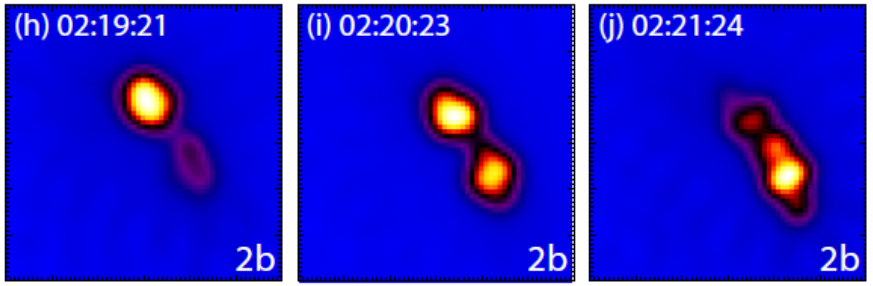
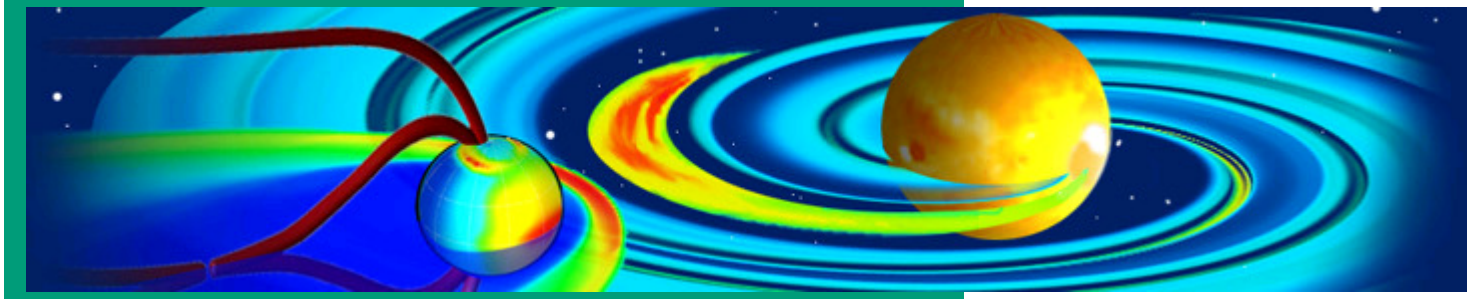
Plasmoid Releases in the Heliospheric Current Sheet and Associated Coronal Hole Boundary Layer Evolution

Claire Foullon





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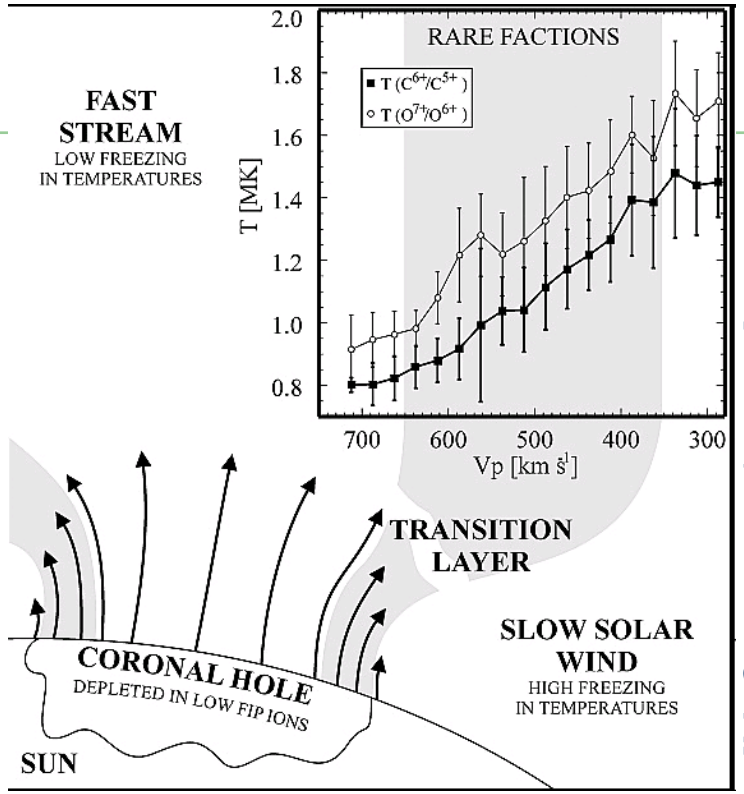
INTRODUCTION

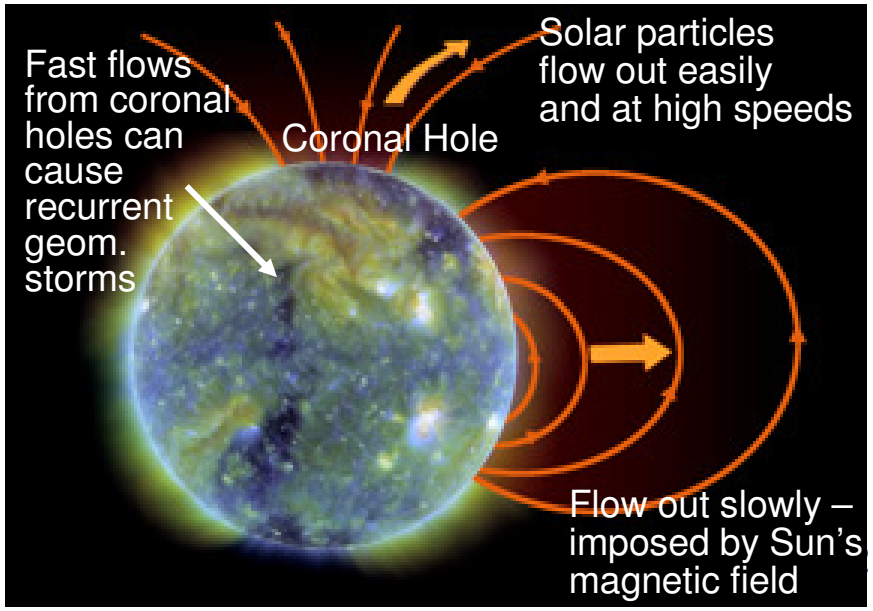
Coronal Hole Boundary Layers (CHBLs)

- Boundary Layers: plasma mixing and transfer across the fast-slow stream interfaces.
- CHBLs: inverse dependence of the solar wind speed on coronal freeze-in temperatures *[e.g. Geiss et al., 1995; McComas et al., 2002].*

An understanding of their formation and evolution can shed light on the dynamics of coronal holes and the HCS, as well as the formation mechanisms of the slow solar wind.



[McComas et al., 2002]



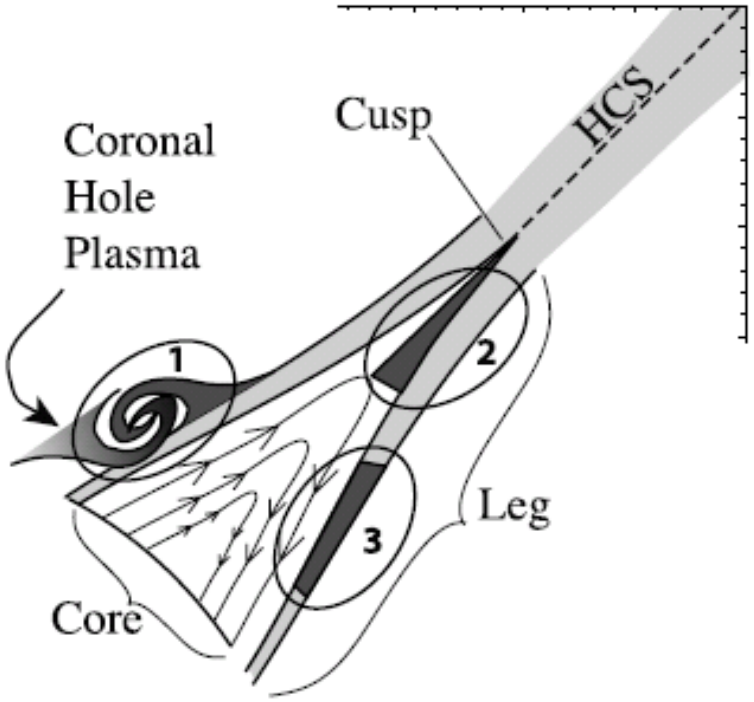
Helmet streamer and slow wind

Three potential sources

(1) **Mixing of plasma inside the brightness boundary with that from adjacent coronal hole**, *e.g. Kelvin-Helmholtz instability*.

