THEMIS observations of mid-tail reconnection and dipolarization fronts

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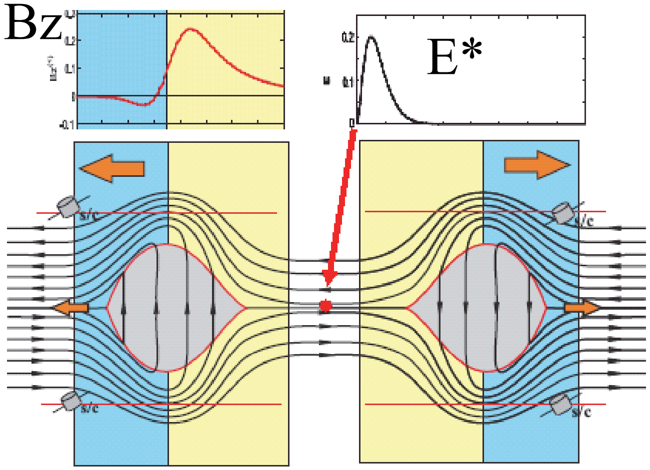
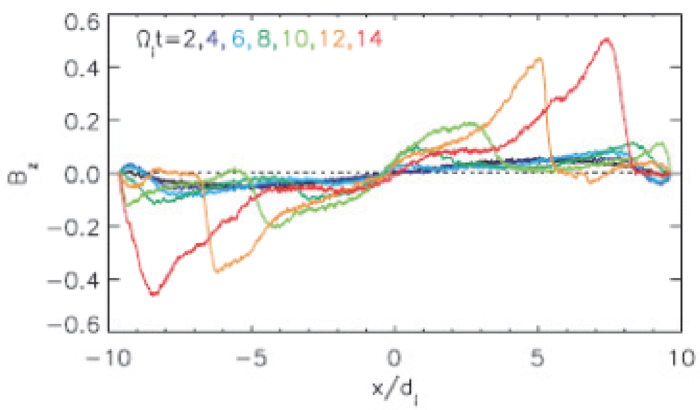
THEMIS

Transient RX, *Semenov et al., 1984*



Kiehas et al., 2009



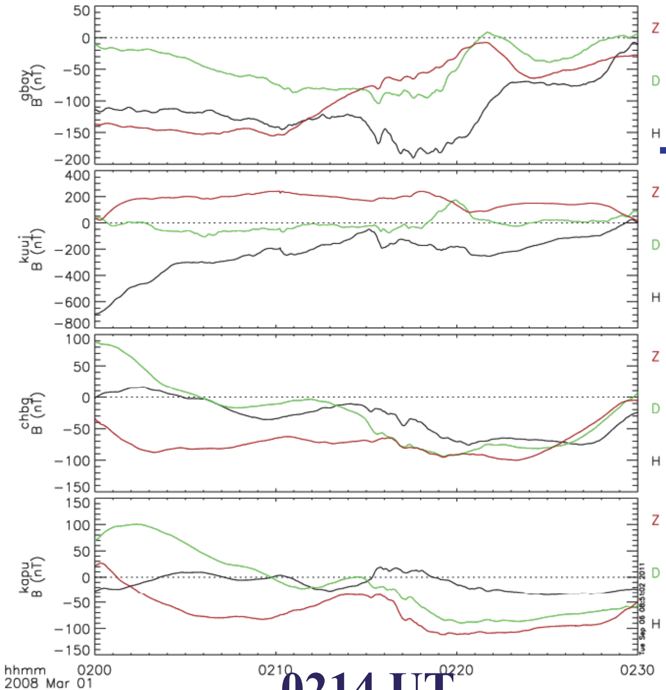
PIC simulations of TRX,
Sitnov et al, 2009

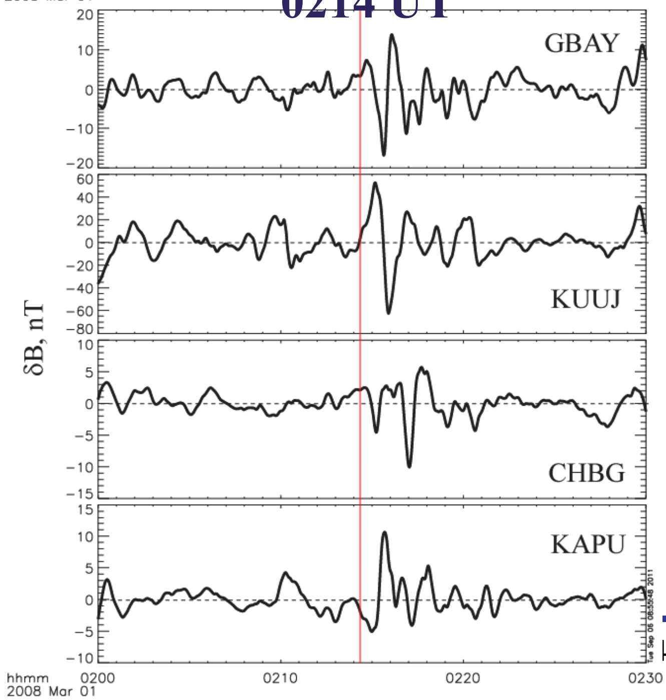
- Scenario 1: DF is a consequence of *transient reconnection* (RX) in the mid-magnetotail. Timing between RX and DF should be consistent with reconnection outflow velocity. *Ballooning/interchange* may lead to azimuthal structuring and further steepening of the front *(M.Nakamura et al., 2002; Pritchett & Coroniti, 2010)*.
- Scenario 2: DF appears as a consequence of local thinning (min Bz) of the magnetotail plasma sheet leading to ballooning *(e.g., Zhu et al., 2009, Pritchett & Coroniti, 2010, Birn et al, 2011)* or “melon seed” *(Sitnov et al., 2011, submitted)* instability *prior to* fast mid-tail reconnection.
- RX itself is complex process, including “slow” and “fast” phases.

