Fermi and Betatron Acceleration of Suprathermal Electrons behind Dipolarization Fronts

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Outline

- Introduction
- Dipolarization front (DF) – multiscale
- Fermi & Betatron behind DF
- Conclusion

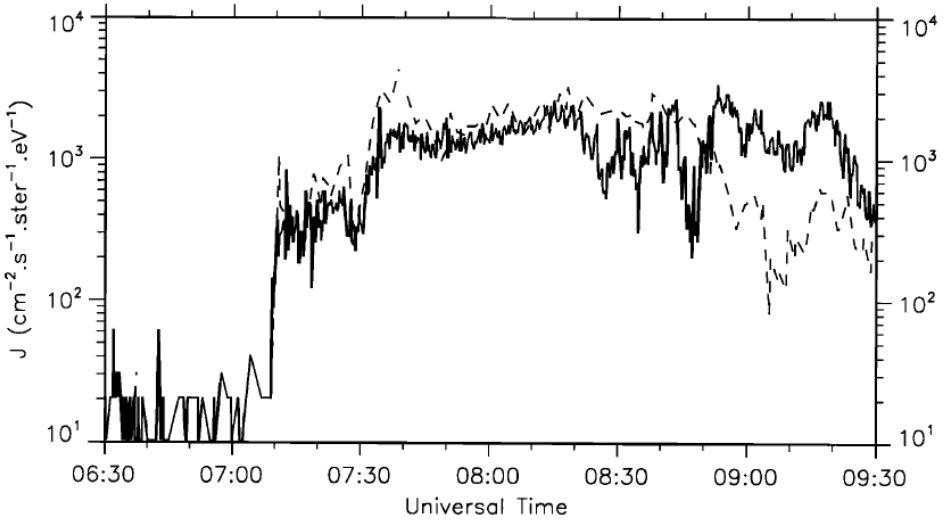


Figure 2. Parallel (dotted line) and perpendicular (solid line) flux of 10 keV electrons observed by Interball-Tail between 0630 UT and 0930 UT.

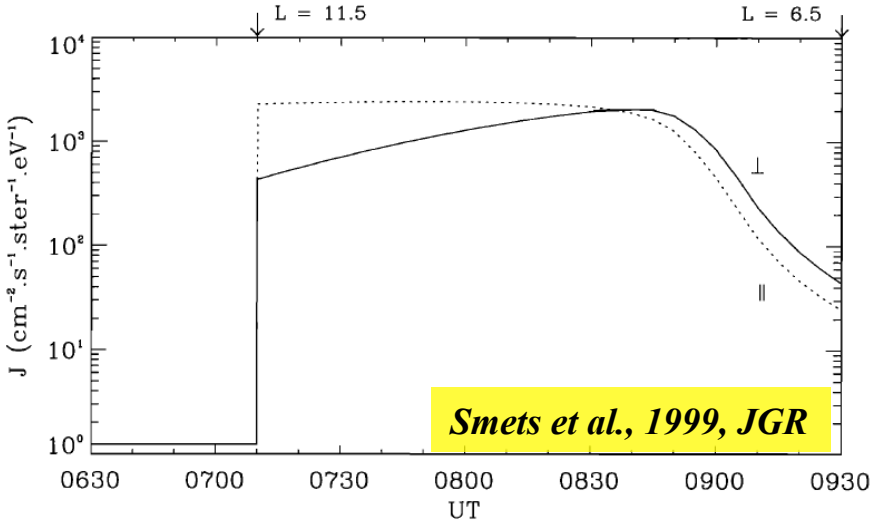
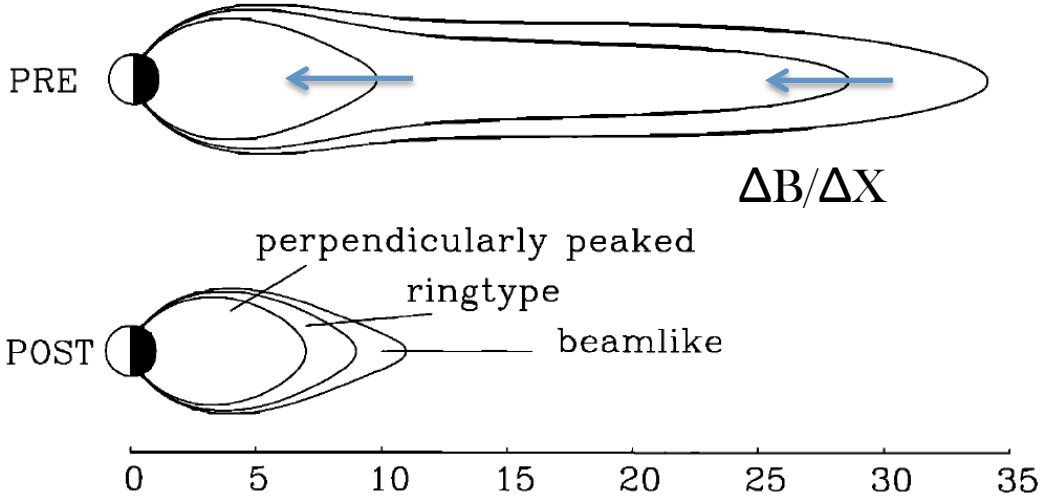


Figure 4. Computed parallel (dotted line) and perpendicular (solid line) flux of 10 keV electrons as function of time. Dipolarization starts at 0710 UT.



7. Schematic view of the three distinct domains in the near-Earth tail and their evolution dipolarization with corresponding $\Theta - \Phi$ spectrograms.

$$E_{1//} = (L_0 / L_1)^2 \cdot E_{0//} = F_f \cdot E_{0//}$$

$$E_{1\perp} = (B_1 / B_0) \cdot E_{0\perp} = F_b \cdot E_{0\perp}$$

- when dipolarization happens
  - tail region – beamlike
  - transition region – ringtype
  - near-Earth -- perpendicular

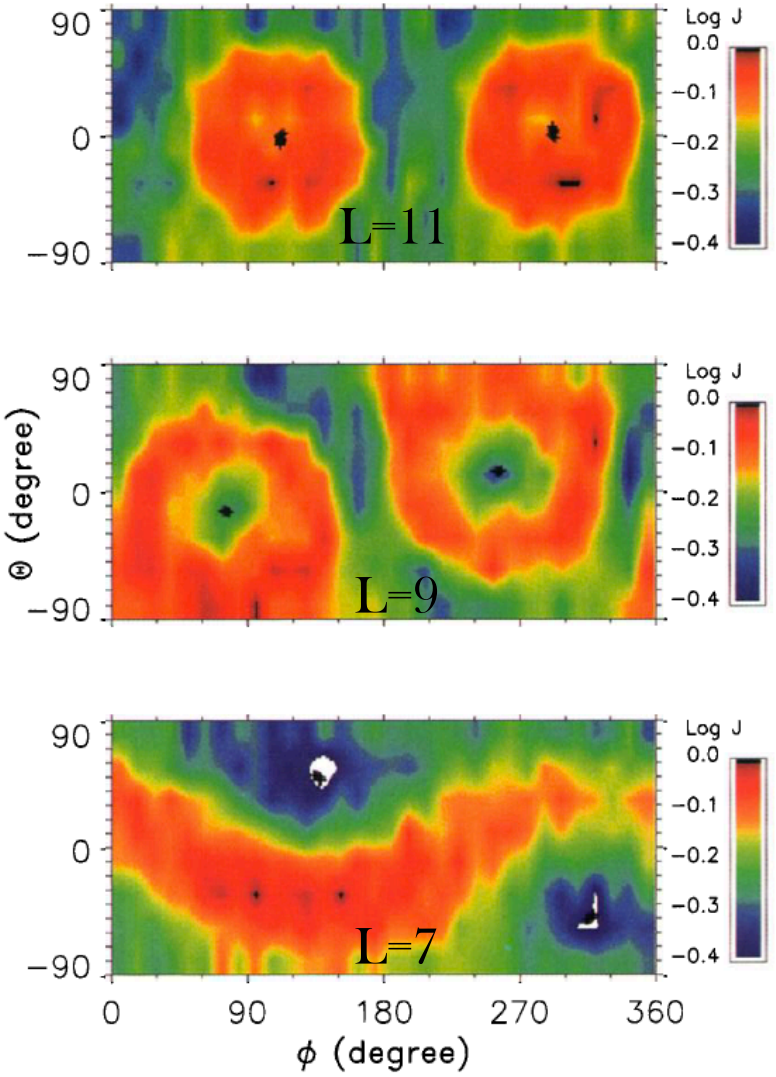


Plate 1. Observed Θ – Φ spectrograms for 10 keV electrons at (a) 0828 UT, (b) 0838 UT, and (c) 0918 UT.