(2) **Plasma from just one side in the core, just below the cusp** → *Depletions in He/H lying to one side of the HCS*

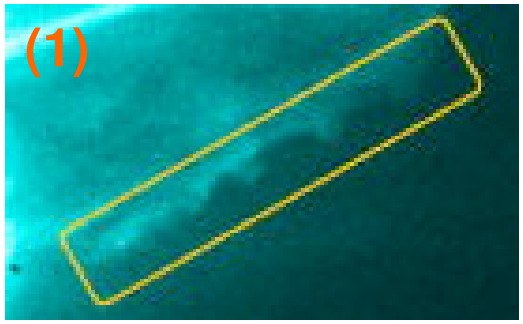
(3) **Quasi-steady flows from the legs of streamers.**



[Suess et al., 2009]

Adapted from poster:
Magnetic Kelvin-Helmholtz instability at the Sun

[Foullon et al., ApJL, 2011]



Formation of Plasmoids

Depletions in He/H originate in the 'core' or the helmet of the streamer, based on

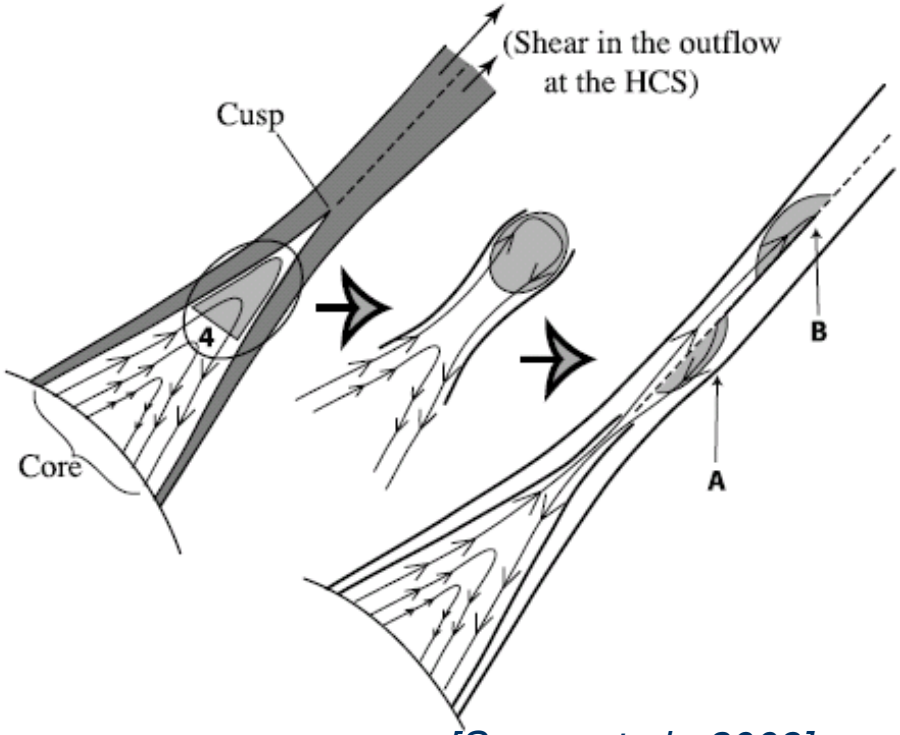
(1) correlation between He/H and O/H depletions

(2) SOHO/UVCS results indicate O depletions occur in the core of streamers *[e.g. Raymond et al, 1997]*.

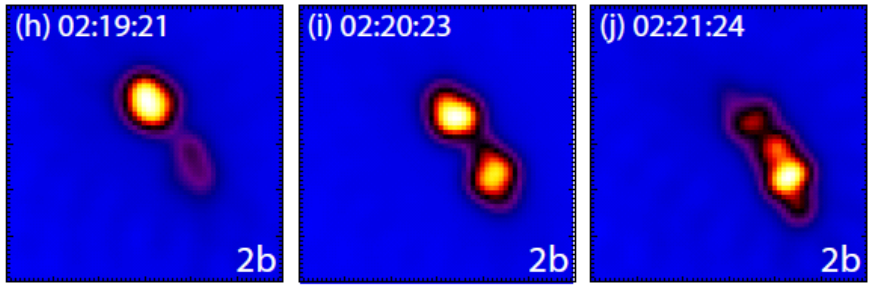
Transient blobs escaping from the streamer core being sheared along the HCS

(1) streamer 'puffs', interpreted as small-scale CMEs *[e.g. Sheeley et al., 1997].*

(2) plasmoids, seen in X-rays *[e.g. Ohyama & Shibata, 1998].*



[Suess et al., 2009]



[Foullon et al., 2010]

Formation of Plasmoids

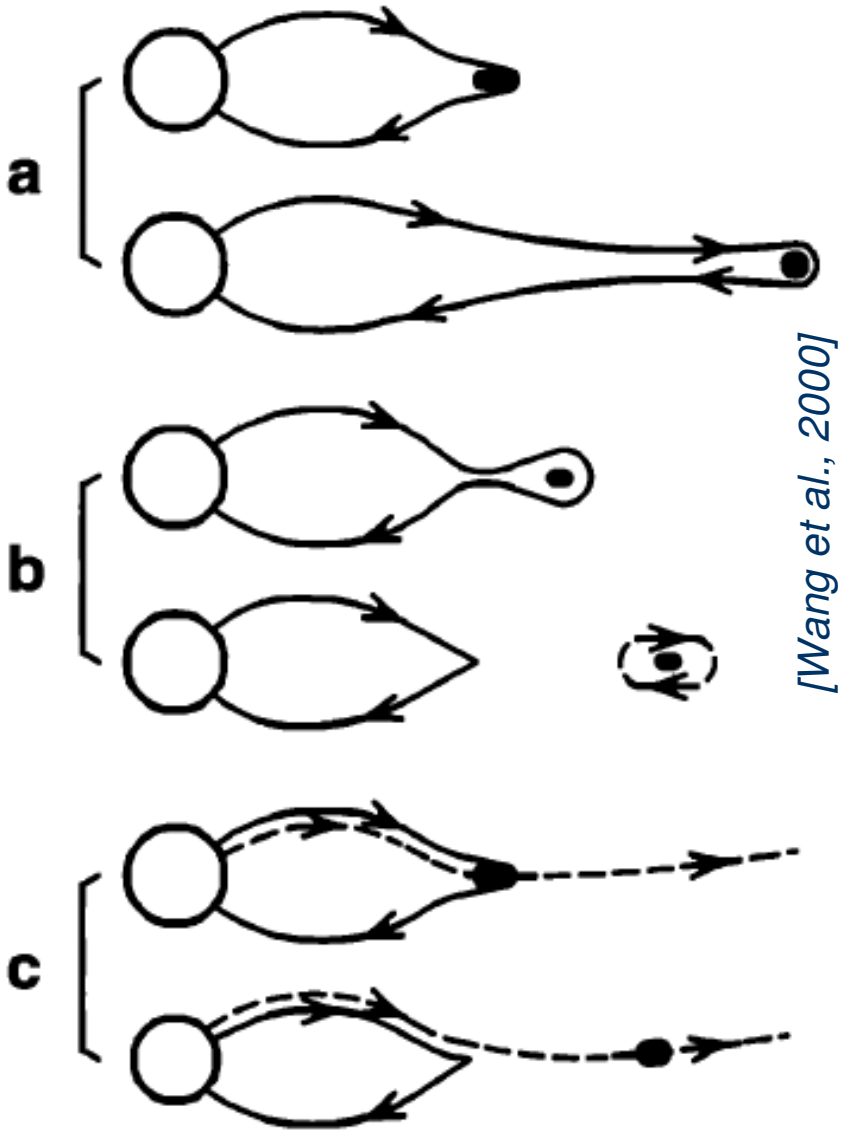
Three possible mechanisms

a) **Outward pressure of the trapped material, stretching the loop to infinity.**

b) **X-type neutral point pinching off detached plasmoid** → *in 3D: cross-section of flux rope with both ends still attached to the Sun.*

