COROTATING STREAMS OBSERVED BY STEREO.

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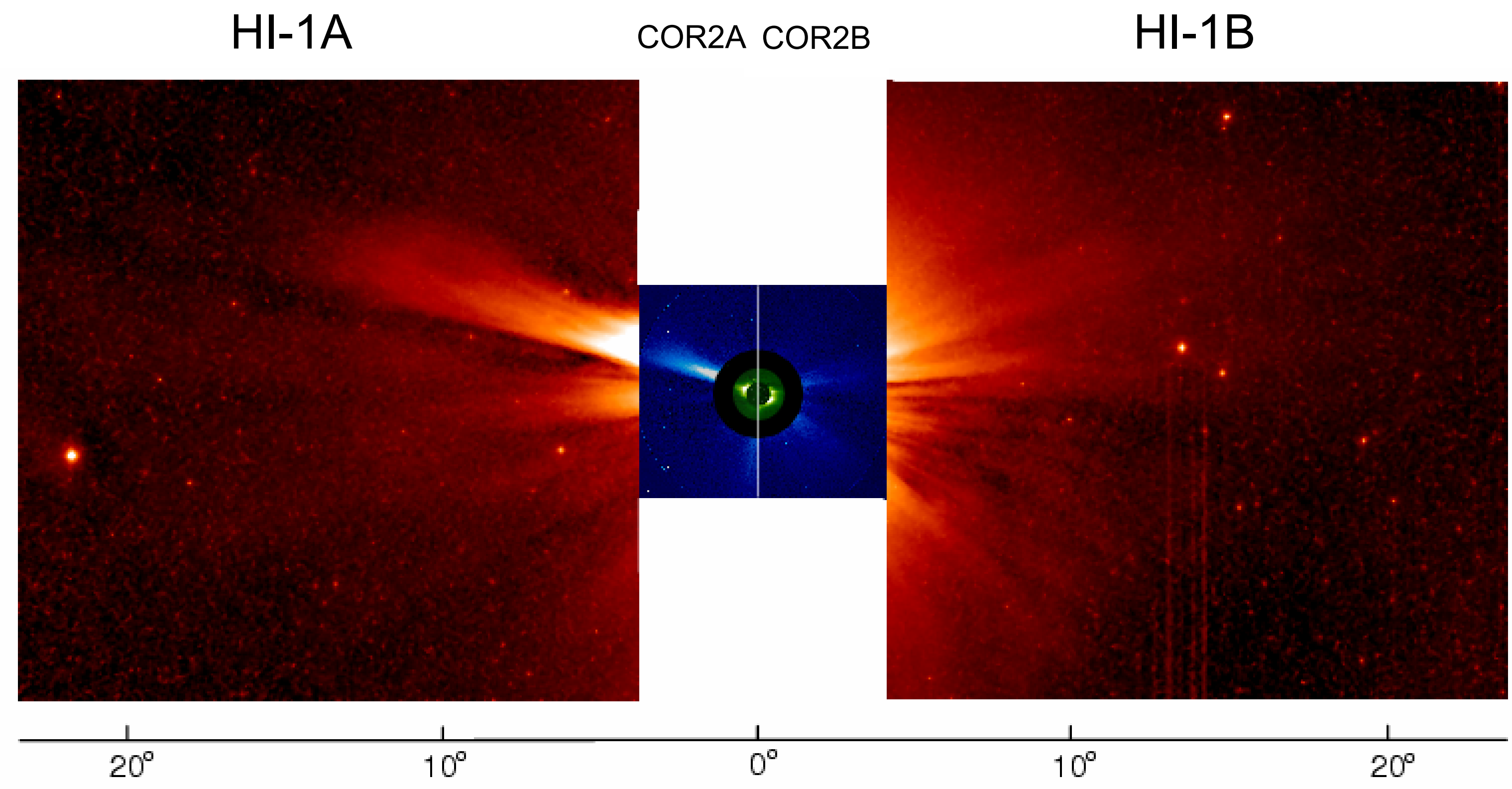
Streamers observed with COR and HI



Elongation angle along the central row

Rouillard et al., JGR, 2008

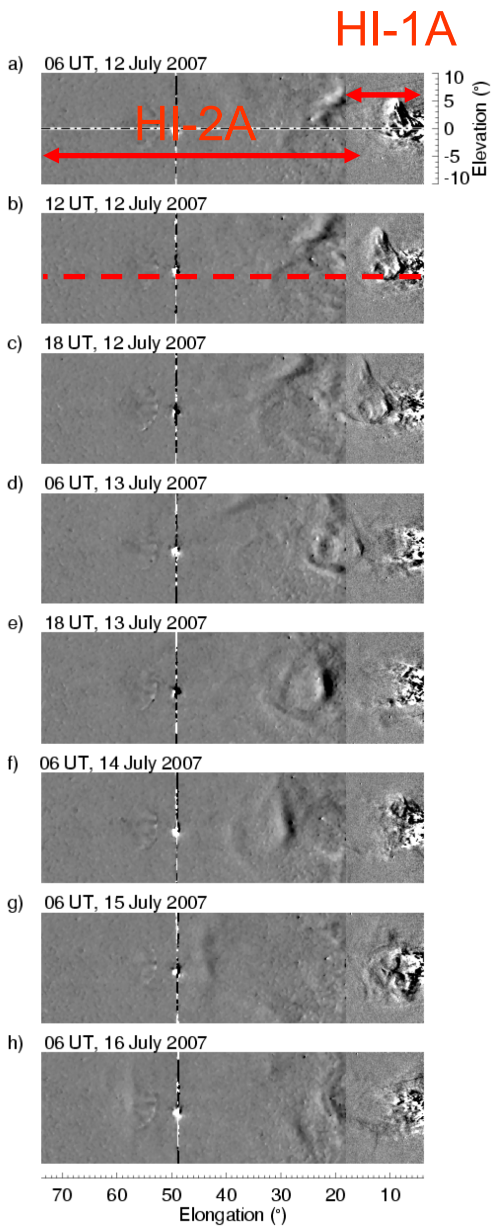
HI observations

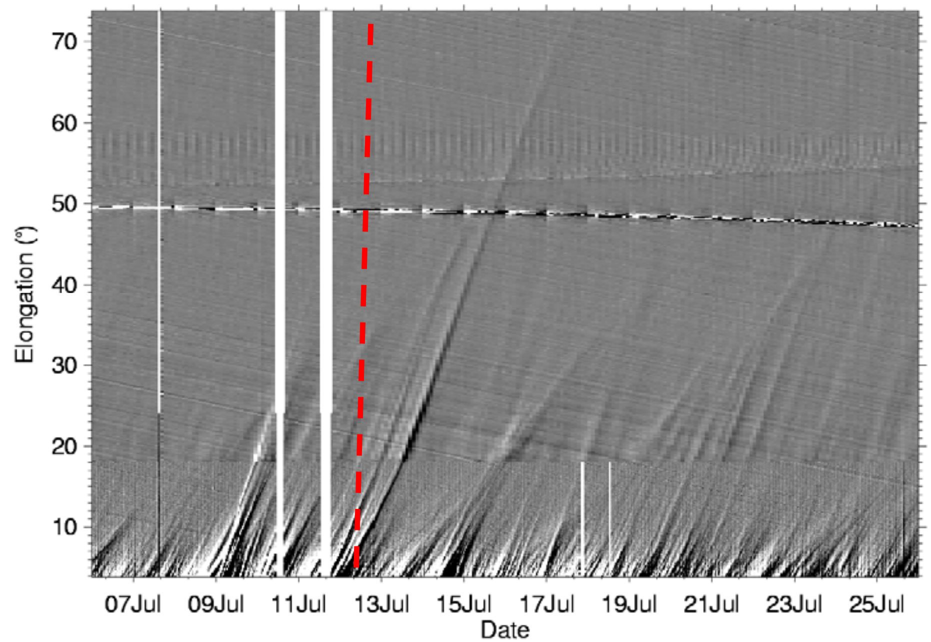
→ HI can observe many out-flowing parcels of varying brightness in each recorded frame (images can be complicated and we are still at solar minimum!)

→ These parcels can be linked to dense ejecta (CME-type), the variability solar wind or even Corotating Interaction Regions.

→ Techniques had to be developed to 'educate' ourselves on what HI is observing.

