Production of Energetic Electrons by Magnetic Reconnection

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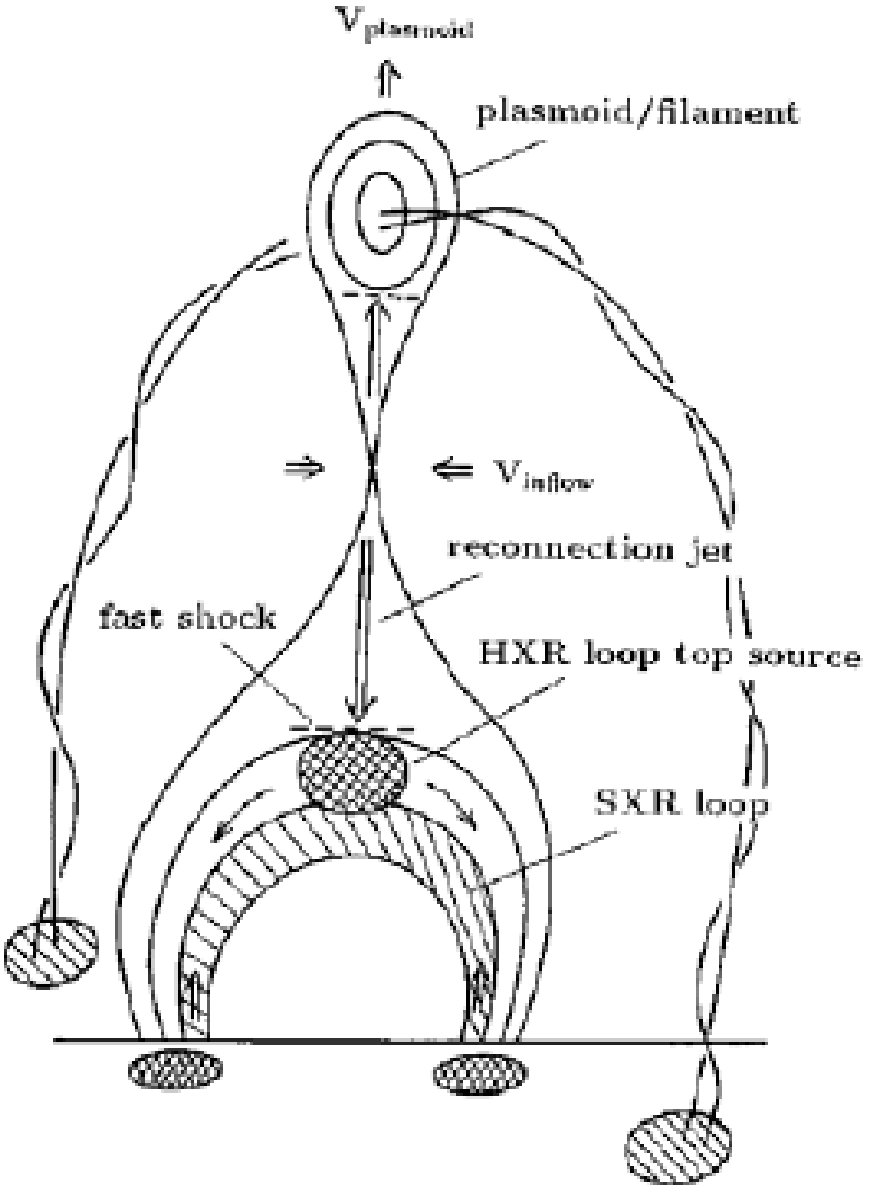
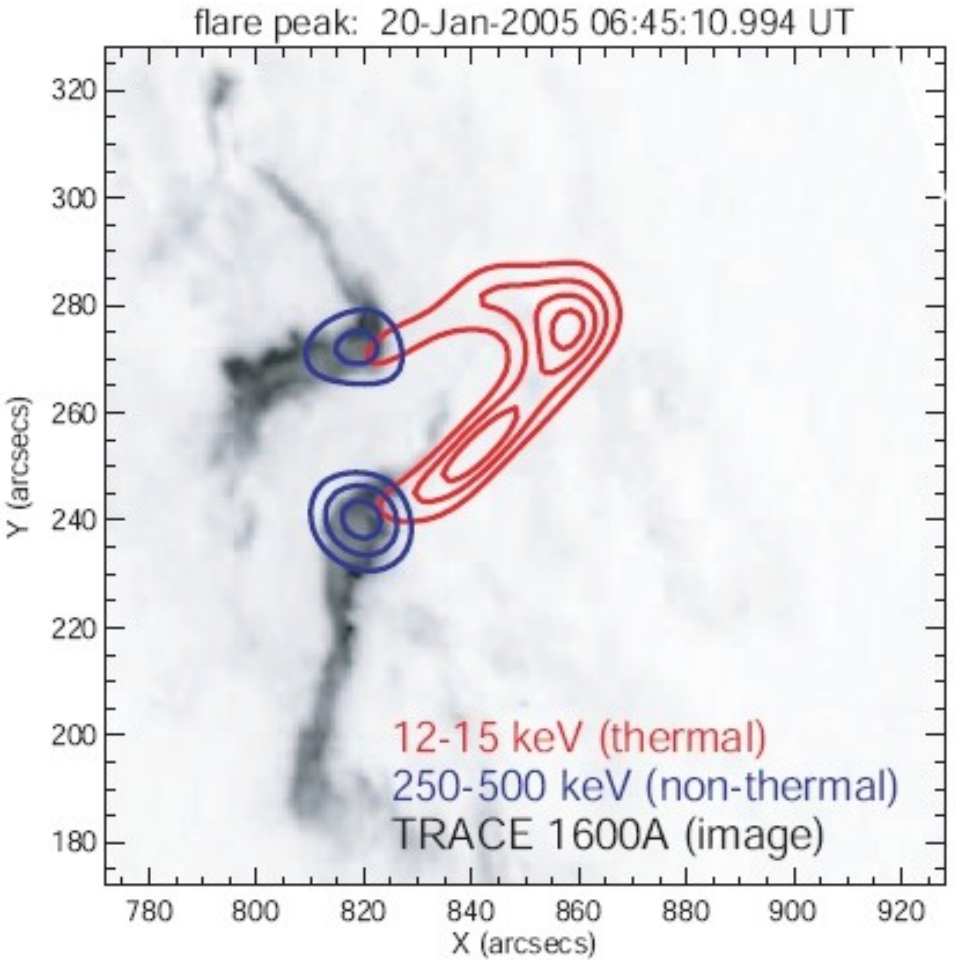
MR2012, Princeton