c) **Interchange reconnection.**

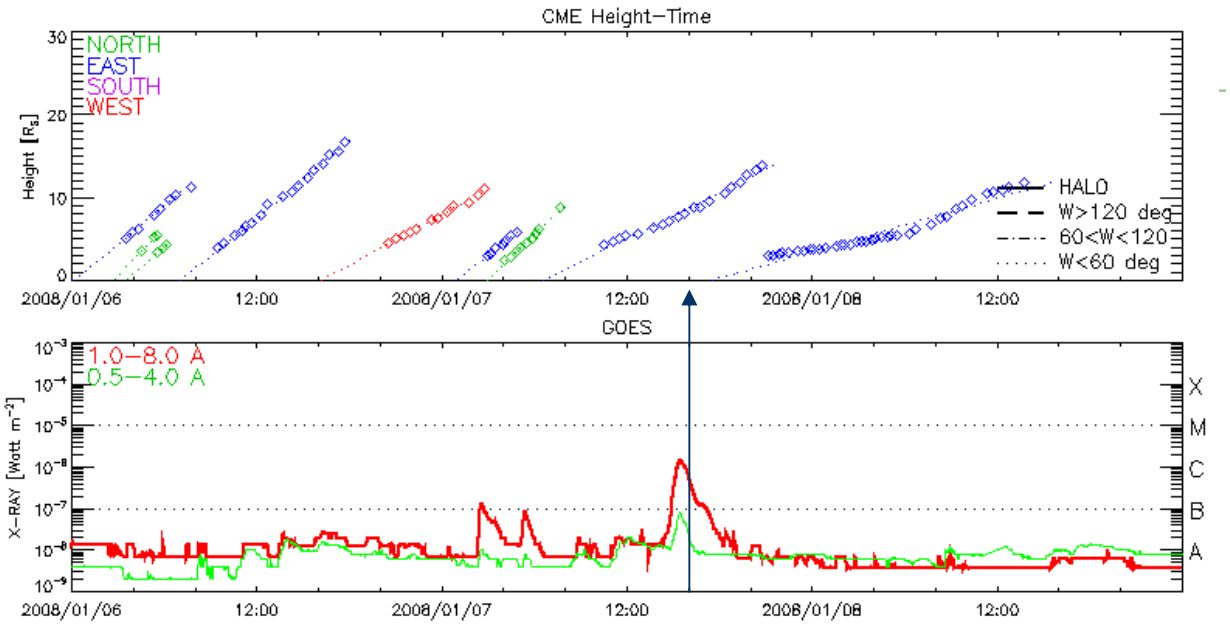
Slow solar wind (at least in part): transient events from **magnetic reconnection** generated **either at the cusps** of streamers **or between the coronal hole boundaries and the cusps of streamers**.

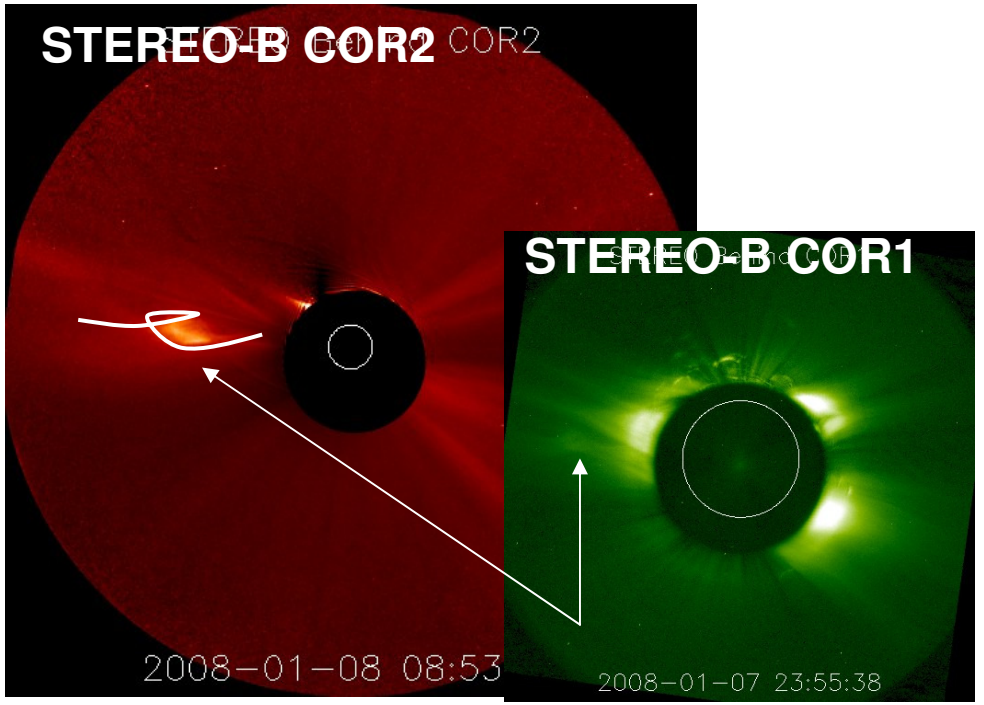


[Wang et al., 2000]

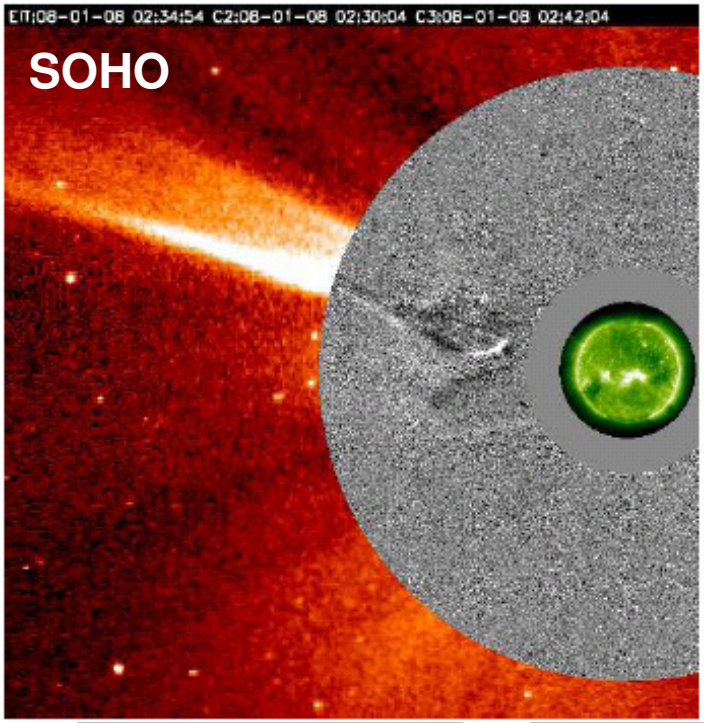
REMOTE OBSERVATIONS

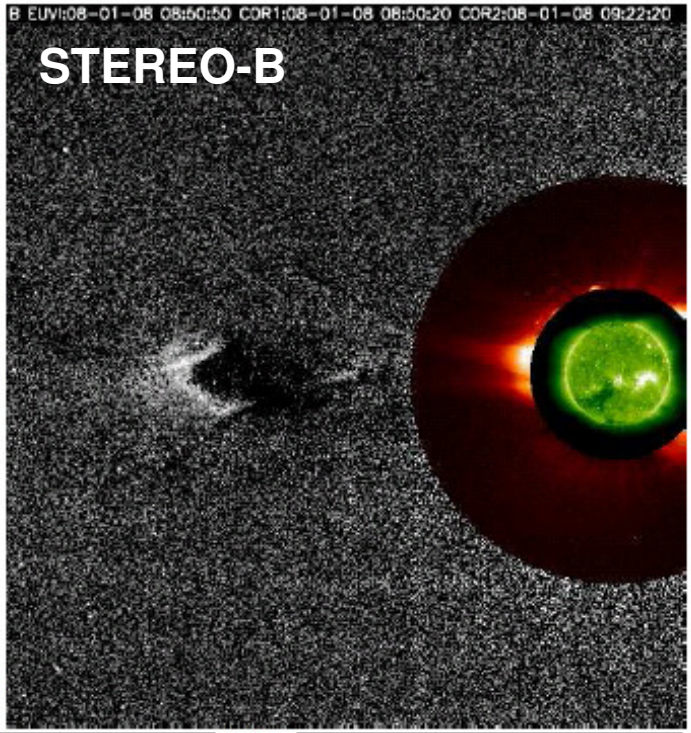
2008 January 7
-**Long decay X-ray flare**: C1.4 GOES-class, 15:27 UT
- **Slow elongated & twisted plasmoid-ejecta**, from around 16 UT