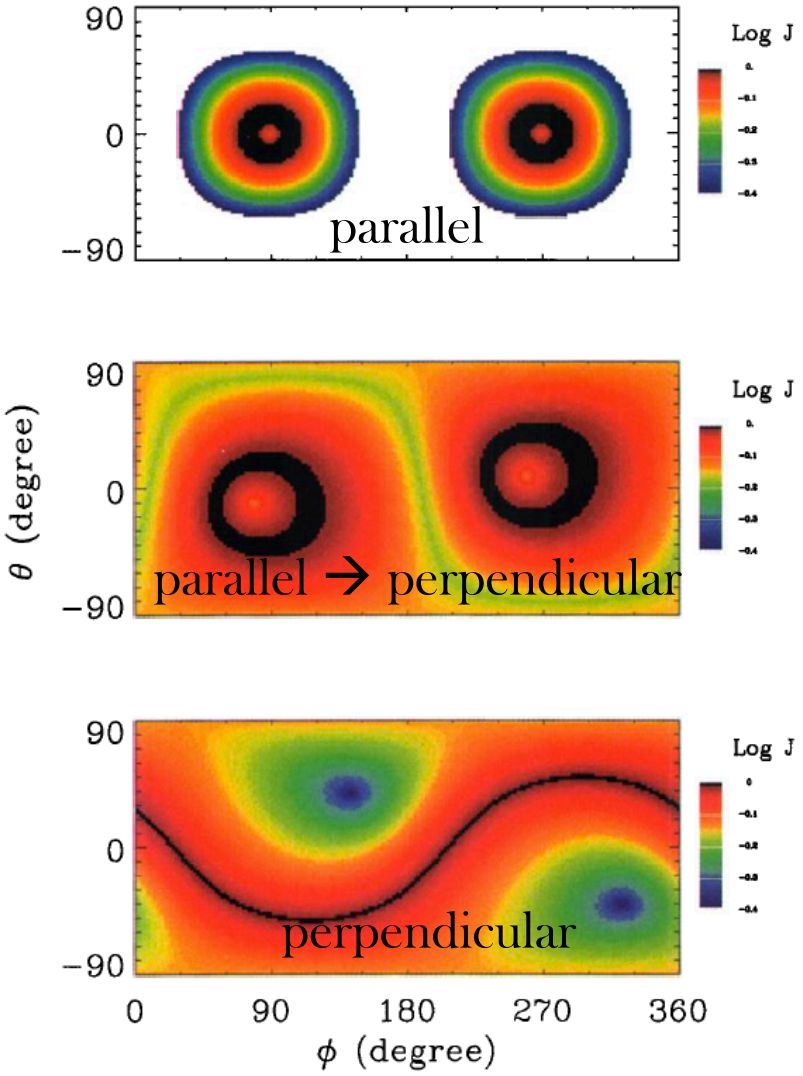
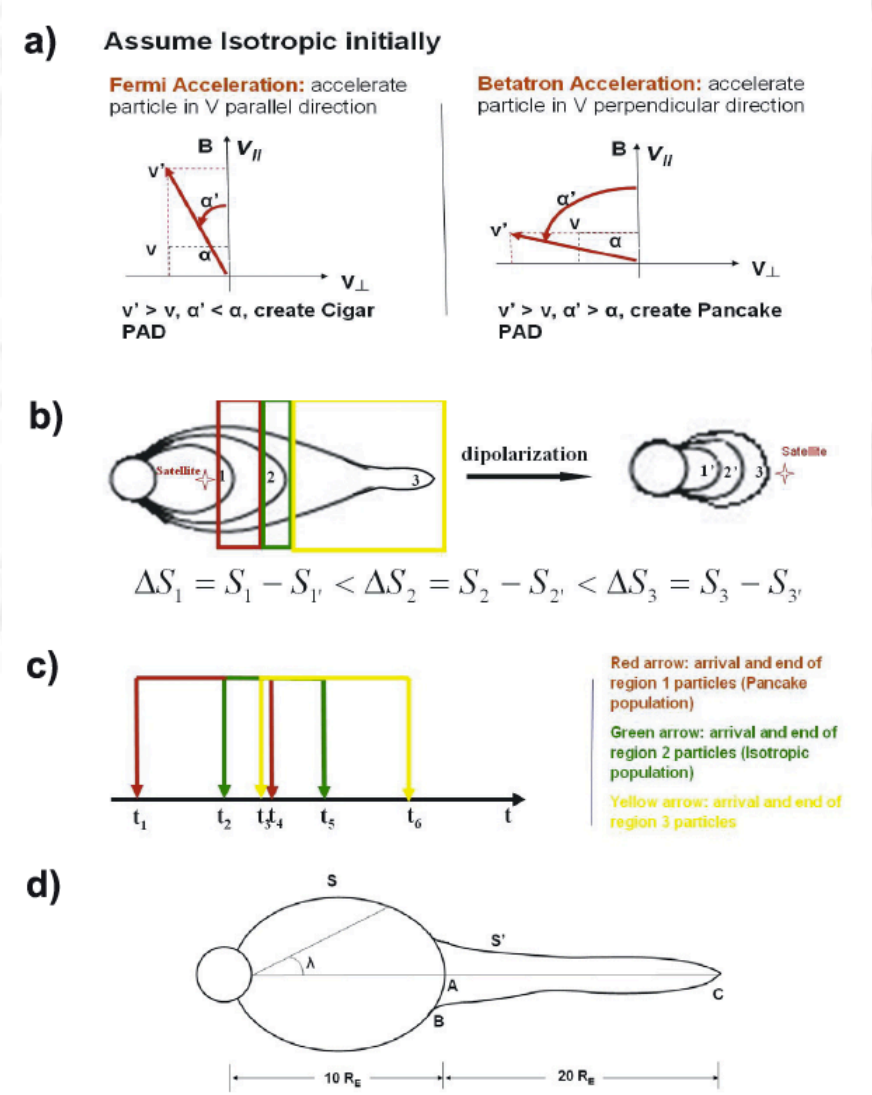


Plate 2. Computed Θ – Φ spectrograms for 10 keV electrons at (a) $L = 11$, (b) $L = 9$, and (c) $L = 7$.

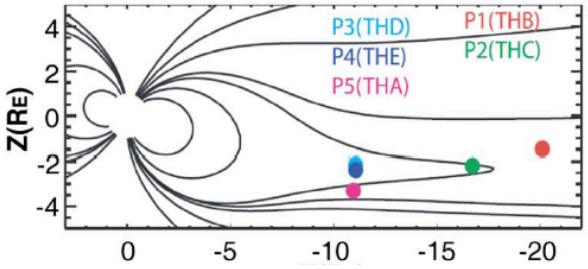
Smets et al., 1999, JGR



Wu et al., 2006, GRL

- tail-like region (region 3)
  - -- parallel & anti-parallel – cigar
- transition region (region 2)
  - -- isotropic
- near-Earth region (region 1)
  - -- pick at 90deg -- pancake

- dipolarization from tail to near-Earth
  - -- cigar to pancake
  - -- Fermi to betatron



➢ contradictory observation?

Deng et al., 2010, JGR

❖ tail-like region (P1 & P2)