Motivation

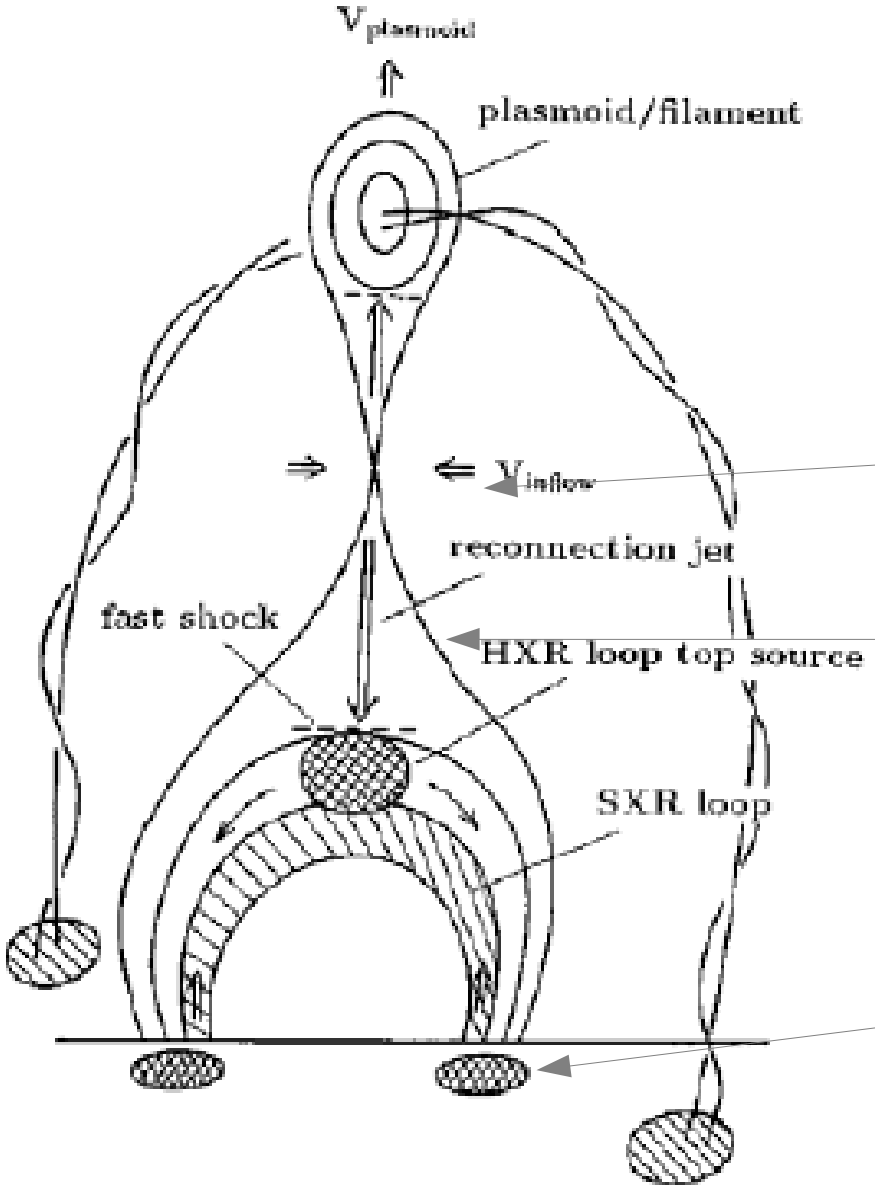


Shibata 1996



Krucker et. al, 2006

Flare vs Substorm

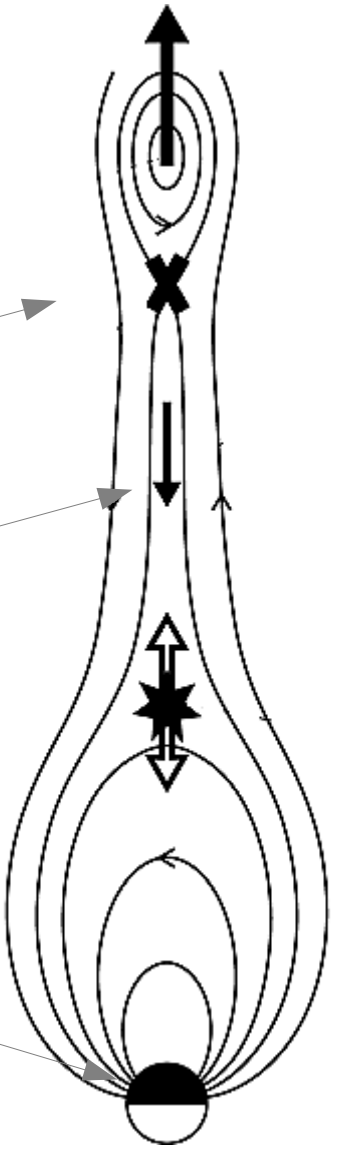


Shibata 1996

X-line

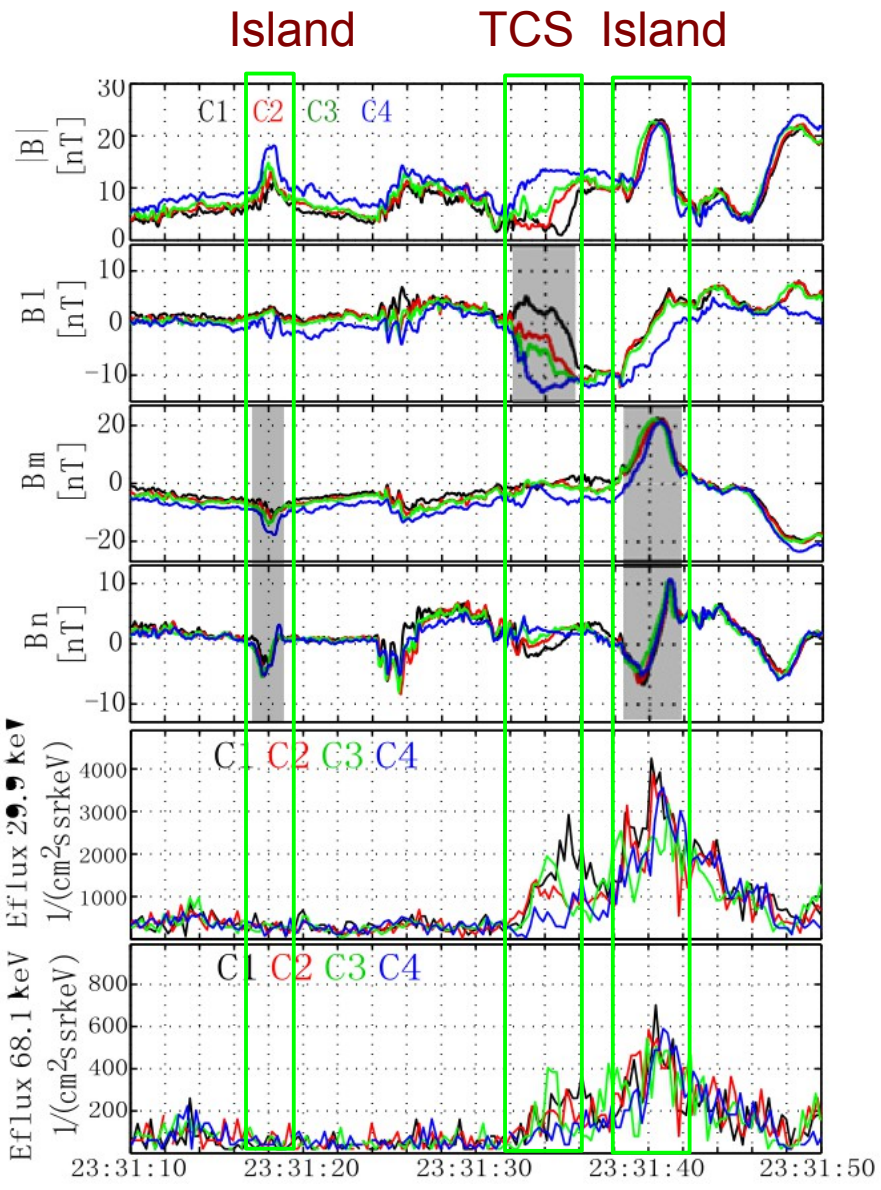
