IRF

Jet Braking in the Earth's Magnetotail: Observations of Wave-Particle Interactions

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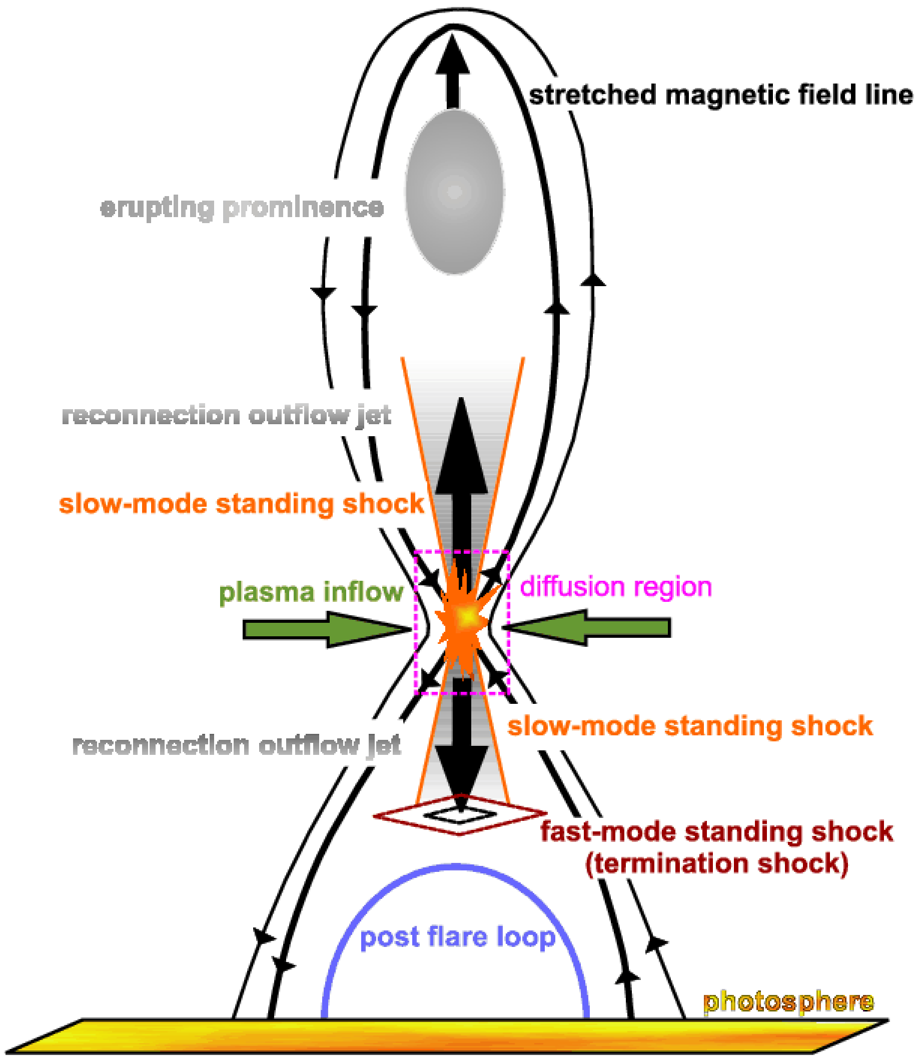
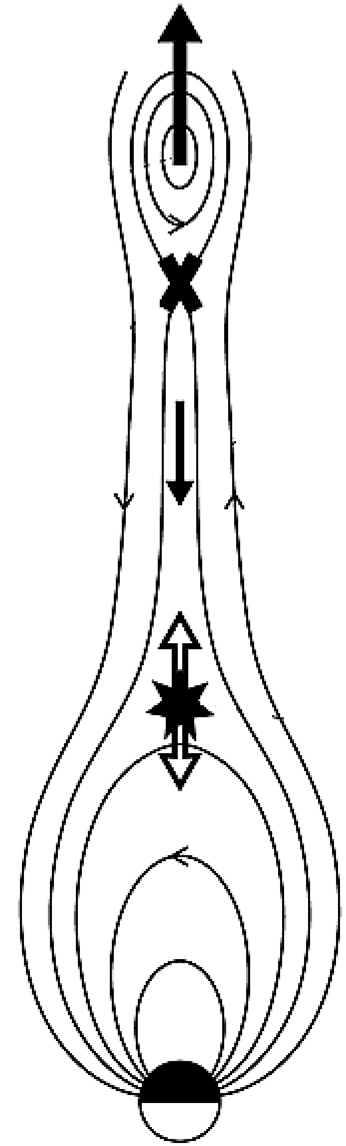
Nordic Cluster Meeting, Uppsala, 2011

