Cold Dense Plasma Sheet Formation During Northward IMF

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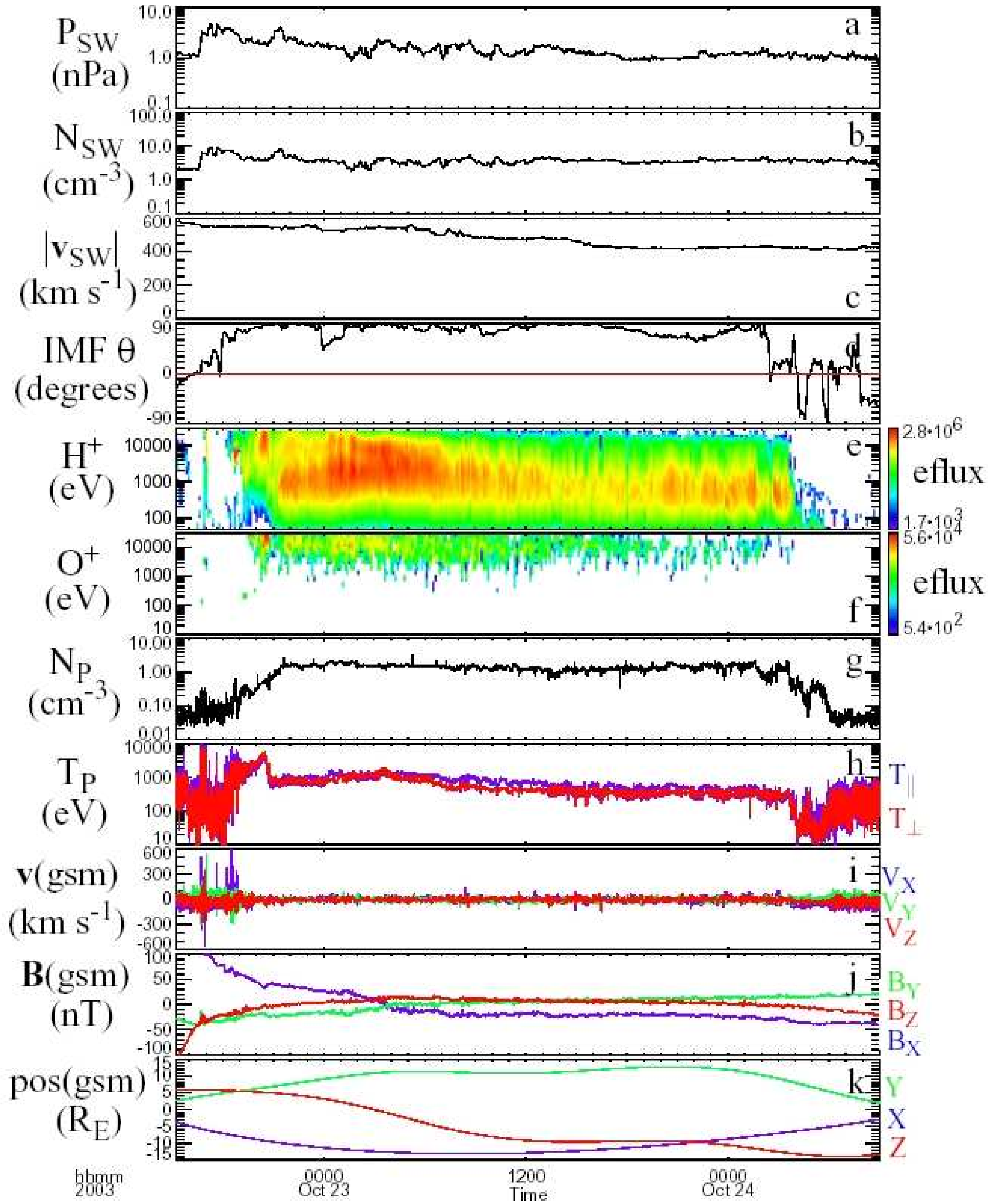
The Plasma Sheet

- During moderately active and active times the plasma sheet is filled with hot, tenuous plasma, N~0.1 cm^{-3}, T~5 keV.
- The supply of plasma sheet plasma is thought to come from the solar wind via magnetopause reconnection and the plasma mantle, and from ionospheric outflow.
- During very quiet times and northward IMF one would thus expect that the plasma sheet density decreases because the plasma supply, both from the solar wind and the ionosphere, gets reduced.
- However, often the opposite is observed: the plasma sheet plasma becomes denser, up to several cm^{-3}, and colder, T~1 keV or less.
- One such event occurred on October 23-24, 2003, when the IMF was northward for more than 30 h and Cluster II observed a cold dense plasma sheet in the near-Earth tail.