Reconnection jet

HXR / Aurora

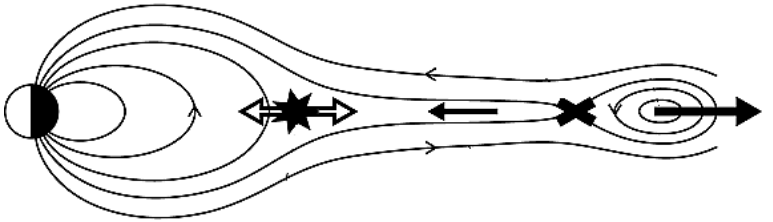


Miyashita 2009

Electron acceleration in the diffusion region



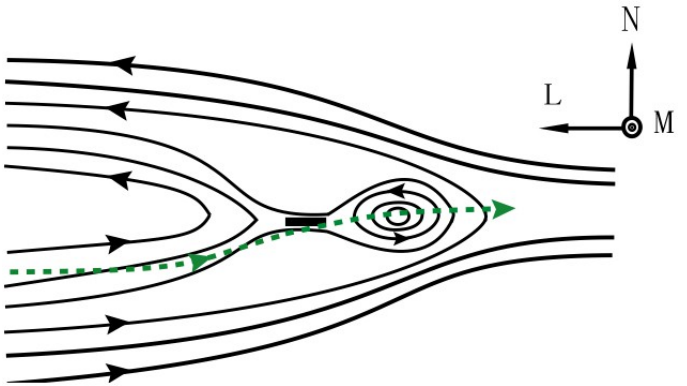
[Huang et. al., 2012, GRL]



