Plasma Sheet Energy Conversion as Observed by Cluster

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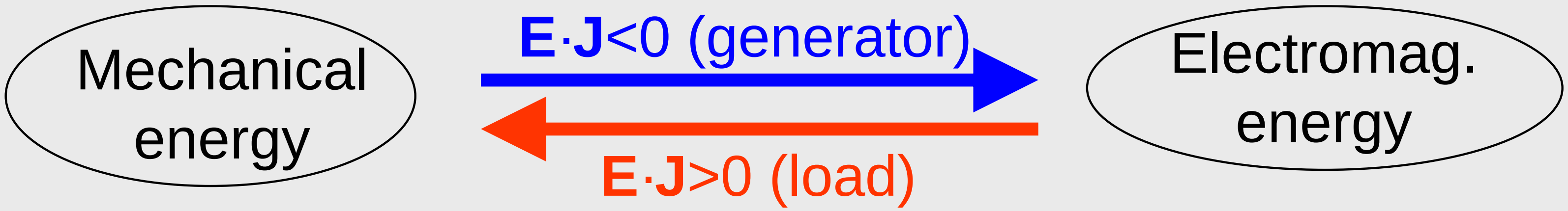
Intro

- Energy conversion:



- Using Cluster we investigate local energy conversion by computation of **E·J.** Energy sources/sinks can be identified and examined by *in-situ* data.

- In the plasma sheet:
  - **E** from CIS (full **E** vector) and EFW (spin plane components). EFW Ey (duskward) is used to cross-check CIS.
  - **J** from the magnetic field measured on the four satellites (Curlometer method).

- Reference system is important since **E** is not invariant. Choose the system where irreversible energy dissipation takes place: the neutral wind system ≈ GSE.

Intro

- We search for energy conversion events, May – Dec 2001, when the Cluster apogee (19 RE) moved from the dawn MS/BL, through the plasma sheet, to the dusk MS/BL.

  Here: mid July – mid October, with Cluster apogee in the plasma sheet.

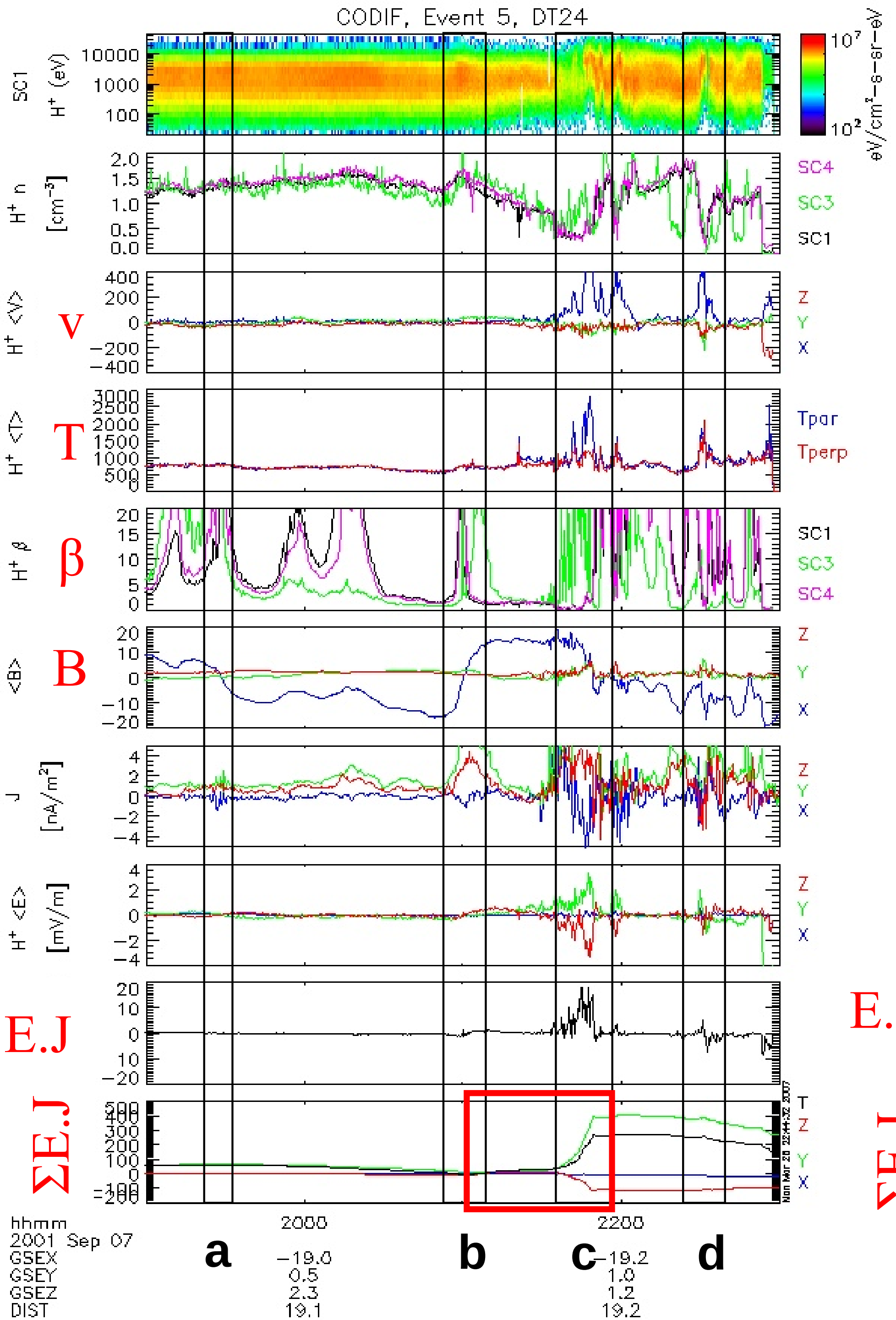
- Near Cluster apogee, reversible ('motor') processes dominate the conversion of magnetic to mechanical energy, and the plasma sheet behaves, on average, as a load. We try to reveal is the structure of this load.

- Concentrated generator regions are also observed in our data – less frequent and with lower power densities than the loads.