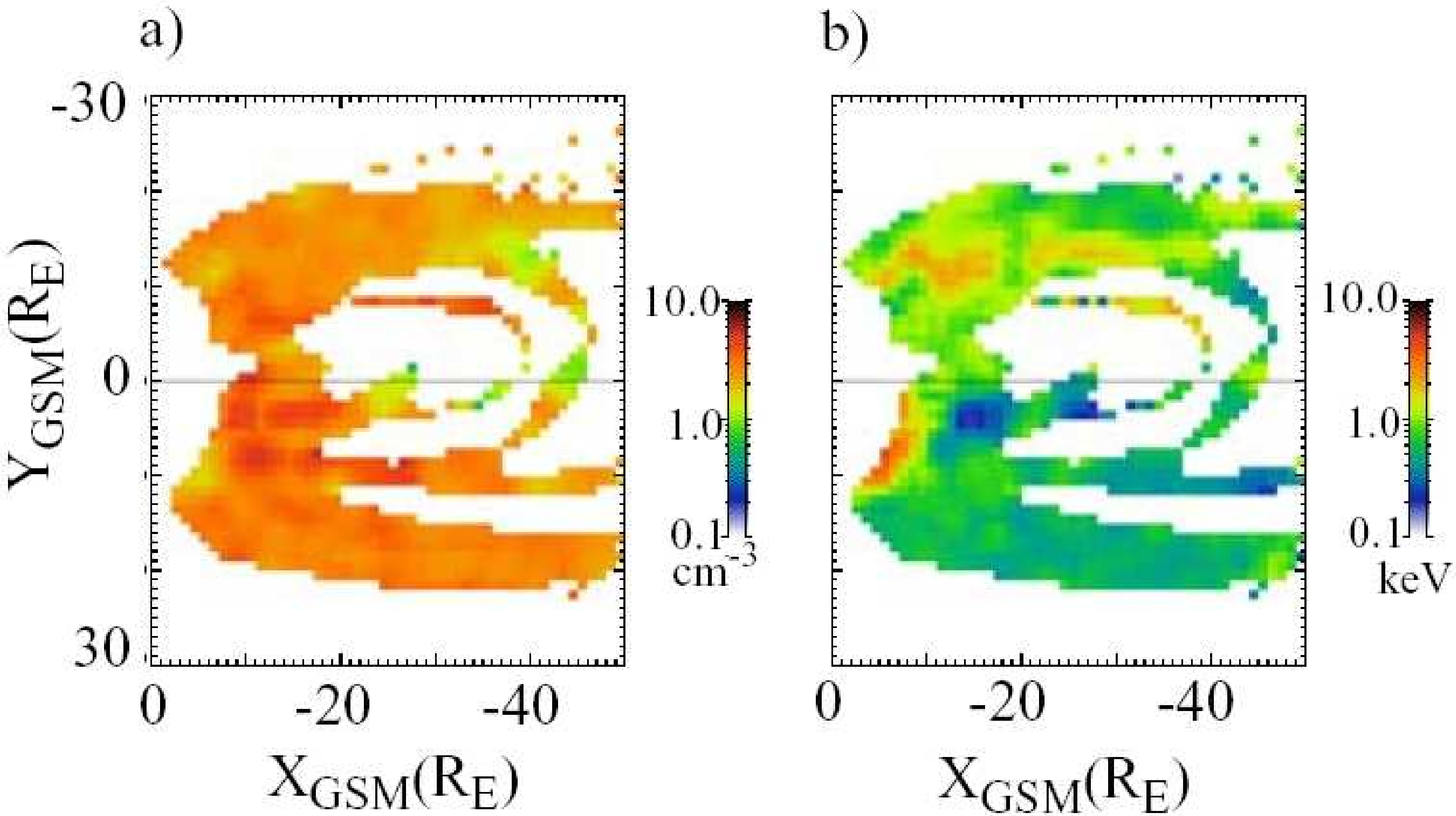
October 23-24, 2003 event overview

- >32 hours of due north IMF.
- Nothing else special in SW/IMF.
- Cluster II in PS around (-10,10,0)
- CDPS ramps up over ~3 hours.
- PS becomes dense (>1 cm^{-3}) and cold (<1 keV).
- CDPS disappears after IMF turns E-W and then southward.