Cluster is inside the ion diffusion region

- initially in a thick current sheet (many c/ω_{pi})
- first island is observed, no effect on energetic electrons
- *thin current sheet (TCS) and increase electron fluxes*
- *second magnetic island with additional increase in fluxes*

Cluster trajectory



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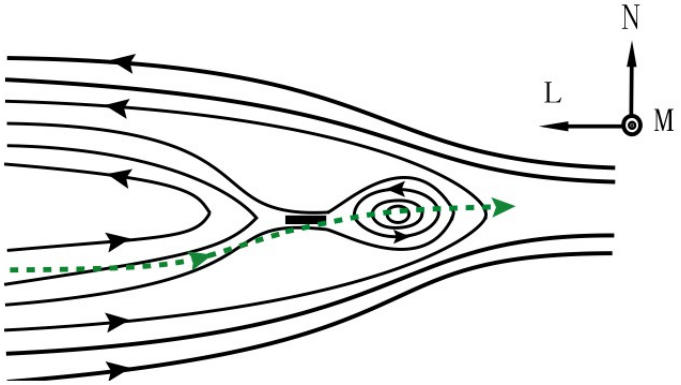
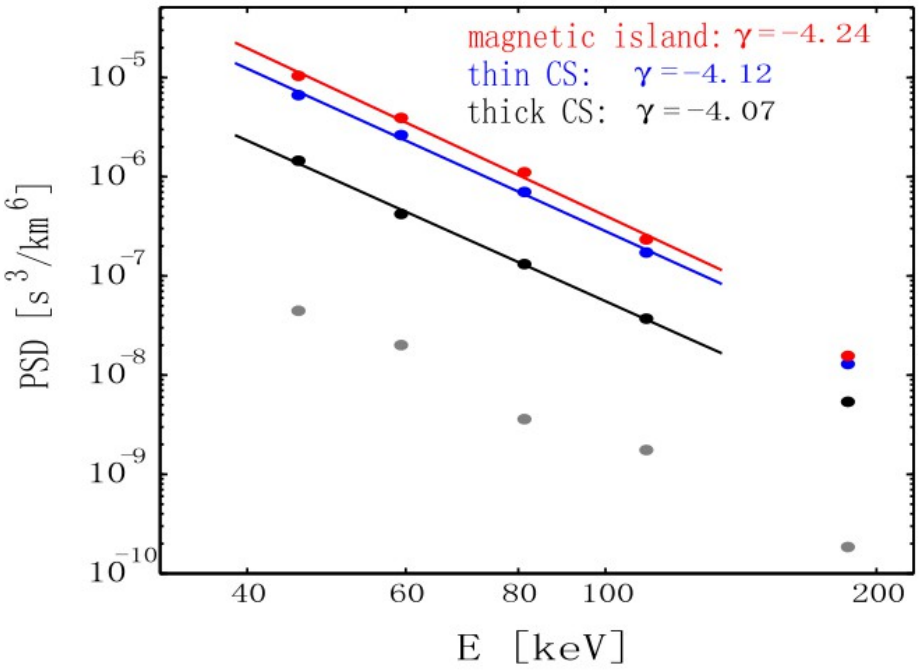


Two step electron acceleration:
- *in a thin current sheet (TCS)*
- *inside a magnetic island*

Acceleration is adiabatic and limited by the increasing gyroradius of the particles with respect to the TCS/island thickness

Not all islands have energetic electrons!



[Huang et. al., 2012, GRL]

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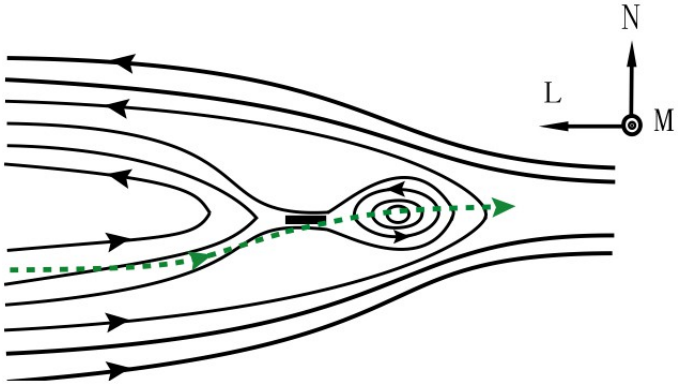

