Summary on Magnetospheric Plasmas

by
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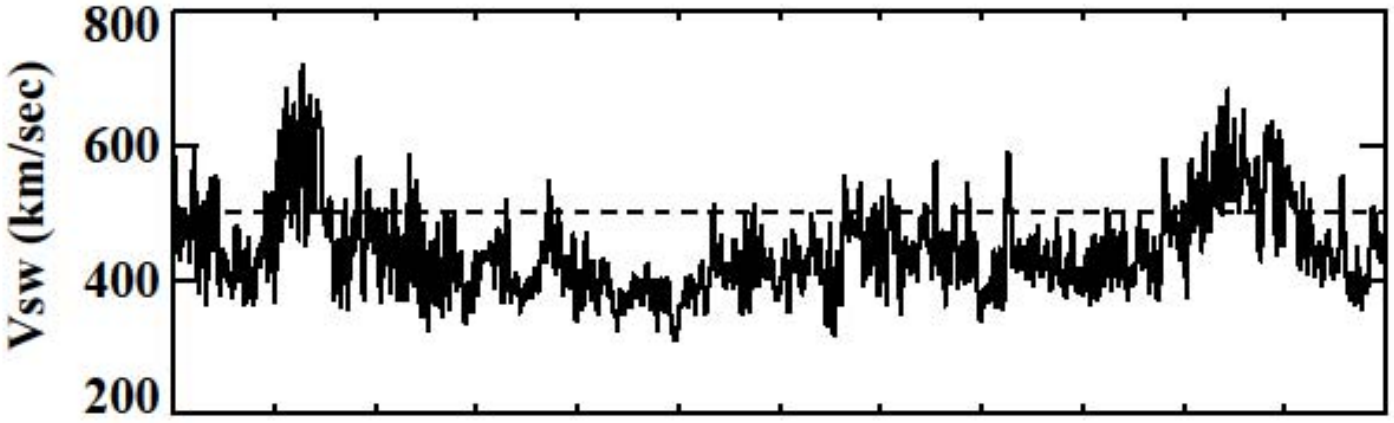
Modern Challenges in Non-linear Plasma Physics

Honoring the career of Dennis Papadopoulos

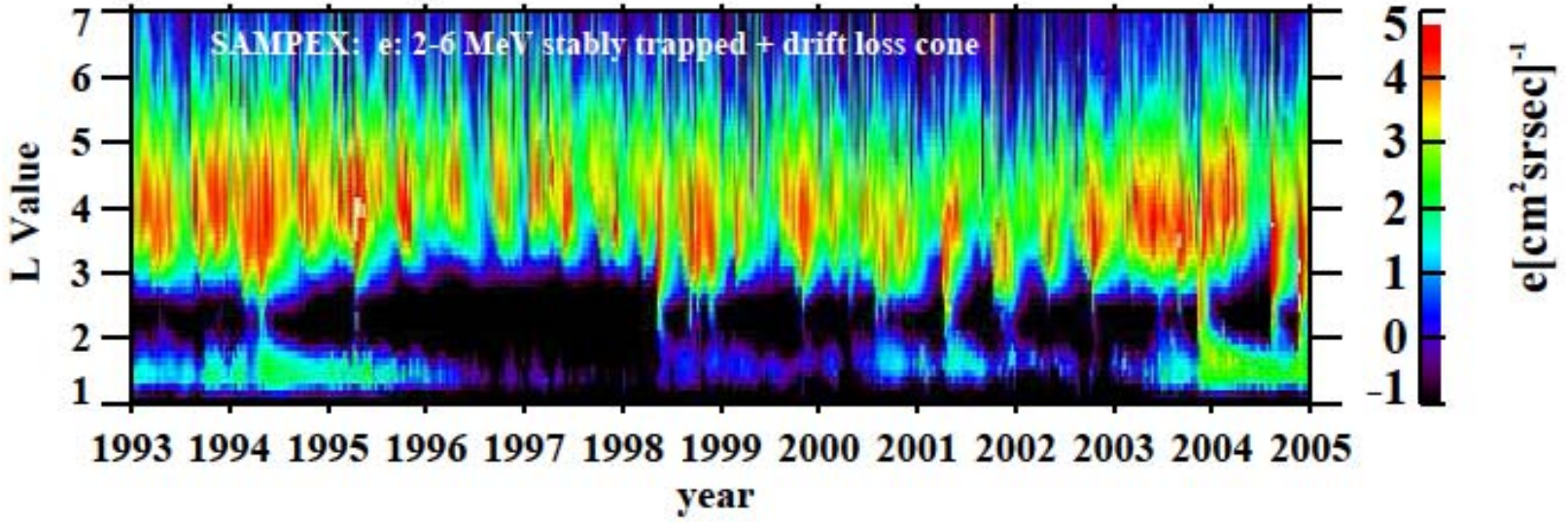
June 15-19, 2009 Halkidiki, Greece

(Baker presentation)

Solar Wind Control of Radiation Belts!



Amazing control:
V_{sw} > 500 km/s!!

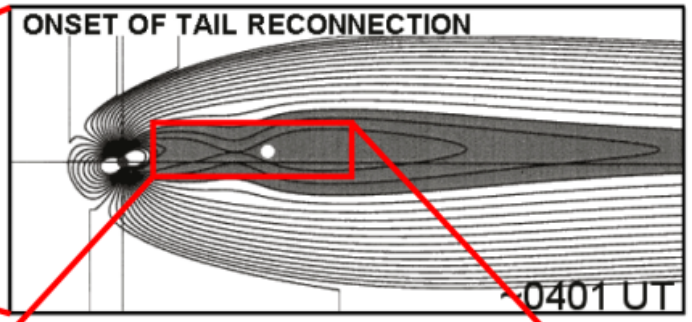


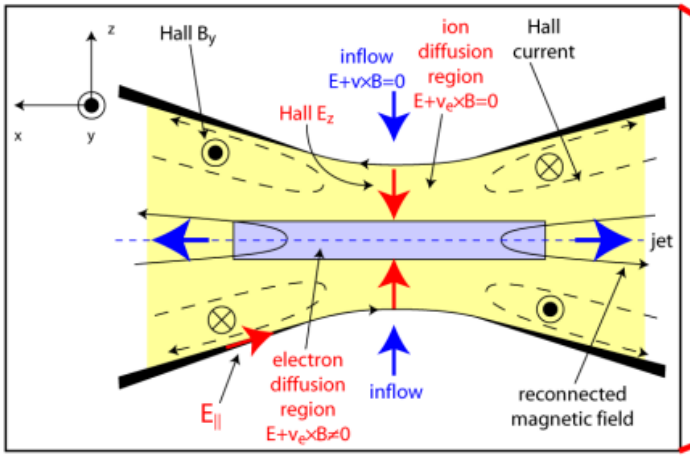
(Baker presentation)