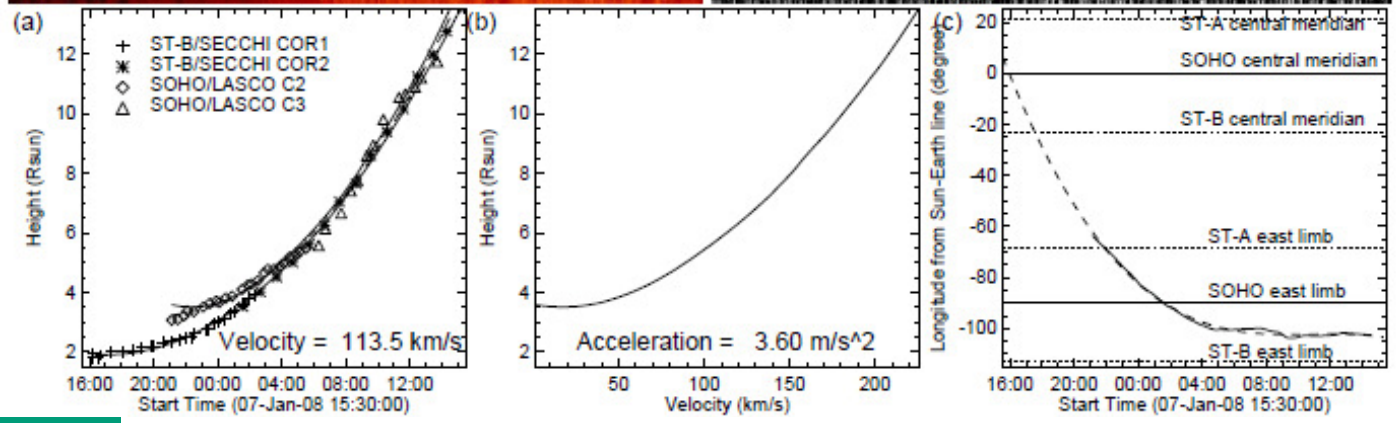




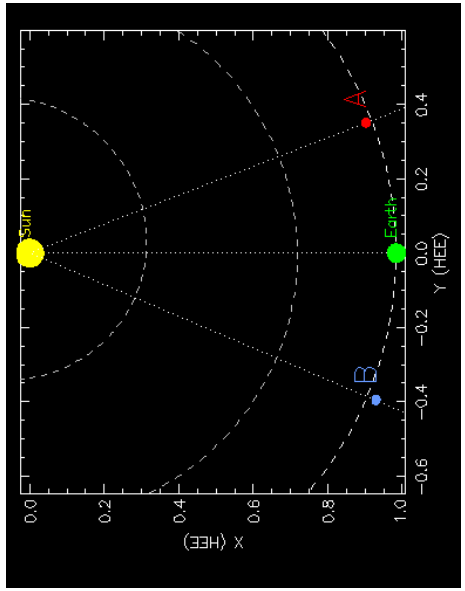
Triangulation using SOHO & STEREO-B



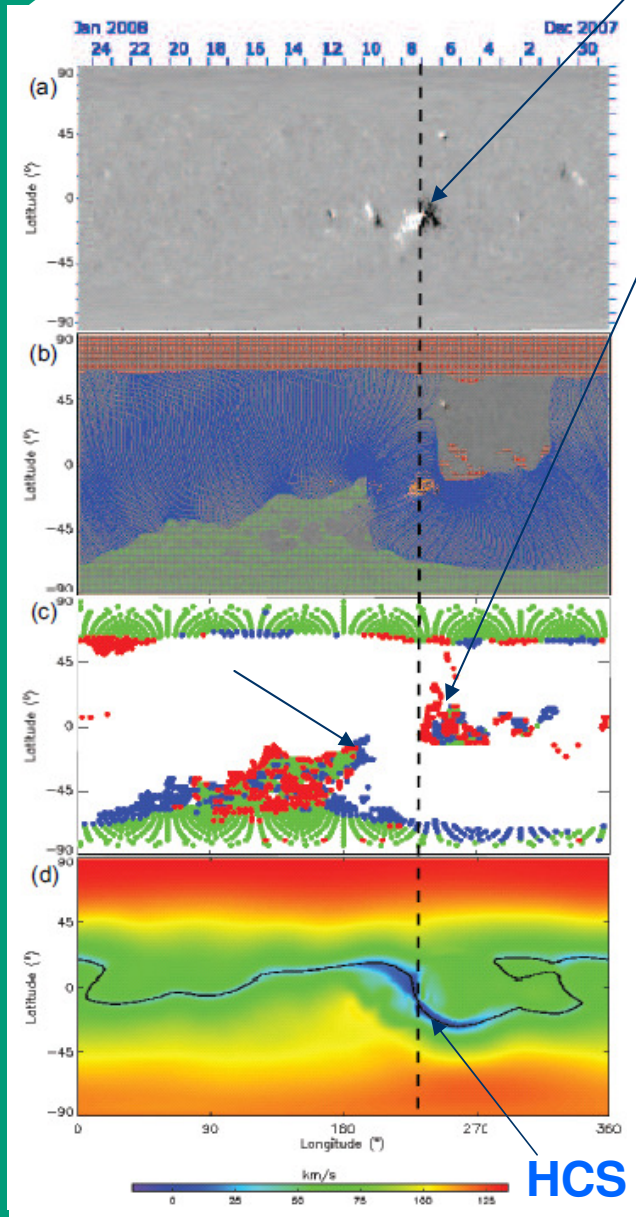




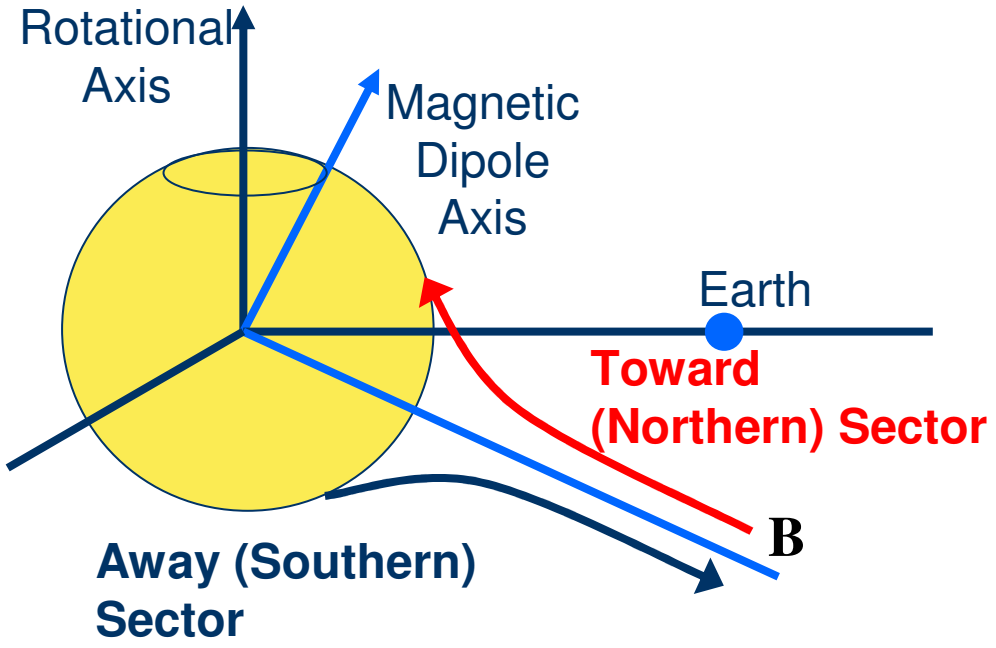
- **Slowly accelerated**
- **Strong Eastward deflection** until about 4 UT on January 8,
- **Origin close to the flaring AR** (NOAA 10980)