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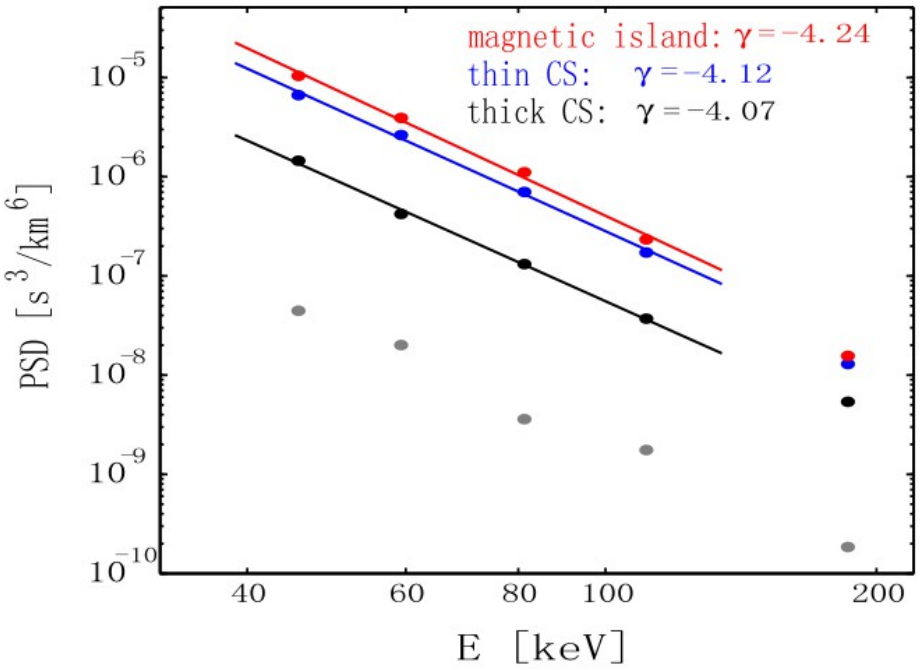
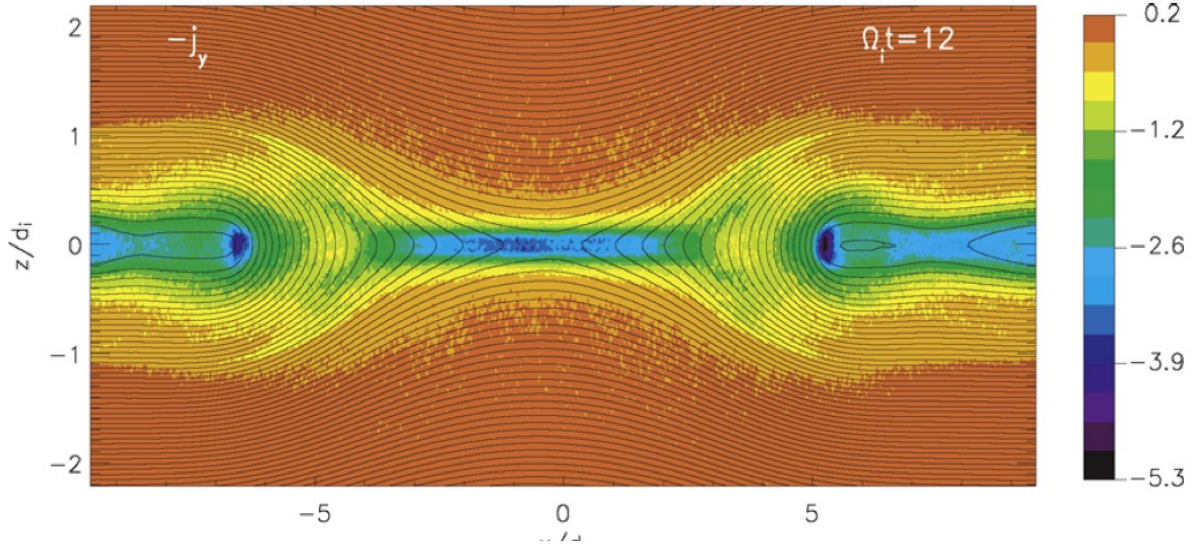
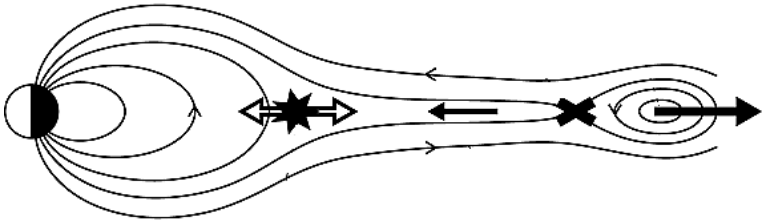
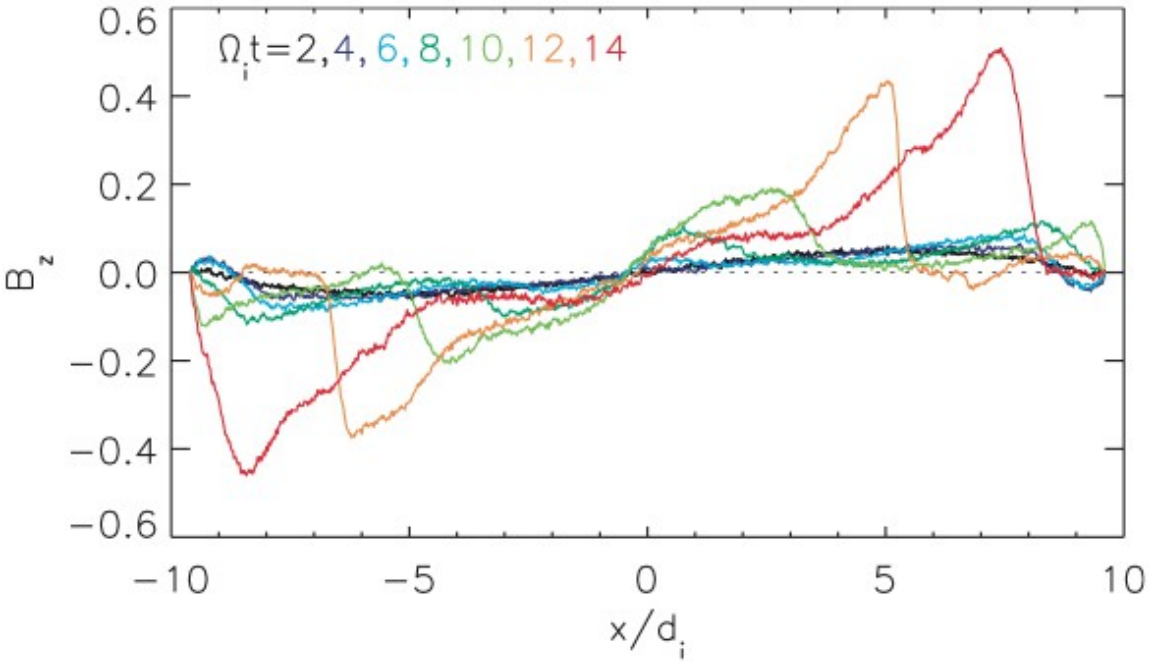