-- perpendicular

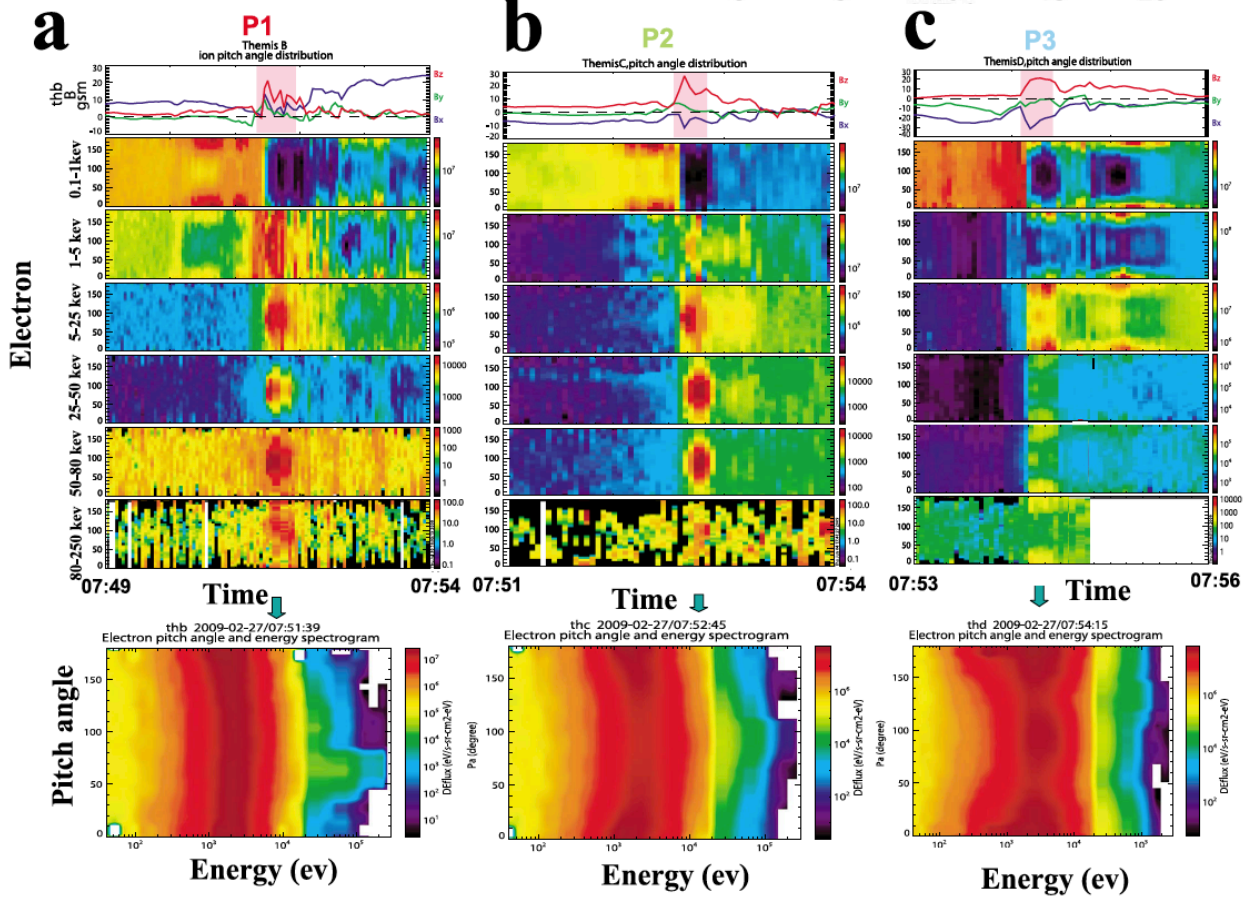
-- pancake

❖ near-Earth region (P3)

-- parallel & anti-parallel

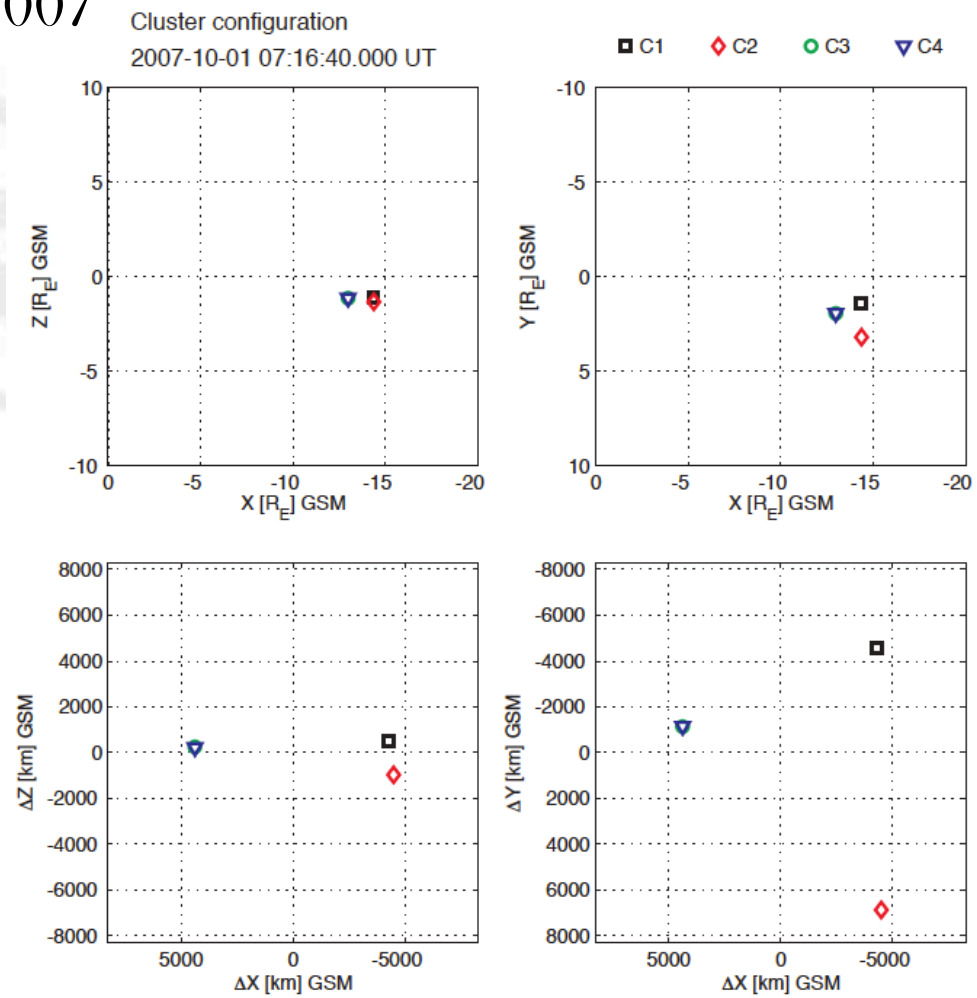
-- cigar

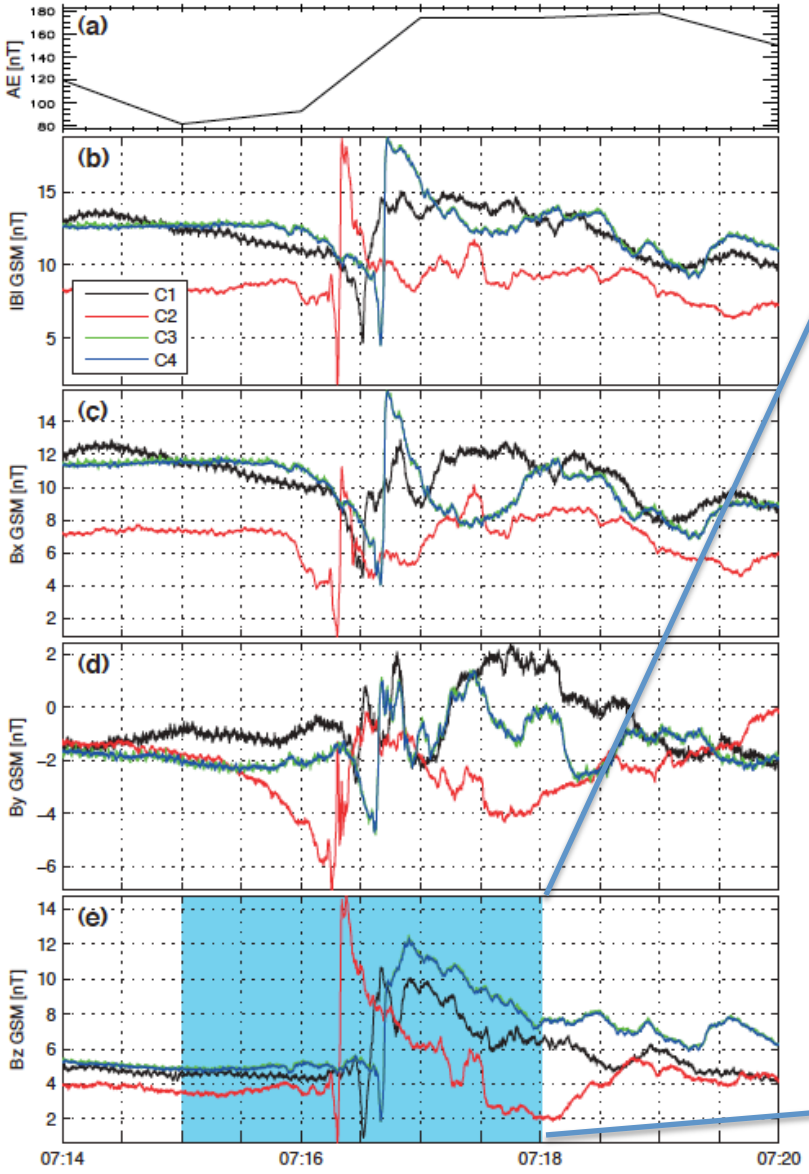
Betatron → Fermi?