REMOTE OBSERVATIONS

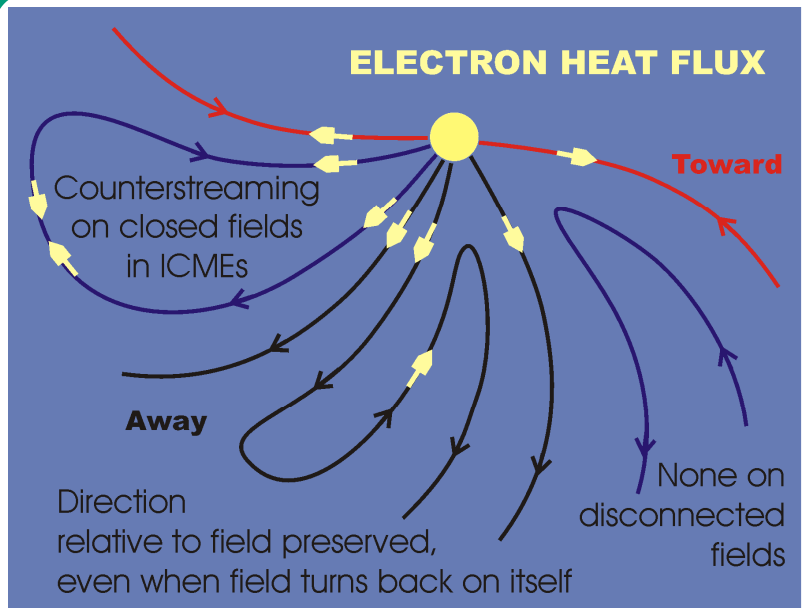


- AR centred on the disk, located across the field inversion neutral line, thus at the base of the helmet streamer belt.
- Coronal holes with **inward** and **outward** IMF polarity.

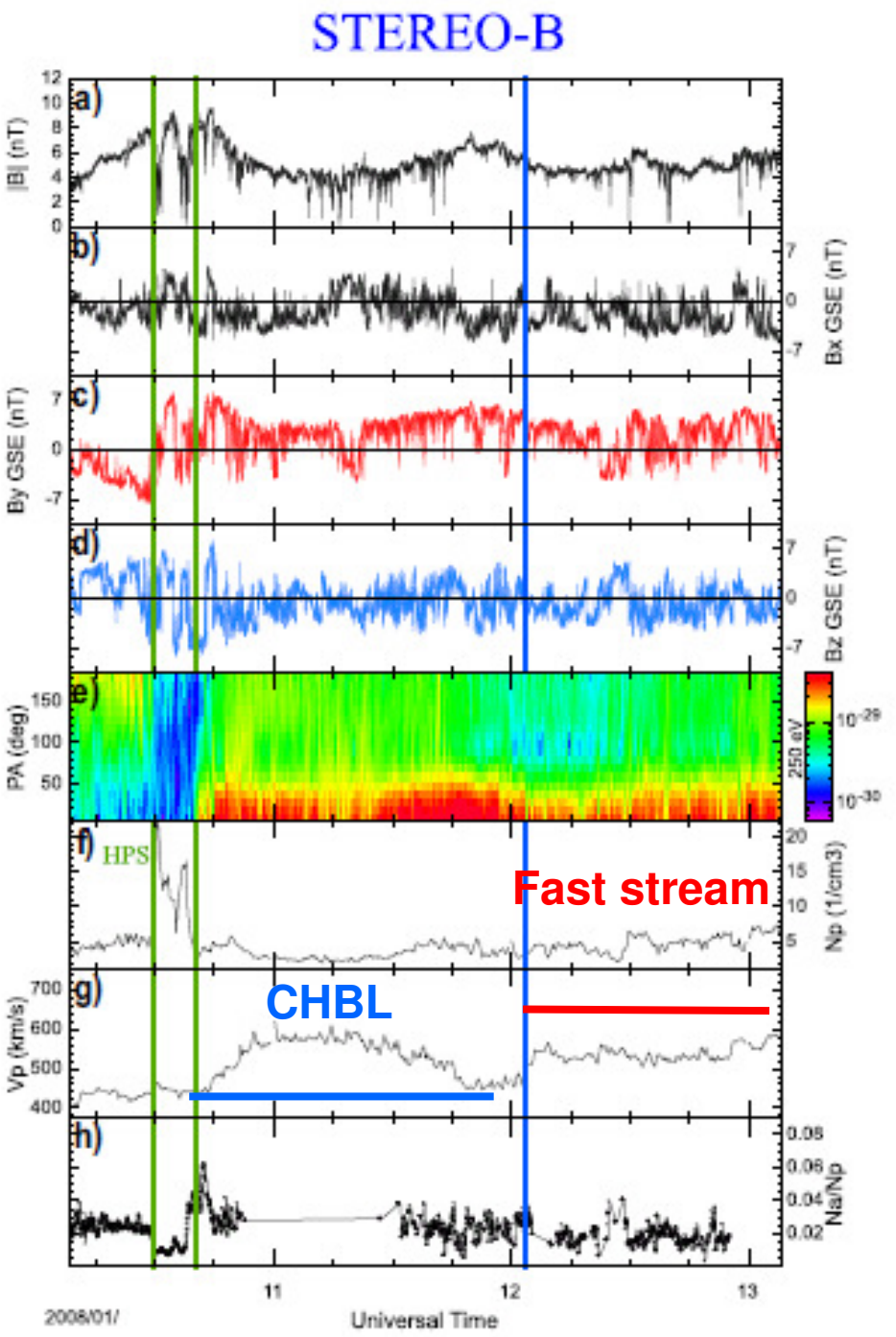


In this period near solar minimum, the **toward sector** (sunward IMF) is connected to the northern solar magnetic hemisphere, and the **away sector** (anti-sunward IMF) to the southern hemisphere.

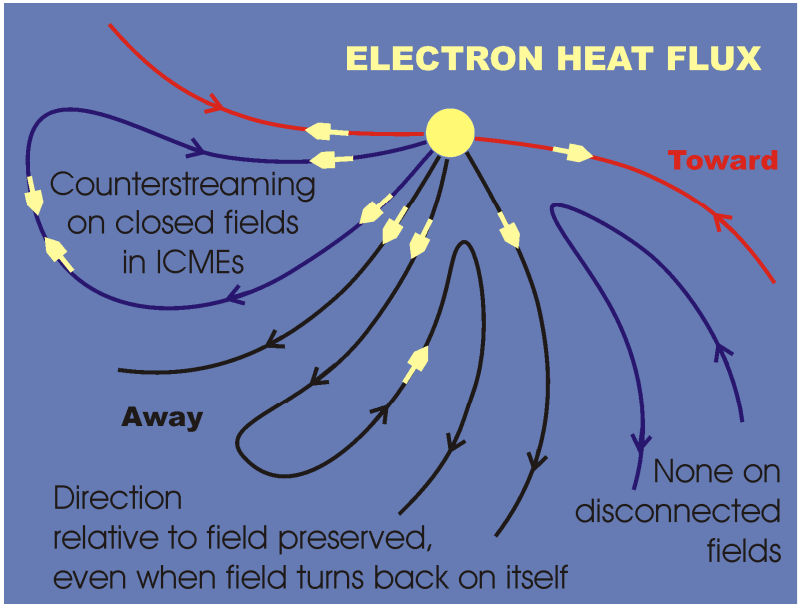
IN-SITU OBSERVATIONS



To correctly identify the HCS crossing(s), we use suprathermal electrons as sensors of magnetic topology.