[Huang et. al., 2012, GRL]

Dipolarization fronts – transient reconnection

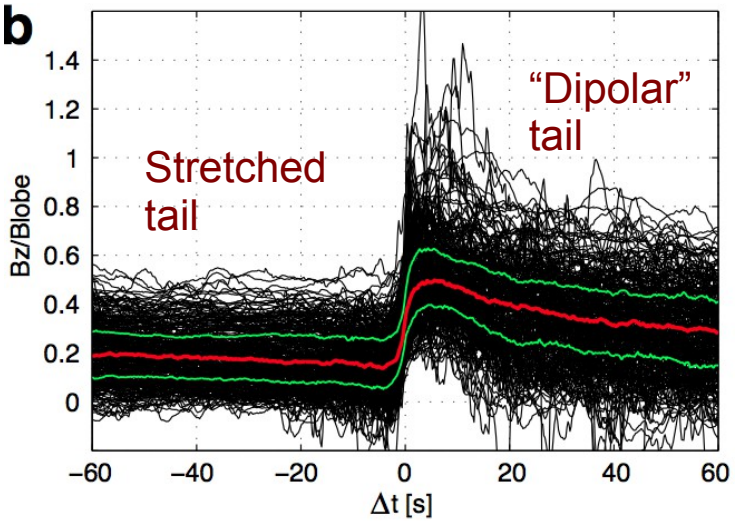






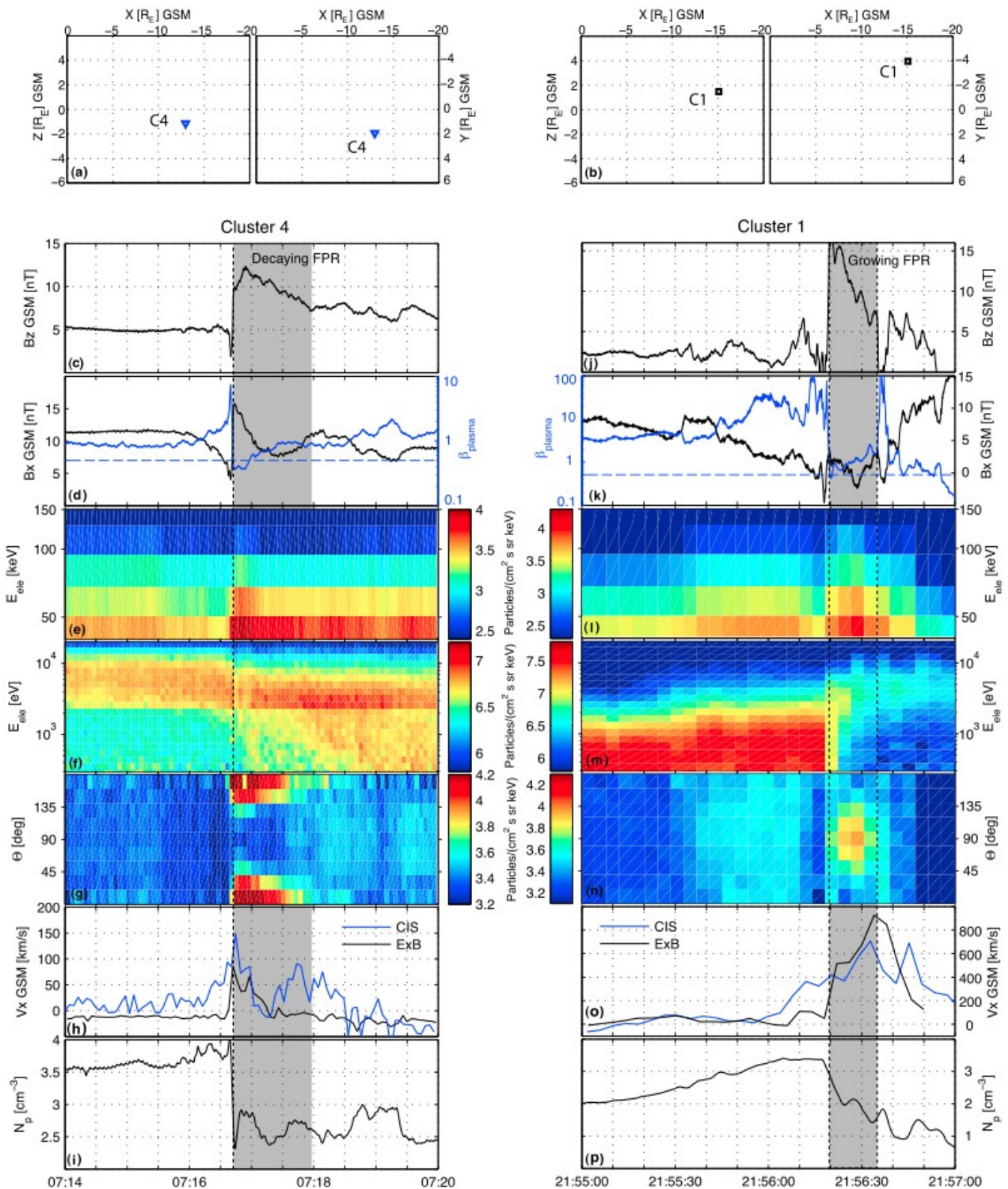
[Sitnov et. al., 2009, JGR]