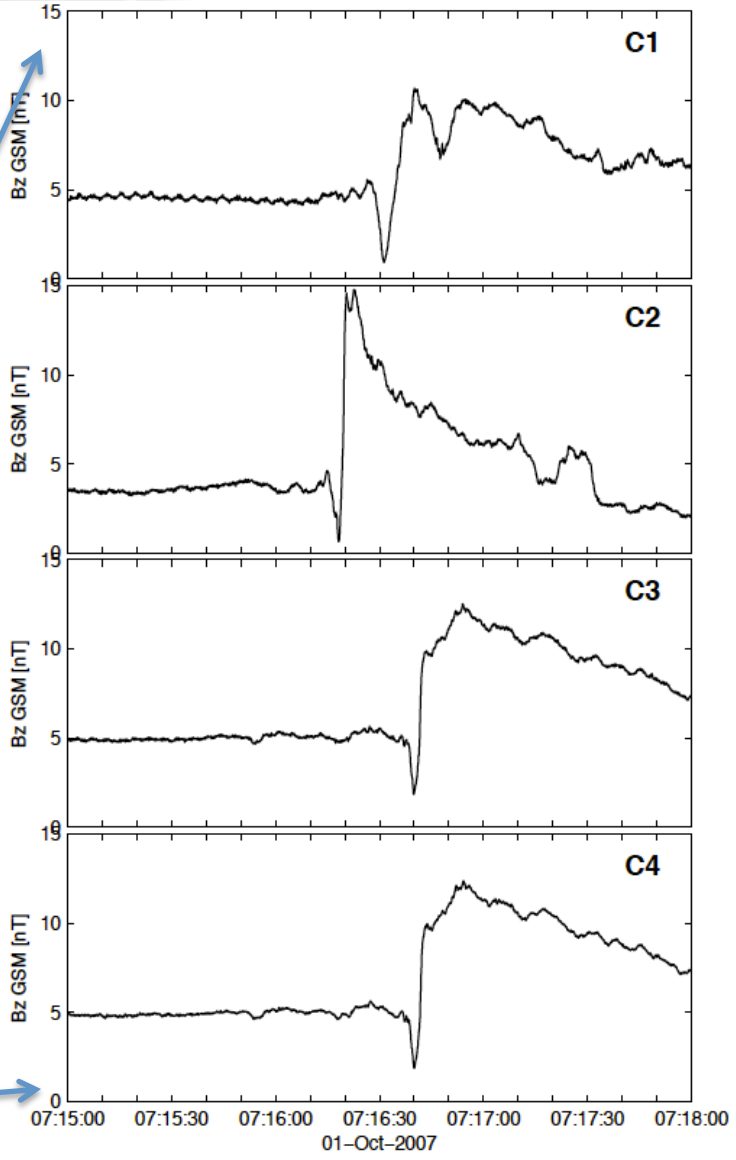


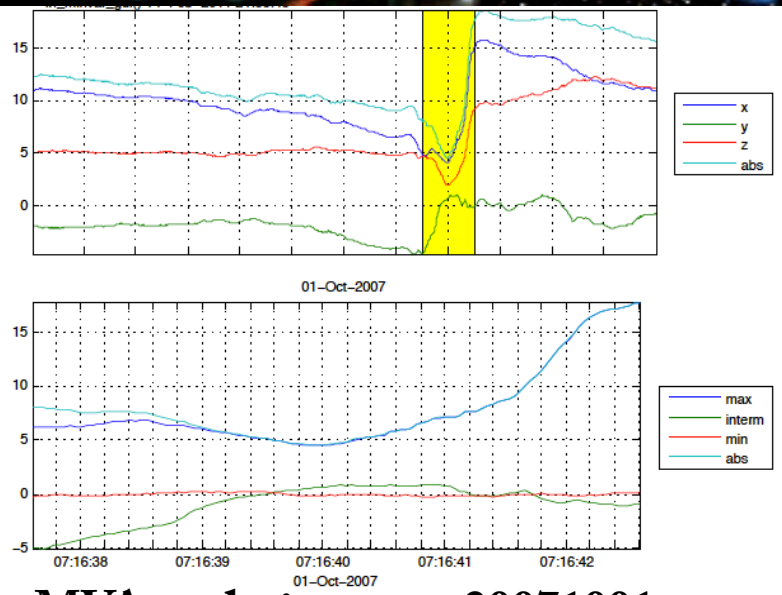
➢ Dipolarization event in Oct 2007

- ➢ Satellite location
- ❖ mid-tail region
  - -- Xgsm≈15 Re
- ❖ Multi-scale observation
  - -- ~30km between C3 and C4
- ❖ ΔY lager than ΔZ

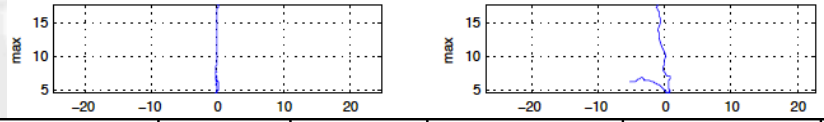



(a)
AE [nT]
(b)
IBl GSM [nT]
C1
C2
C3
C4
(c)
Bx GSM [nT]
(d)
By GSM [nT]
(e)
Bz GSM [nT]
07:14
07:16
07:18
07:20

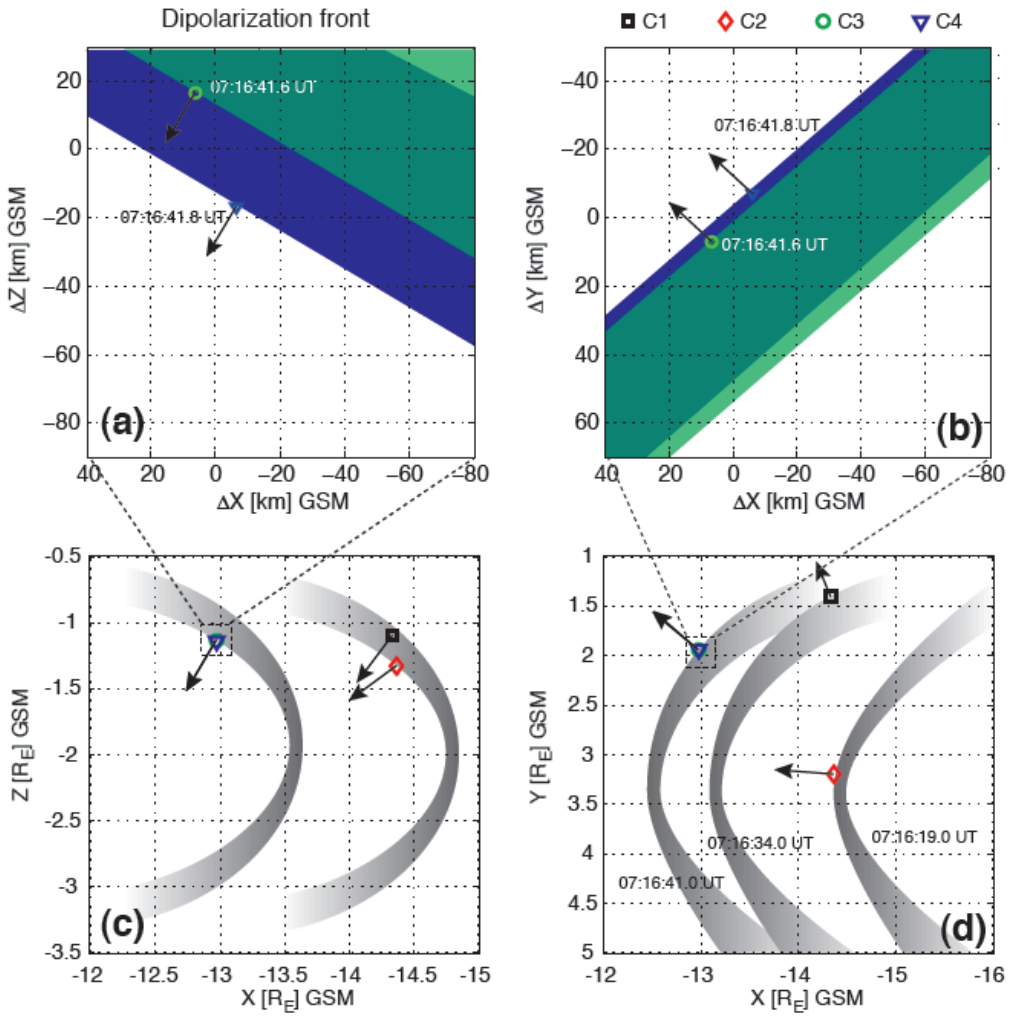

C1
C2
C3
C4
Bz GSM [nT]
07:15:00
07:15:30
07:16:00
07:16:30
07:17:00
07:17:30
07:18:00
01–Oct–2007