Creating J-plots from difference images of Hi1A



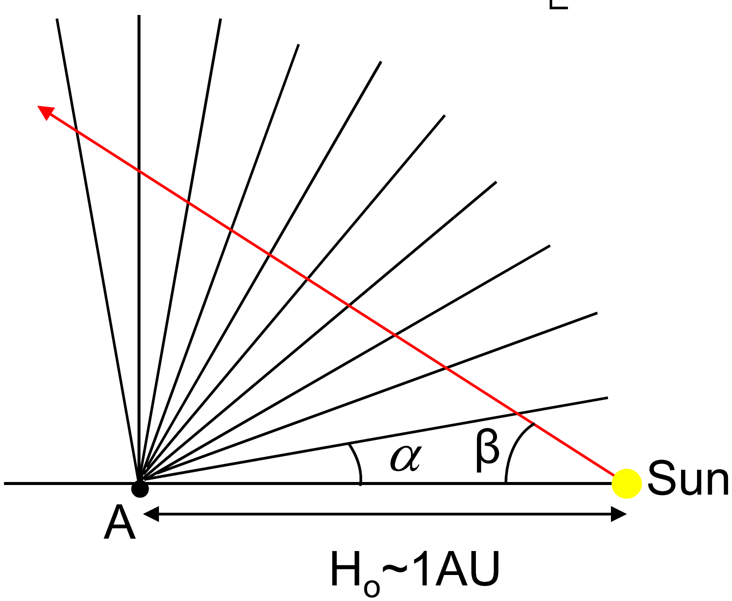


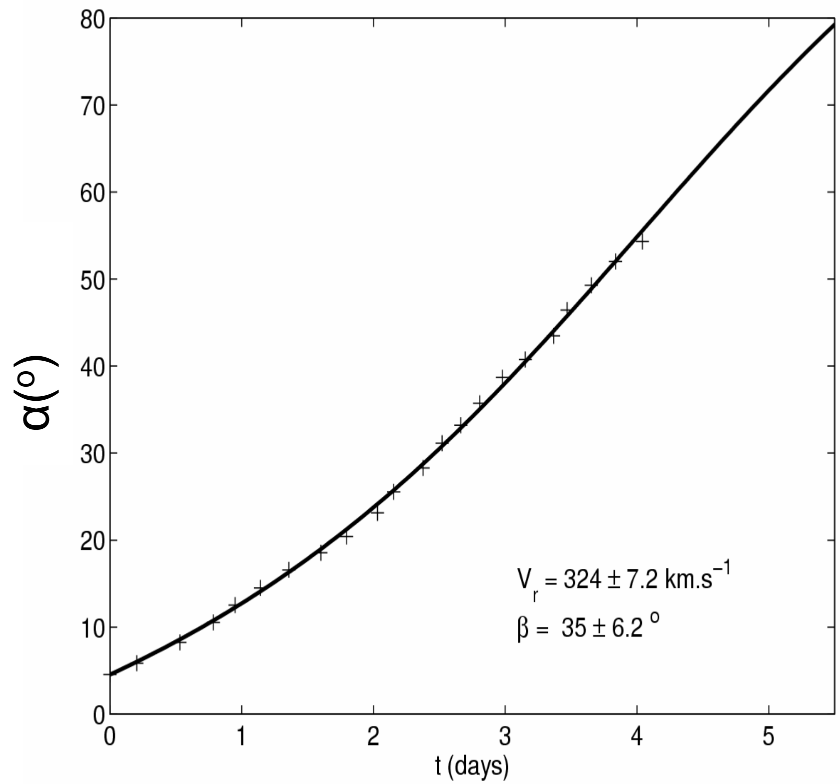
J-maps are created by extracting the central row of each image and plotting it vertically (Davies et al., 2008).

Apparent Acceleration

Assuming the CME propagates radially out and at a constant speed, the elongation variation with time $\alpha(t)$ will not be a straight line:

$$\alpha(t) = \arctan\left[\frac{vt\sin(\beta)}{H_o - vt\cos(\beta)}\right]$$





Sheeely et al., JGR (1999)

Trajectories of radially out-flowing transients

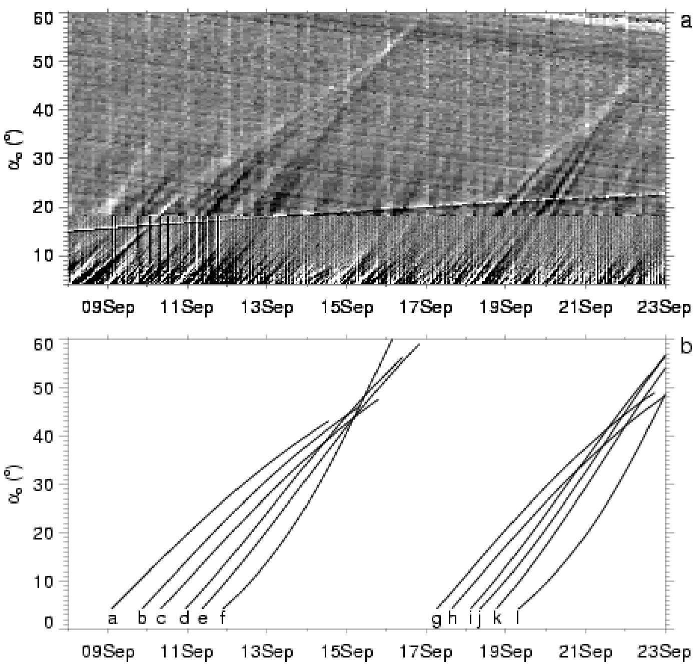
The fitting technique was found extremely successful at:

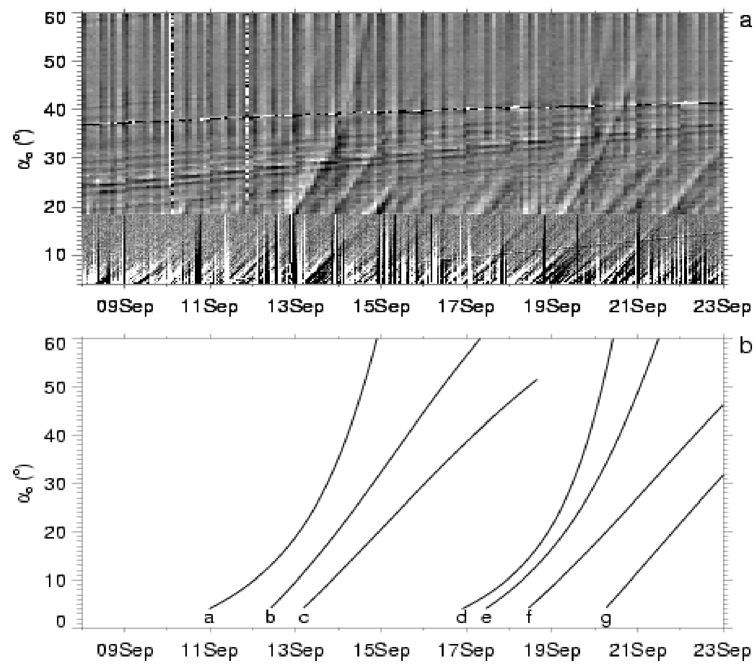
→ Determining whether CMEs would hit particular planet (e.g: 2 CMEs tracked to Venus) or spacecraft (e.g.: Ulysses)

→ The accuracy of the fitting depends on the extent of the tracks in the J-maps.