Multi-Scale Phenomena in Magnetospheric Substorms

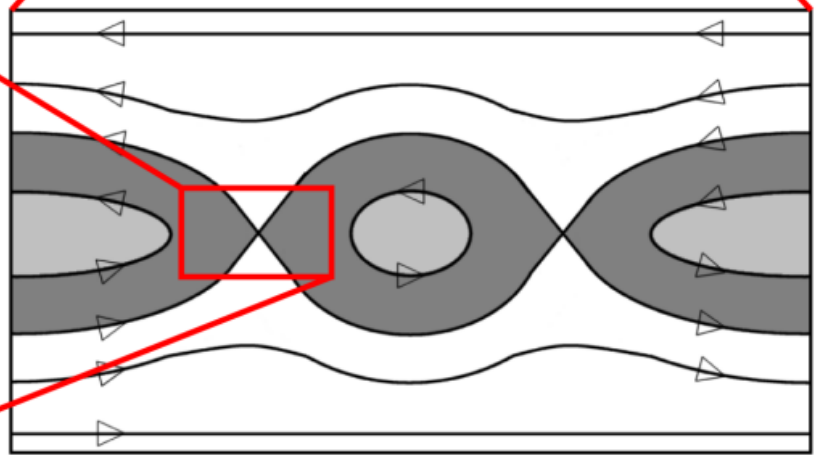
Sun-Earth Coupling

Magnetospheric Energy Loading





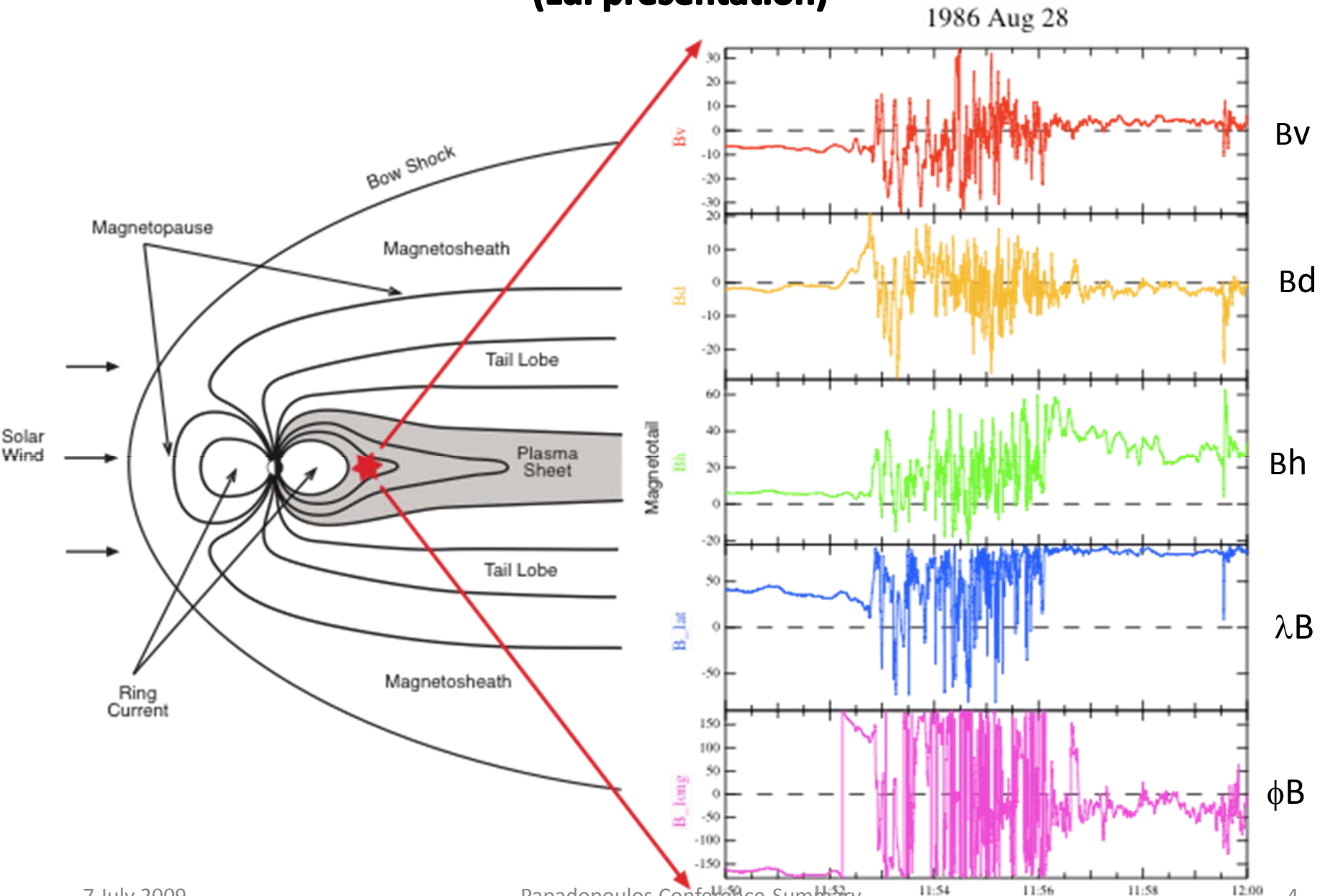
Diffusion Region Physics



Reconnection and Reconfiguration

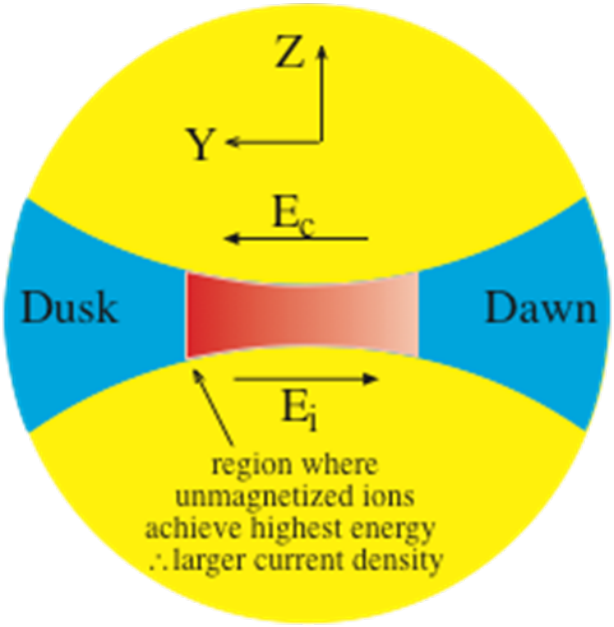
Current Disruption and Dipolarization

(Lui presentation)



Substorm Features From CCI Mechanism

(Lui presentation)



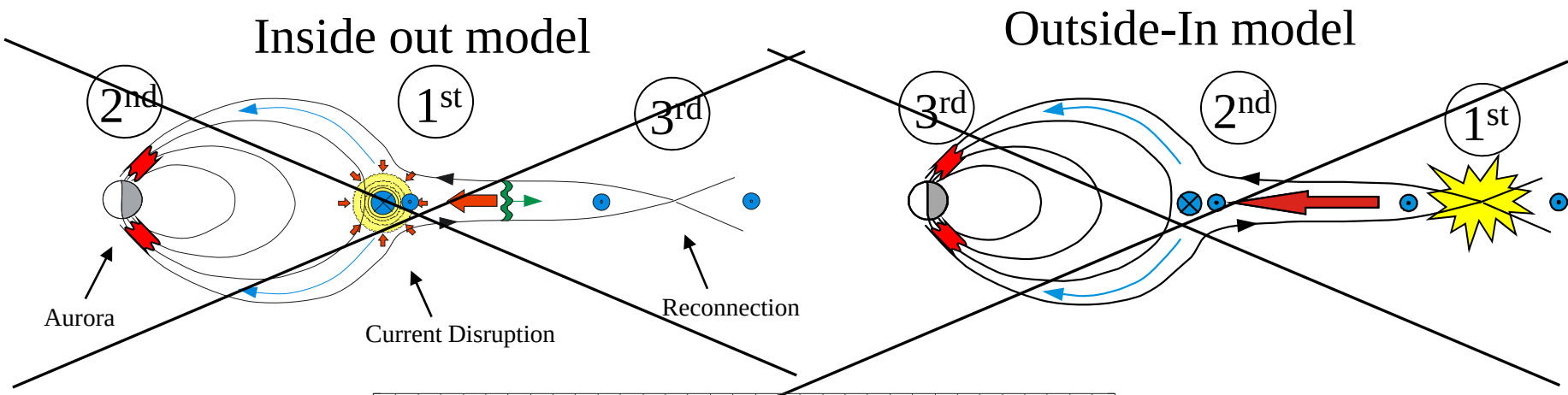
E_c = Cross-tail electric field due to solar wind magnetosphere dynamo
E_i = induced electric field from increase in tail lobe magnetic flux