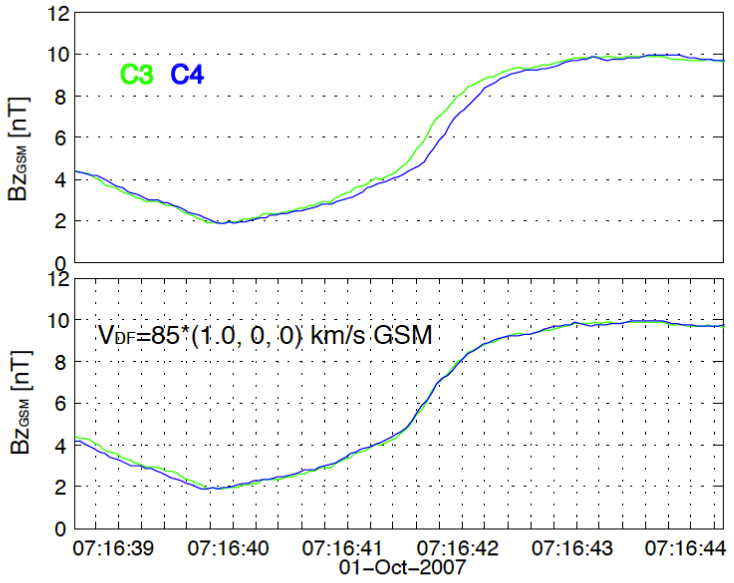
MVA analysis— case 20071001

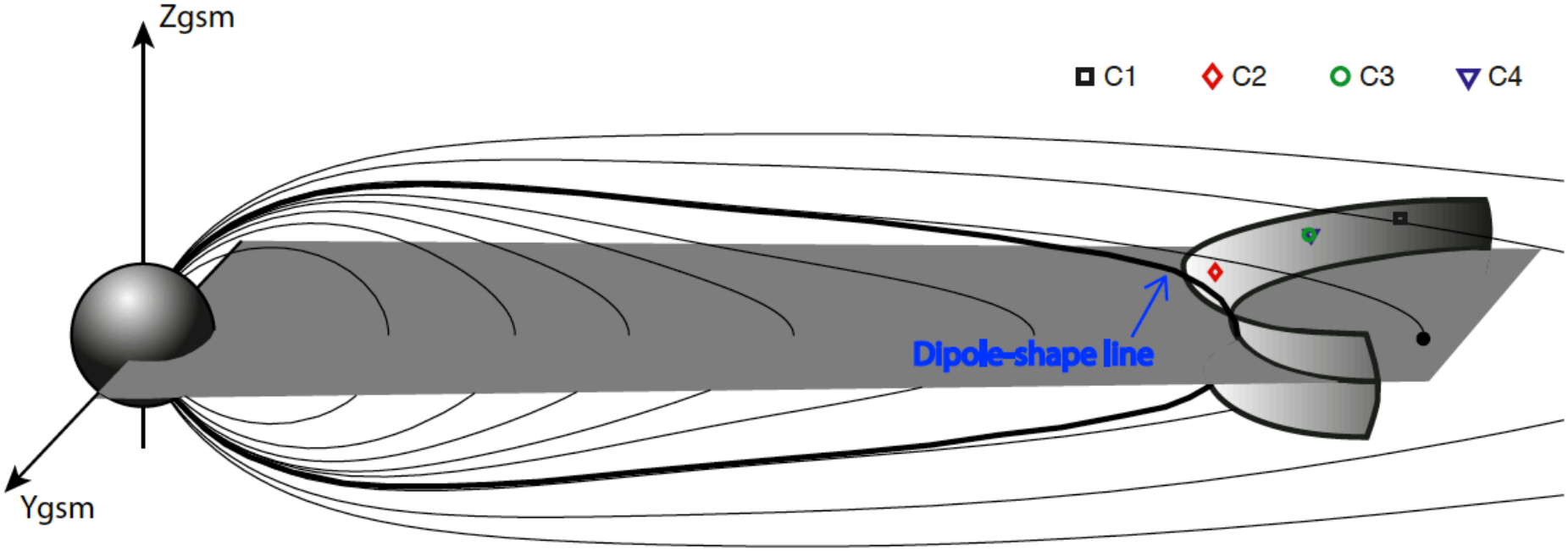


SC	UT	λ1, λ2, λ3	λ2/λ3	R1	R2	R3
C1	07:16:28.216Z → 07:16:35.186Z	L1=4.43 L2=2.28 L3=0.0221	100	[0.92 0.17 0.36]	[0.23 0.52 −0.82]	[−0.33 0.84 0.44]
C2	07:16:18.207Z → 07:16:20.482Z	L1=36.5 L2=1.2 L3=0.011	110	[0.59 −0.07 0.80]	[0.09 1.00 0.02]	[−0.80 0.06 0.59]
C3	07:16:37.461Z → 07:16:42.492Z	L1=14.2 L2=3.7 L3=0.0398	93	[0.87 0.02 0.49]	[0.18 0.92 −0.36]	[−0.46 0.40 0.79]
C4	07:16:37.582Z → 07:16:42.618Z	L1=14.2 L2=3.25 L3=0.0182	180	[0.87 0.04 0.50]	[0.16 0.92 −0.36]	[−0.47 0.39 0.79]

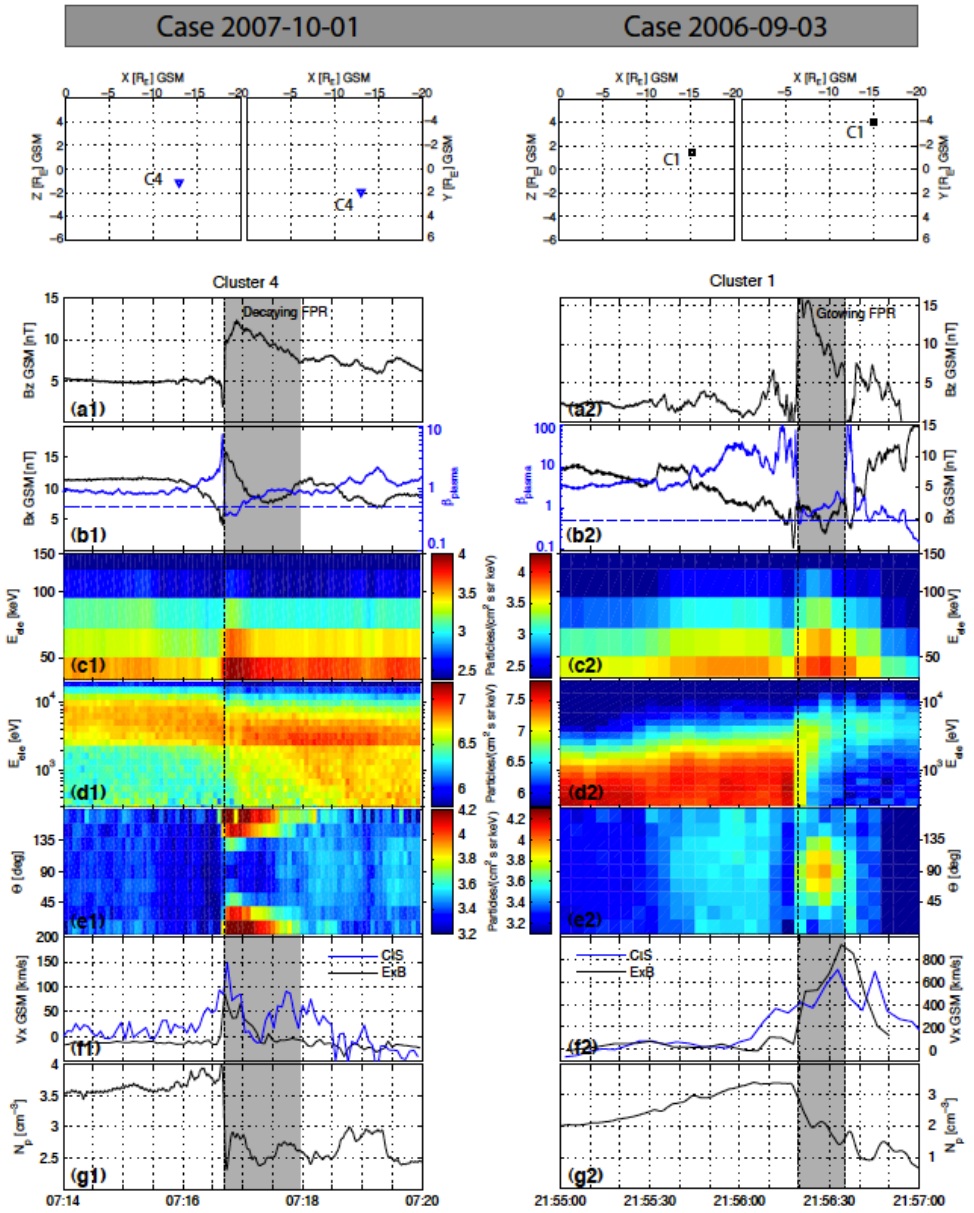


- 2D dipolarization front
  - Propagation velocity
    - -- Assume propagate along Xgsm