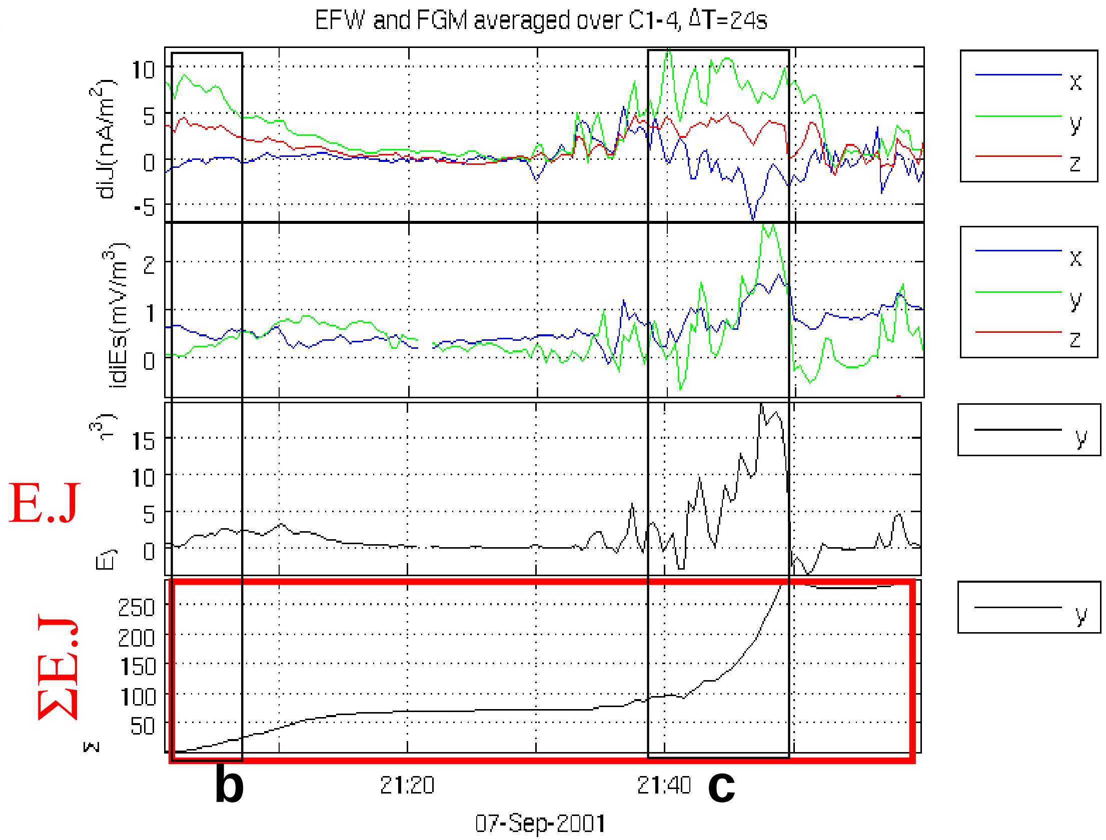
- We present two load events and one generator:
  - **L1** from Sep. 7, 2001: big load close to the neutral sheet.
  - **L2** from Aug. 29, 2001: small/moderate load in the PSBL.
  - **G1** from Sep. 19–20, 2001: generator in the PSBL.

- We conclude with a brief inventory of other events. (Prelim. investigation.)