- CCI can explain naturally why substorm onset location is preferentially skewed towards the pre-midnight local times.
- Its onset is tied to an existing auroral arc (Samson et al., 1991).
- Even though CCI is an internal mechanism, it can explain naturally why northward turning of IMF after a period of southward IMF can trigger a substorm:

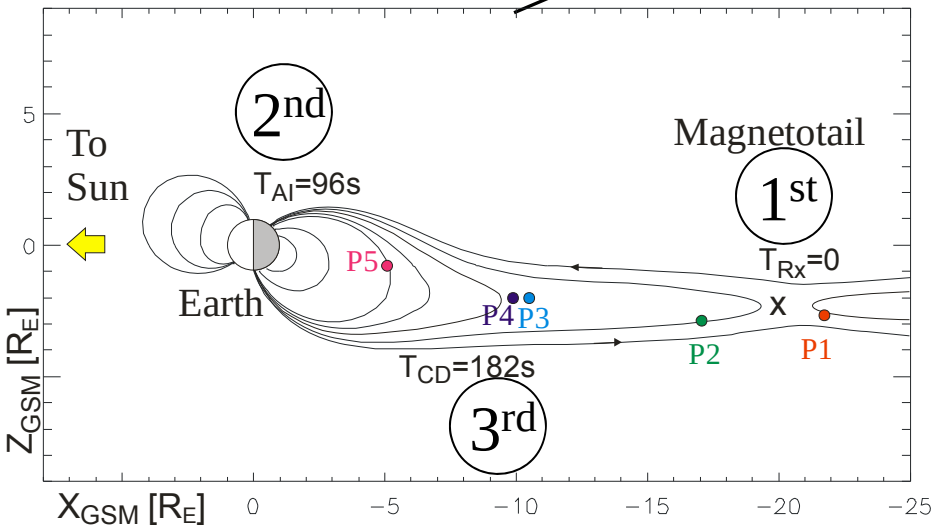
  Ei during substorm growth phase (southward IMF) can substantially reduce Ec and a northward turning of IMF reduces cancelling of Ec by Ei, allowing ions to pick up more energy and thus producing a larger current density to start CCI.