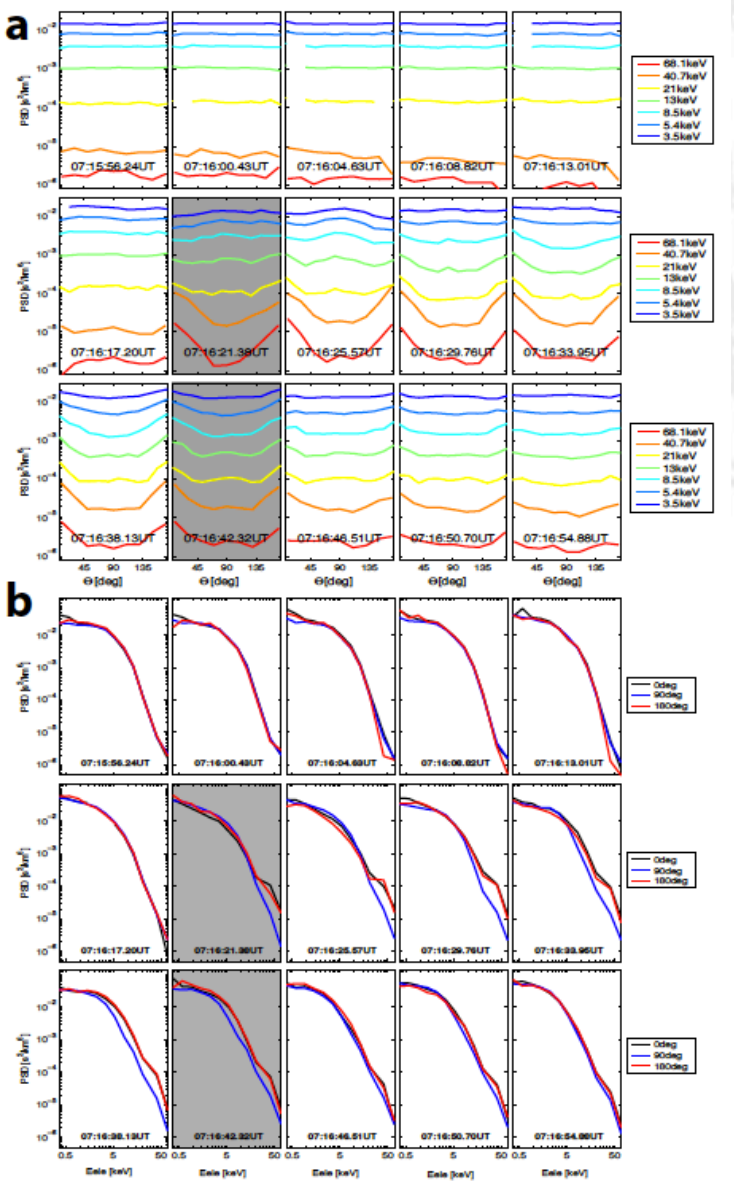


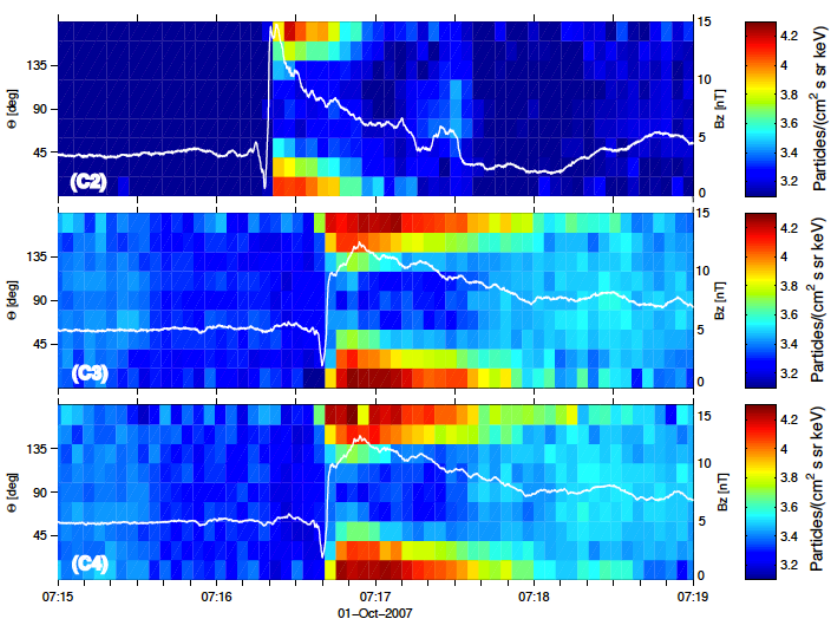


3D dipolarization front cartoon

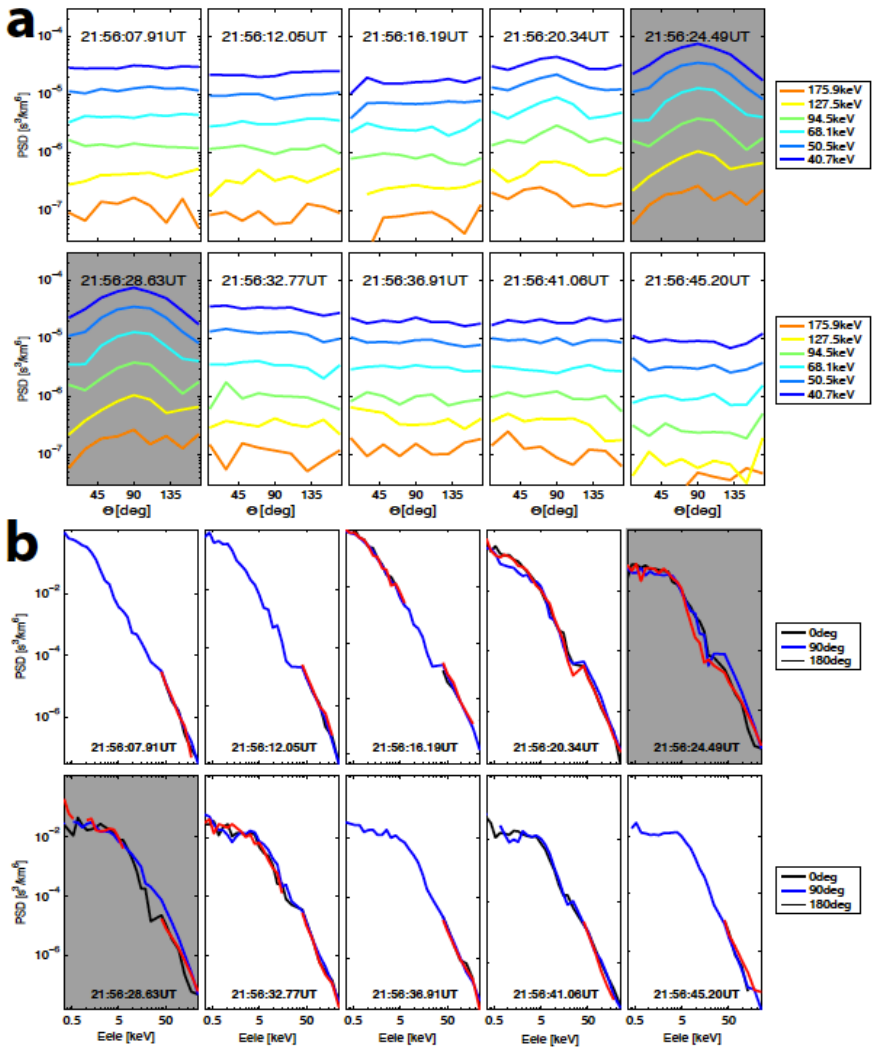


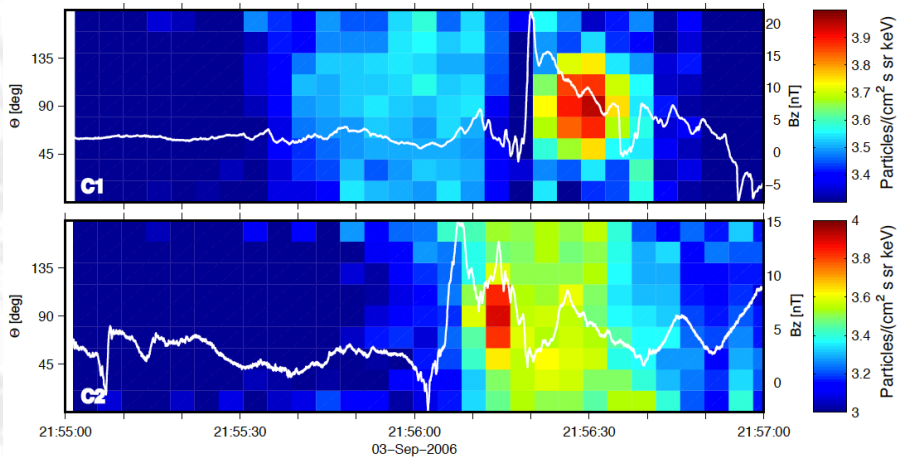
- Case 20071001
  - Fermi acceleration
  - Decaying FPR (flux-pileup-region)
  - Beta>0.5
- Case 20060903
  - Betatron acceleration
  - Growing FPR (flux-pileup-region)
  - Beta>0.5





- Case 20071001
- Pitch-angle distribution
- Before DF
  - -- isotropic
- Inside decaying FPR
  - -- parallel & anti-parallel





- Case 20060903
- Pitch-angle distribution
- Before DF
  - -- isotropic
- Inside growing FPR
  - -- perpendicular