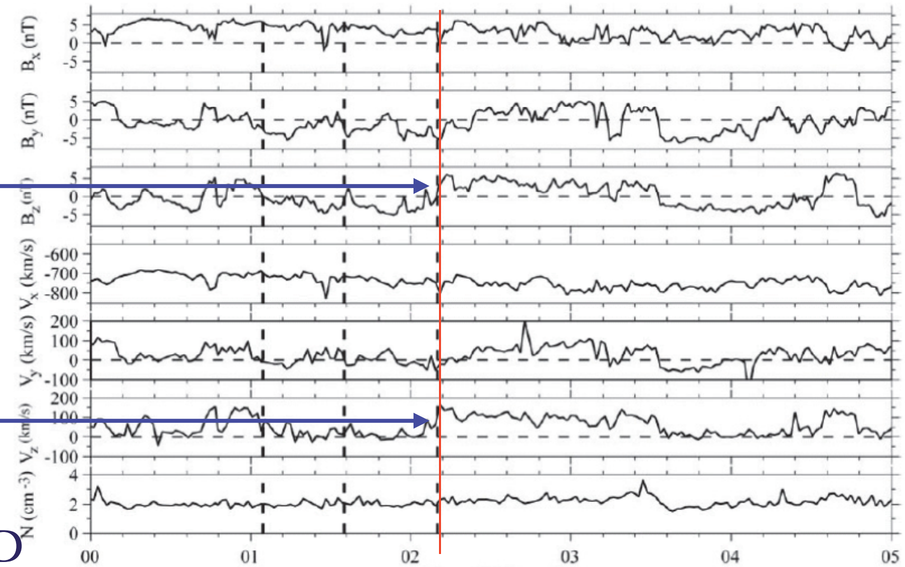
- THEMIS major conjunction events with signatures of RX and DF
- Timing of RX and DF

2008-02-26
Angelopoulos et al., Science, 2008
2009-02-07
Oka et al. GRL submitted
2008-03-01 – this work

08-03-01/02:15:00 (Kp = 5+)