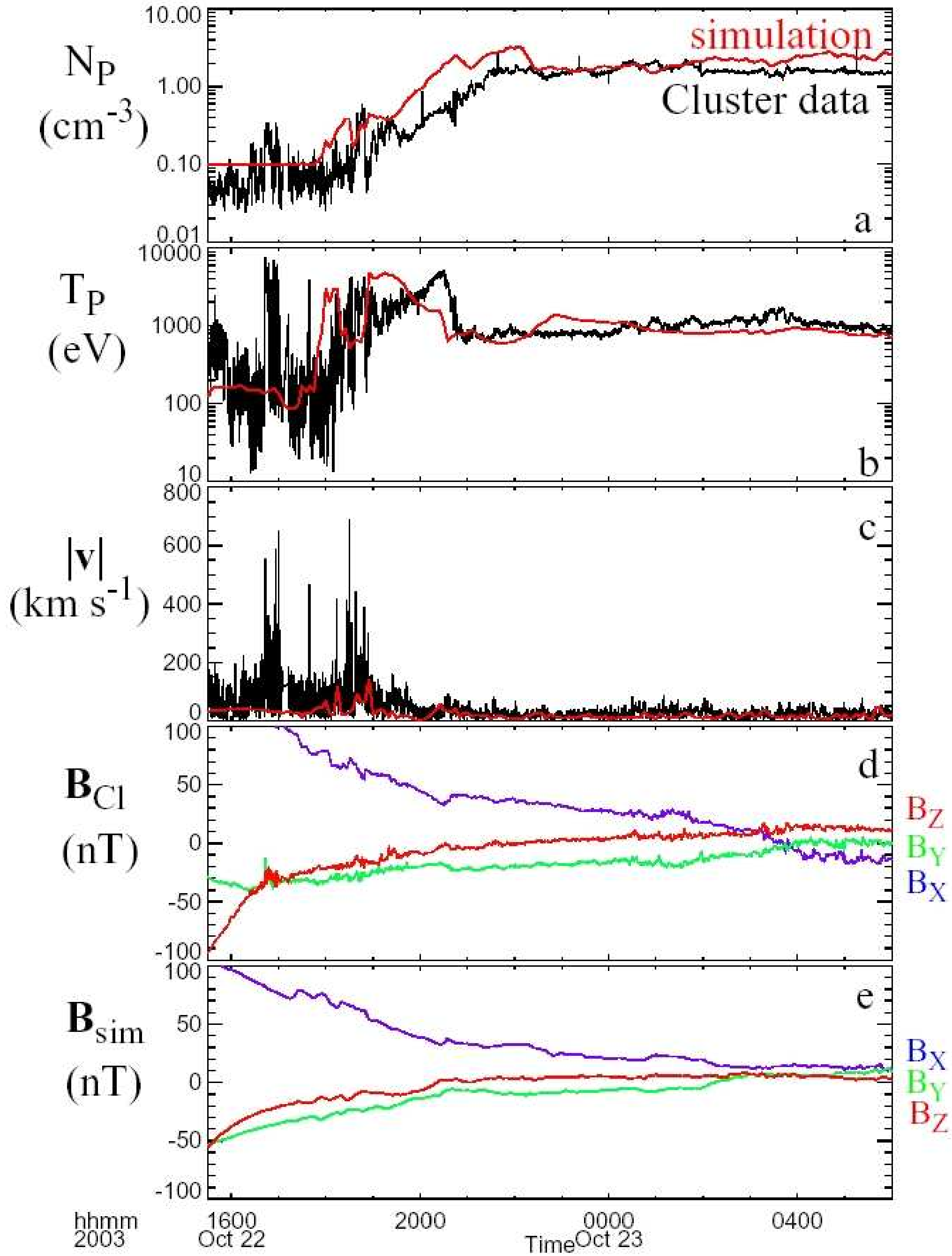
DMSP plasma sheet temperature

- DMSP data show that CDPS is not local, but entire plasma sheet becomes cold (data courtesy of Simon Wing, JHU/APL) .



Simulation

- A global simulation was run for this event with the OpenGGCM using ACE data as input.
- Time series at the Cluster location compare favorably with the data.
- In particular, the simulation matches the CDPS density, temperature, and flow velocity, as well as the rise time.



Tail plasma density

- A cut at x=-7.5 R_E shows how the plasma enters from the flank.
- The movie covers the first 10 hours of the event.

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

Tail plasma temperature

- A cut at x=-7.5 R_E shows how the plasma cools as it enters the tail.

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

Tail plasma velocity

- A cut at x=-7.5 R_E shows how the plasma becomes increasingly stagnant.