→ We are improving the code to account for spacecraft orbital motion, etc…

CIR tracks converge in A and diverge in B





Tracks converge in A

Tracks diverge in B

→ *Sheeley et al., ApJ, 2008, Sheeley et al., ApJL., 2008*

→ *Rouillard et al., GRL, 2008; Rouillard et al., JGR, 2008*

Elongation variations: corotating source

Two scenarios:

→ We are observing dense plasma expelled from the helmet streamers

→ We are observing successive plasma parcels compressed by Corotating Interaction Regions

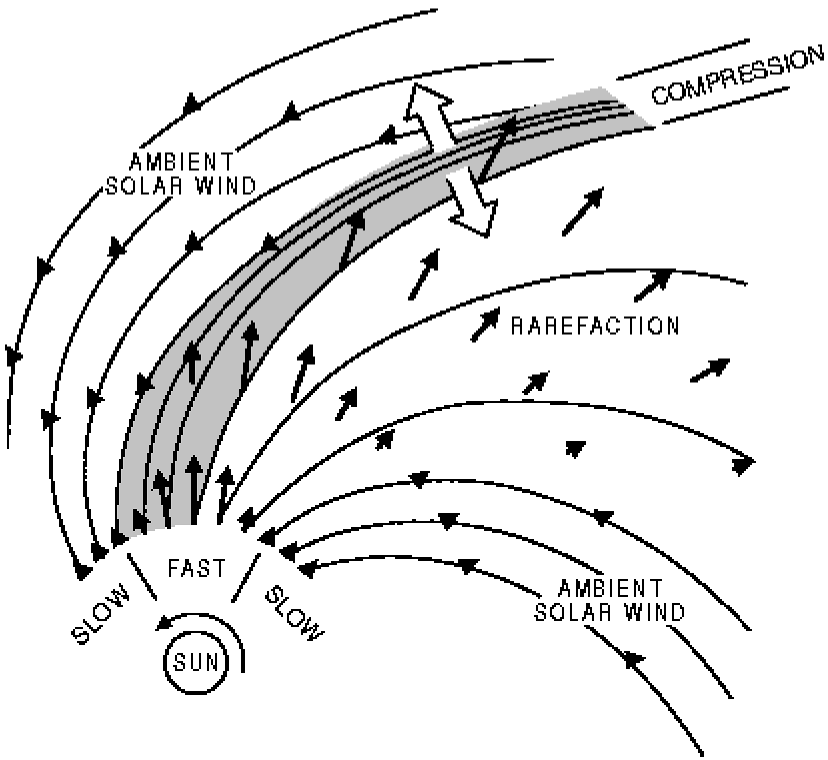
The parcels' trajectory was systematically rooted in the streamers and where the Streamer belt underwent latitudinal excursions where fast wind usually follows after slow wind (*Rouillard et al., 2008; Sheeley et al., 2007*).

In most cases (but not all!) the parcels are faint in HI-1 cameras and intensify in HI-2 (*Sheeley et al., 2008; see also Vourlidas et al., EGU, 2008*).

A one to one relation was found over two months of data between these waves and in-situ CIR passage (*Sheeley et al., 2008; see also Vourlidas et al., EGU, 2008*).

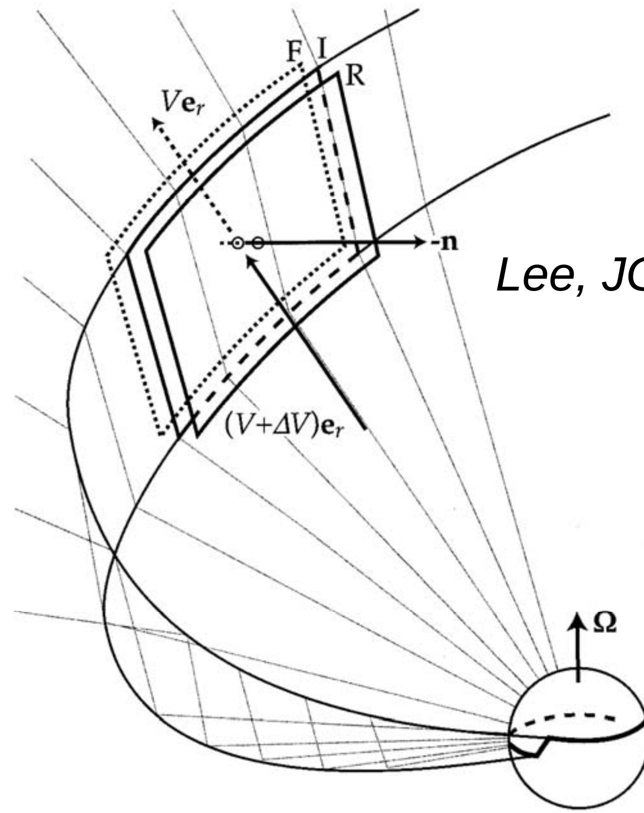
→ Strongly suggests that CIRs are essential for these parcels to appear…

Corotating Interaction Regions



Corotating interaction regions occur where fast wind catches up slow wind, where a stream interface forms.

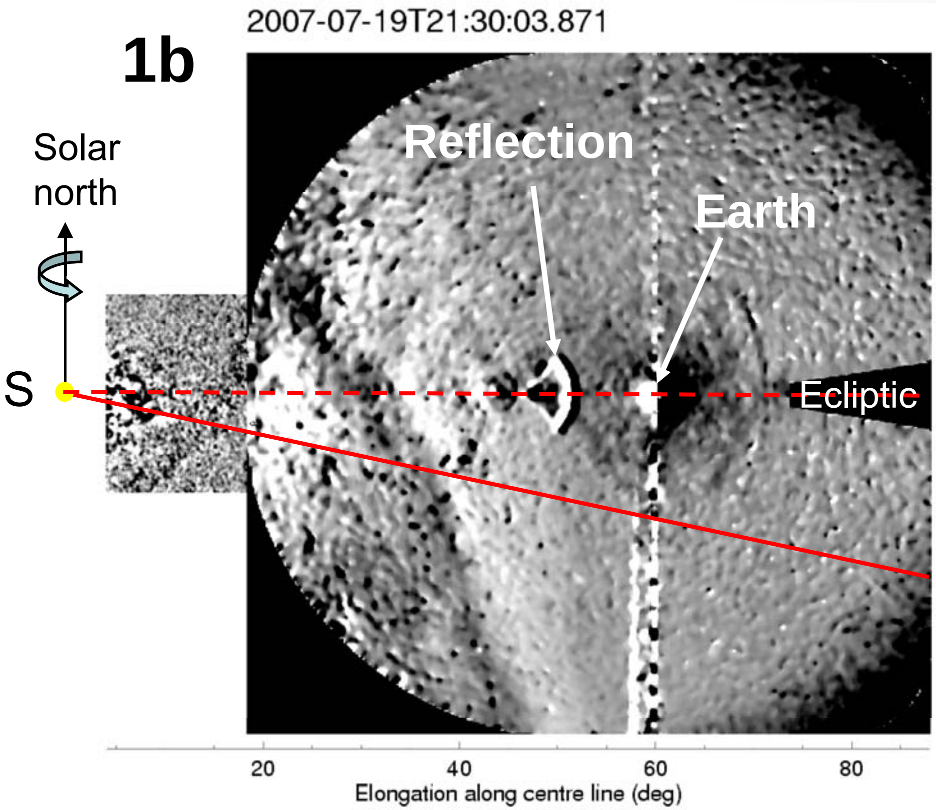
Hundhausen, 1973; Pizzo, 1978

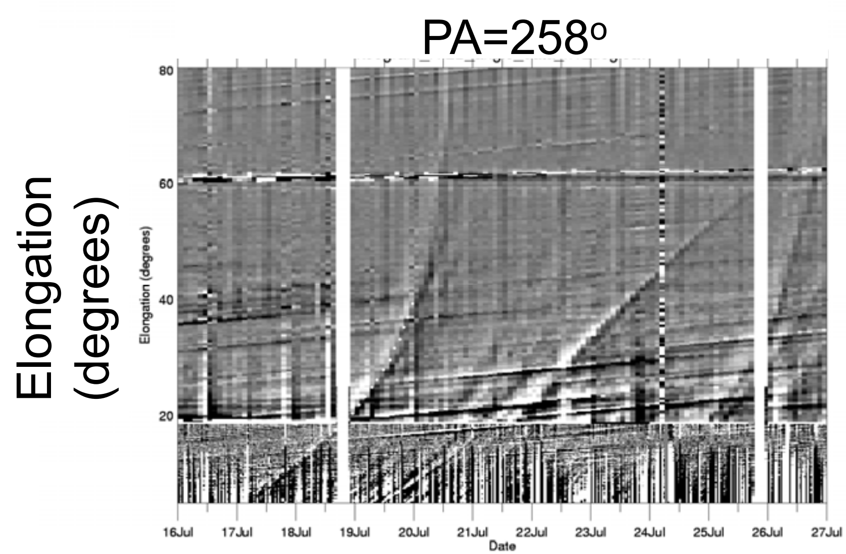


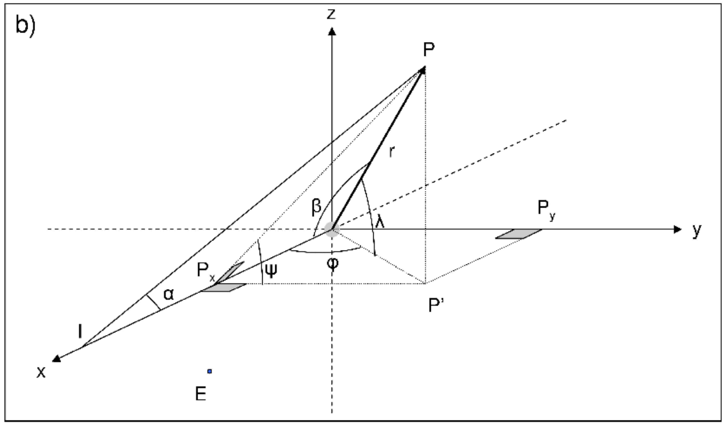
Lee, JGR, 2000

The evolution of the CIR is pressure-driven with an interface where flows are deflected located near the density peak.