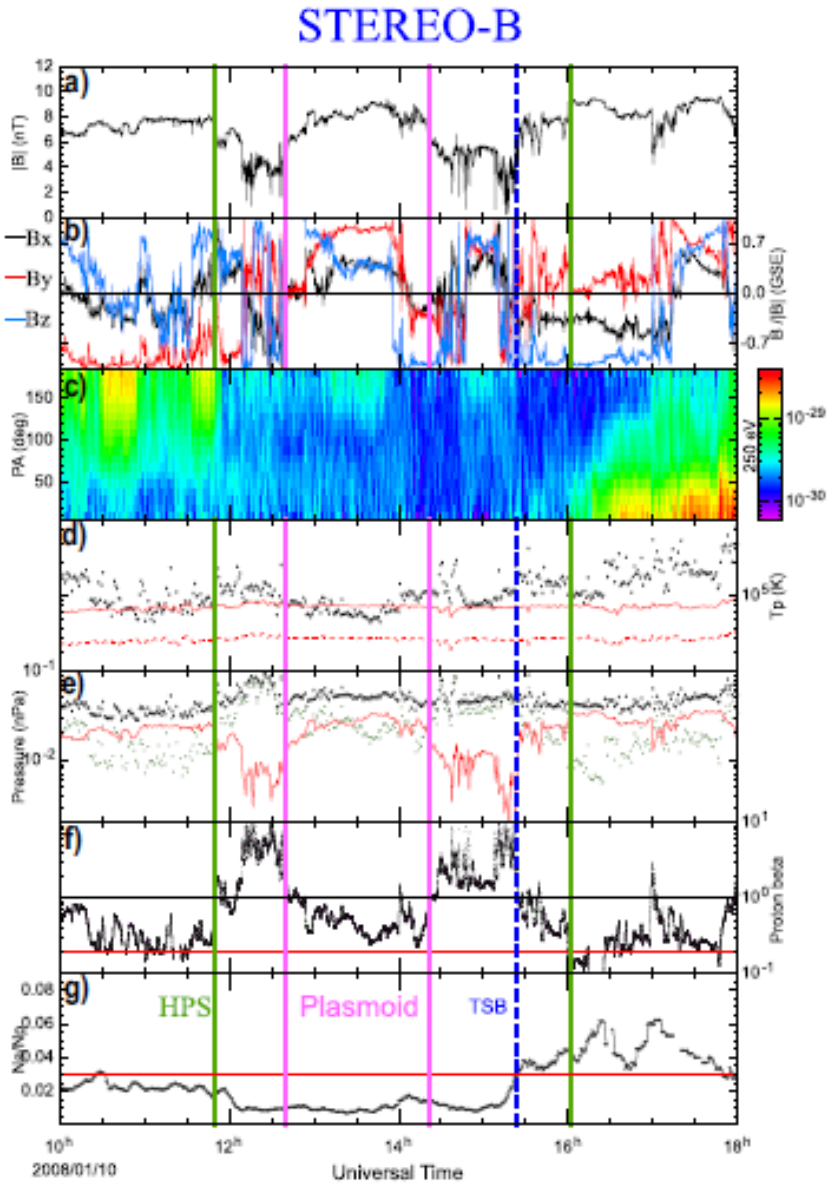


Plasma structures in the HPS as Plasmoids

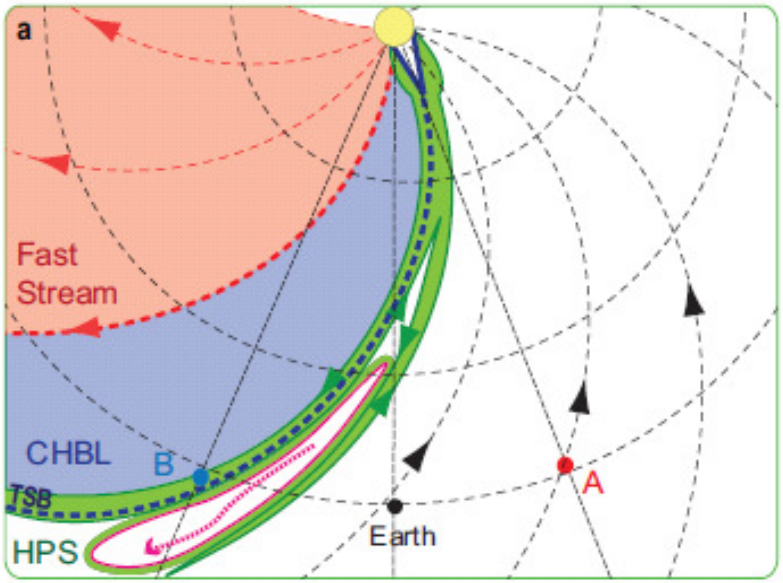


Plasmoid main proxies:

- **Depressions in Tp**
- **Pressure-balanced**, dominated by magnetic /plasma pressure→ flux-rope/ magnetic island type plasmoid *[Ieda et al, 1998]*.
- **Low proton plasma beta,** magnetic field B~2-8 nT

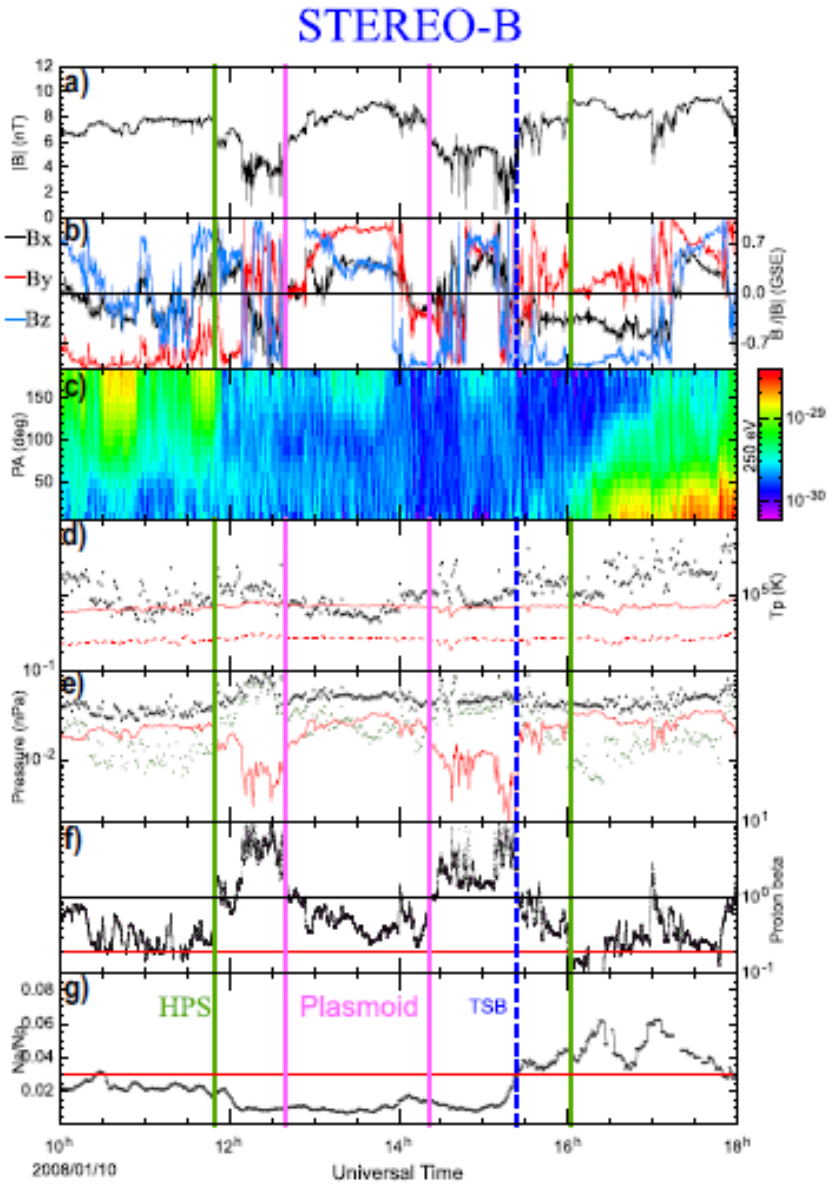


Plasmoid Releases and the HPS Formation



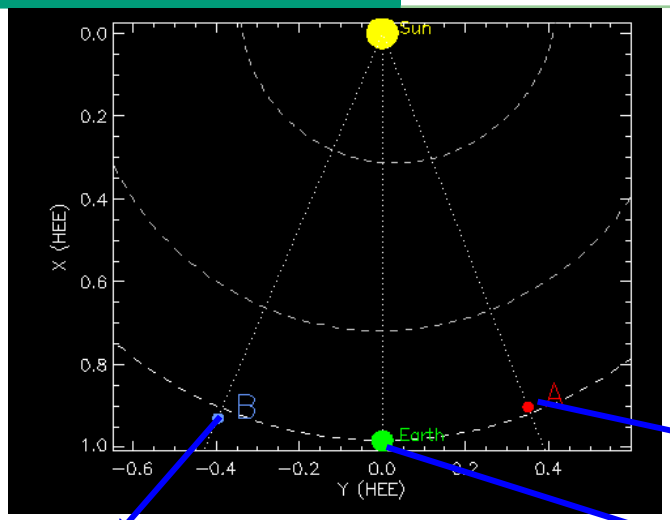
Small-scale transients in the HPS:

- What could maintain the high density in the HPS: the **sheaths** of the plasmoid transients being continuously released.
- First reported evidence of a **detached plasmoid** in the HPS (STEREO-B).