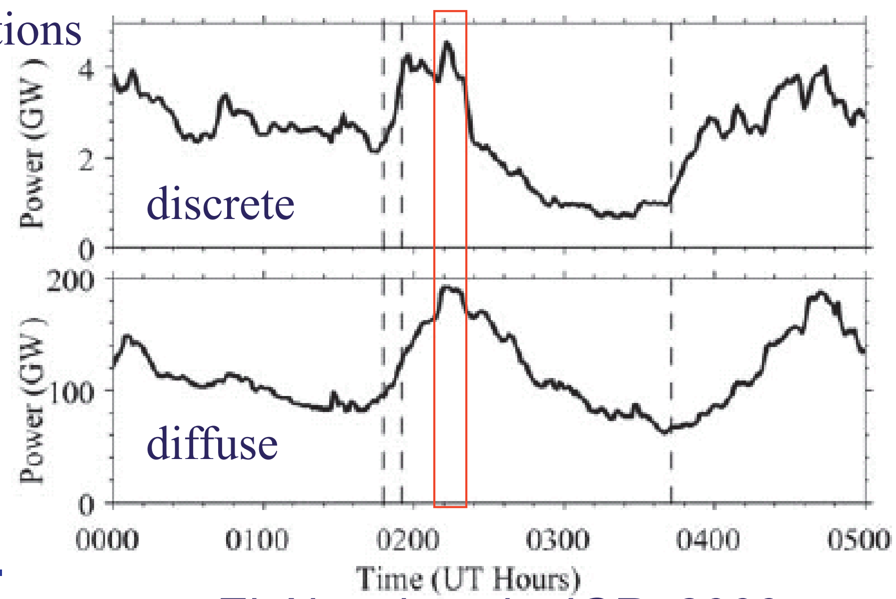




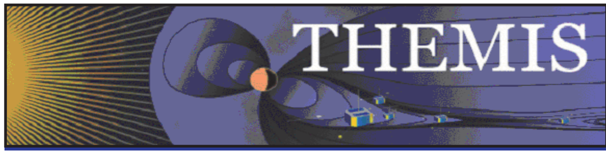


MHD simulations

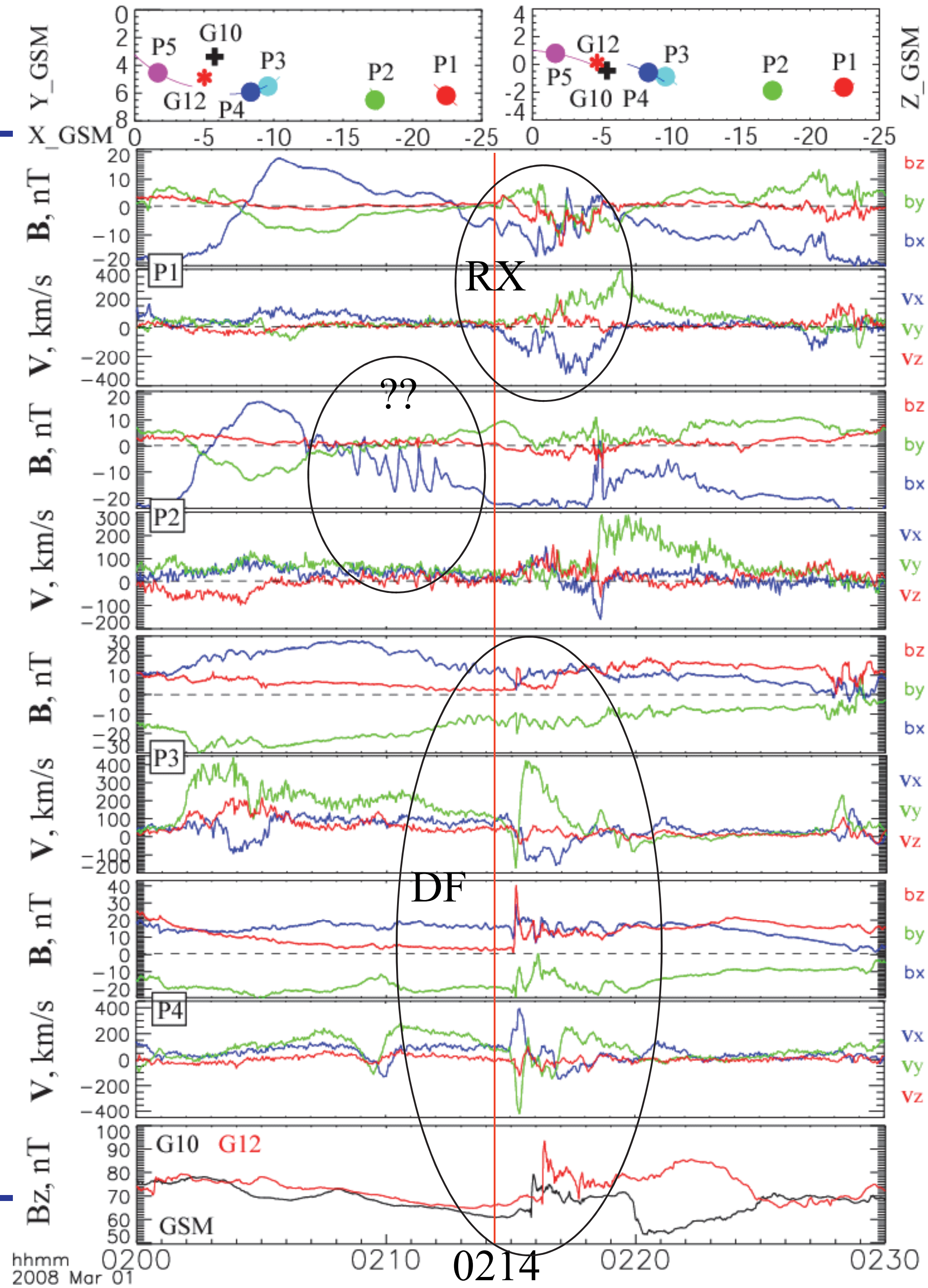
IONOSPHERE



El-Alaoui et al., JGR, 2009

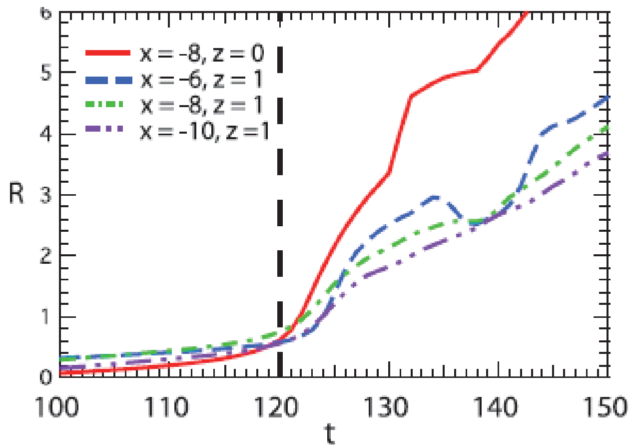


- **P1**: TW flow with Bz<0 (RX)
- **P2**: Bx oscillations @ PS;
  PS → PSBL;
  Vz > 0
- **P3,P4**: decrease in Bz indicates CS stretching,
  Duskward/Earthward flow:
  CS thinning;
  Dipolarization front (DF)
  Opposite flows at P3 and P4 behind DF.
  Timing: P4 → P3
- **G-10,-12**: jump in Bz (DF);
  |Be| < 5 nT prior to DF;
  anti-correlation in Bz behind the front.
  Timing: G10 → G12



Timing: Cumulative Flux Transfer

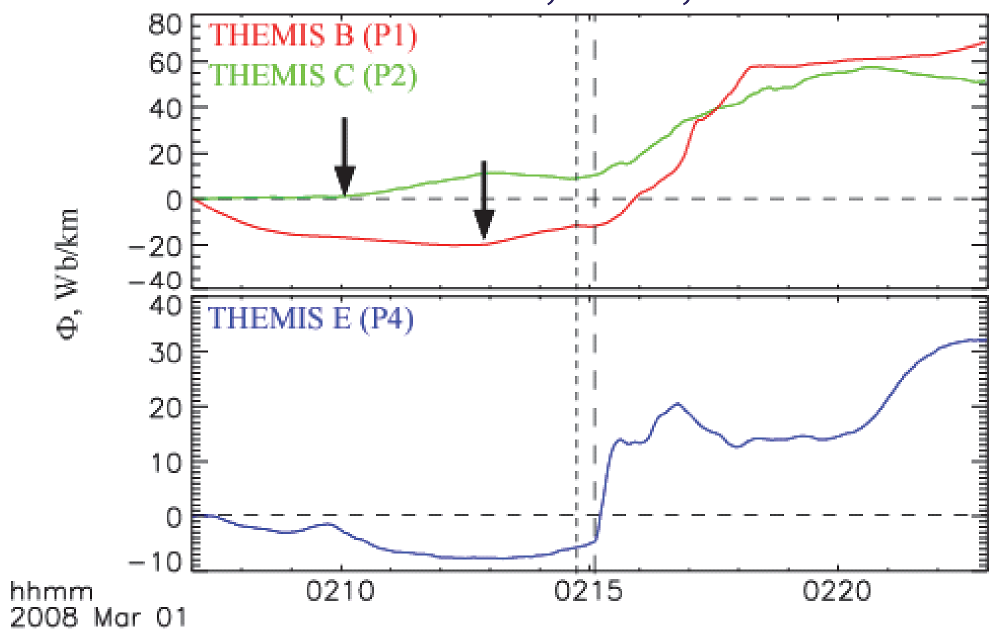
3D MHD simulations of RX in the magnetotail