Tracking one of the CIR-associated parcels

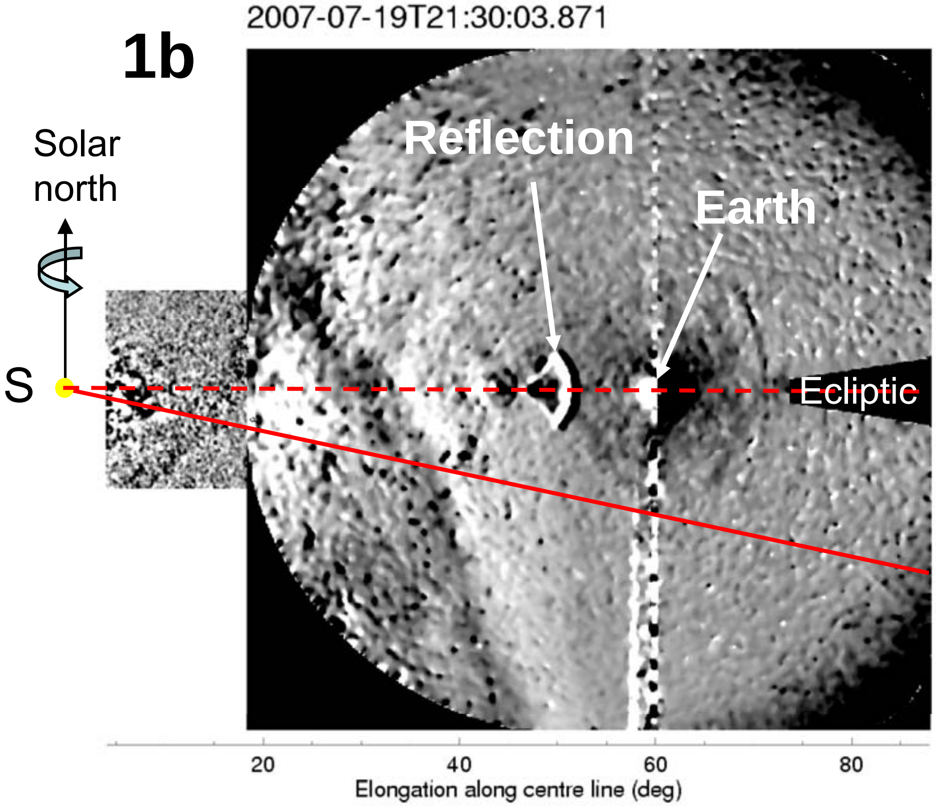


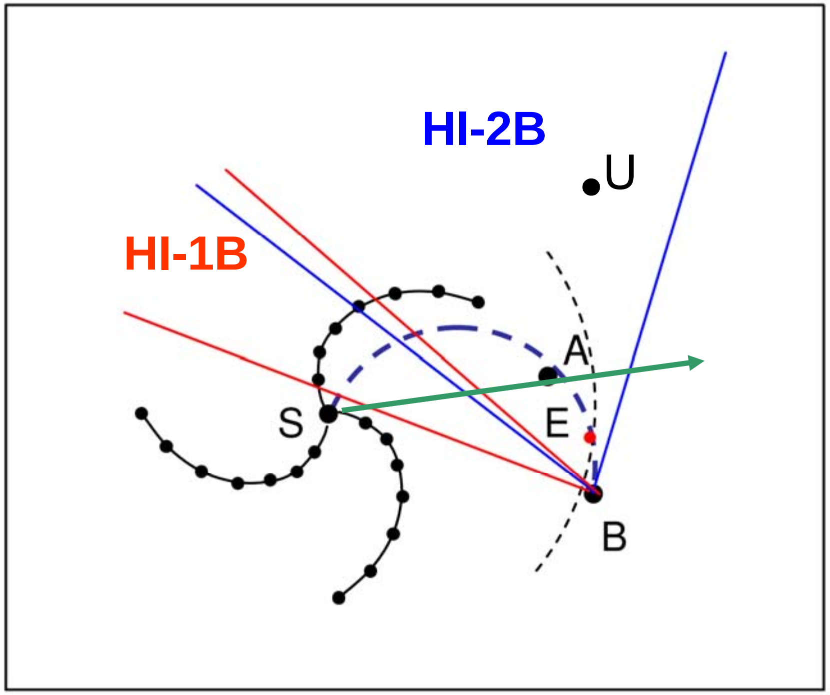




We tracked a large out-flowing wave in the HI-1/2 B images

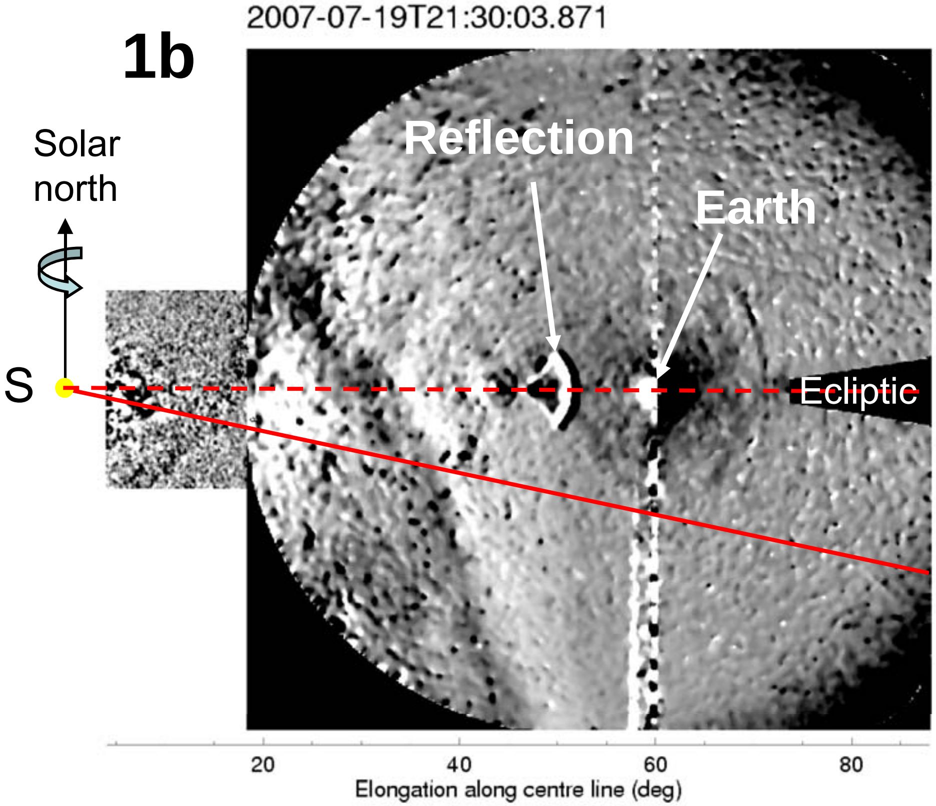
Tracking one of the CIR-associated parcels