➢ Modeling

treat electrons in quiet plasmasheet as source

Best fitting the observation

$$E_{1//} = (L_0 / L_1)^2 \cdot E_{0//} = F_f \cdot E_{0//}$$

$$E_{1\perp} = (B_1 / B_0) \cdot E_{0\perp} = F_b \cdot E_{0\perp}$$

❖ case 20071001

-- F_f=1.96

-- Reconnection site at Xgsm≈-21 Re

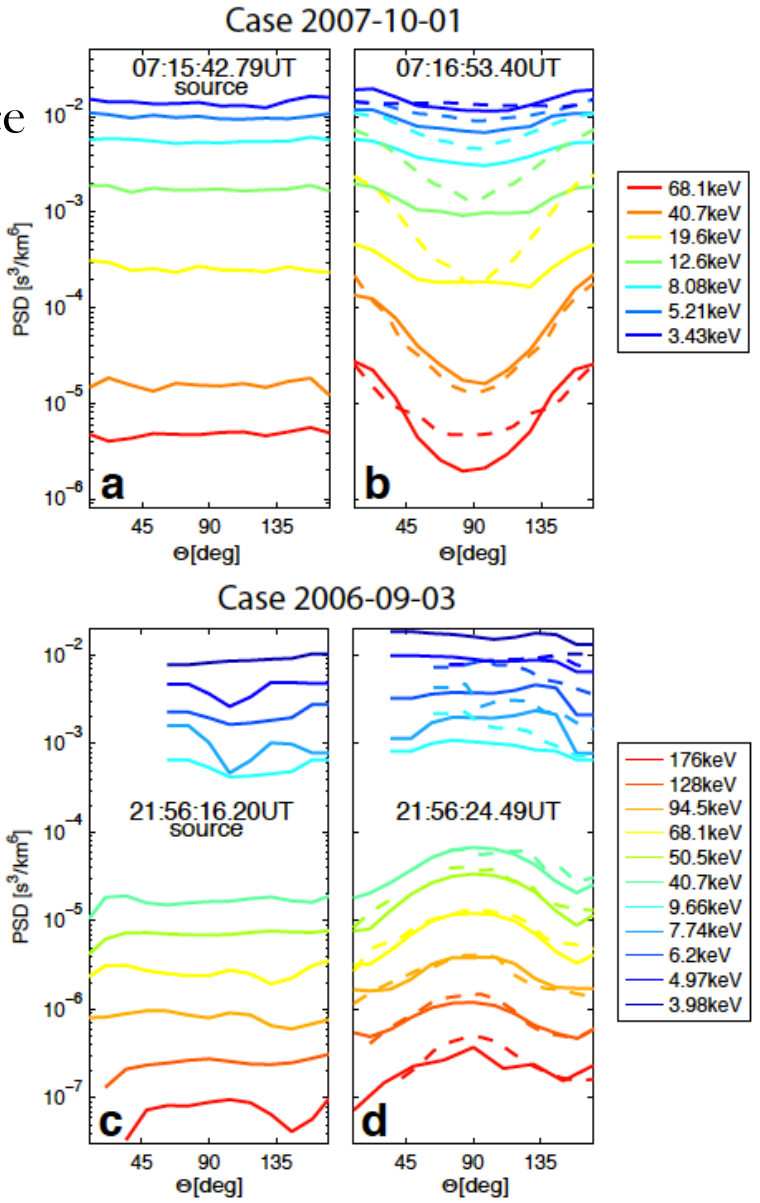
❖ case 20060903

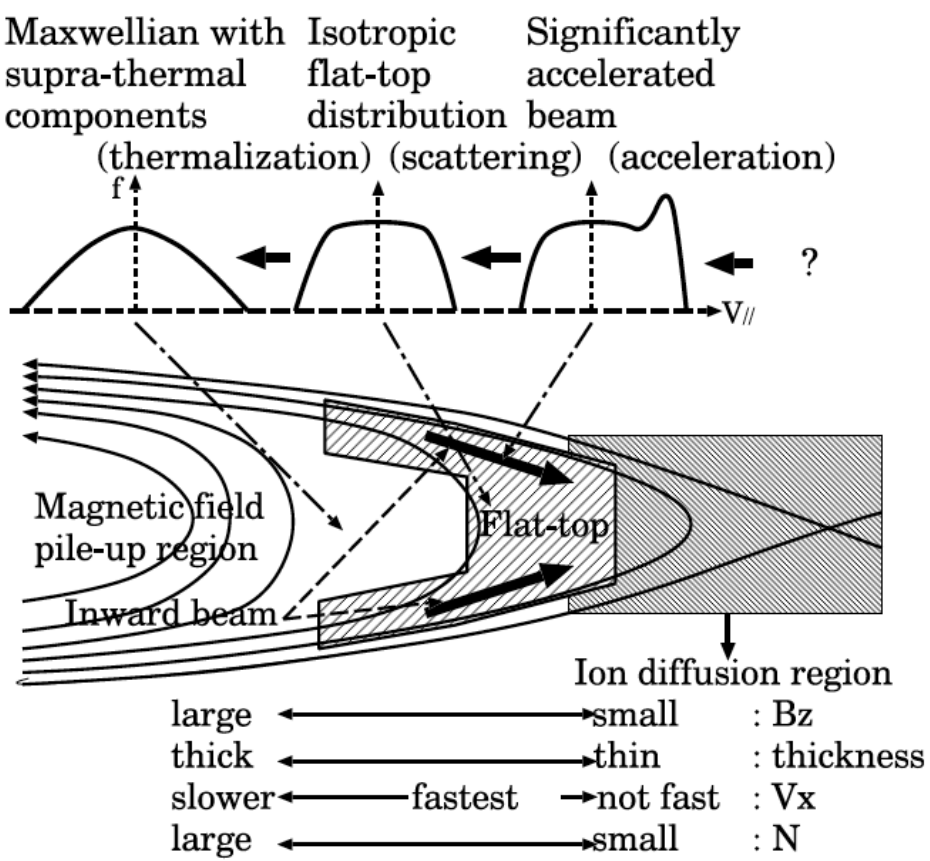
-- F_b=1.6

-- F_f=1.13

-- Reconnection site at Xgsm≈-17 Re

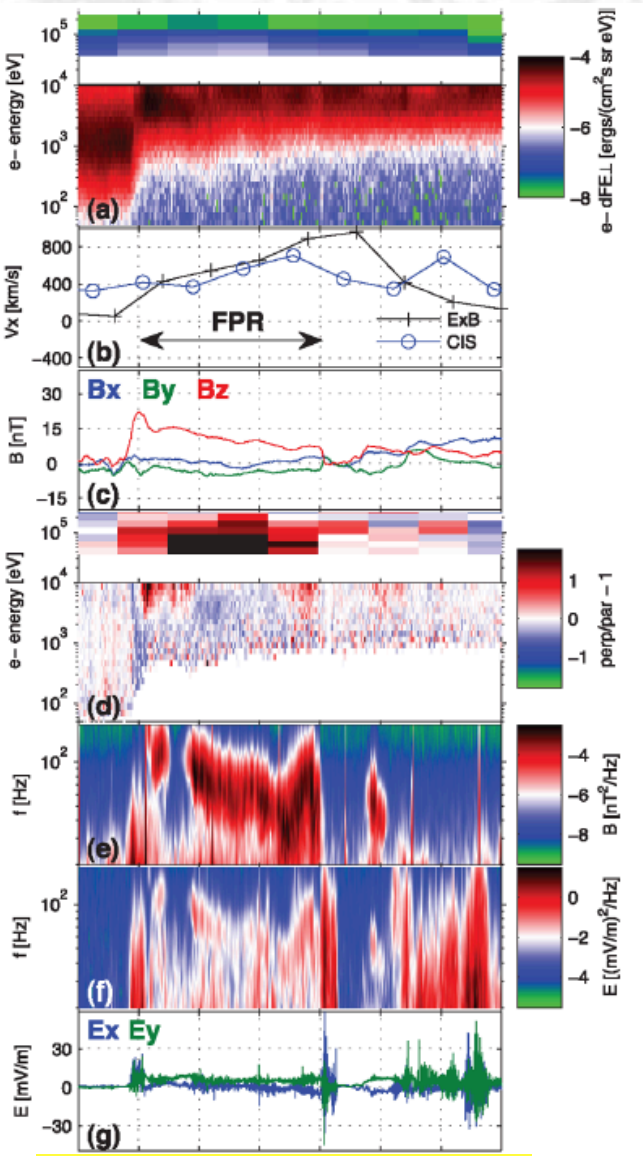
❖ Bad fitting for <20 keV electrons





Asano et al, 2008, JGR

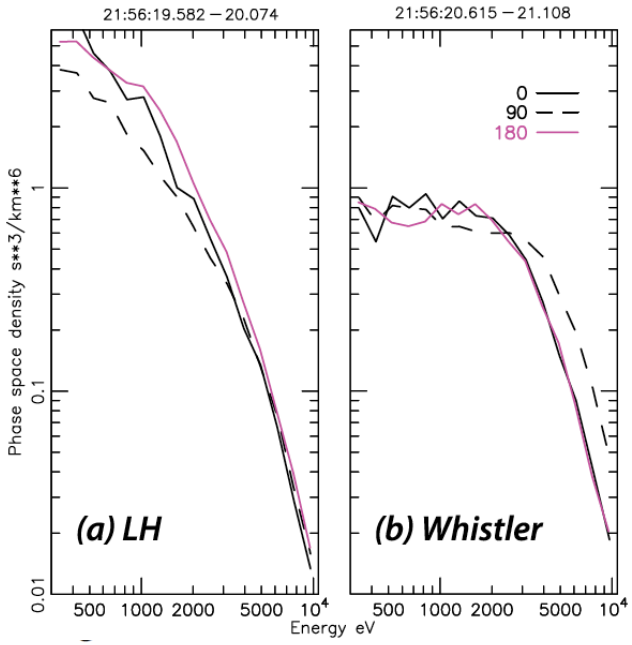
- Assumption of source is too rough
- Electrons in quiet plasma sheet and diffusion region are different
- In diffusion region, Flat-top distribution are observed frequently.
  -- Energy shoulder at ~14 keV
- In quiet plasmasheet, kappa distribution are observed



Khotyaintsev et al, 2011, PRL

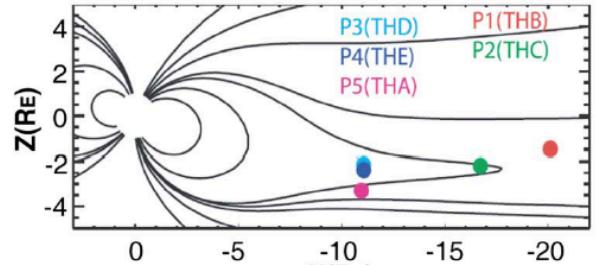
- Wave-particle interaction

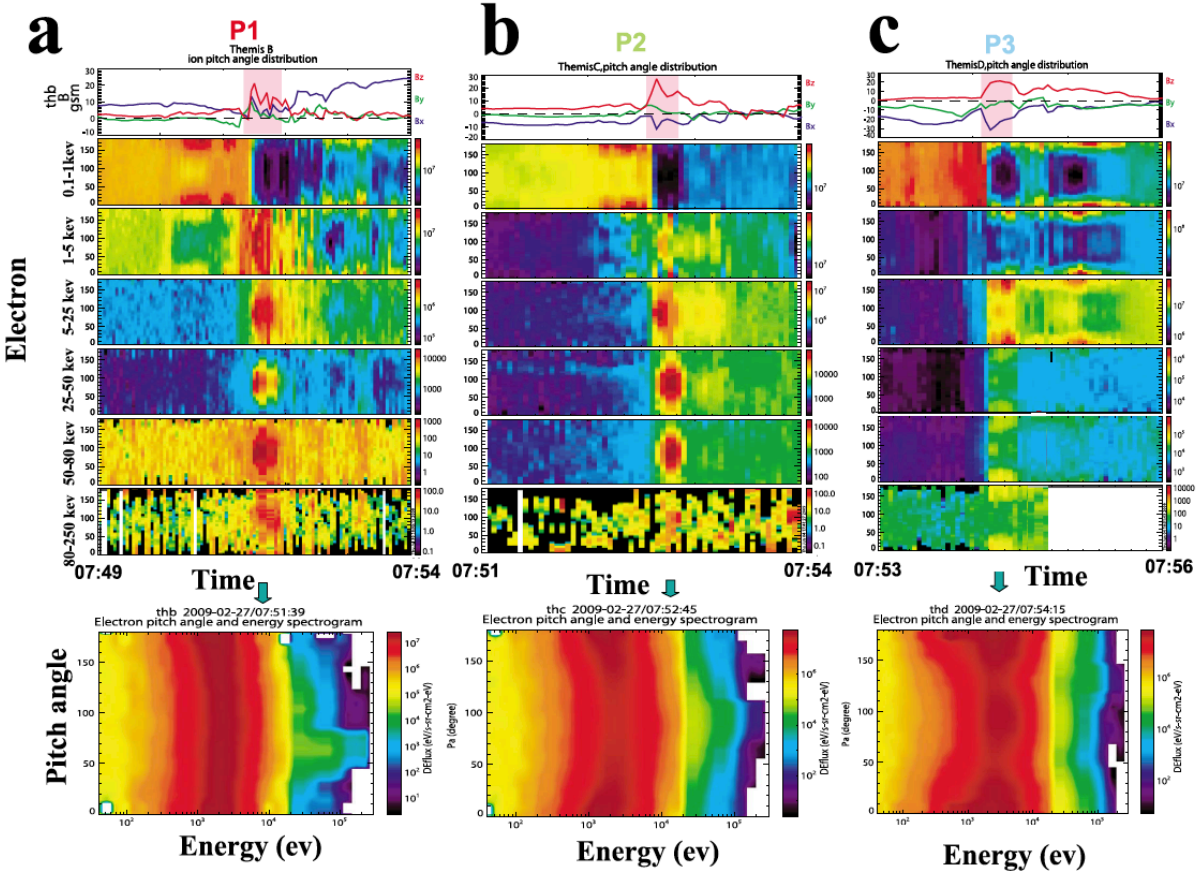
  more effective for low-E electrons due to stronger pitch angle diffusion and larger density gradient along the diffusion curve