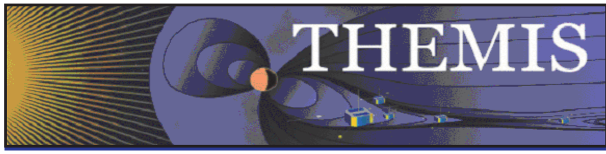
Birn et al, JGR, 2011

$\Phi = -\int [V \times B]_y \, dt$

J.Liu et al., JGR, 2011



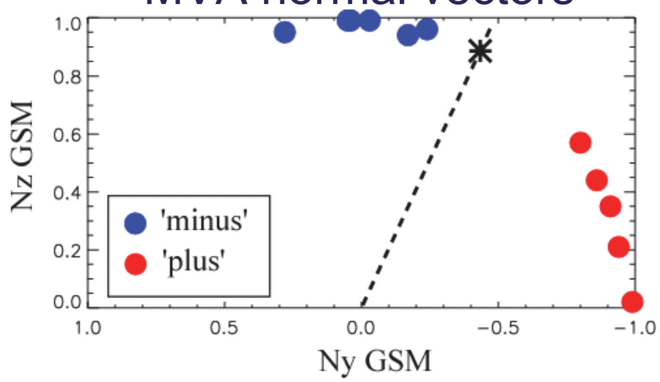
- 2-step process: "slow" regime → "fast" (or "burst") regime
  - P2: "Slow" FT 0210 UT, "Fast" FT 0214:45 UT
  - P1: "Fast" FT 0215:08, P4: DF 0215:06
- Timing: DF was formed *before* fast regime start at P2



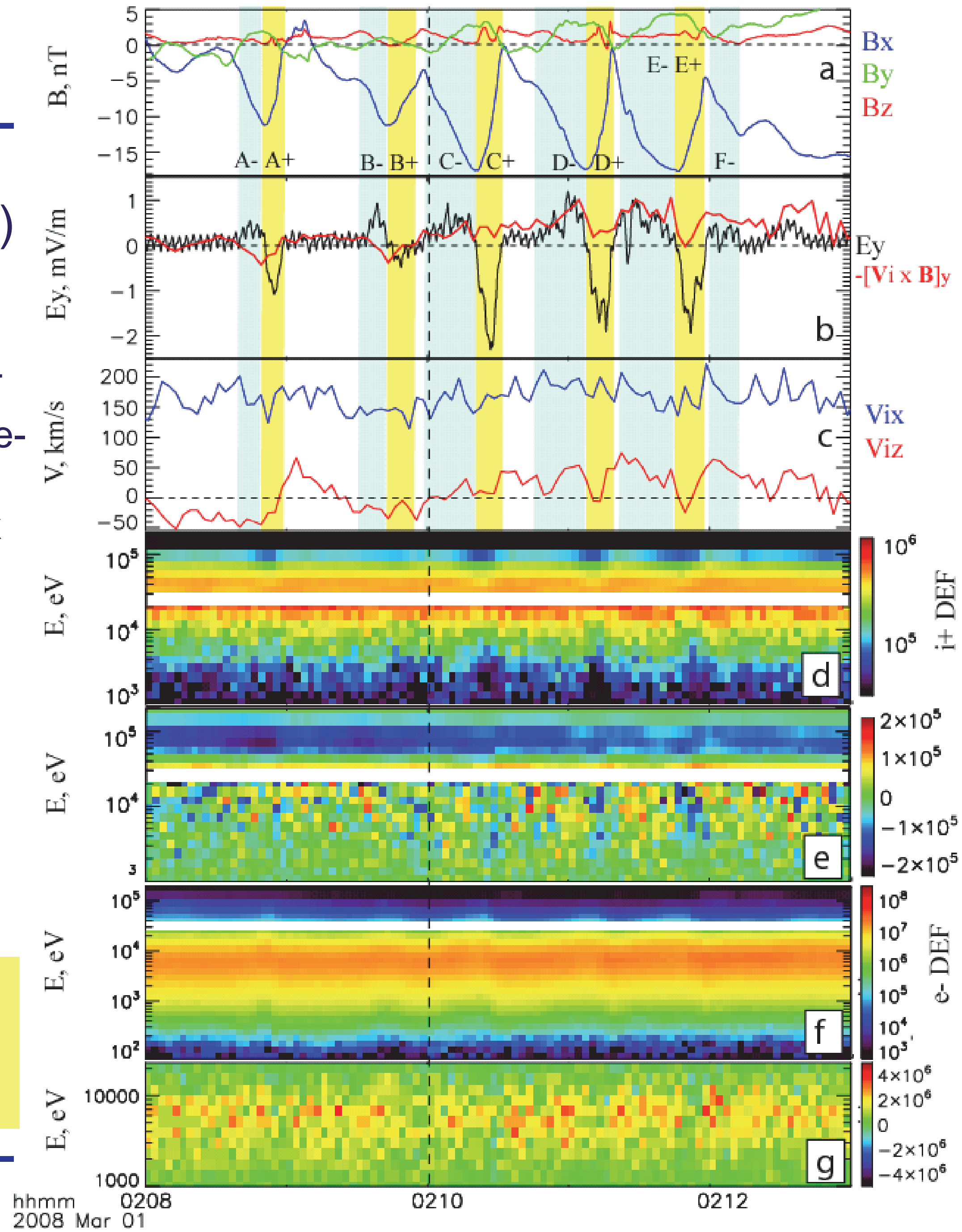
P2 Observations at Cumulative Flux Transport Onset (0210UT)

- Bx oscillations
- Positive-negative E-field variations
- Mainly northward ion Vx after 0210 UT
- Decrease in HEi+ and increase in HE e- fluxes during "plus" intervals
- Increase-decrease in i+ and e- NS flux