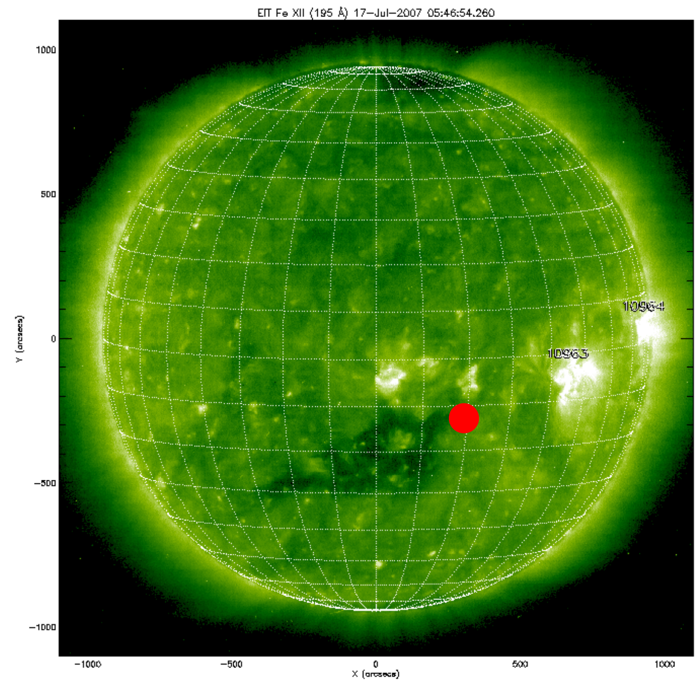




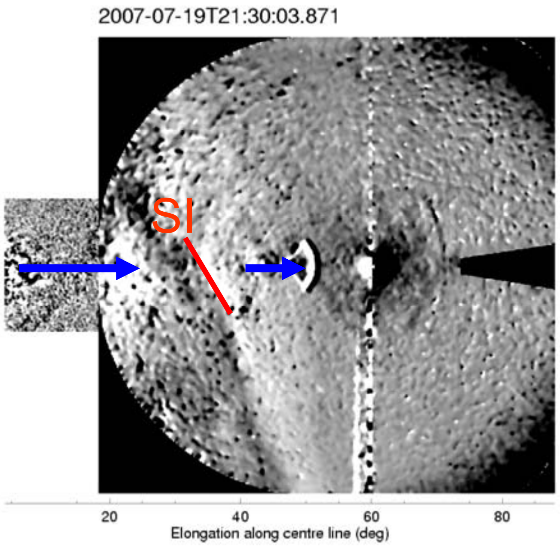
The estimated trajectory was towards STEREO A.

Tracking one of the CIR-associated parcels

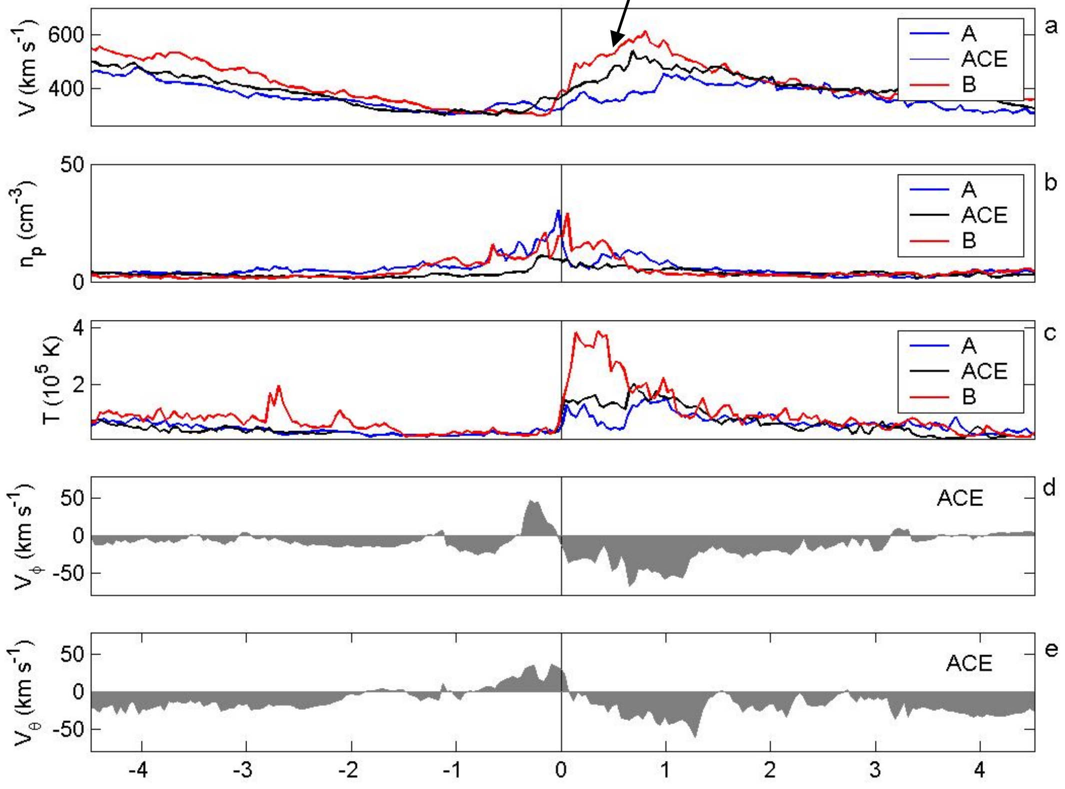




The source region was located on the western boundary of a coronal hole.



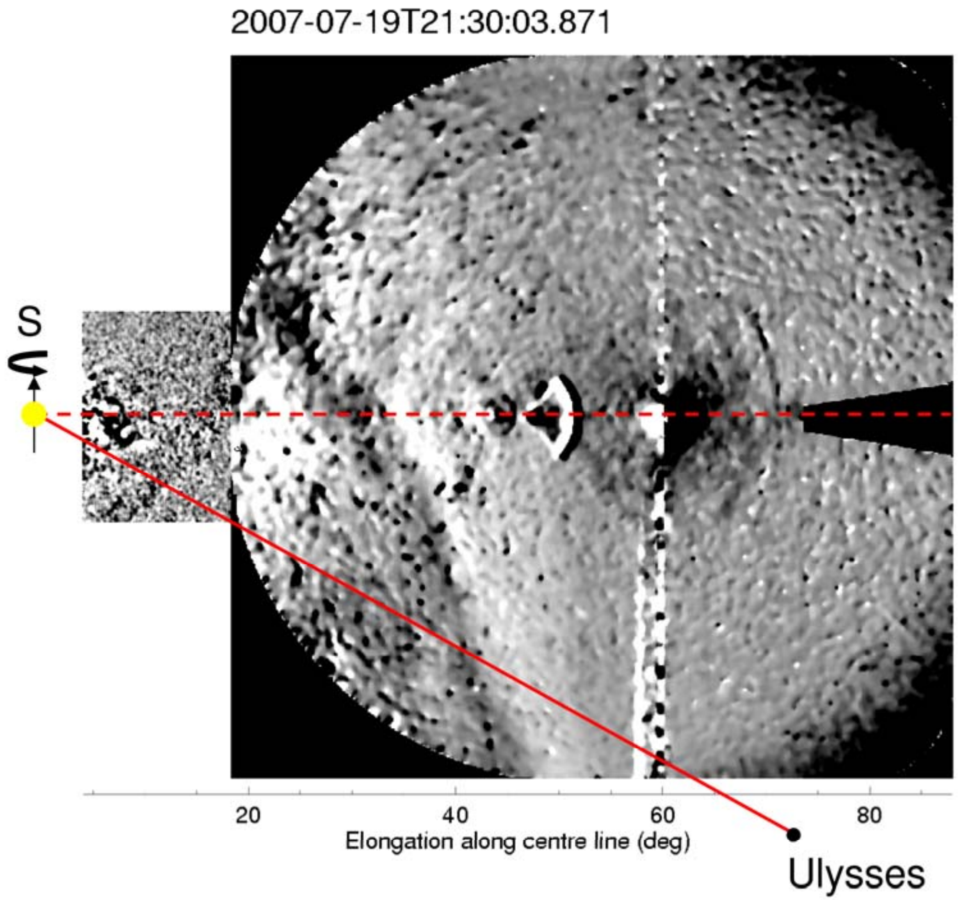
STEREO B is located 2 degrees south and experiences faster solar wind than A.



Days from SI passage

The flow deflections were consistent with fast wind from a southern coronal hole deflected by a stream interface normal pointing northward.

Ulysses observation of the CIR.