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

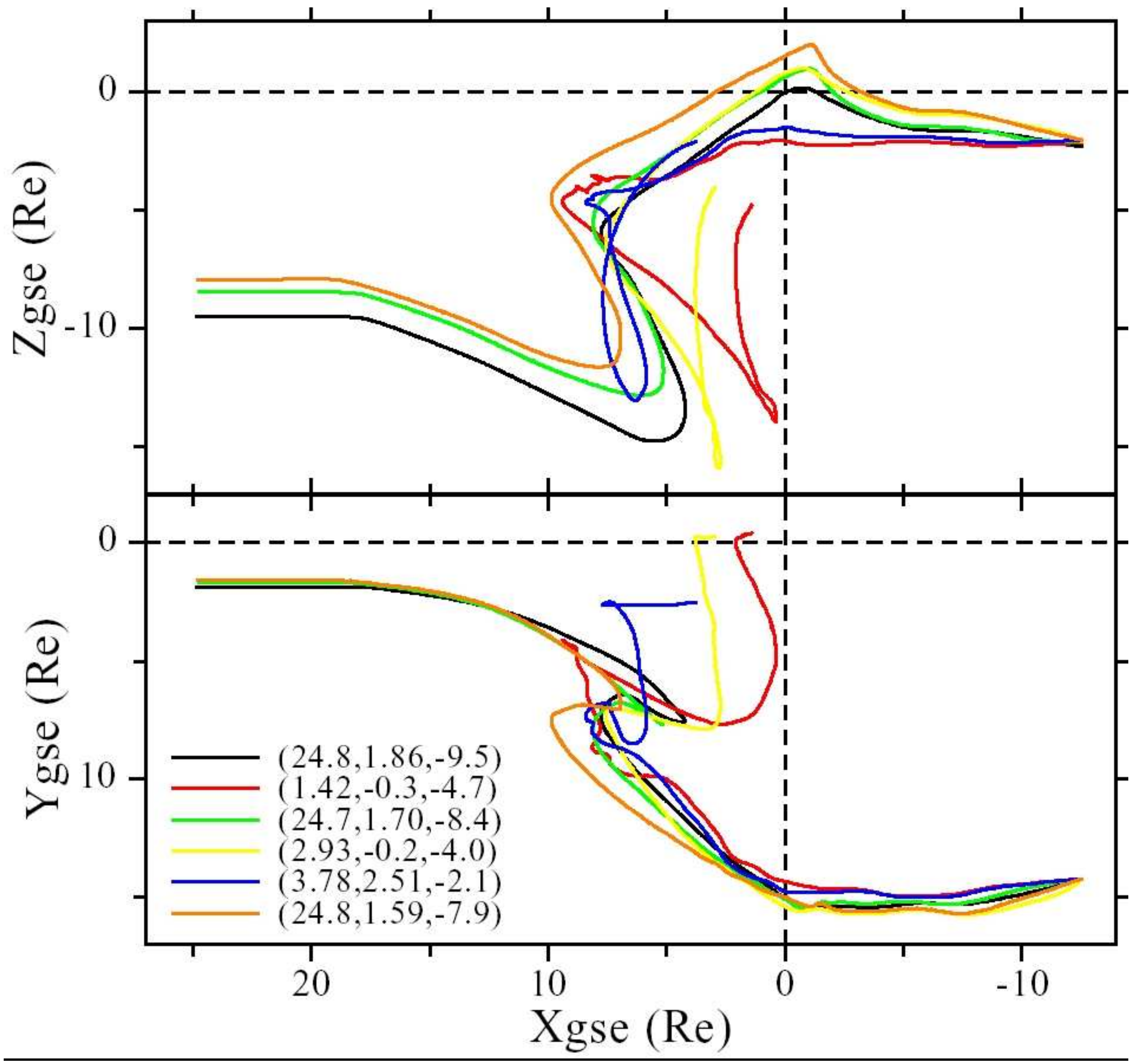
Entry process: Kelvin-Helmholtz waves?

- A cut at z=0 R_E shows shows no evidence for K-H waves at the flank magnetopause.
- Surface waves get excited by SW density fluctuation, but they do not seem to be correlated with plasma entry.