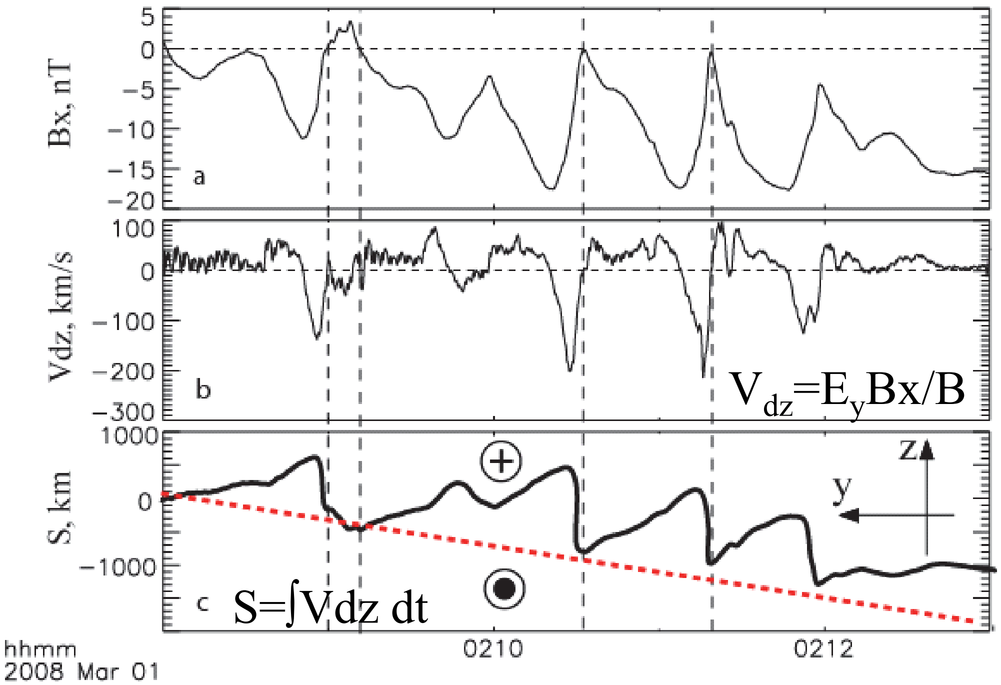
MVA normal vectors

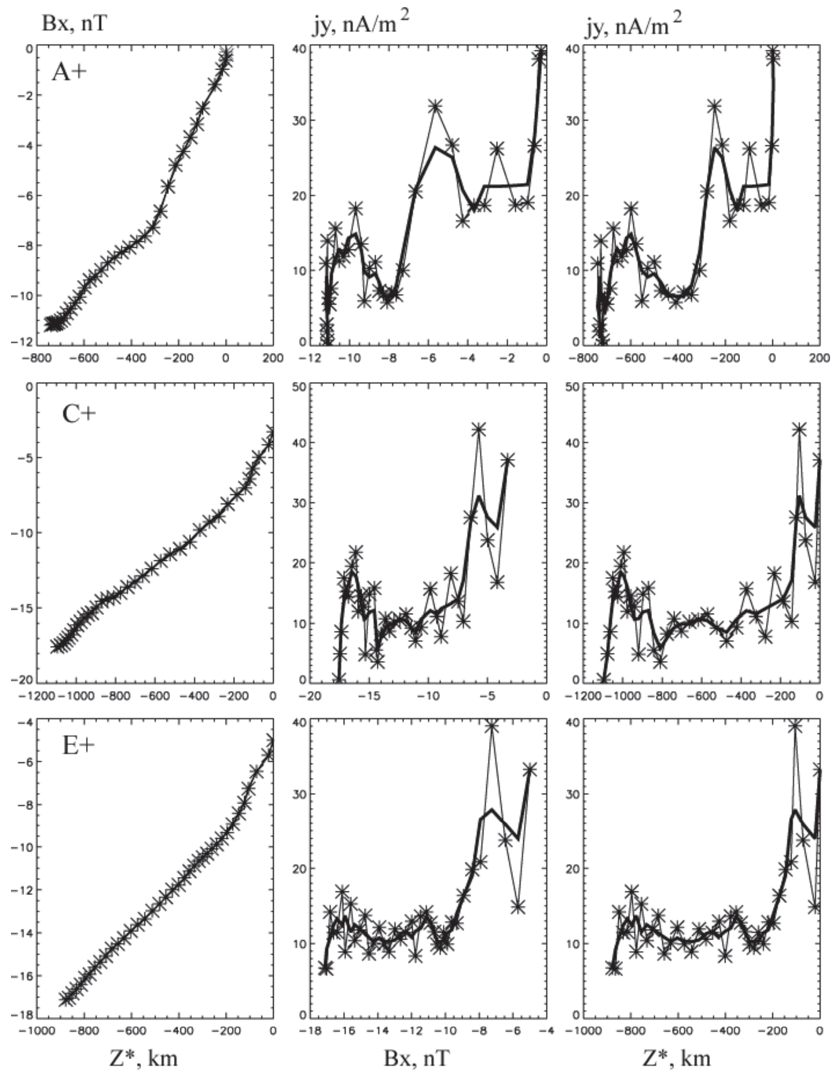


➢ Rapid current sheet flapping: surface waves (ripples) on the current sheet



Reconstruction of Flapping Current Sheet Structure

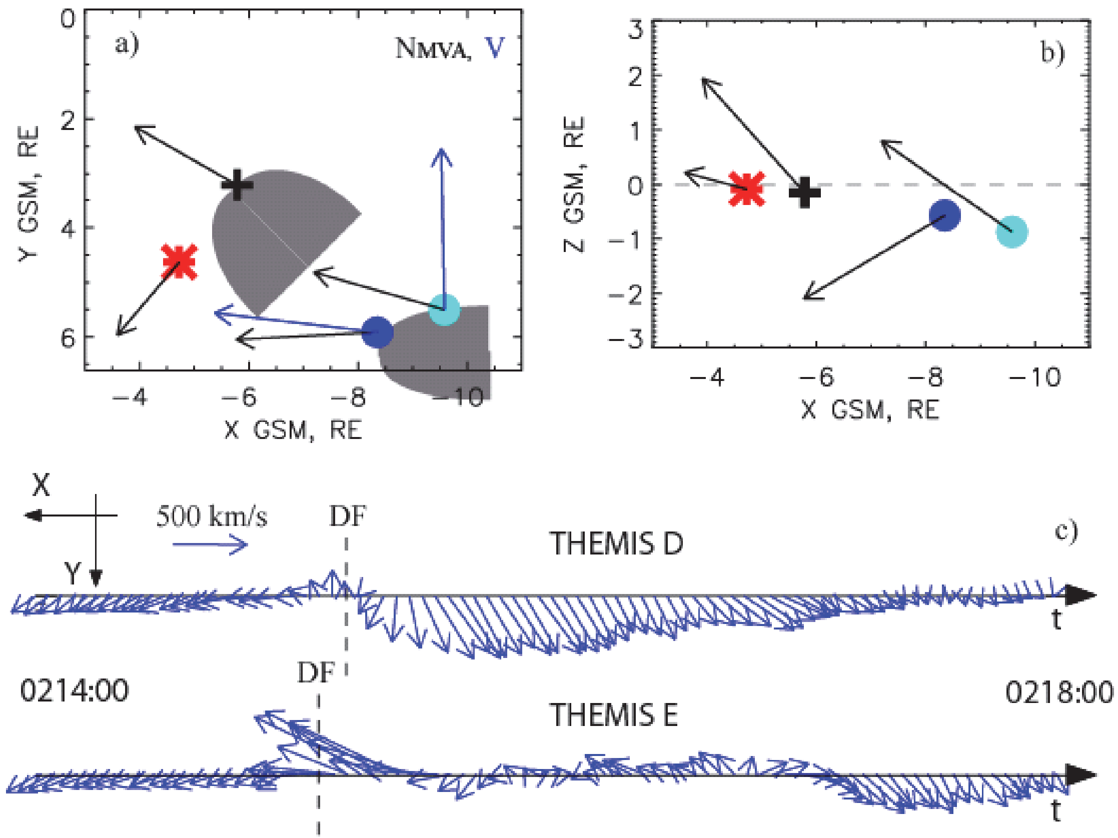