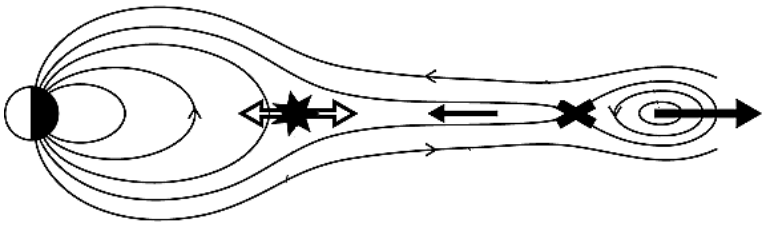
Cluster data for 2001-2009



[Fu et. al., 2012, GRL]

Acceleration at DFs



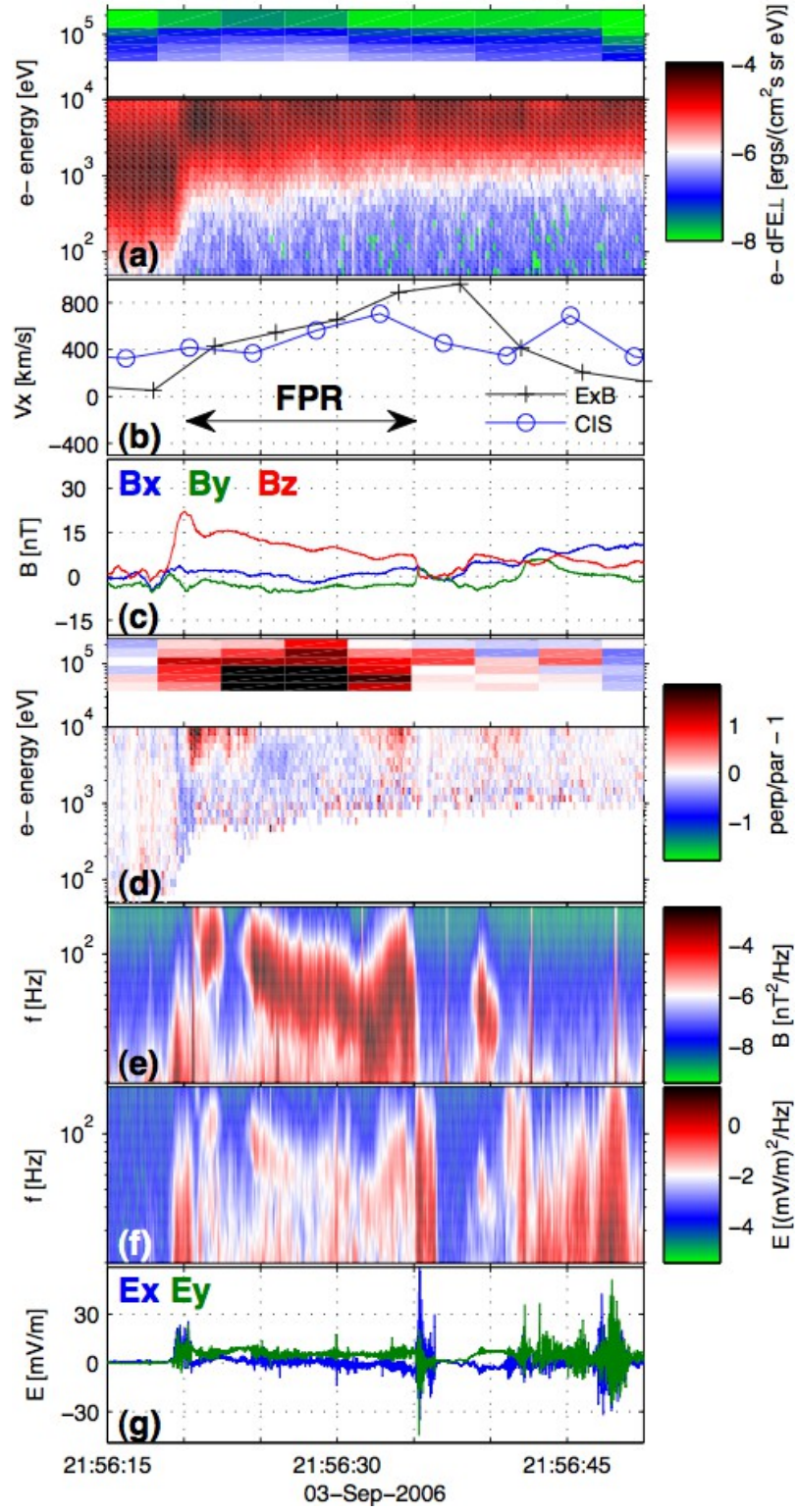


50% of the DF events observed by Cluster are associated with measurable increase of supra-thermal electron fluxes

Different pitch-angle distributions observed depending on the whether the FPR is growing/stable/relaxing.