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

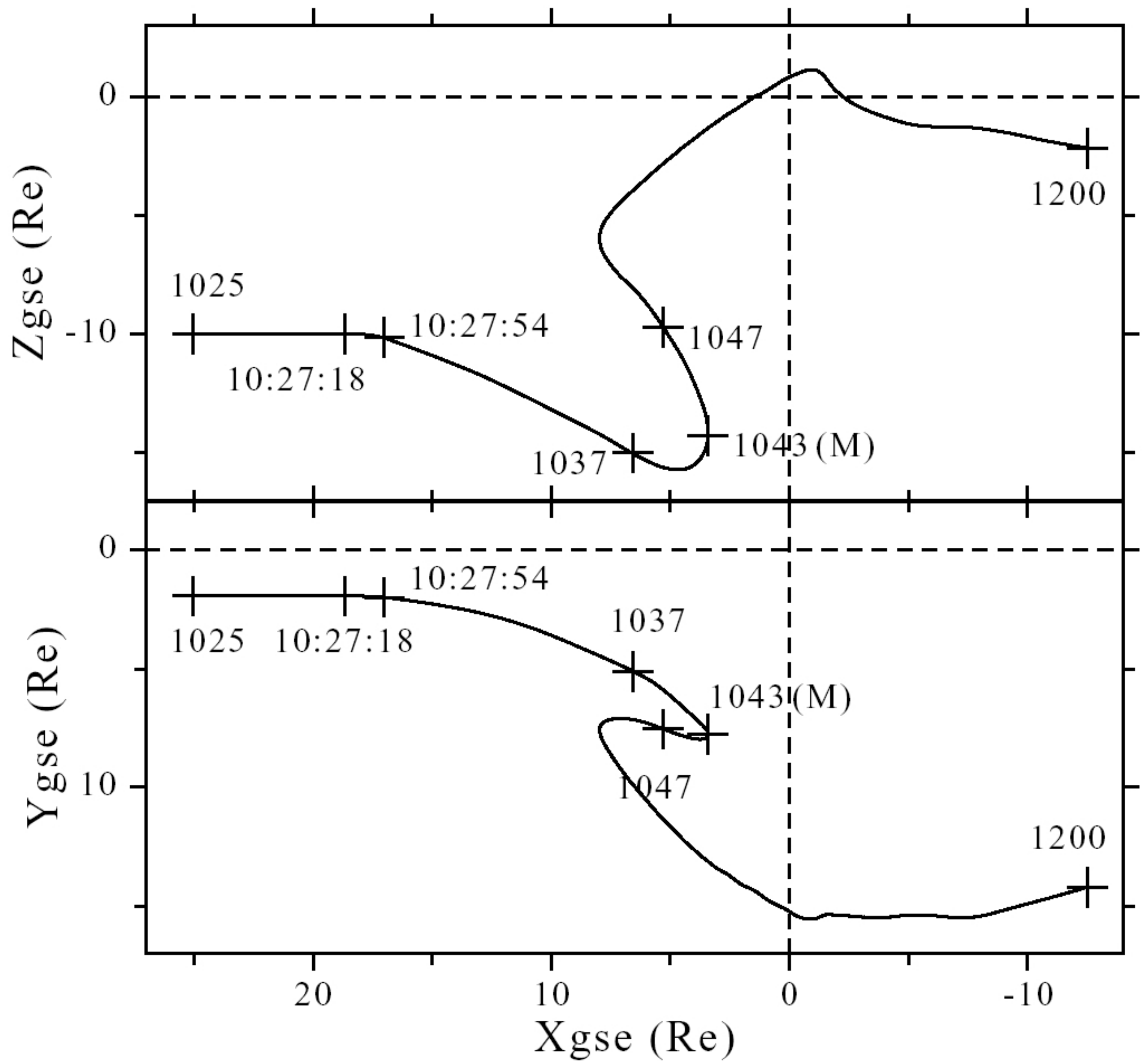
Entry process: Fluid element tracing

- Fluid parcels are traced backward in time from locations at or near the CLUSTER spacecraft.
- Fluid parcels pass at a common location through the magnetopause.
- They either come from the inner magnetosphere or from the solar wind.