- Flapping: a set of folds on CS
- Flapping amplitude ~1000 km
- Embedded TCS with H~400 km (~c/ω_{pi})
- Local jy max at the CS periphery
- "Triple-peak" structure in the center (?)

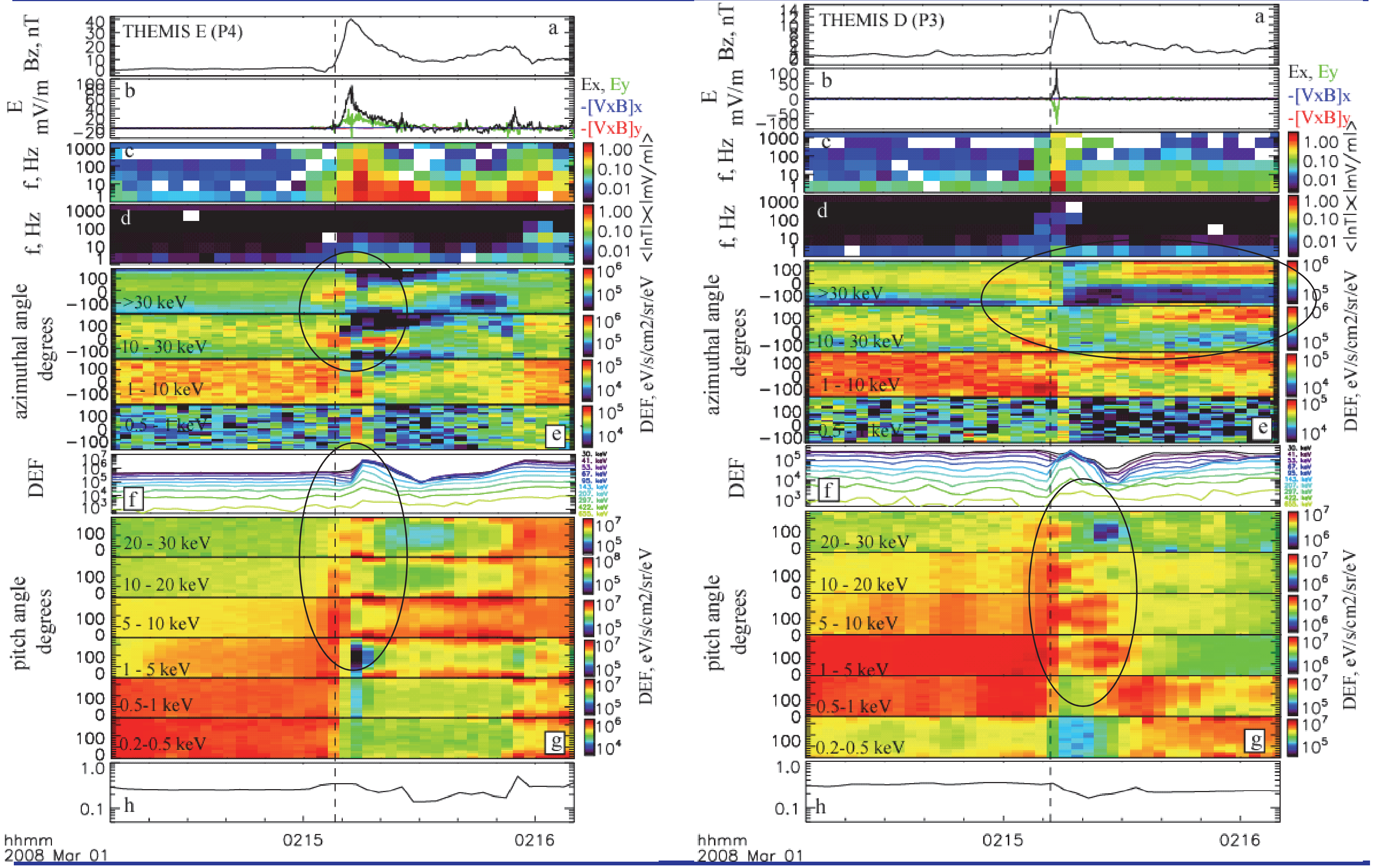
P3/P4 & GOES 10/12 Observations in the near-Earth PS