Summary of timing results (Angelopoulos presentation)

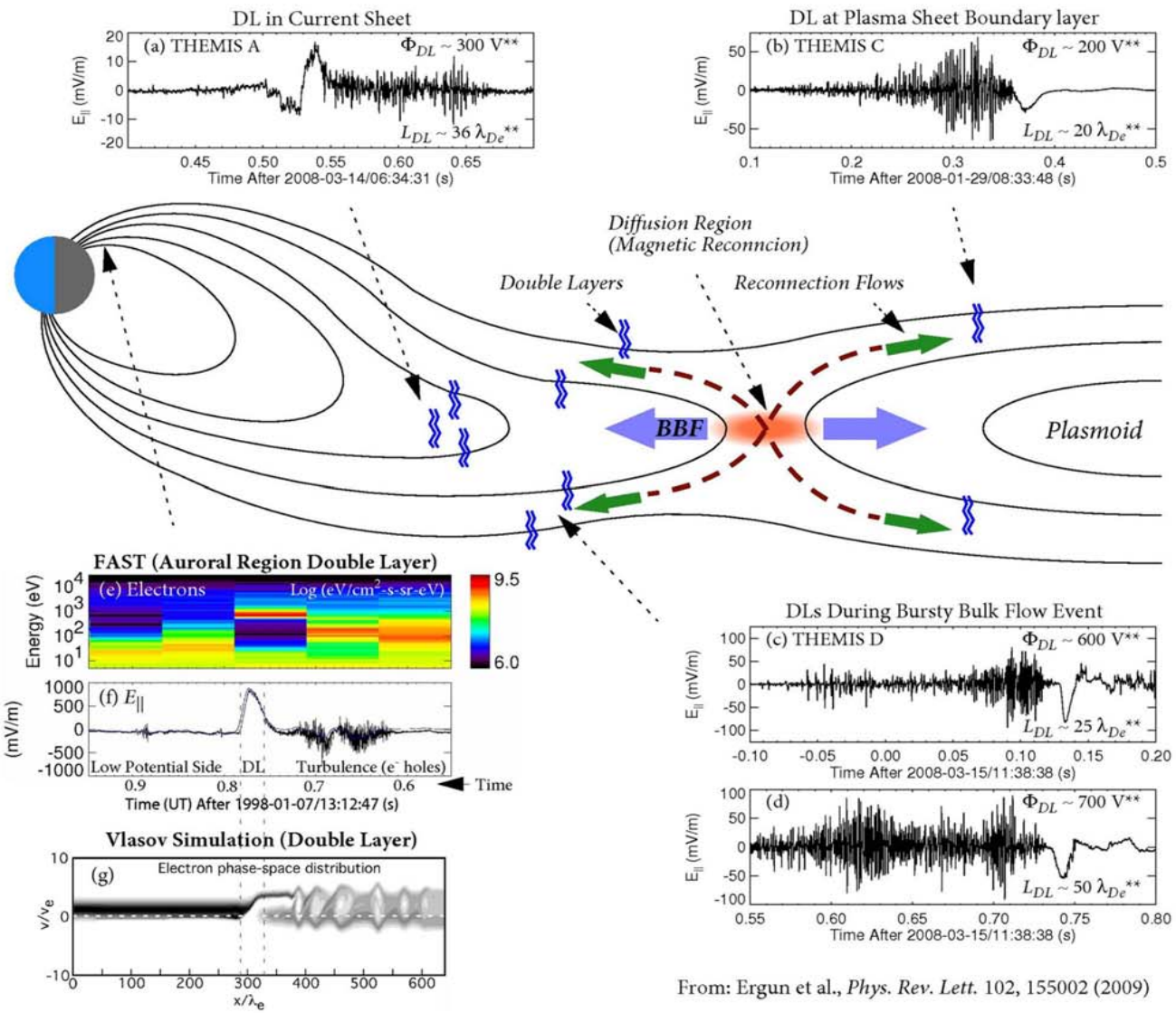
Note: what was observed was not the classical time sequence:
Aurora brightens before near Earth dipolarization
Moreover the time delay seems short for Alfven wave propagation



THEMIS finds:

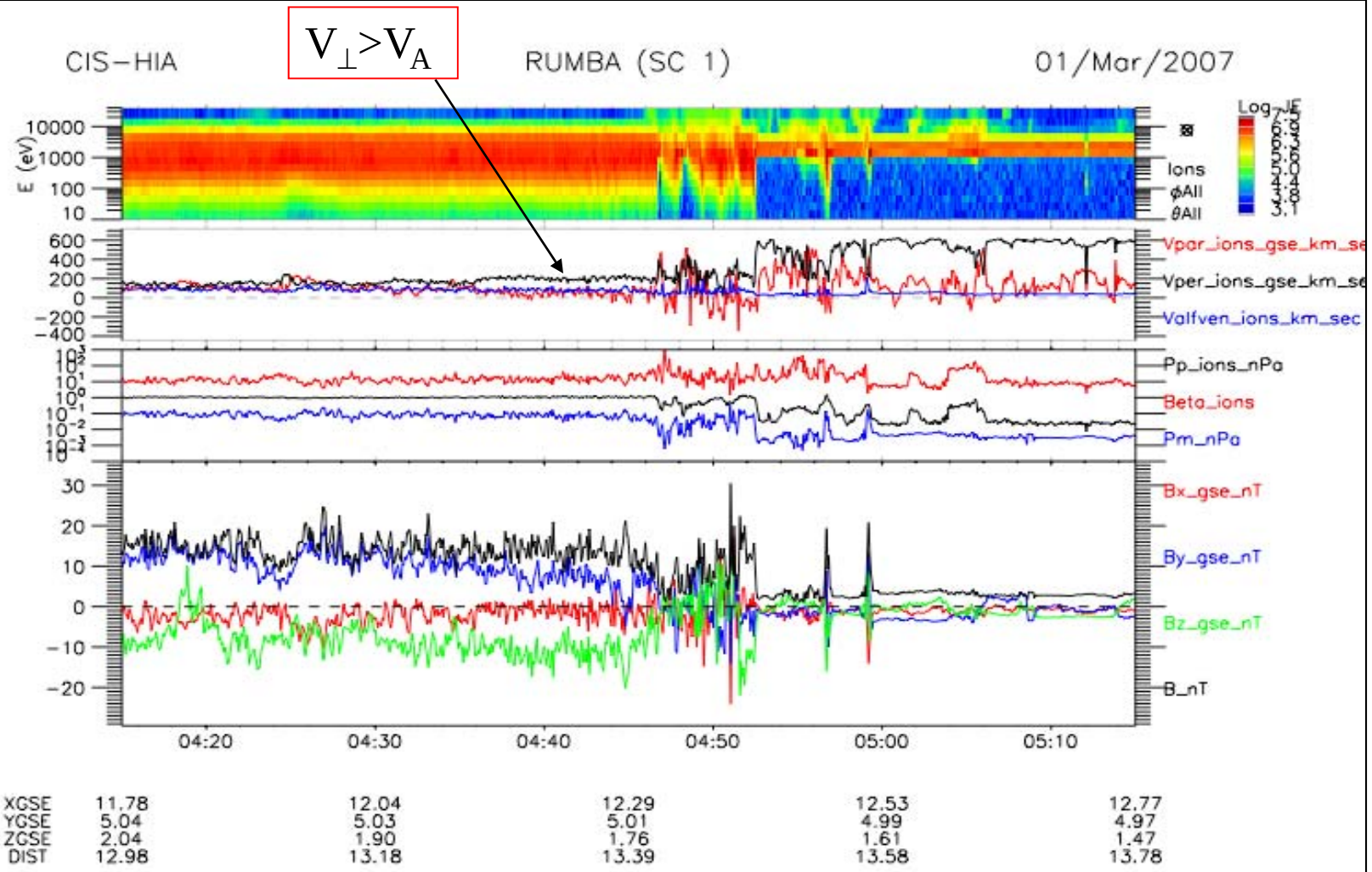


(Angelopoulos presentation)



From: Ergun et al., *Phys. Rev. Lett.* 102, 155002 (2009)

Unexpected super-Alfvénic flow in Magnetosheath (Parks presentation)