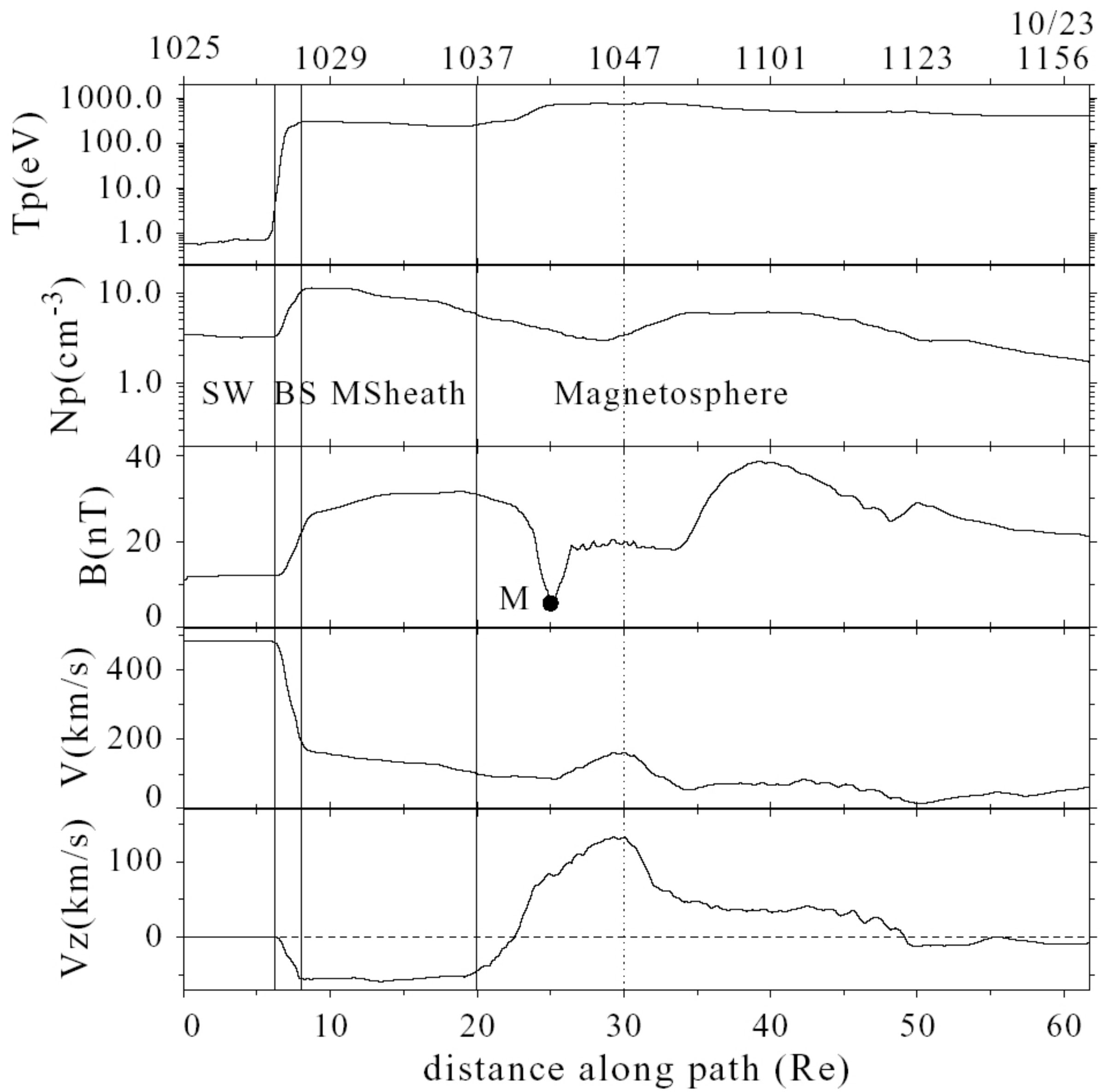
Entry process: Fluid element tracing

- A typical fluid element takes about 1.5 h to get from the solar wind to the CLUSTER location.