- THM P3/4 – GOES 10/12 timing: earthward propagation of the front
  - P3 – P4 timing: -6 s
  - G10-G12 timing: 25 s
  - G10 Be = 66 nT
  - G12 Be = 51 nT
- P3/4 & G10/12 timing: non-planar front and earthward-dawnward propagation
  - Bulk flow in XY plane: opposite direction at P3 (duskward) and P4 (mainly dawnward) behind the front
- Vortex motion or gradP-drift?



Similar results in simulations:
Birn et al., 2011, Merkin et al., (submitted)

P3 & P4 Observations



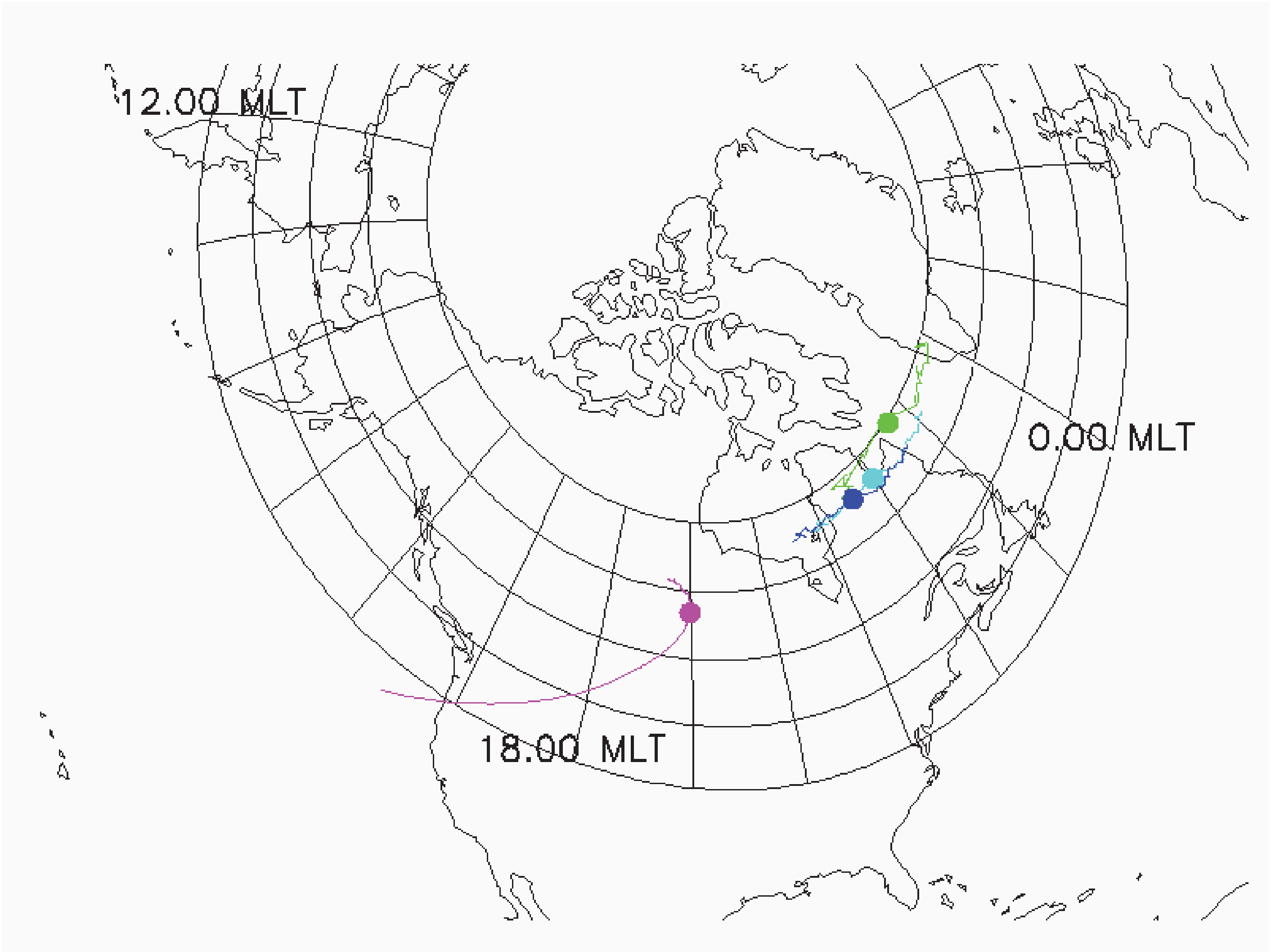
Summary & Open Questions

- ➢ Midtail: Signatures ofreconnection (Vx<0 & Bz<0) at X≈-22 RE;
- ➢ Near PS: Earthward-moving dipolarization front between X≈-10 & -5 RE;
- ➢ Activity started at X≈-16 RE
  - gradual increase in the magnetic flux transfer rate (Φ);
  - In ~5 min → burst-like enhancement in Φ;
  - Flapping waves on CS surface with amplitude of 1000 km
  - Non-Harris CS structure: embedded TCS (tripple-peak?) in the center & a peak at the perephery
- ➢ Dipolarization front in the Near-Earth PS:
  - Appeared in ~5 minutes after the initial flux transfer increase;
  - Simultaneously (within 0.5 min) with fast flux transfer onset => appeared on slow phase → Scenario 2 seems possible.
  - Earthward and dawnward propagation of the dipolarization front;
  - Non-planarity of the front;
  - Vortical bulk flow behind/around the front (?)
  - Difference in filed and particle signatures at two points separated by <1 RE in Y

? RX & Flapping (kinking): what drives what? What does flapping CS structure tell us about RX? Comprehensive 3D modeling is needed.