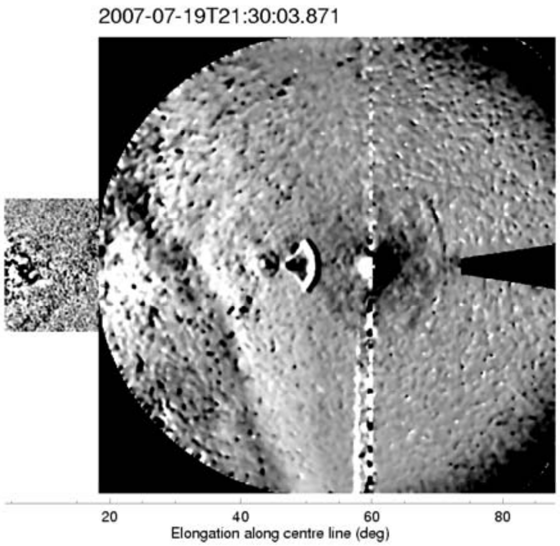


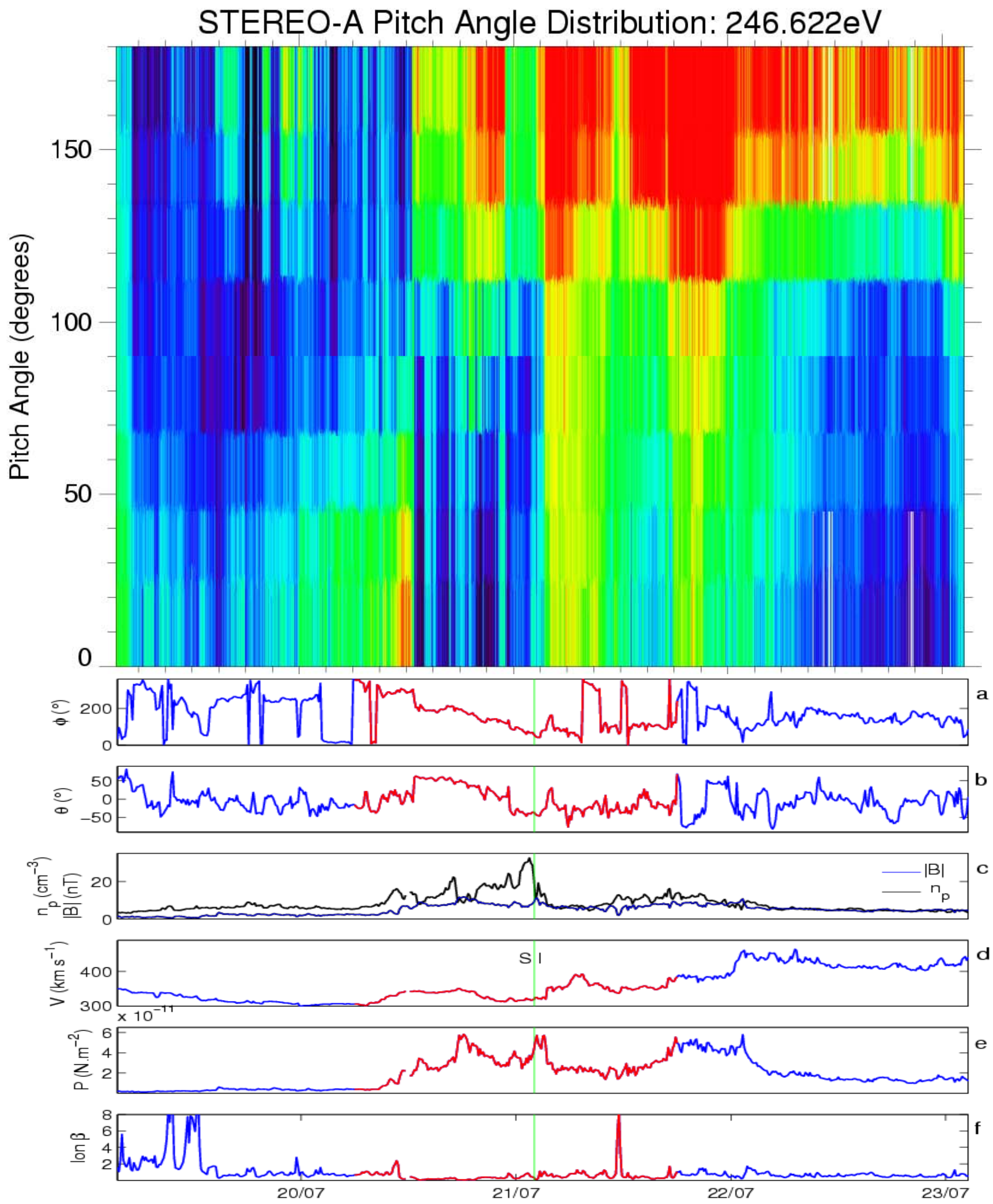
Ulysses confirms the presence of very slow flow and a CIR at a latitudes of -20^{o} a few days later.

The arrival time of the CIR agues for a very steep interface.

The fast wind is also deflected southwards at Ulysses.

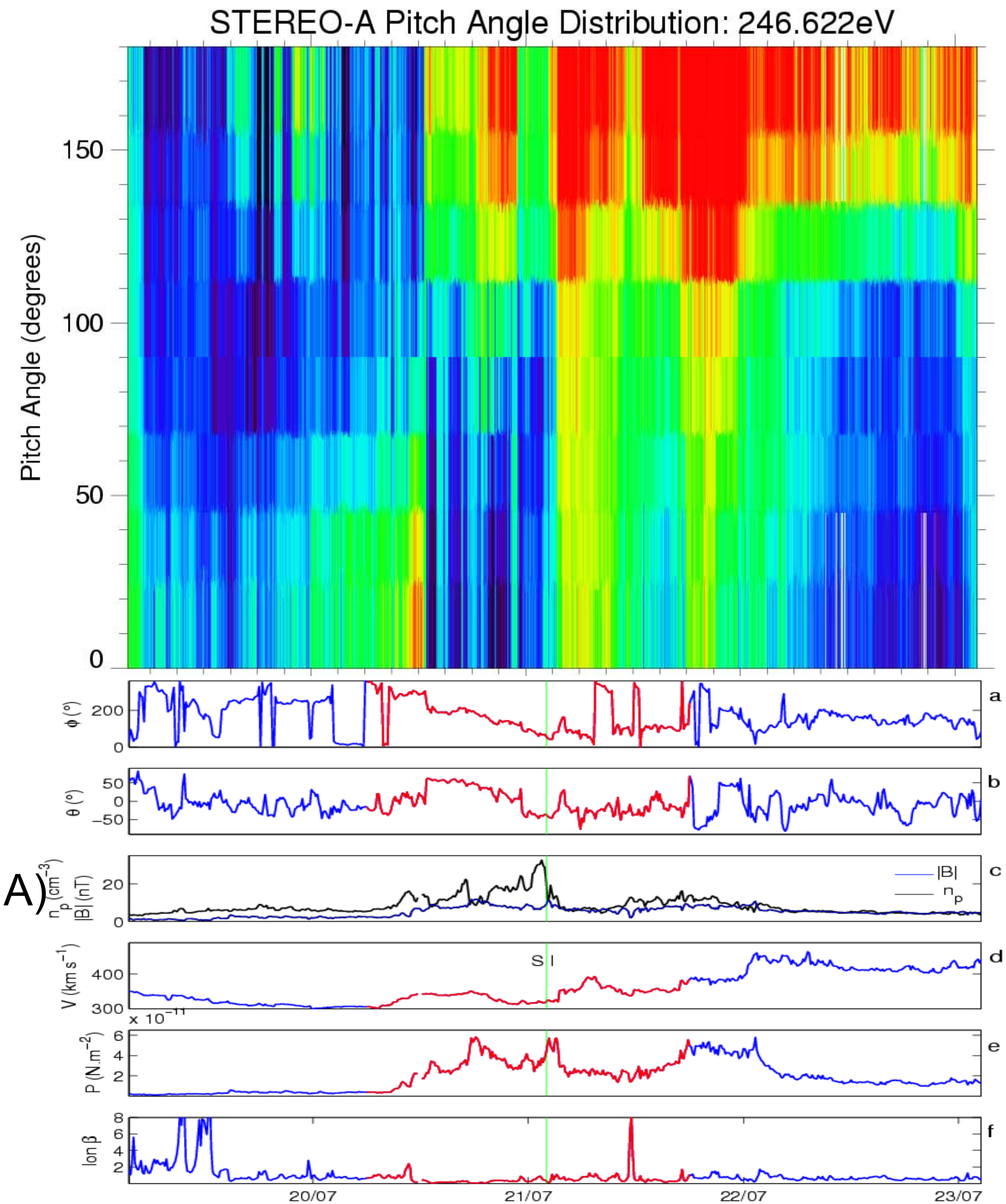
Ulysses confirms the strange polarity of the southern coronal hole (northern polar coronal hole polarity).