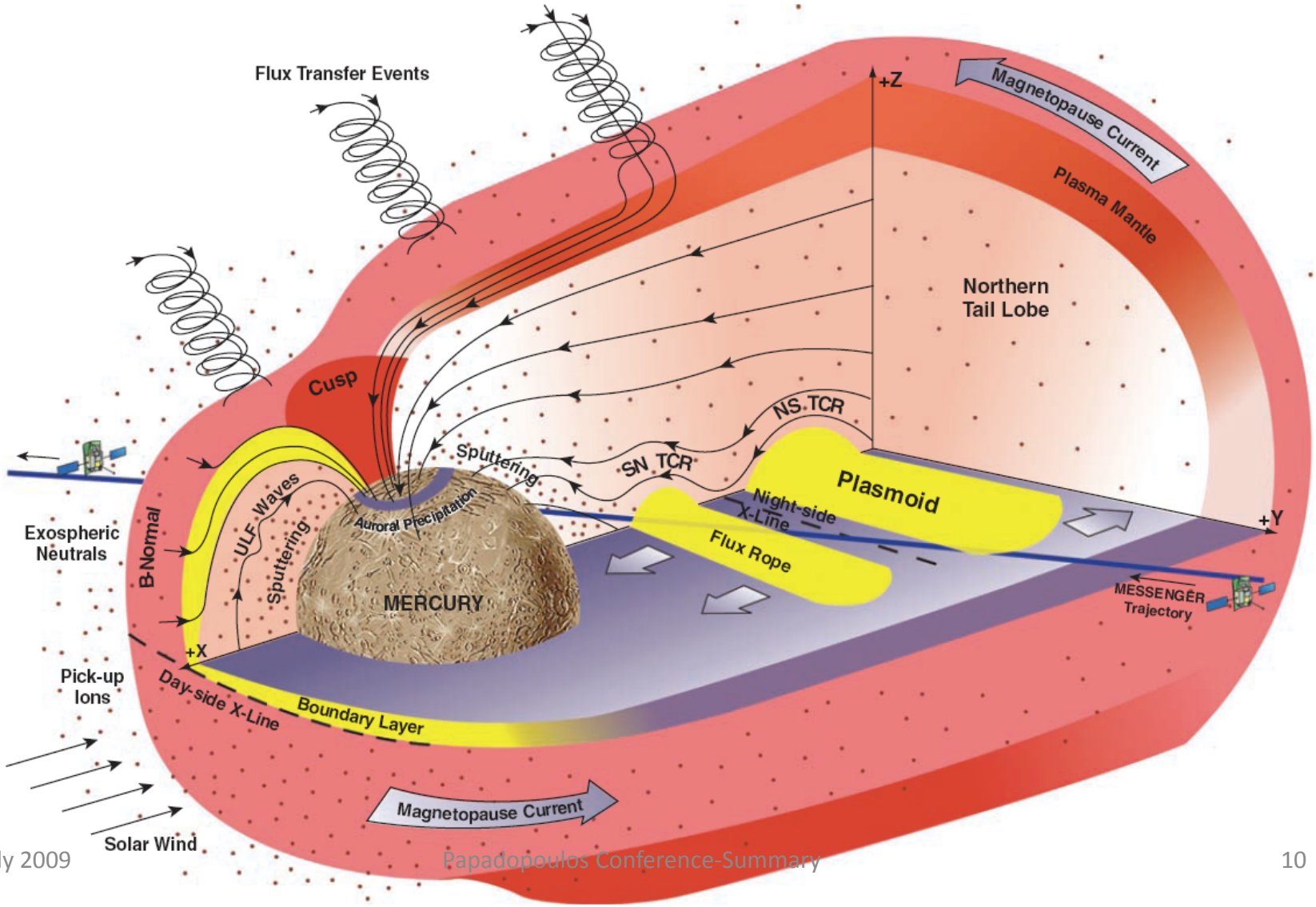


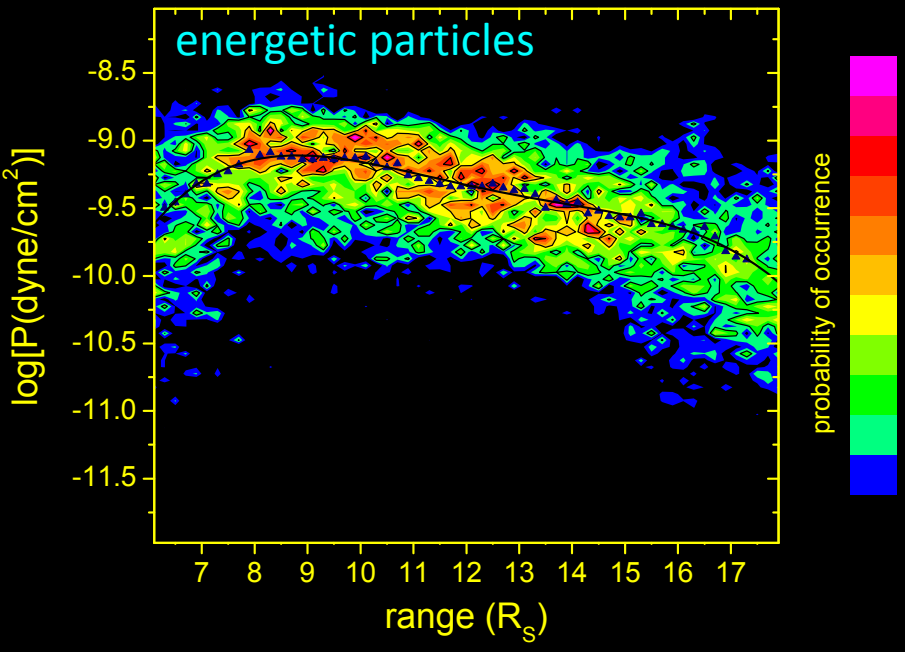
Statistics of Magnetosheath flows (Parks presentation)

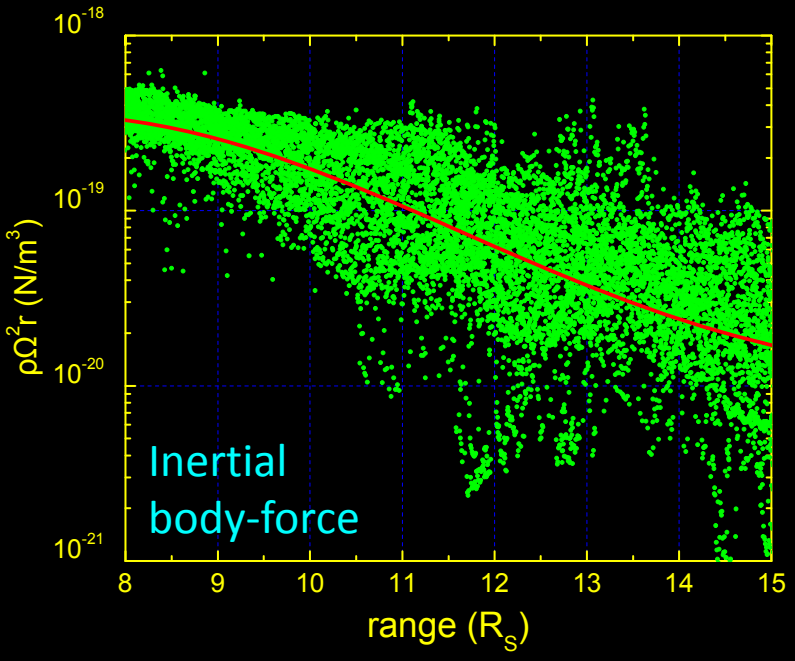
~100 bow shock crossings indicate ~80 crossings show $V_{msheath} > V_A$ in the magnetosheath. These events occur on the dayside (dawn-noon-dusk sectors).

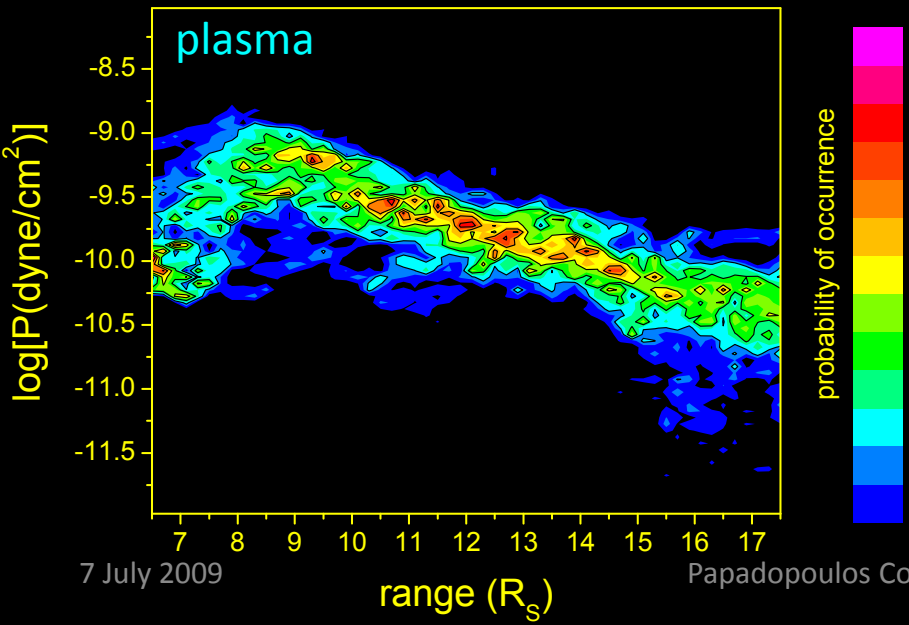
These results are *not* consistent with shock theories that predict downstream region plasma flow is sub-Alfvénic (sub-sonic) and plasma has been thermalized.