? What are mechanisms of front formation on “slow” RX phase? Is ballooning in a play? Comprehensive 3D modeling is needed.

Back Up Slides


12.00 MLT
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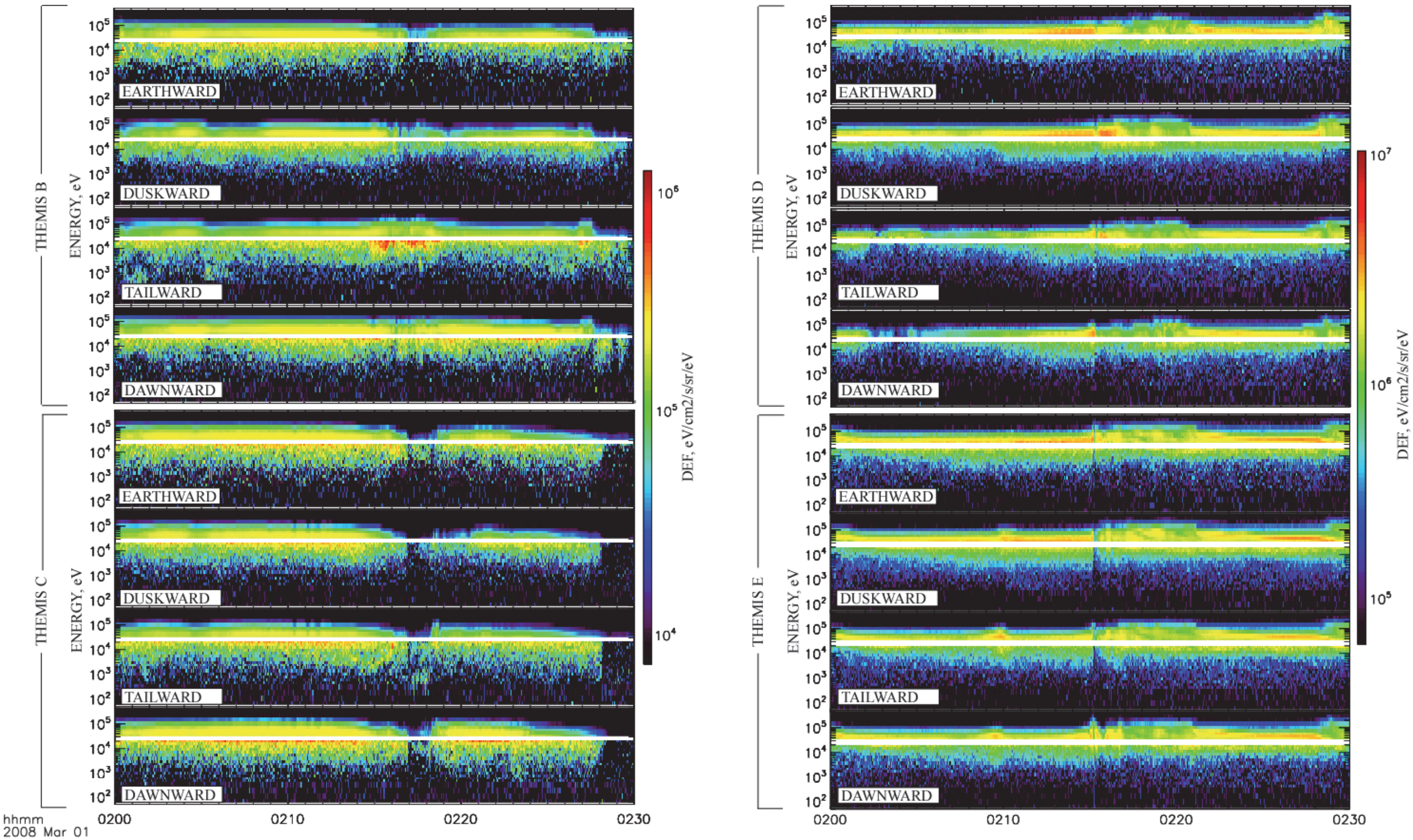
THEMIS B
THEMIS C
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ENERGY, eV
EARTHWARD
DUSKWARD
TAILWARD
DAWNWARD
DEF, eV/cm2/s/sr/eV
hhmm
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0200
0210
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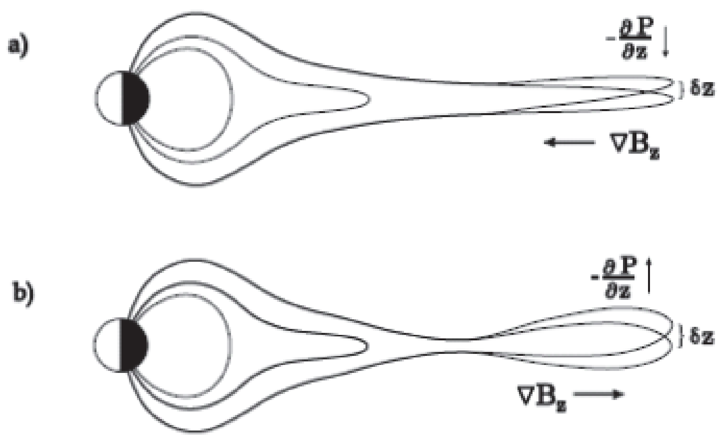
0230



- Flapping model:
- TCS "double-gradient" instability
  Erkaev et al., JGR, 2009