The STEREO-A in-situ data can be used to provide a diagnostic of the solitary wave.

258 eV pitch angle distribution from SWEA STEREO A



Azimuth of B field (IMPACT A)

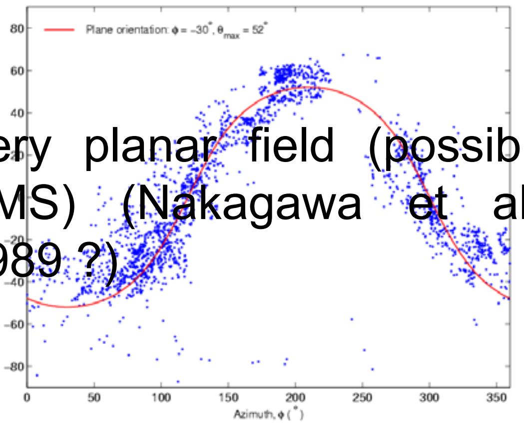
Elevation of B field (IMPACT A)

B field and ion density (+Plastic A)

Ion Speed (Plastic A)

Total pressure (+Plastic A)

Ion beta (+Plastic A)

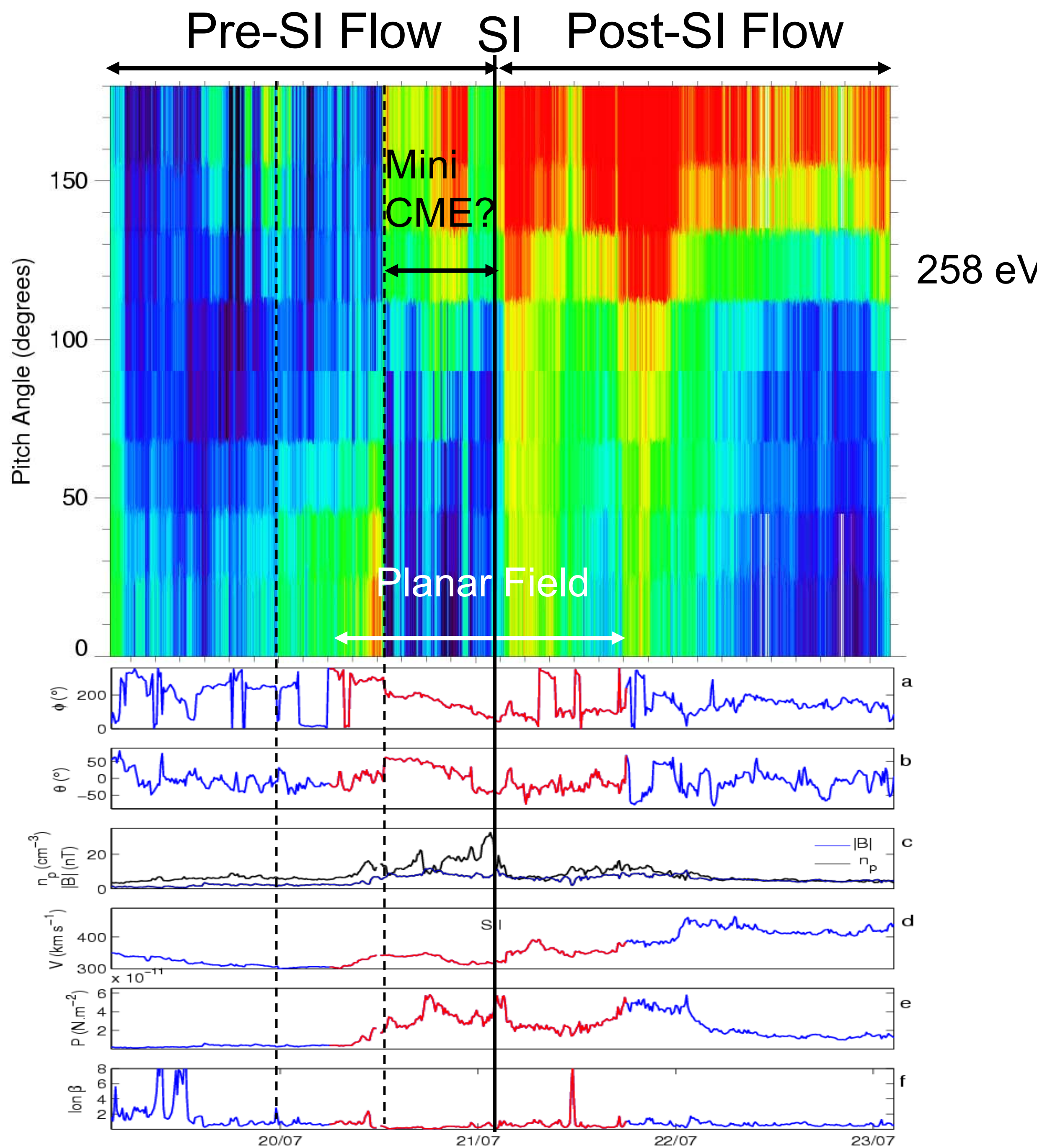


Very planar field (possibly PMS) (Nakagawa et al., 1989 ?)

Evidence of a smooth rotation, azimuth and elevation angle + low ion beta: a mini CME?

Sector boundaries with no current sheets (Crooker et al., 2004 ?)

→ Consistent with refolded field lines ahead of a flux rope compressed into a highly planar structure.