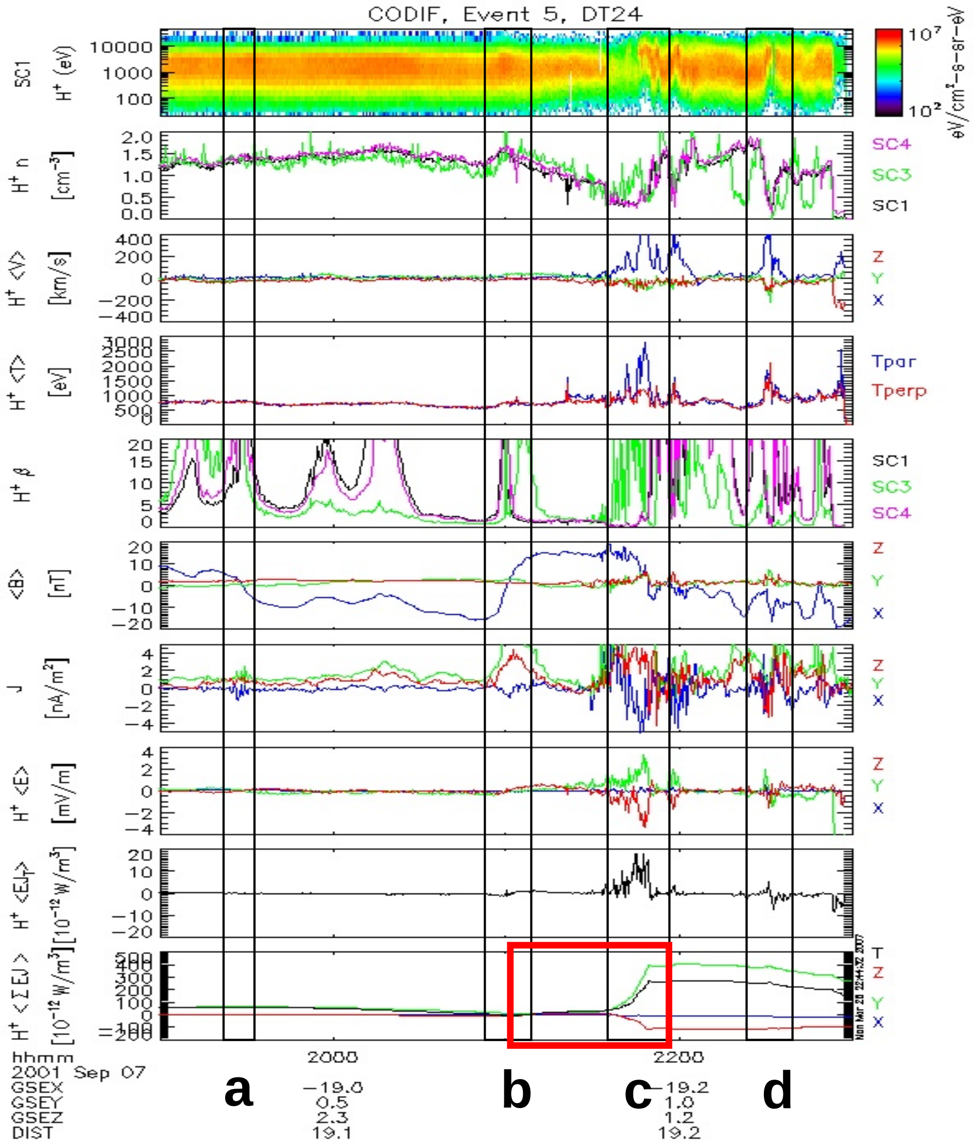
ℬ Load Event L1: Data ℬ

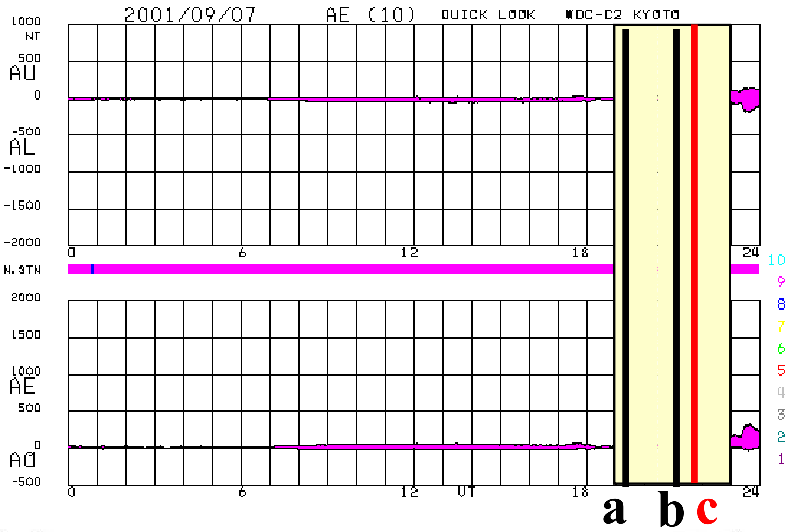


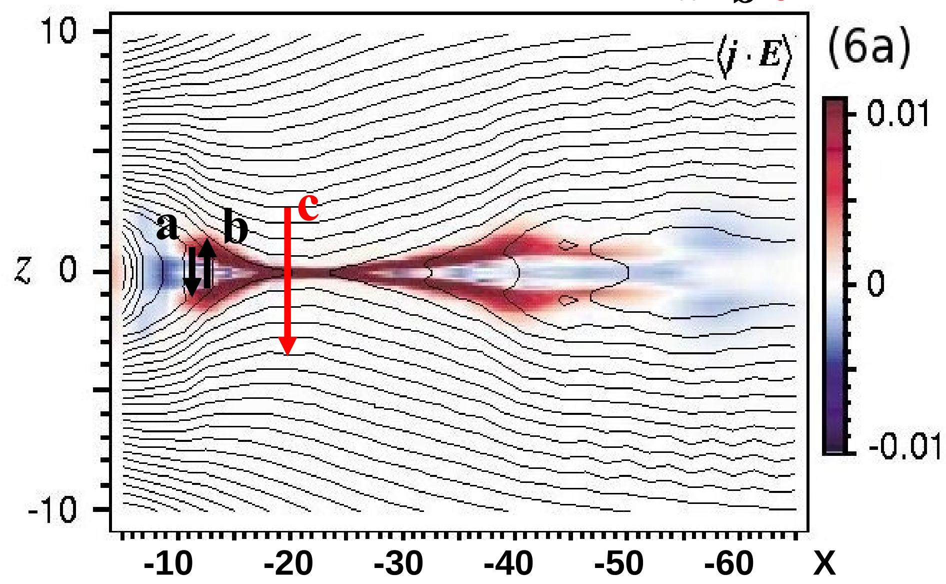
- **Big load** (**L1c**) close to the neutral sheet (high β) and midnight, associated with bulk flow (mainly field aligned) and temperature anisotropy ($T_{\|} > T_{\perp}$).
- No significant load is observed near the neutral sheet when the bulk flow is missing (**L1a**, **L1b**).
- Bulk flow not necessarily assoc. with a load (**L1d**).
- Good quality agreement between the (**L1c**) EyJy seen by CODIF and EFW.