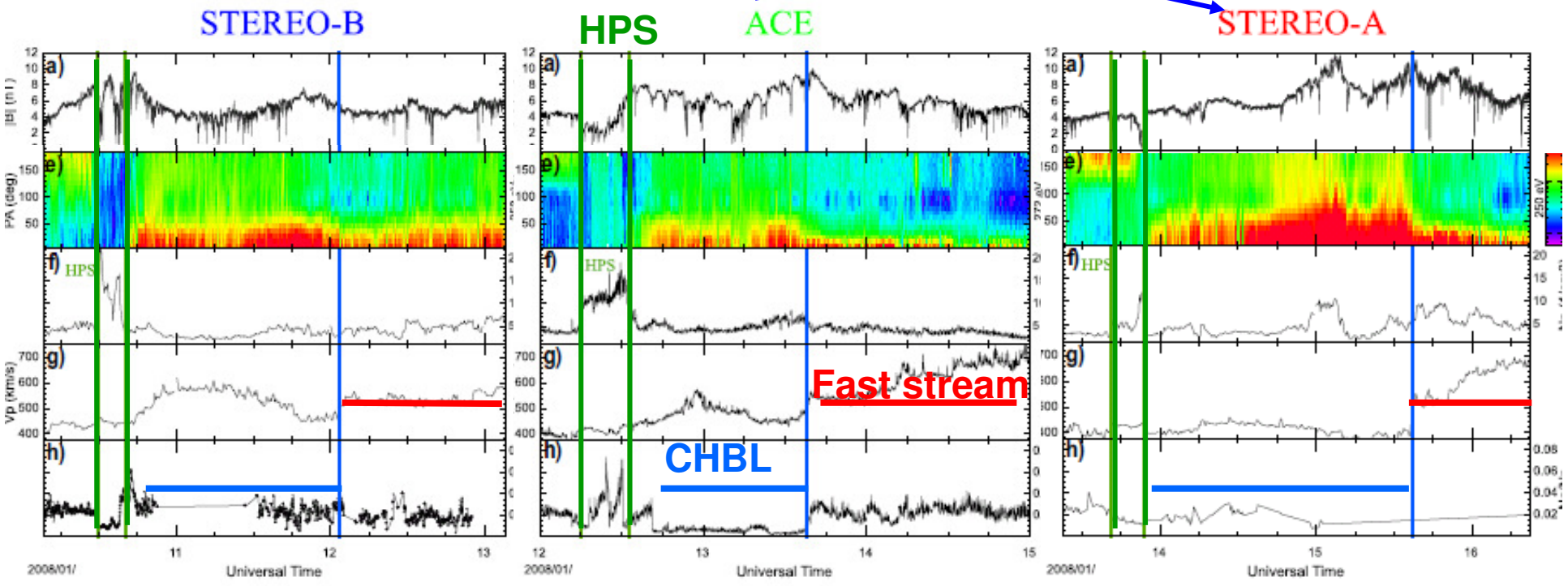


IN-SITU OBSERVATIONS

Multi-spacecraft study of CHBL



CHBL-stream: use composition signatures to distinguish stream of coronal hole or streamer belt origins & follow its evolution as it is chanelled along the HCS.



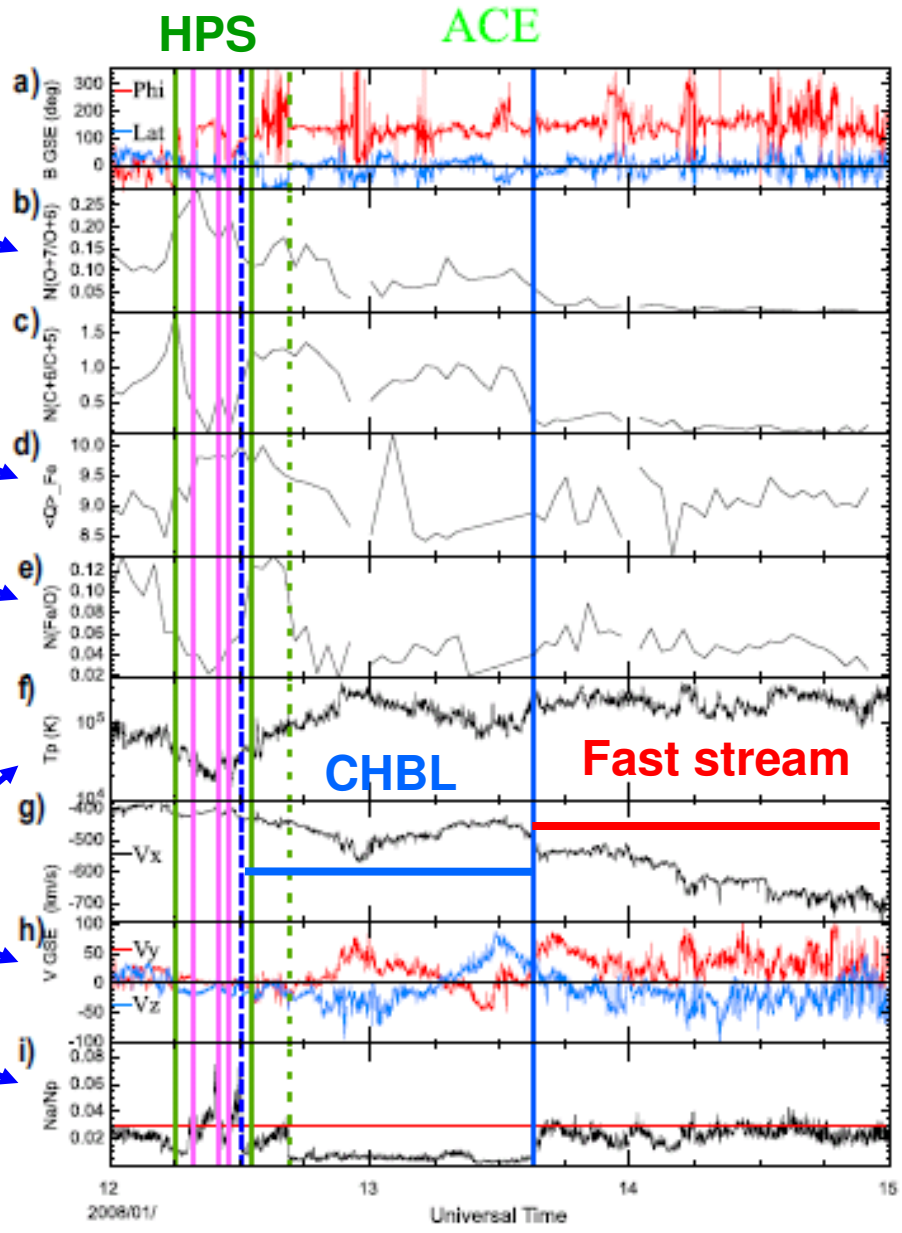
CHBL Properties near Earth

Ion composition signatures:

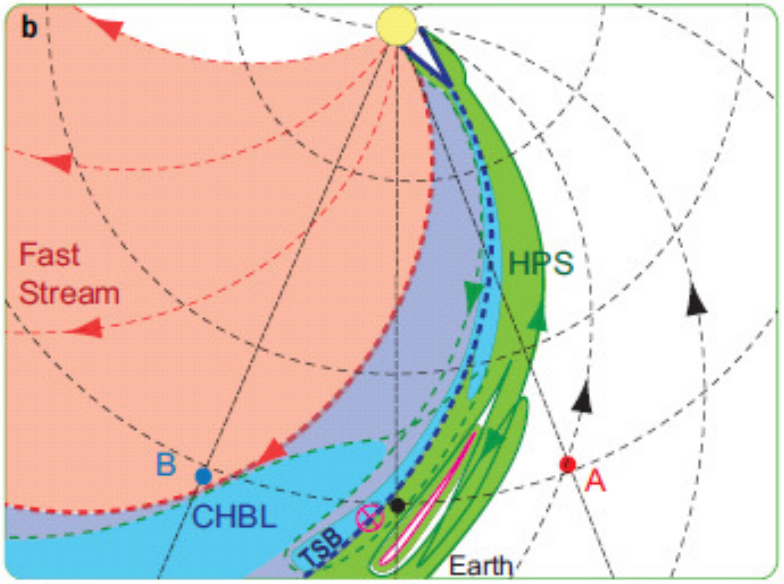
- CHBL: solar wind speed increasing with gradually changing abundances.
- CHBL iron charge states intermediate between the HPS and the fast stream
- Fe/O ratio decreases at the leading edge of the CHBL.