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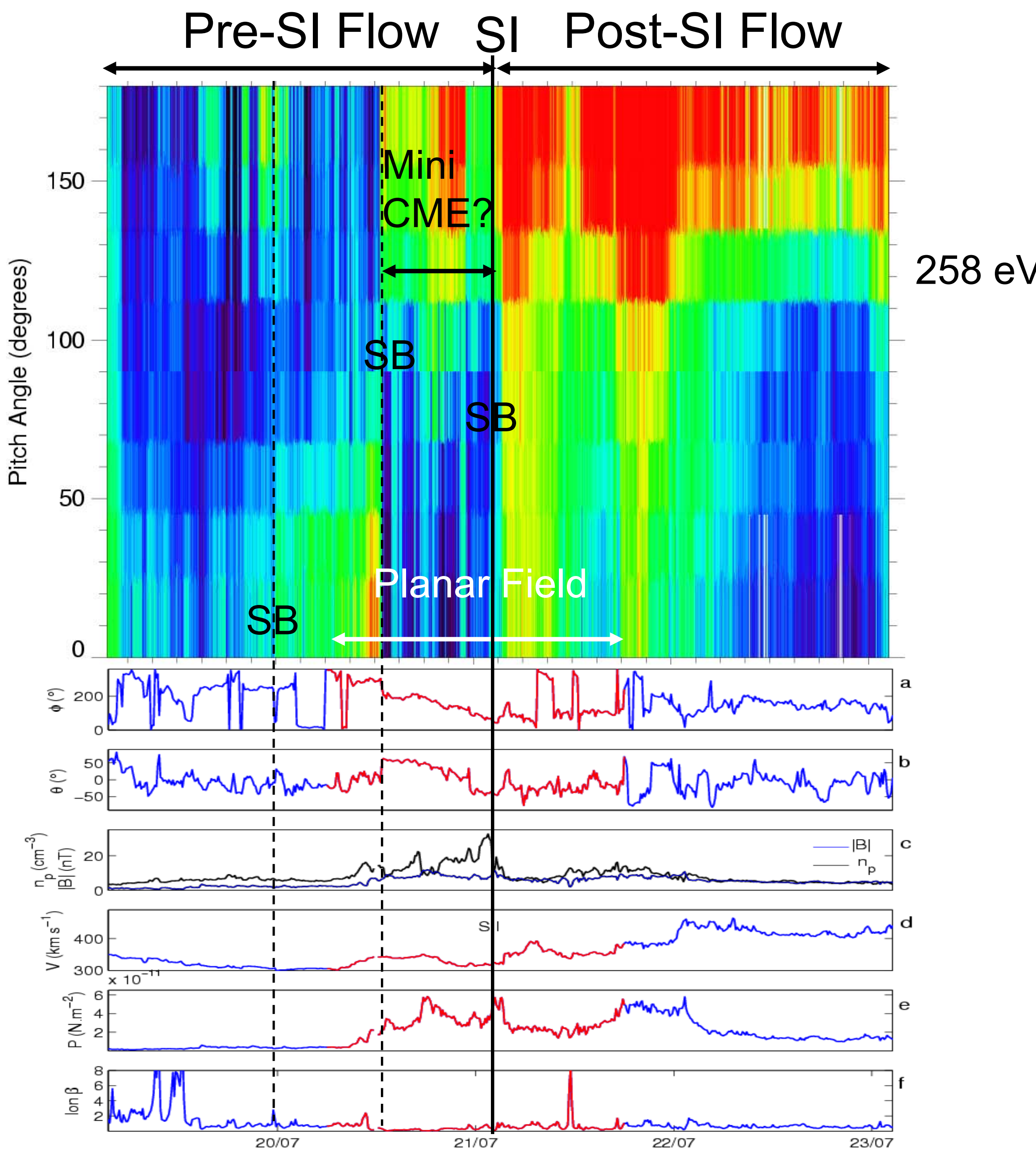
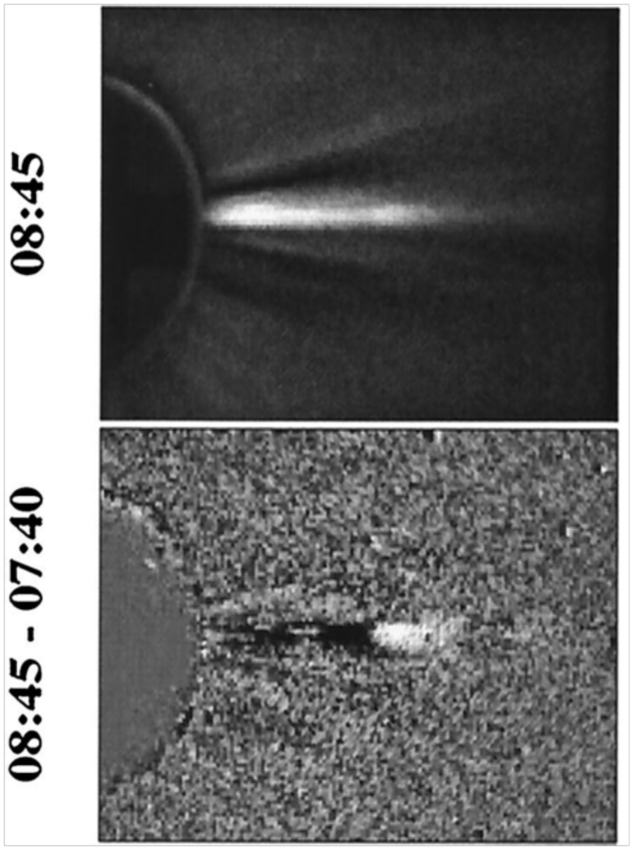
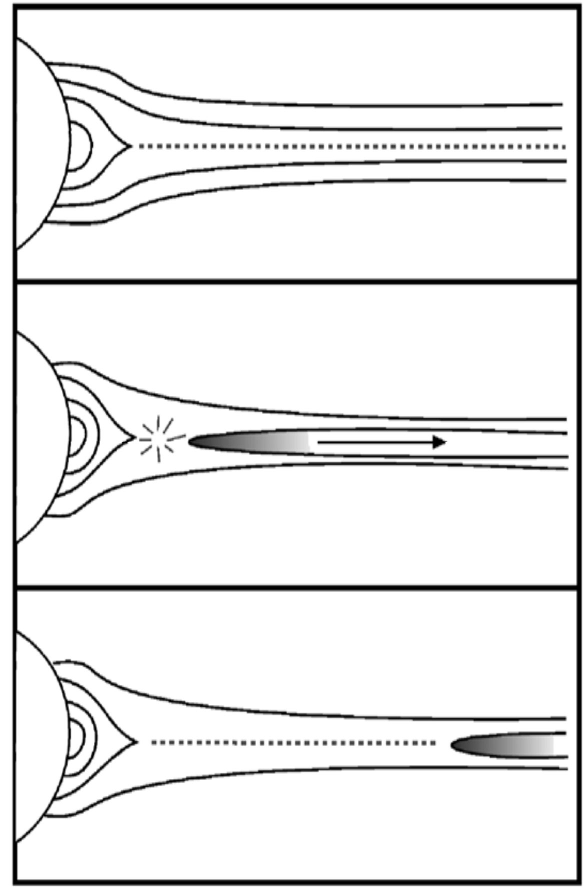


Reconnection at the tip of a single current sheet



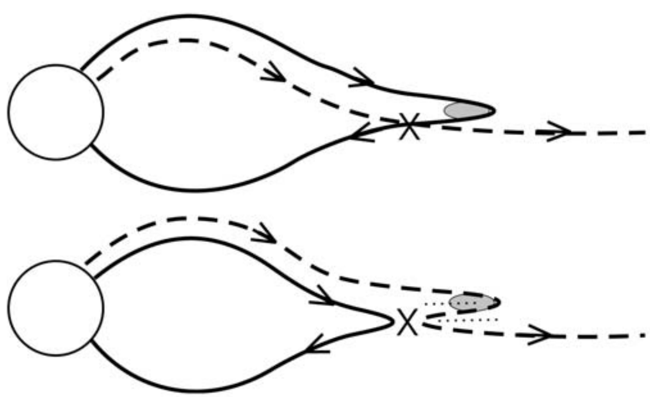
Observation: Sheeley et al., 1999
Wang et al., 2000



Theory: *Dahlburg and Karpen, 1997*
Van Aalst, M.K. et al., ApJ., 1999;
Wang et al., ApJ., 1998, 2000

Reconnection at the tip of a single current sheet

Three studies point to interchange reconnection as a source of blobs.



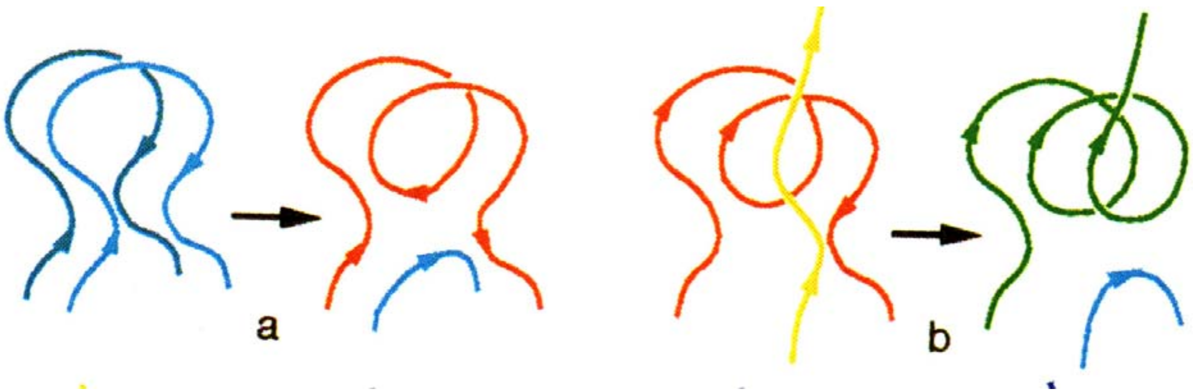
Wang et al. (2000), tracked plasma blobs in C2 and C3.

Zurbuchen et al. (2001) analysed magnetic holes (in-situ) and argued from uniformity of the oxygen isotope ratios that reconnection must occur high in the corona

Crooker et al. (2004) studied the variability of the heliospheric plasma sheet (in-situ).

Reconnection at the tip of a single current sheet

The flux rope found inside this CIR could have formed following a scenario of the type of Gosling et al. (1995).



Electron spectrograms argue that the field line is open the presence of a flux rope suggests there was eruption of a loop structure near the neutral line.

⟶ We need more events to see which scenario of field reconnection is most likely.

Conclusions

Corotating Interaction regions are heliospheric structures that HI can observe (which was unforeseen).

Building on the Helios and SoHO heritage HI shows that the density spiral of CIRs has a longitudinal structure.

Plasma blobs are disconnected continuously and entrained in CIRs and are thought to be very important in the recycling of the heliospheric field.

→ Implications solar wind magnetosphere coupling: probably should be investigated in the context of the accepted Russel-McPherron effect and CIRs (Borovsky and Steinberg, 2006; Finch, 2008).

→ Implications solar minimum cosmic ray modulation (Heber et al.,1998) and solar maximum cosmic ray modulation by CIRs (Rouillard et al., 2006)

→ Centennial changes in heliospheric field (Rouillard et al., 2007)