Load Event L1: Interpretation



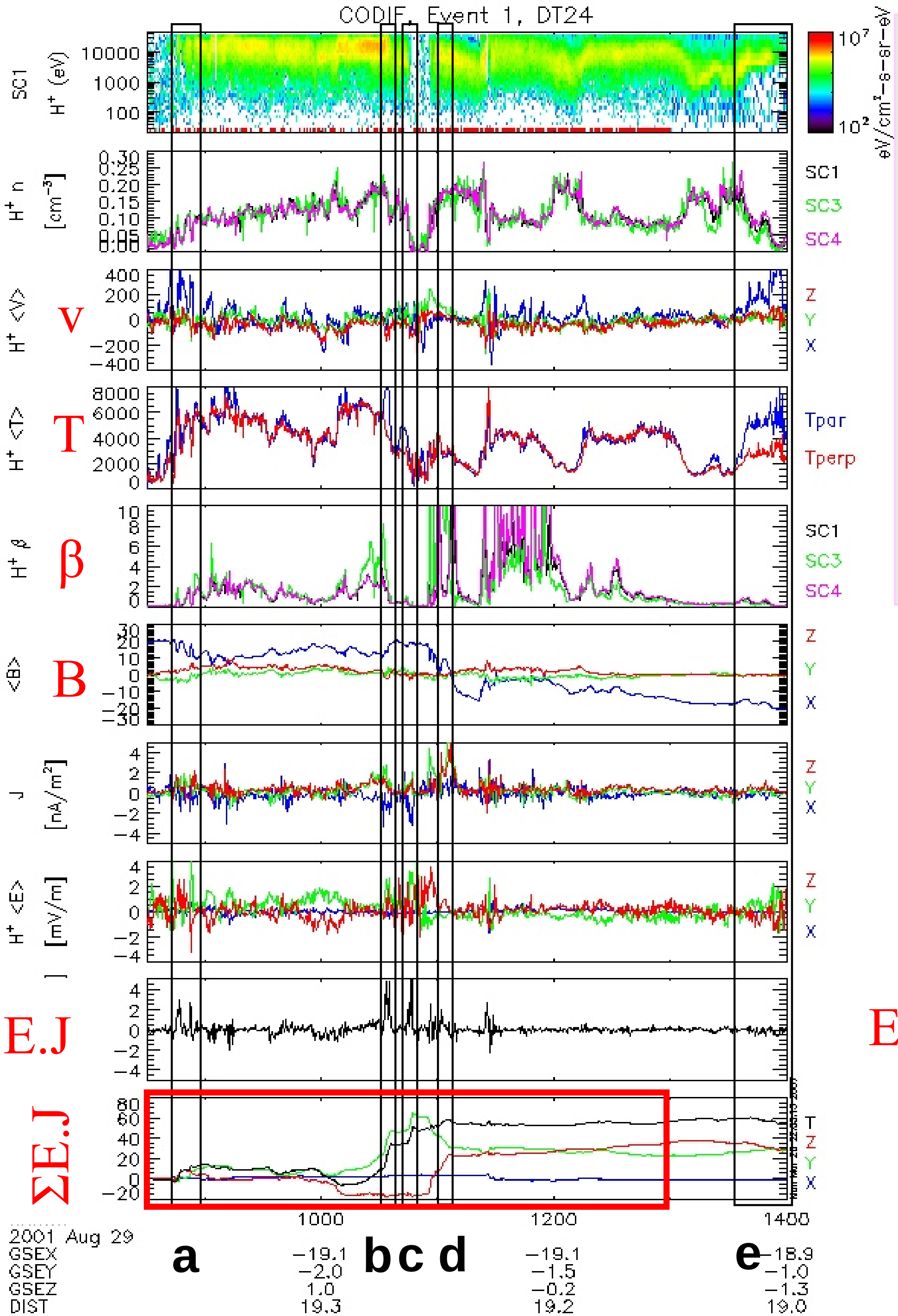




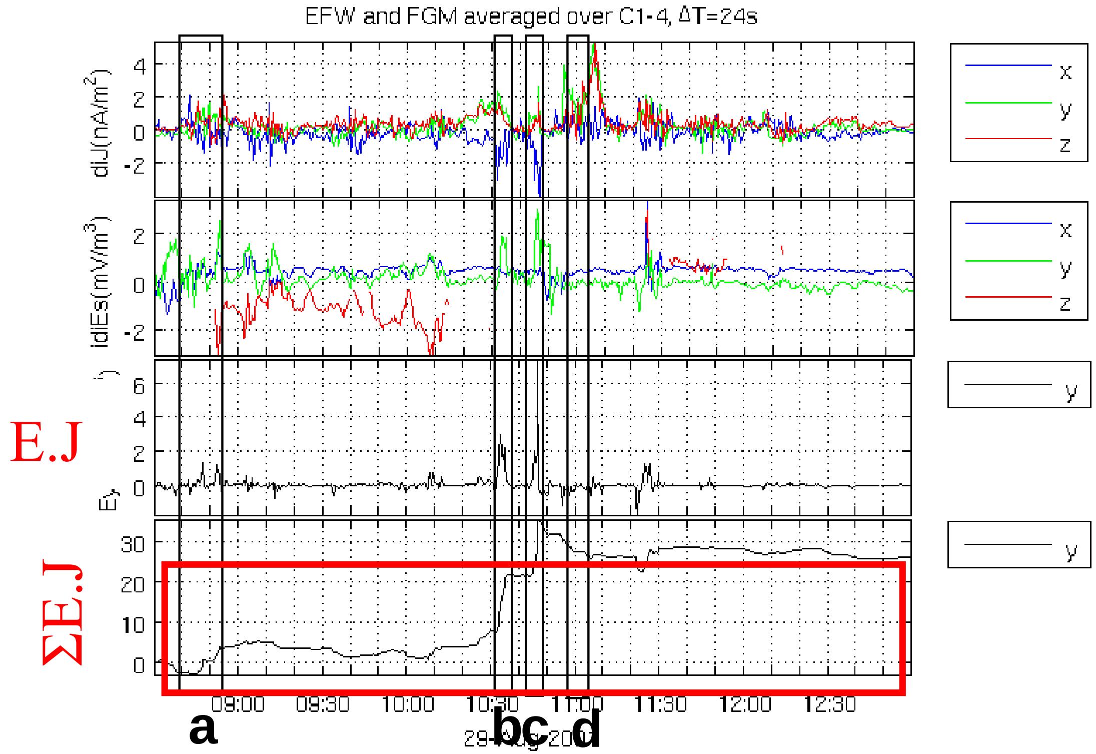
Birn and Hesse, Ann.Geophys, 2005.

- Loads in the magnetotail (simulation by Birn & Hesse, 2005): Substantial change between (**b**) and (**c**) with the reconnection site moving towards Earth. Possibly related to the substorm development.
- **L1c** in the beginning of expansion phase or end of growth phase?