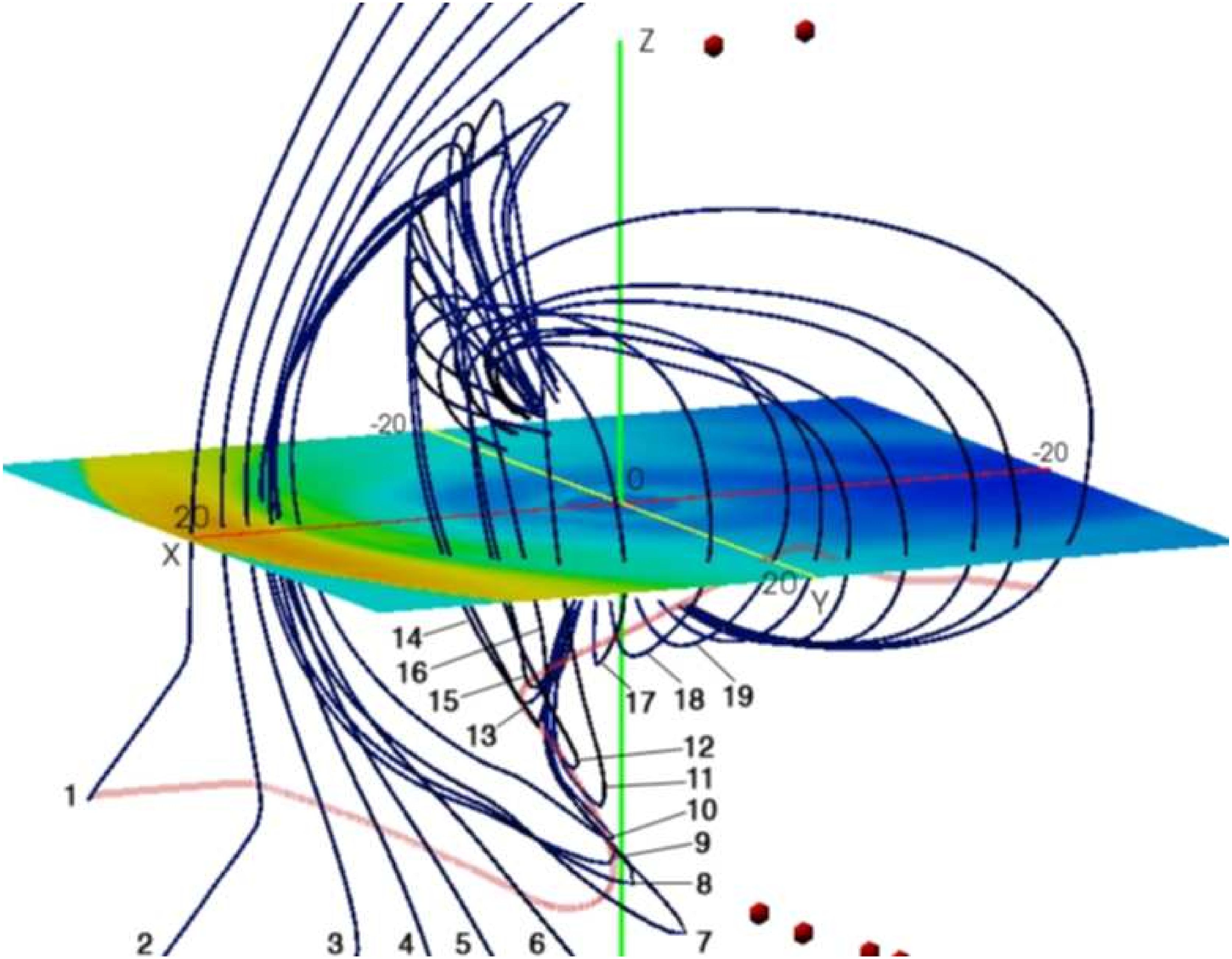


Fluid element tracing: Parameters along path

- **The fluid element encounters a minimum in B (point M) where it gets heated and briefly accelerated.**
- **Subsequently the fluid element slowly drifts into the tail, cooling and de-compressing.**