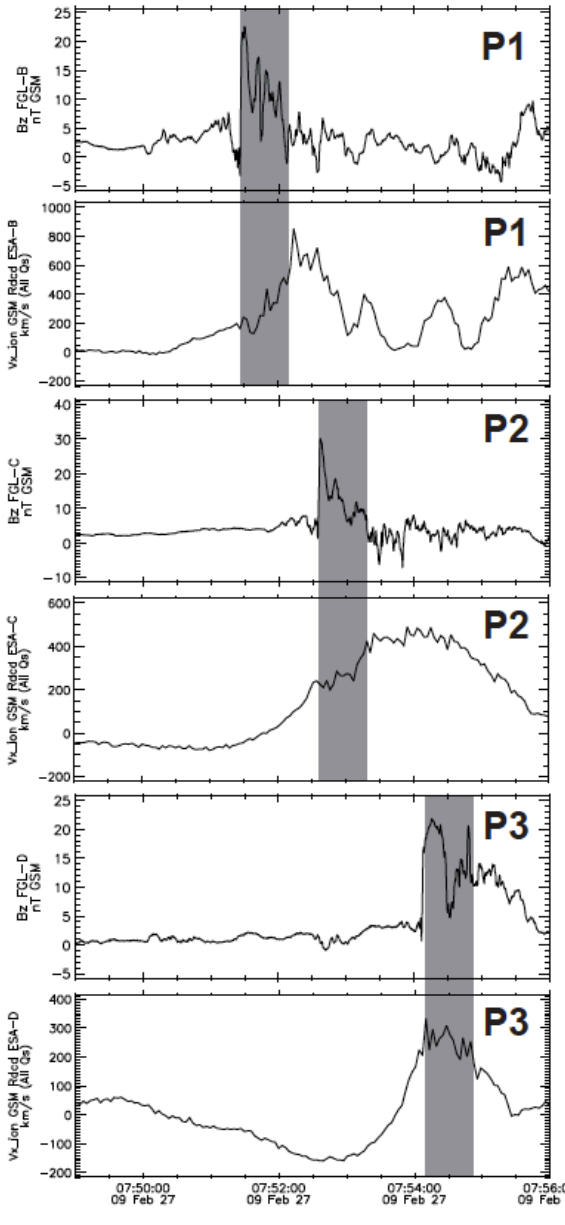
versible). 3. Whistler-mode wave-particle interaction limits the electron anisotropy caused during the betatron acceleration process at lower energies. The resulting distribution has limited anisotropy below 2 keV, and is more anisotropic at higher energies. 4. Strong lower-hybrid drift

- Themis investigation





Deng et al., 2010, JGR



Conclusion

Fu et al, 2011, GRL

- Flux-pileup-region (FPR) is just behind dipolarization front (DF)

  it is sometimes called reconnection jet

- BBF peak co-locate with DF => decaying FPR => flux tubes expand

  BBF peak locate behind DF => growing FPR => flux tubes are pushed together

- Fermi acceleration is observed in decaying FPR

  it is caused by the shrinking length of flux tubes

- Betatron acceleration is observed in growing FPR

  it is caused by a local compression of magnetic field

  betatron can appear in tail-like region although magnetic field is stretched

- Both Fermi and betatron work well in the modeling for >40 keV electrons

  <20 keV electrons may be affected more by wave-particle interaction

The End

thx