . .

- requires only one spacecraft;
- requires well-known equations of Billings [1966];
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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