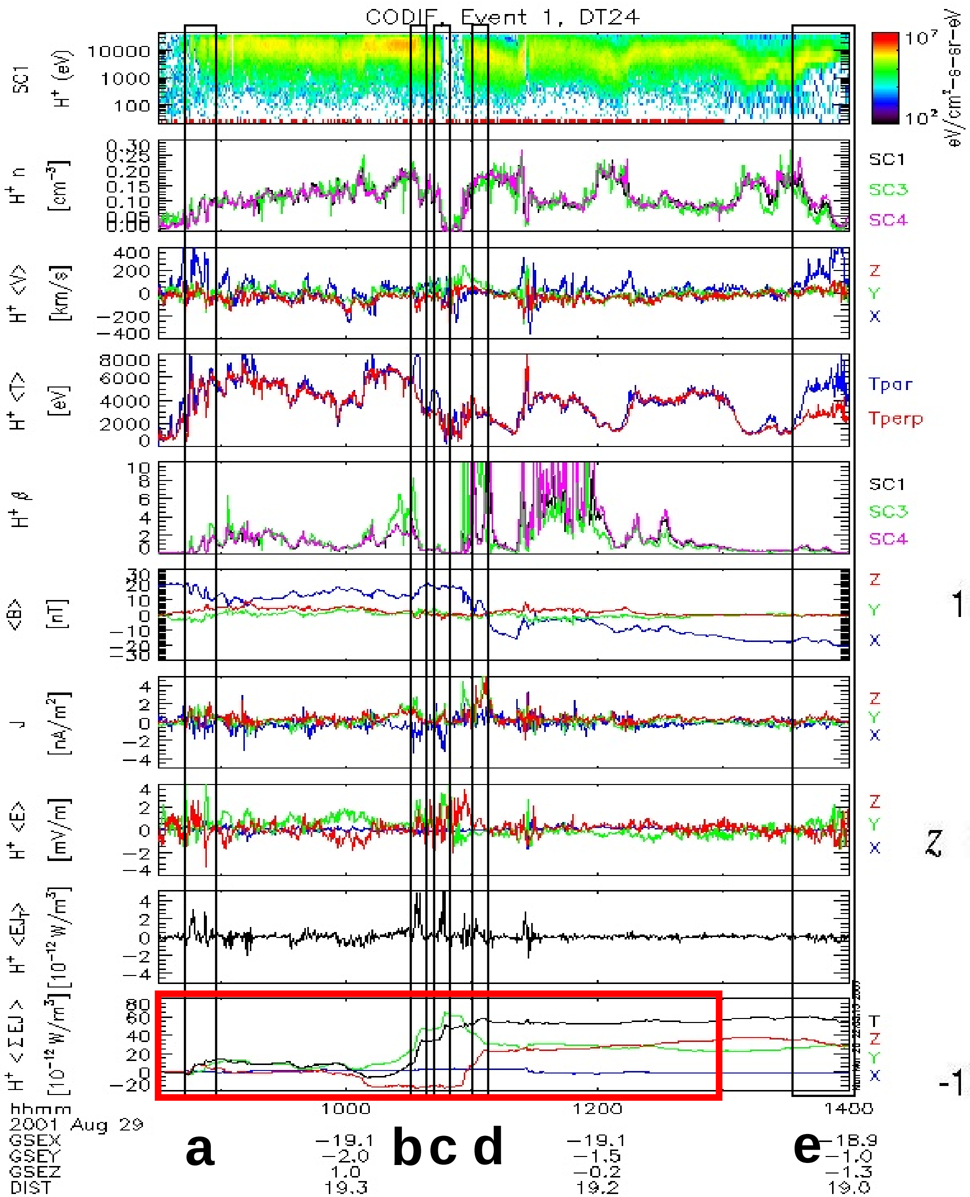
ℬ Load Event L2: Data ℬ

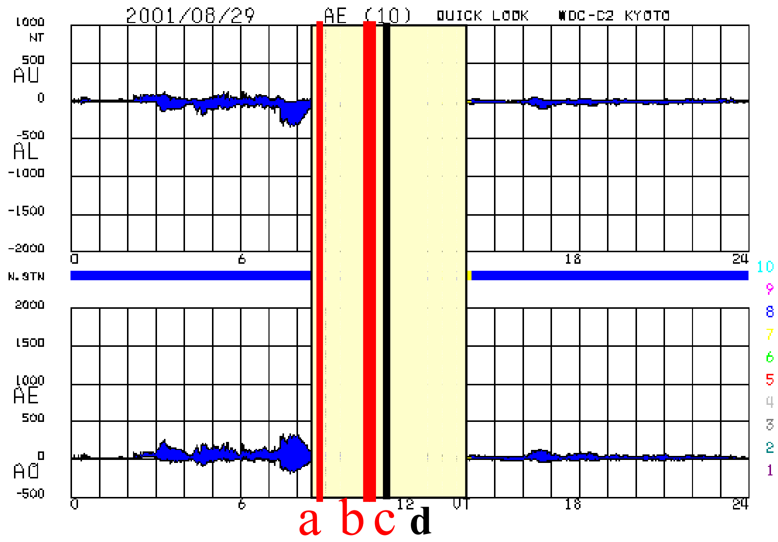


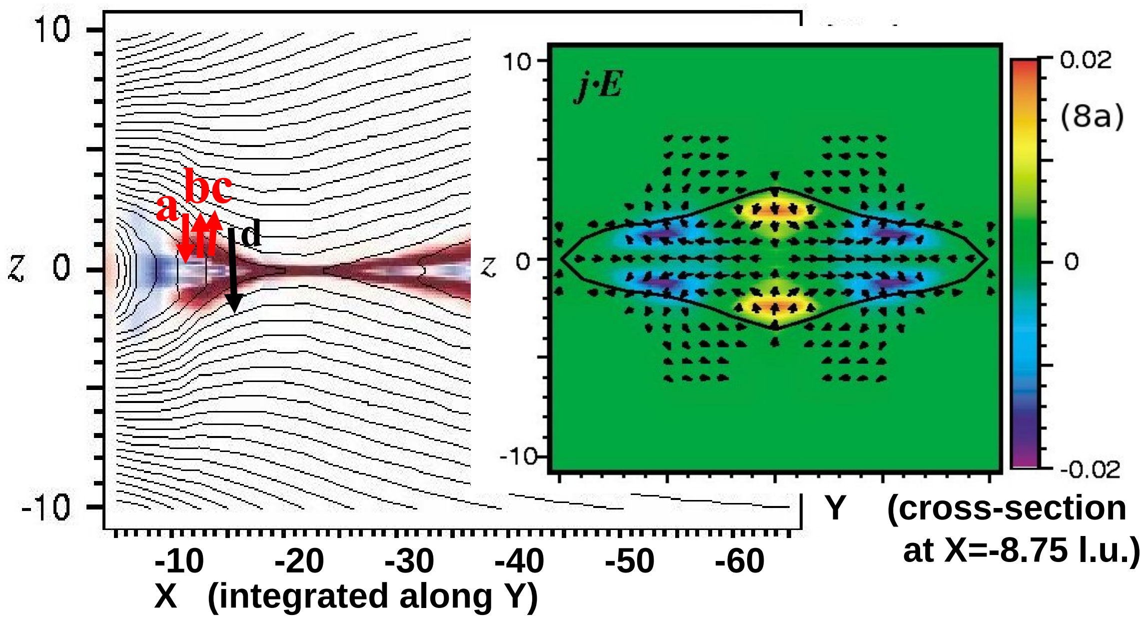
- **Small/moderate loads** (**L2a**, **L2b**, **L2c**) near the PSB (low/moderate β).
- **L2a** assoc. with field aligned flow. **L2b** assoc. with Z bulk flow (untypical). **L2c** at the edge of field aligned flow. **L2b**, **L2c** assoc. with temp. anis. ($T_{\parallel} > T_{\perp}$).
- No load when crossing the neutral sheet (**L2d**).
- Neither bulk flow nor temperature anisotropy are necessarily associated with a load (**L2e**).