Mercury's magnetosphere presents a challenge to standard Earth analog for substorms (Slavin et al, Science, 324, 606, 2009) (Baker et al presentation)









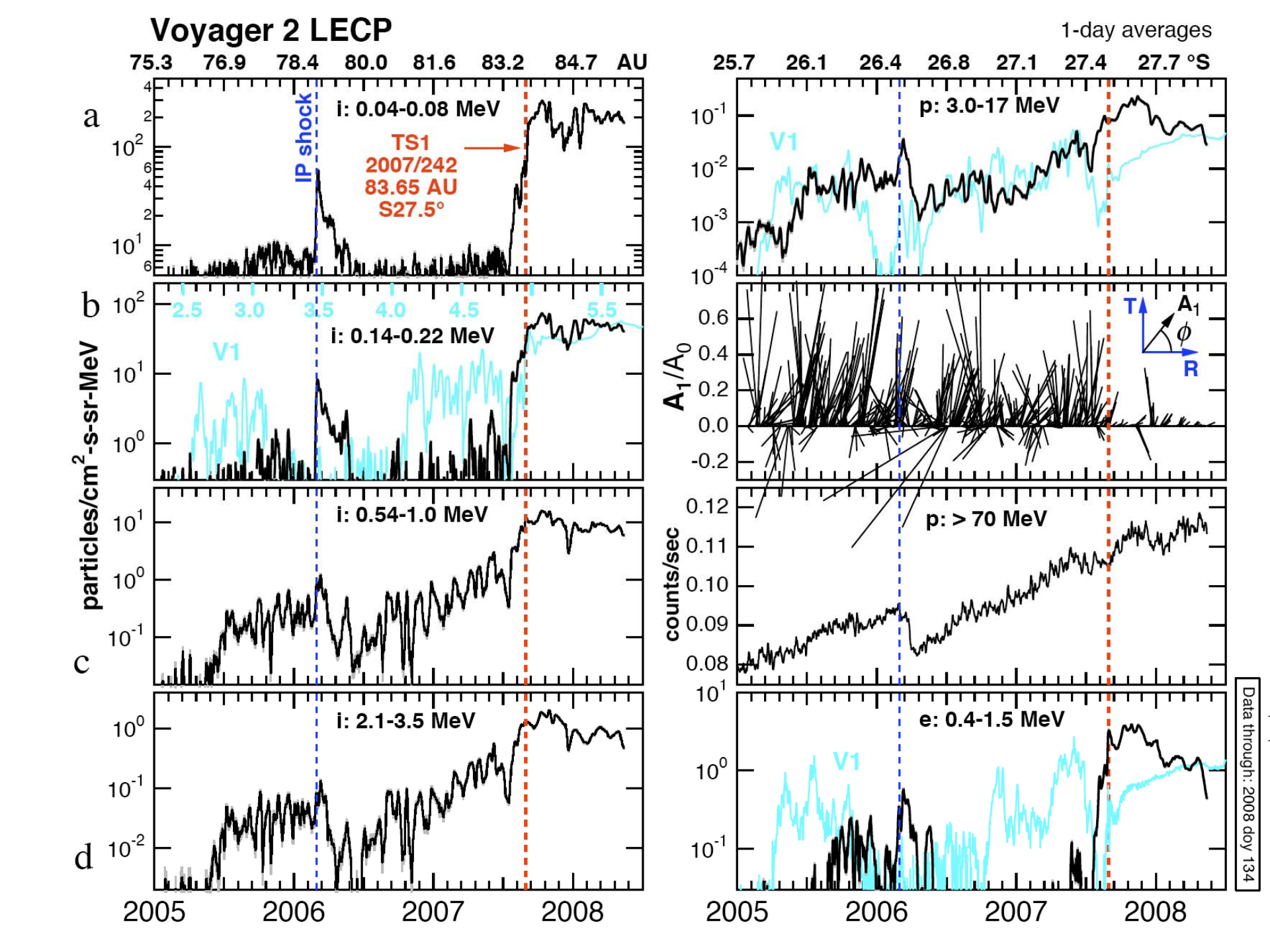
After 5 years in orbit we have sufficient data to look into the statistical behavior of the system

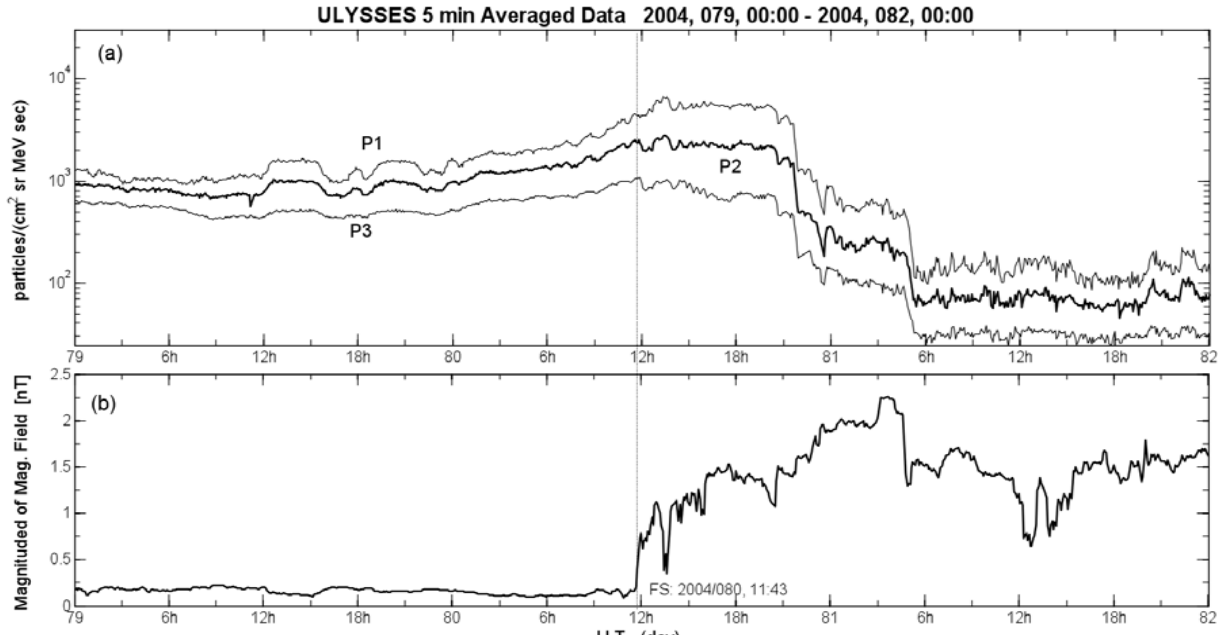
However, the dynamic nature of the Saturnian magnetosphere appears almost overwhelming!