[Fu et al., 2011, GRL]

[Fu et al., 2012, in preparation]



Flux pile up at DFs

Reconnection jet front (dipolarization front) is propagating slower that the jet itself

Magnetic flux pileup behind the front

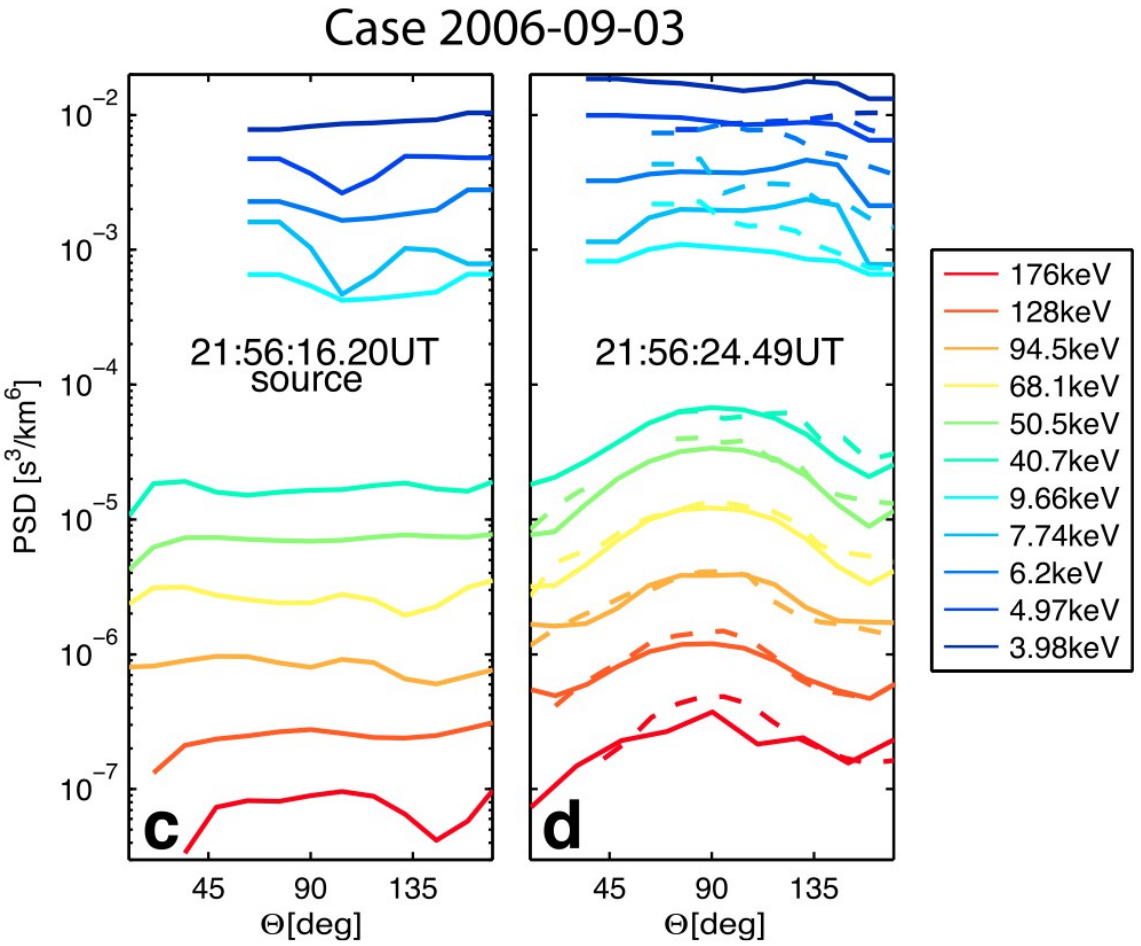
Increased anisotropy of Te

Whistler waves in the Flux pile up region:

- Generated by Te anisotropy (perp>parallel)
- Effectively scatter electrons in pitch-angles
- Serve as a “smoking gun” evidence for betatron effect

[Khotyaintsev et al., 2011, PRL]

Energetic electrons at DFs



[Fu et al., 2011, GRL]

$$\mu = \frac{\frac{1}{2}mv_{\perp}^{2}}{B}$$

Acceleration is adiabatic for energies >> Te.

But not at thermal energies, due to strong scattering by waves!

Summary

- Acceleration of electrons at the X-line
  - In the thin current sheet
  - In the magnetic island
  - adiabatic
- Additional acceleration in the outflow region
  - related to the flux pileup at the outflow jet front
  - Adiabatic (Betatron) for supra-thermal electrons
  - Scattering by waves at thermal energies
- Unsteady reconnection enables additional acceleration mechanism