Flow and field topology

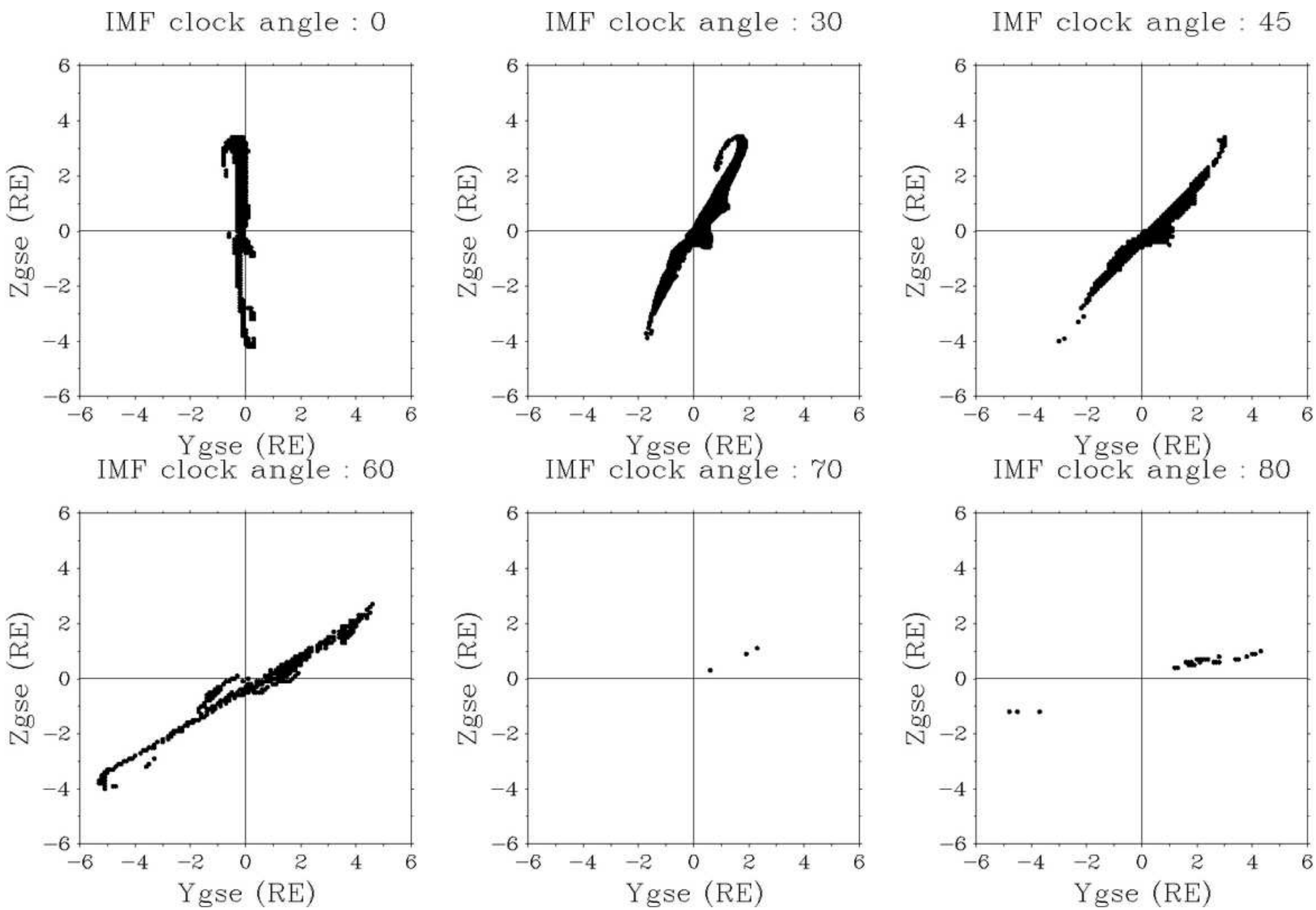


Flow and field topology movie

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

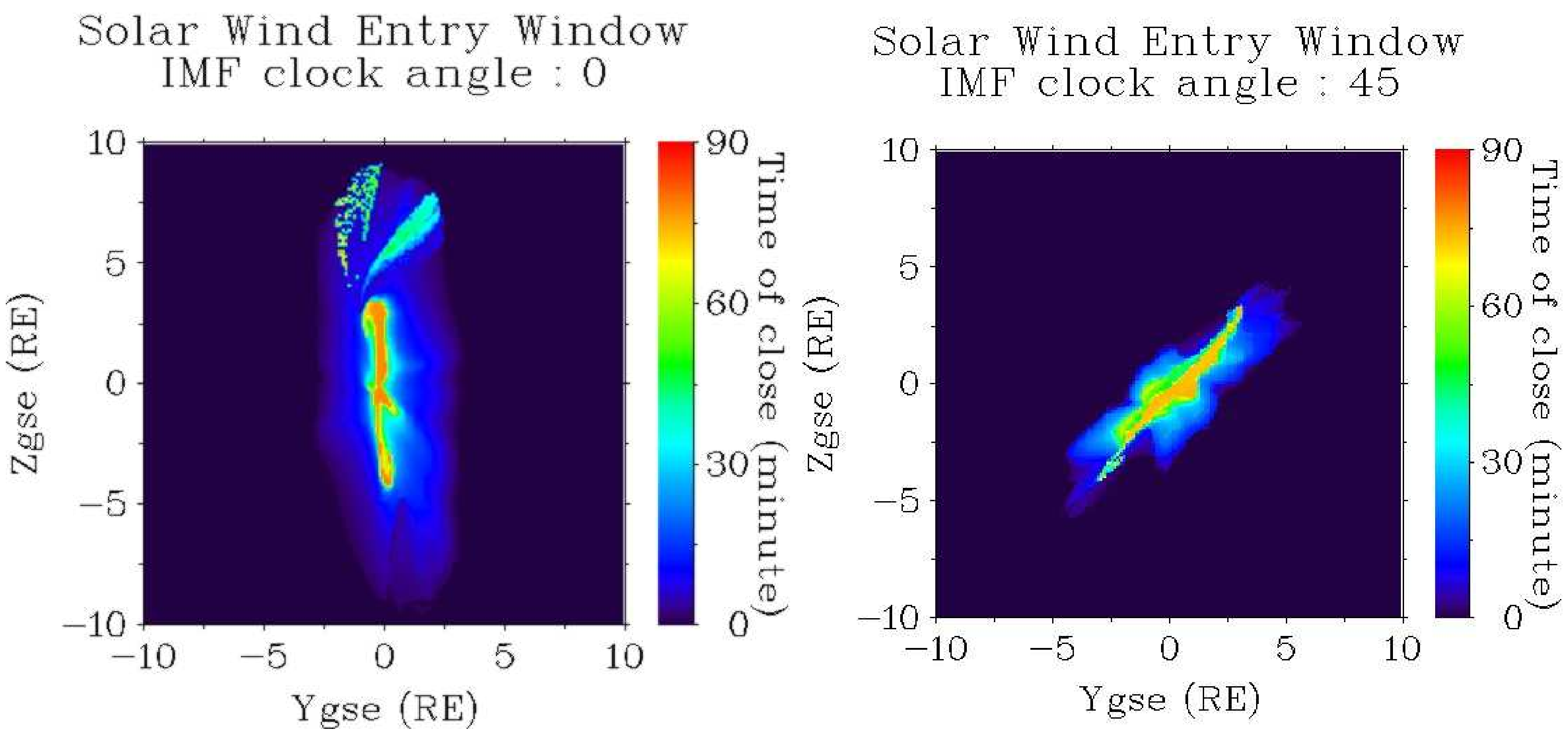
Are flux tubes captured at any clock angle?

Entry window for different clock angles, view from the sun, no dipole tilt, black dots ==> fluid particles that end up on closed field lines ==> 65 deg cutoff.



Closed flux tube dwell time

Many flux tubes get captured but then re-reconnect (closed => open, closed => open => SW). This figure shows how long flux tubes remain closed.



Summary

- The October 23/24, 2003 Cluster event provides an unprecedented opportunity to study the CDPS formation, with >32h of pure northward IMF.
- The simulation reproduces the CDPS formation rather well, including the 3h ramp-up of the plasma sheet density.
- The model suggests that Kelvin-Helmholtz waves play no significant role in the plasma entry process.
- IMF flux tubes, carrying magnetosheath plasma, are captured by nearly simultaneous cusp reconnection and subsequently convected into the tail, where they form the CDPS.
- Simulations indicate ~65^{o} cutoff for dual lobe reconnection with no tilt and no IMF Bx, consistent with recent Cluster observations.
- More multi-spacecraft studies and more simulation studies are needed to follow the entry process and to investigate the eventual replacement of the CDPS with a new hot, tenuous plasma sheet.