B Load Event L2: Interpretation B

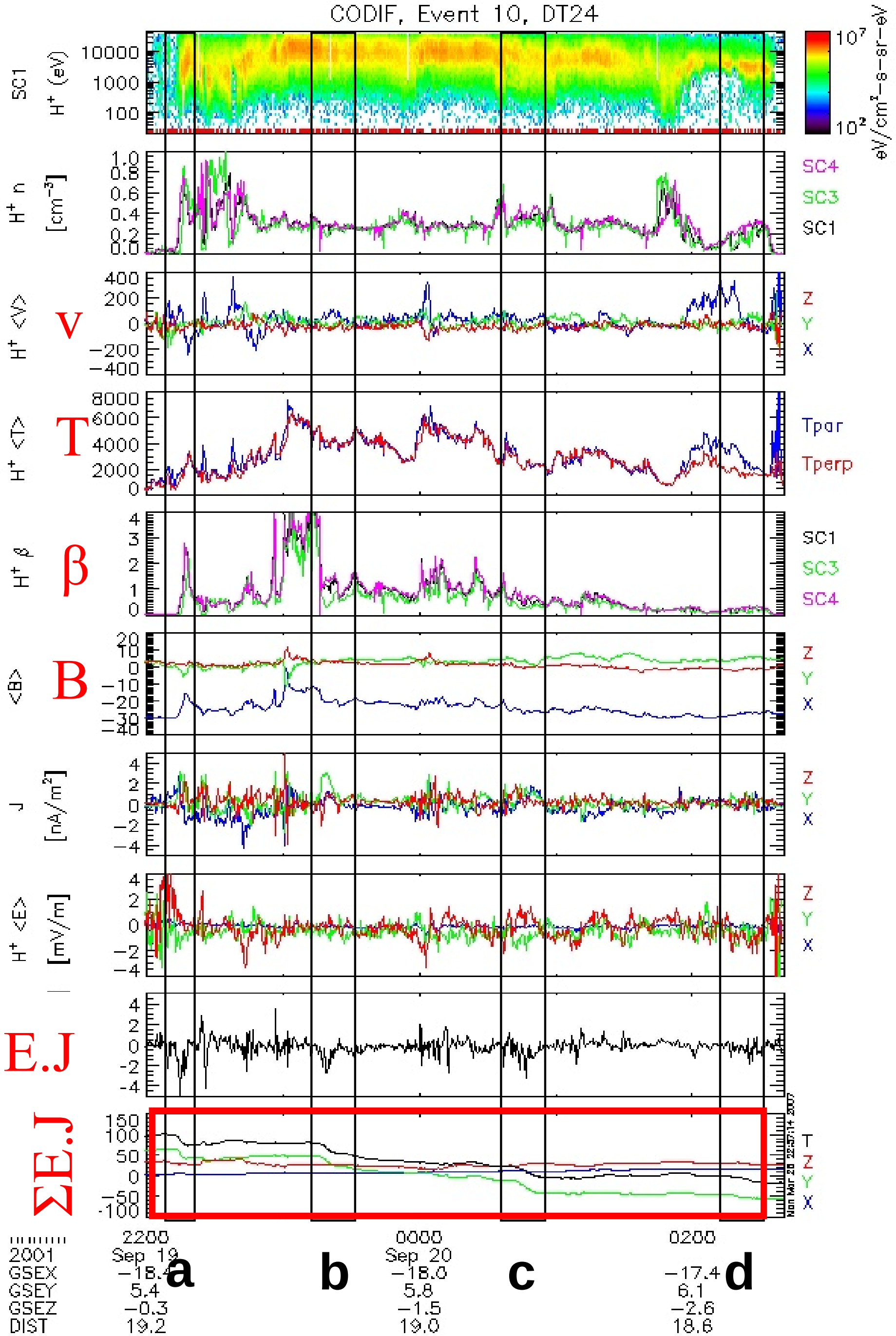




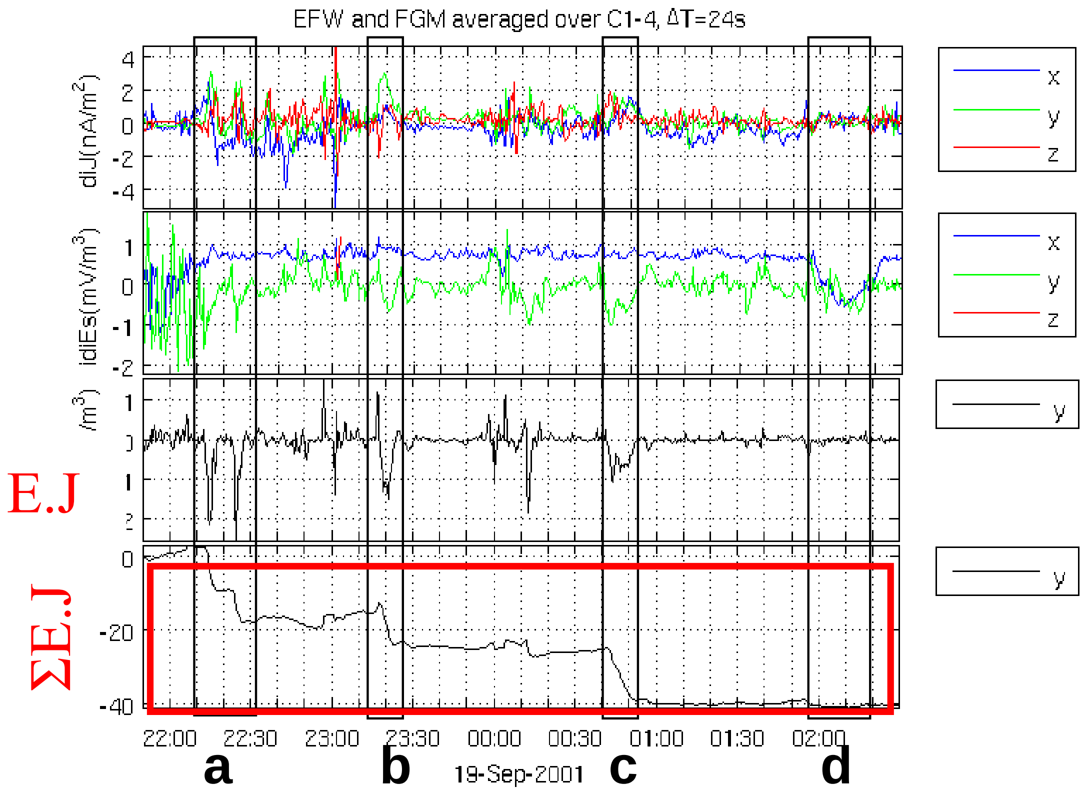


- ➢ Possibly the reconnection site approaches Earth during the substorm expansion phase, but not close enough, so that Cluster eventually crosses the neutral sheet without encountering a load.
- ➢ Even if on average E.J>0, locally one can have E.J=0 (**L2d**), or even E.J<0 (next slide).