Largest CHBL portion is outstanding:

- **Fast stream behaviour:** Tp, flow deviations.
- **Streamer cusp origin:** Depleted in Helium, no corresponding depletion at STEREO-B and A.



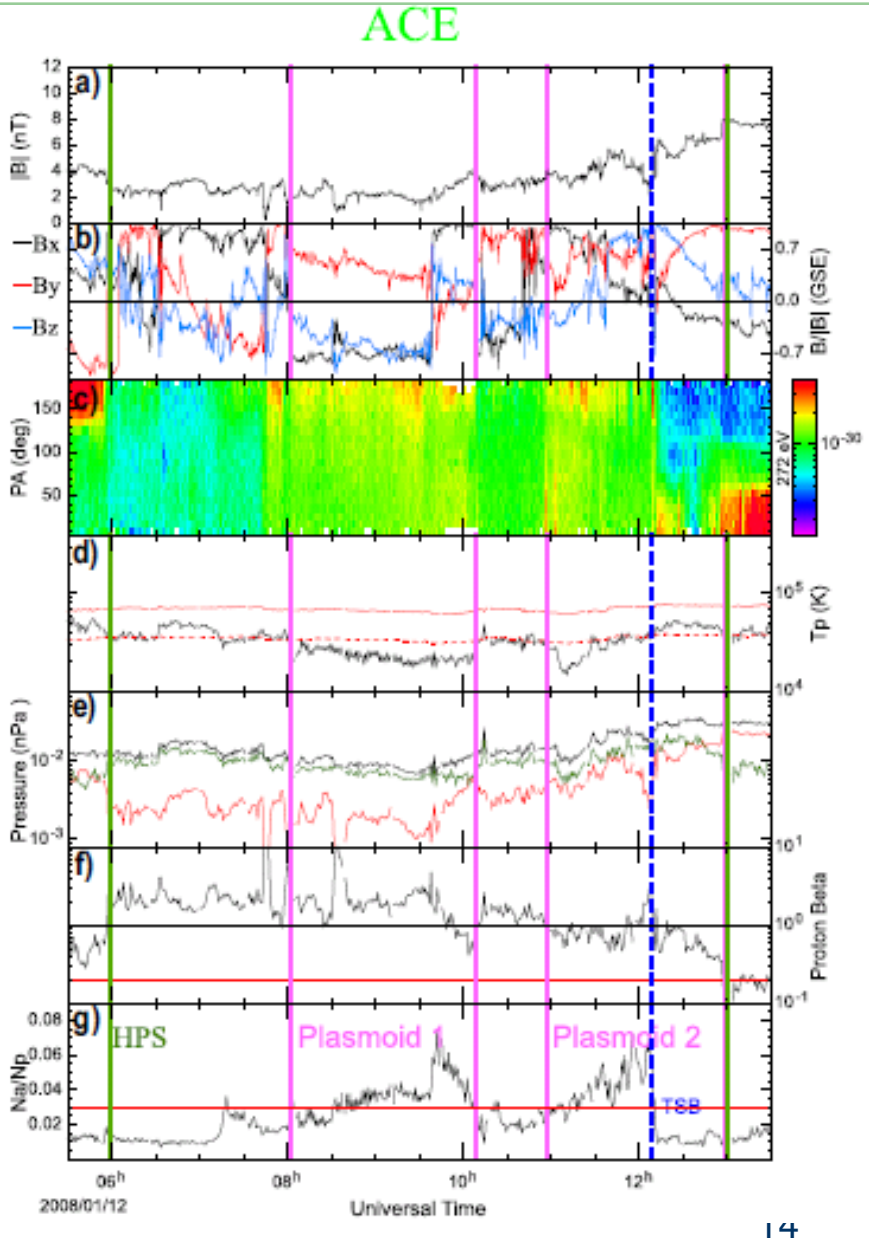
Plasmoid-CHBL Interaction



Small-scale ejecta: reaching considerable longitudinal extent while rising slowly & Eastward deflection → likely interaction with the CH in the away sector.

Likely related to the flare event:

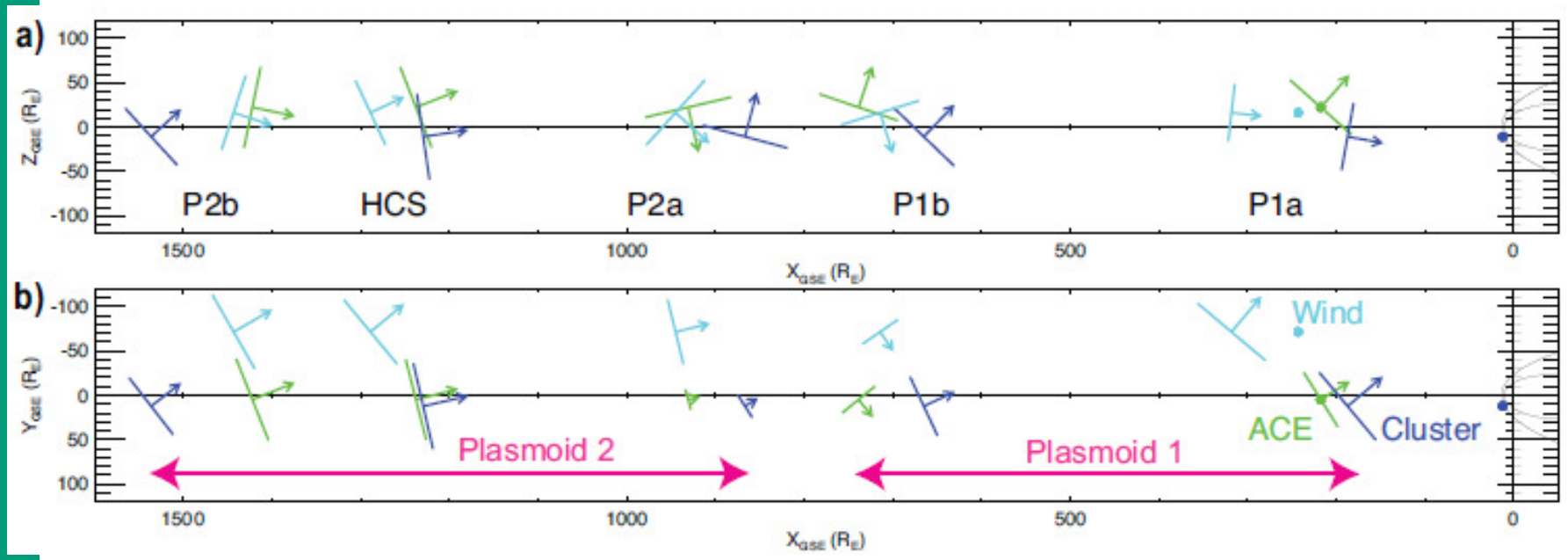
- Two-sided plasmoid, which experiences a flow-shear.
- Outstanding CHBL stream, with mixed origins: affected by the plasmoid transient release.



Plasma structures in the HPS as Plasmoids

Geometry using near-Earth multi-spacecraft:

- **Different propagation times:** Larger radial speeds at the leading edges (P1a, P2a). → transients expanding in their leading parts. → misalignment of discontinuities adjacent to the HCS.
- **Slow solar wind transients broadly convected with the solar wind, but occasional non-planar structures can be present** *[Foullon et al, 2009]*.
- **Speeds 20-30 km/s lower than ambient HPS→ slow ICMEs.**



SUMMARY-DISCUSSION

CHBL Evolution

Looking at the slow solar wind around the HCS as a boundary layer

Differential rotation-driven evolution → asymmetry by interchange:

- HPS (plasmoids) formed on the western flank (toward sector)
- new open coronal field lines (CHBL) on the eastern flank (away sector).

Continuous releases of plasmoids:

- slow ICMEs, small length scales, proton beta<0.5.
- Their sheaths could maintain the high density HPS

→ **Main differences in comparison between Heliospheric/Tail Current sheet dynamics**

Reference: Foullon, Lavraud, Luhman, Farrugia, Retino, Simunac, Wardle, Galvin, Kucharek, Owen, Popecki, Opitz and Sauvaud, *ApJ* 2011