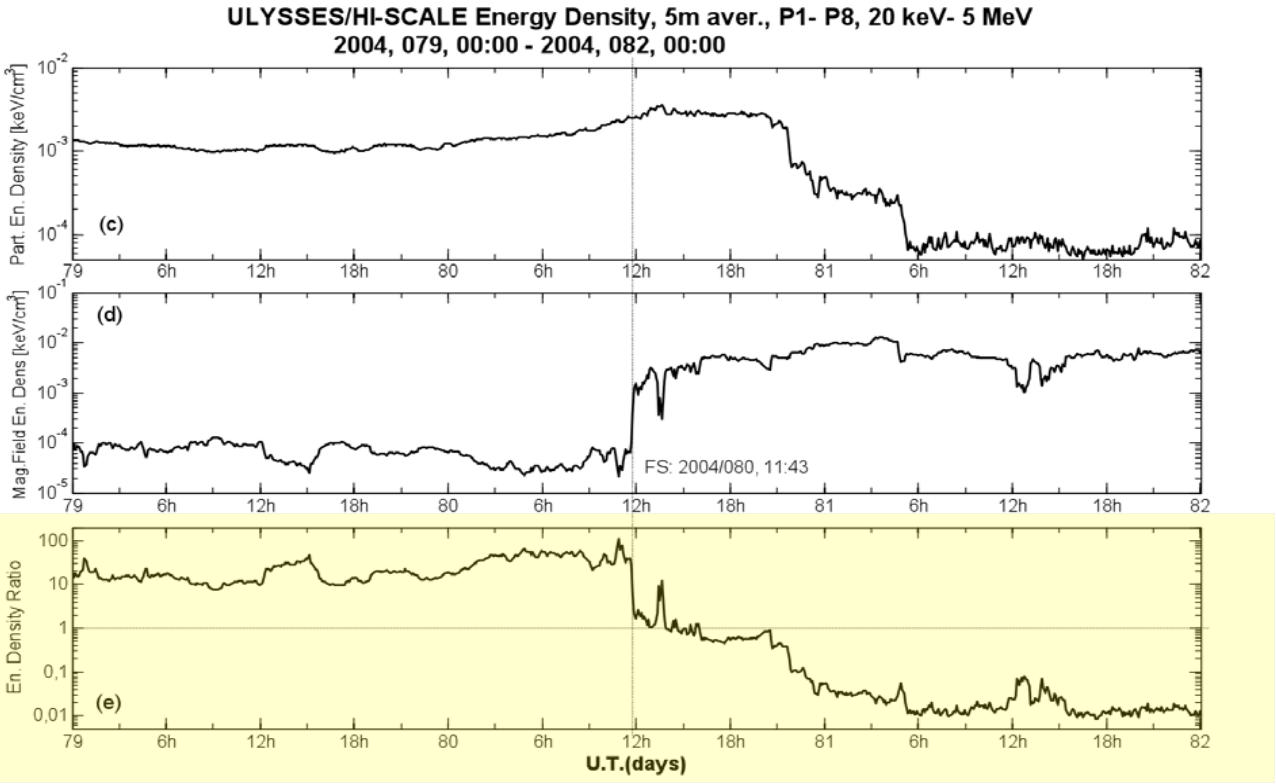
(Sergis et al presentation)

Ion acceleration during reconnection (Drake presentation)

- Fermi acceleration through island contraction is efficient only for super-Alfvenic ions
  - Need seed heating mechanism for ions
- Ions gain significant energy through large-scale Alfvenic flows
  - Does not facilitate the production of particles in the 100MeV to GeV range in the corona $\Rightarrow$ energy gain is reversible
- Parallel electric fields are inefficient accelerators of ions
- Ion "pickup" in magnetic reconnection exhausts is the dominant seed heating mechanism.


Voyager 2 LECP
1-day averages
75.3 76.9 78.4 80.0 81.6 83.2 84.7 AU
25.7 26.1 26.4 26.8 27.1 27.4 27.7 °S
a
b
c
d
i: 0.04-0.08 MeV
IP shock
TS1
2007/242
83.65 AU
S27.5°
i: 0.14-0.22 MeV
V1
2.5 3.0 3.5 4.0 4.5 5.5
i: 0.54-1.0 MeV
i: 2.1-3.5 MeV
particles/cm2-s-sr-MeV
p: 3.0-17 MeV
A1/A0
T
R
A1
ϕ
p: > 70 MeV
counts/sec
e: 0.4-1.5 MeV
2005 2006 2007 2008
Data through: 2008 doy 134





Marhavilas and Sarris Poster

Hi-β in solar wind for E>20 keV

Some Observations (by an Experimentalist)

- Hot (E > a few keV) particles are principal contributors to plasma pressure, yet MHD models treat these as trace particles—a basic defect that has yet to be addressed (But, important step described by Abdalla)
- Field-aligned currents (FAC) have been a fact in magnetospheric physics since 1968, yet FACs are rarely (never?) taken into account self-consistently in modeling the 3-D magnetosphere
- Evidence for multi-scale phenomena continues to mount (Baker, others) and 3-D aspects of reconnection (Karimabadi, Huba, others) suggest that our cartoons and models are rather simplistic (and possibly wrong)
- Quasi-linear diffusion has been a mainstay for both magnetospheric and interplanetary particle transport and acceleration models. If diffusion coefficients are time-dependent (Ram), a whole body of theoretical work over 50 years is wrong (?)
- What is up with the concept of collisionless shock? (Parks). Why not have subsonic flow most (if not all the time) both in Earth's magnetosheath and the heliosheath (Voyager)?


GORDON RESEARCH CONFERENCES
Brewster Academy
June 20 - 24, 1977
"Magnetic Reconnection in Space and Laboratory Plasmas"
F.W. Perkins, Chairman, K. Papadopoulos, V. Chairman

An Alternate Picture (Chapman, Ferraro and Alfvén)

- Solar wind particles crossing **B** will induce EMF
- As the solar wind comes close Earth, it slows down
- A current sheet (CS) forms by inductive process
- The CS intensifies as solar wind continues to push from behind
- CS thins (magnetic field steepens), forms a discontinuity with dimension of < ion Larmor radius (Bow shock)
- Thin CS become unstable and EM waves are generated
- Wave particle interactions heat and accelerate solar wind particles producing a hotter population (Magnetosheath)
- Magnetosheath plasma motion toward Earth induces another CS (Magnetopause).
- This model is simple and avoids the issues of shock physics.