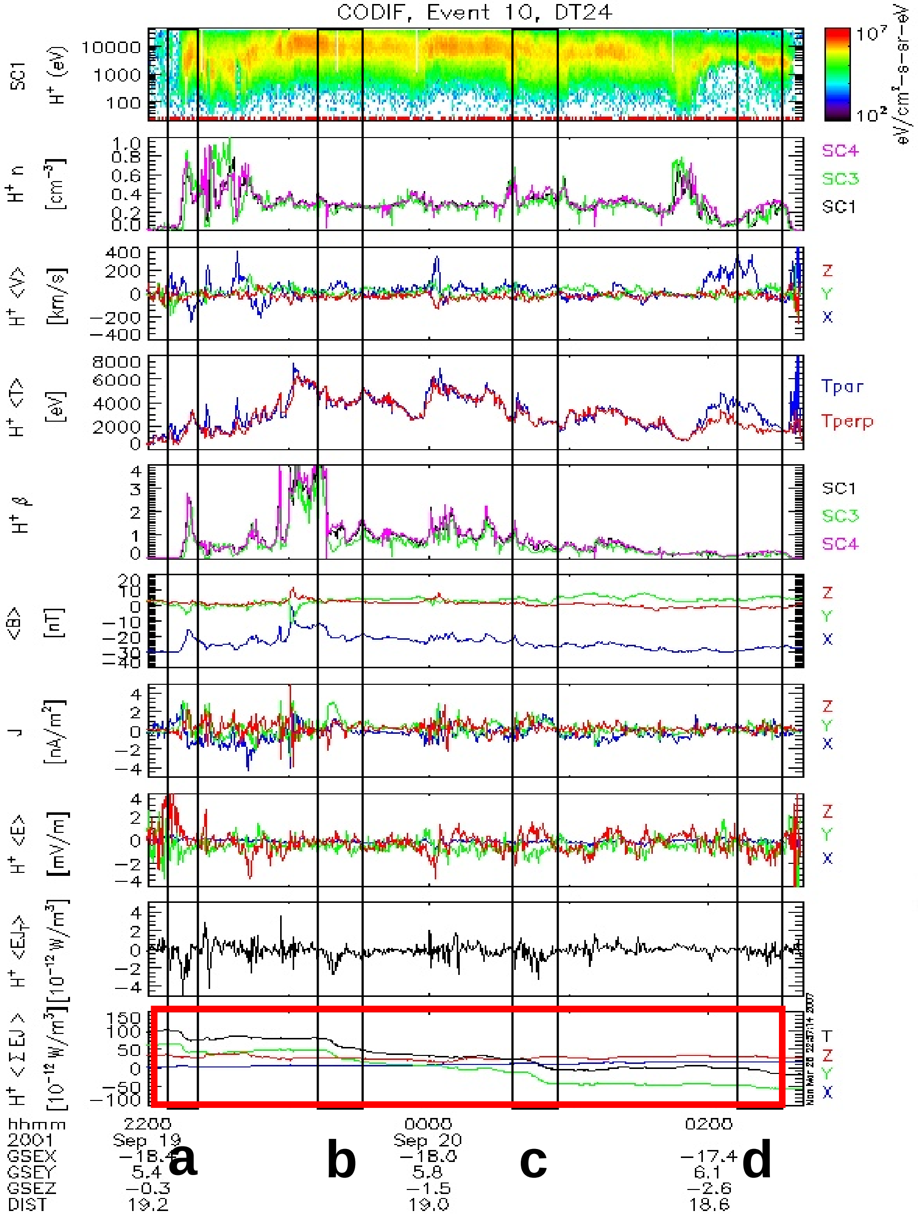
Generator Event G1: Data

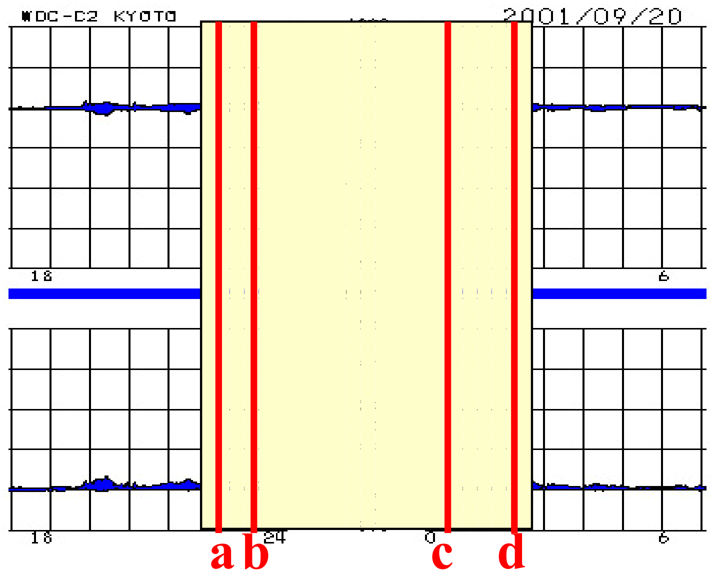


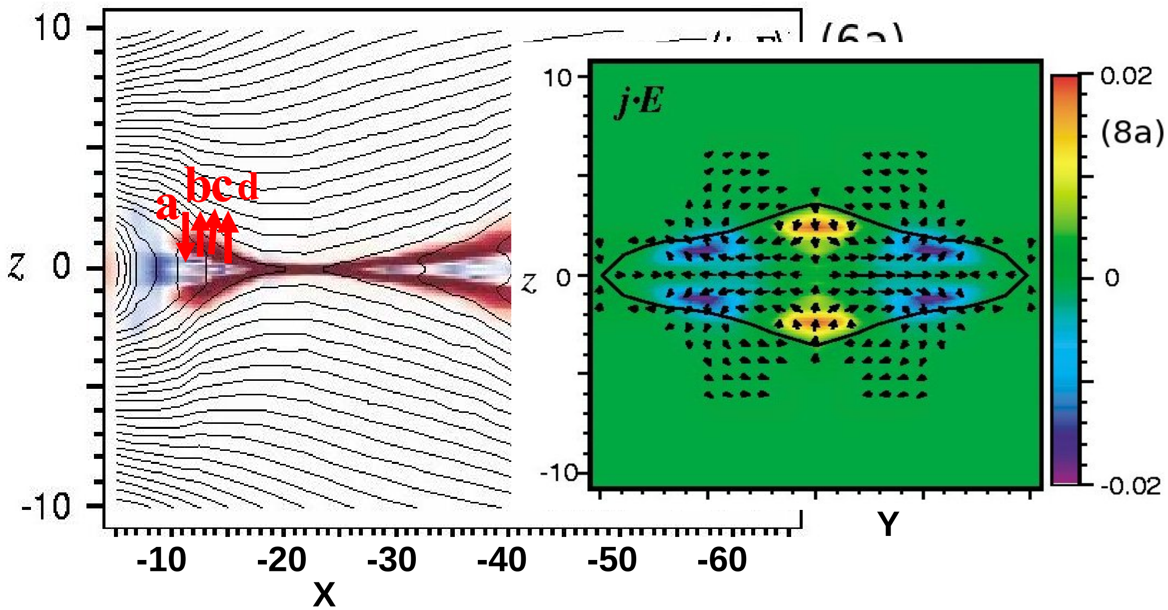
- ➢ Concentrated generator regions in the PSBL, *Marghitu et al. (2006); Hamrin et al. (2006), Ann. Geophys.*
- ➢ Moderate (**G1abc**) or small (**G1d**) power densities.
- ➢ **G1a**, **G1b**, and **G1d** associated with field aligned flow. No field aligned flow for **G1c**.
- ➢ **G1d** associated with temperature anisotropy. No temperature anisotropy for **G1a,b,c**.



ℬ Generator Event G1: Interpretation ℬ







➢ Although the average E.J shows load character (XZ panel), the local signature can still indicate a generator (YZ panel).

C Inventory of Events: Preliminary results C

- 8 events of concentrated big loads max(E.J)~40–100 pW/m^3.
- 18 events of conc. small/moderate loads max(E.J)~4–40 pW/m^3.
- 12 events of concentrated generators max(|E.J|)~2–20 pW/m^3.

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- Are there distributed loads/generators in the data? Not investigated here.

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- As for the temperature anisotropy, $T_{\|} > T_{\perp}$, there is no general trend.

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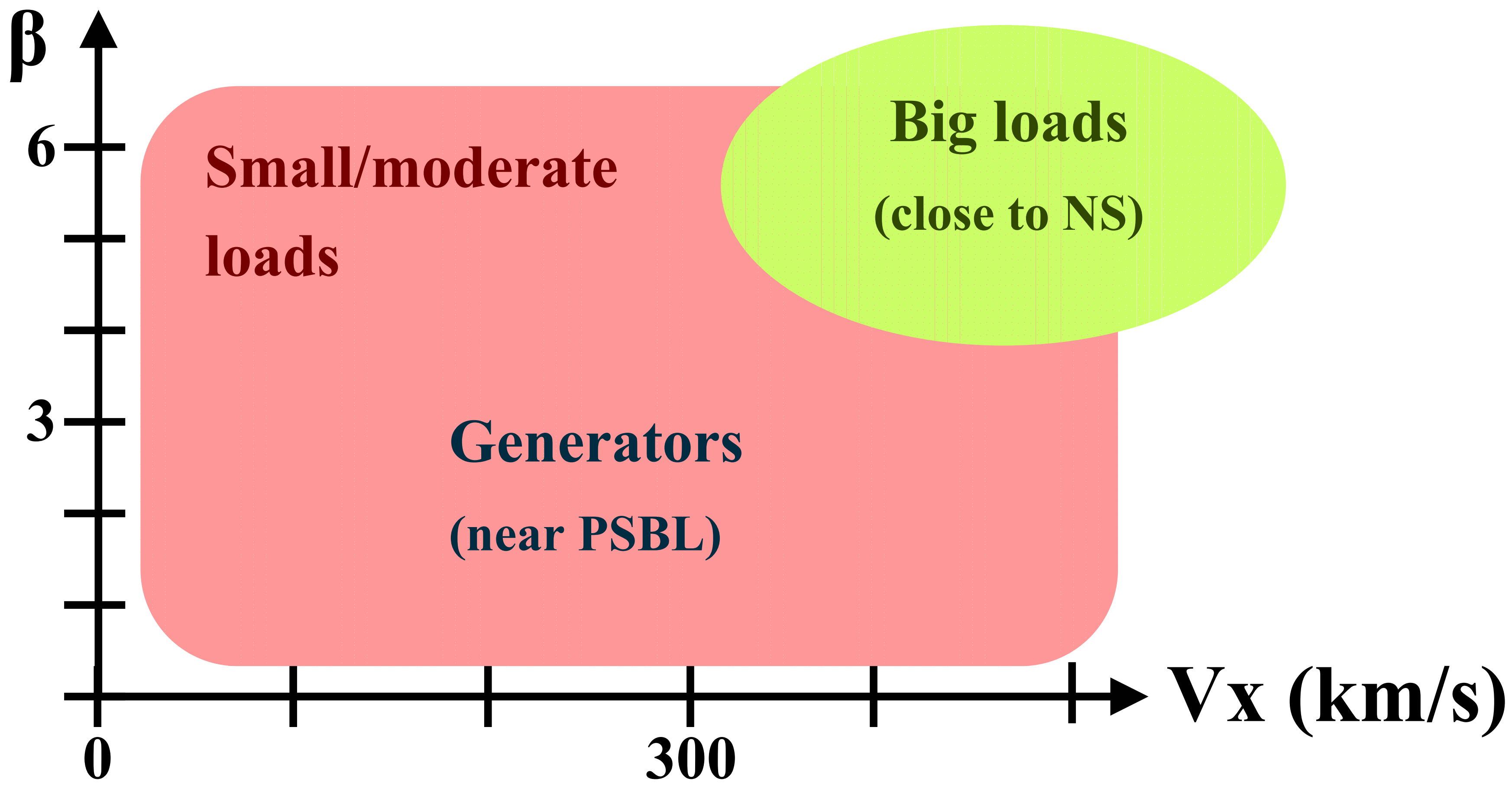

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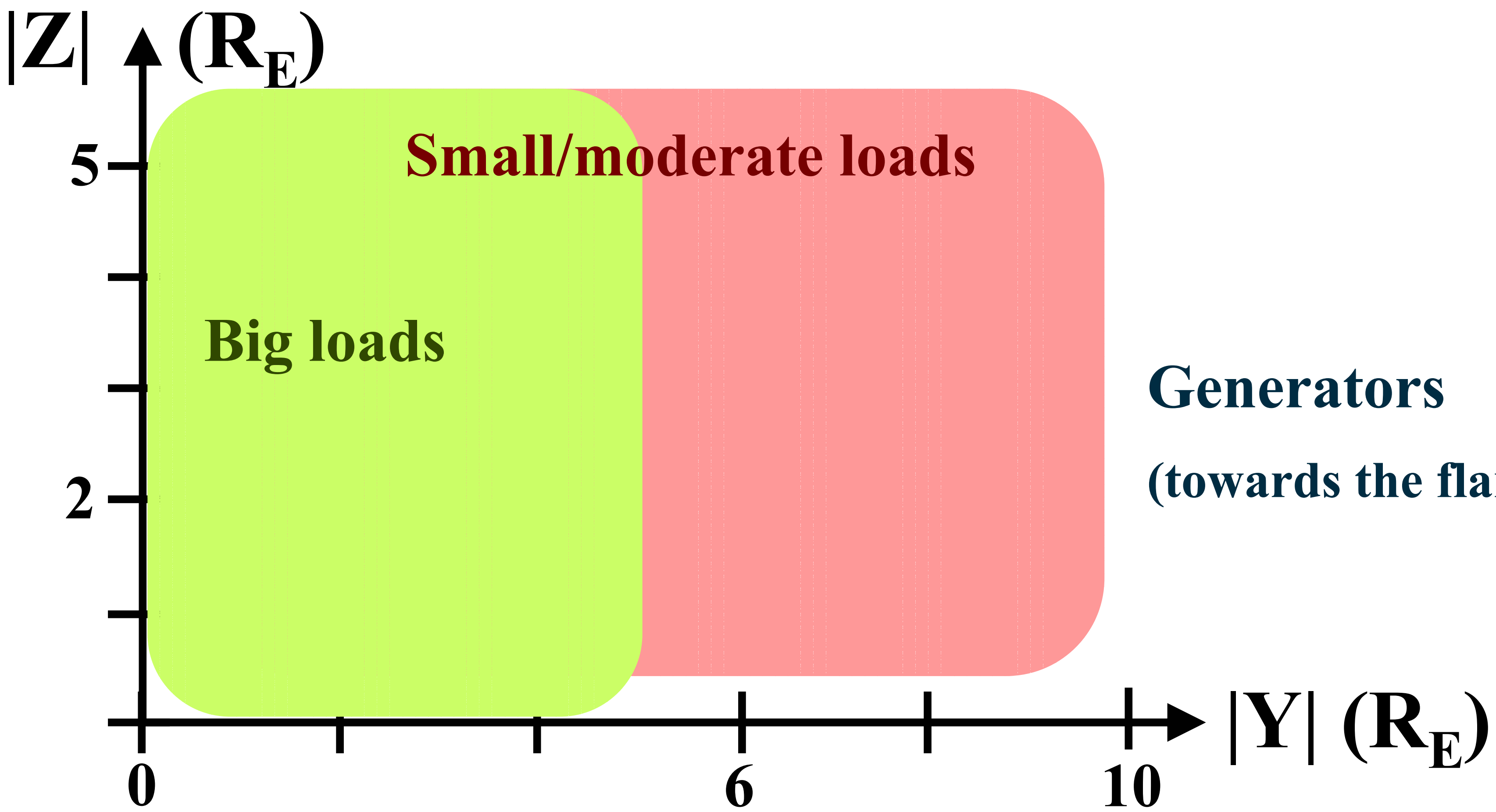

Summary

- Often there are consistent indications in the CIS and EFW data that EC takes place in confined spatial regions.
- Location of the energy conversion regions (ECRs):
  - High power density loads close to the neutral sheet, in high β plasma, and not too far from midnight.
  - Low/moderate power density loads, as well as generators, more towards the PSBL, in lower β plasma.
- Relation to plasma flow and temperature anisotropy, in particular for loads:
  - EC usually related to plasma flow, dominantly along the magnetic field. The reverse is not true. Plasma flow can be observed without EC.
  - Temperature anisotropy often observed with $T_{\parallel} > T_{\perp}$.
- **Possible scenario:** Local plasma acceleration (load) naturally associated with bulk flow, which is thermalized faster in parallel direction ($T_{\parallel} > T_{\perp}$). If the satellite path is far from the acceleration site, one observes just the bulk flow and the temperature anisotropy. If the path is *very* far => just the bulk flow.
- The observations are in decent agreement with simulation results.

Prospects

- Improvement of the event statistics:
  - Automated ECR recognition routine (?)
  - Cluster plasma sheet crossings in 2002 – 2004.
- Closer look at the micro-physics:
  - Detailed structure of loads and generators.
  - Is the plasma flow associated with local acceleration by parallel electric fields, or the Lorentz force is enough?
  - Is the anisotropy indeed related to faster thermalization in parallel direction?
  - Reversible versus irreversible processes – entropy calculation?
- Extension to other regions and missions:
  - Energy conversion at the magnetospheric flanks => better electric field from EFW, as well as EDI.
  - Energy conversion close to the subsolar points.
  - Extension to future multi-spacecraft missions, like THEMIS (the current disruption region), MMS (reconnection sites), Cross-Scale (reconnection sites and shocks).