Reconnection accelerates plasma jets

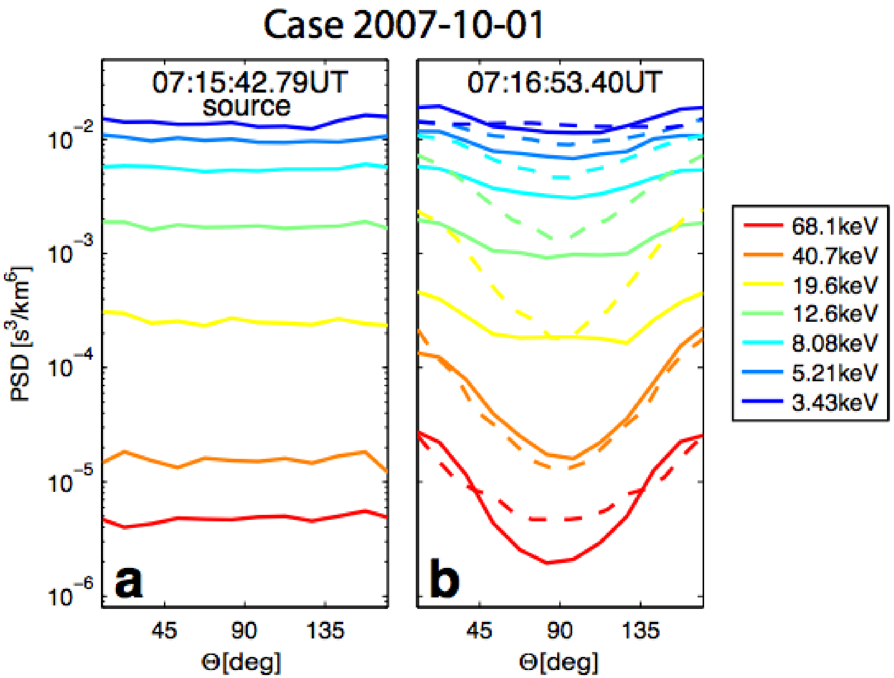


Solar Flare



Magnetospheric Substorm

Fermi

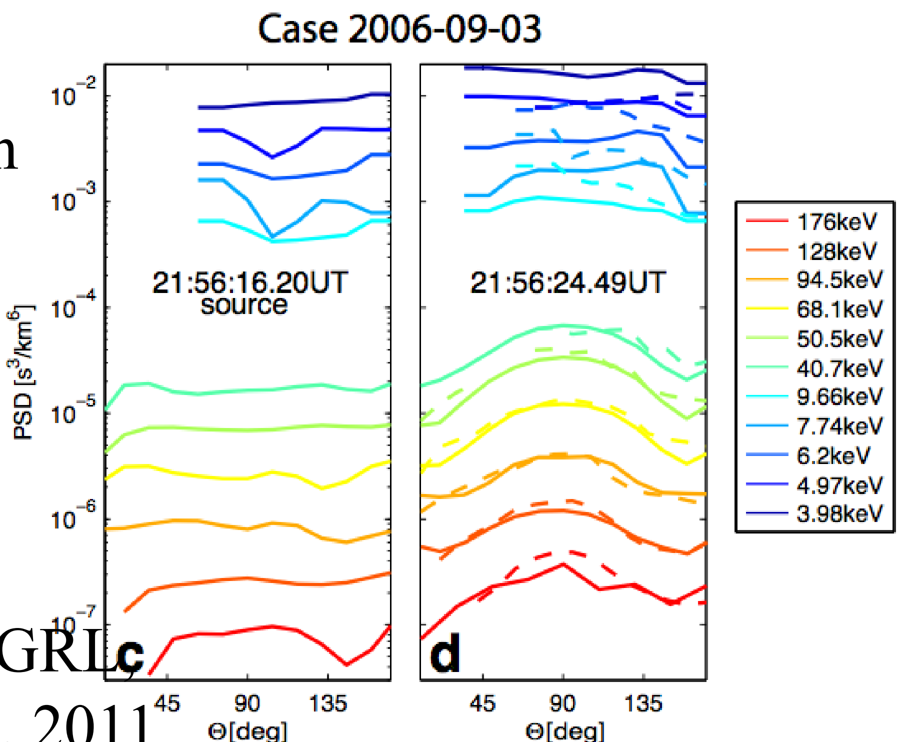


F_F=2

Far from the X-line

No active pileup

Betatron



F_F=1.1, F_B=1.6

Close the X-line

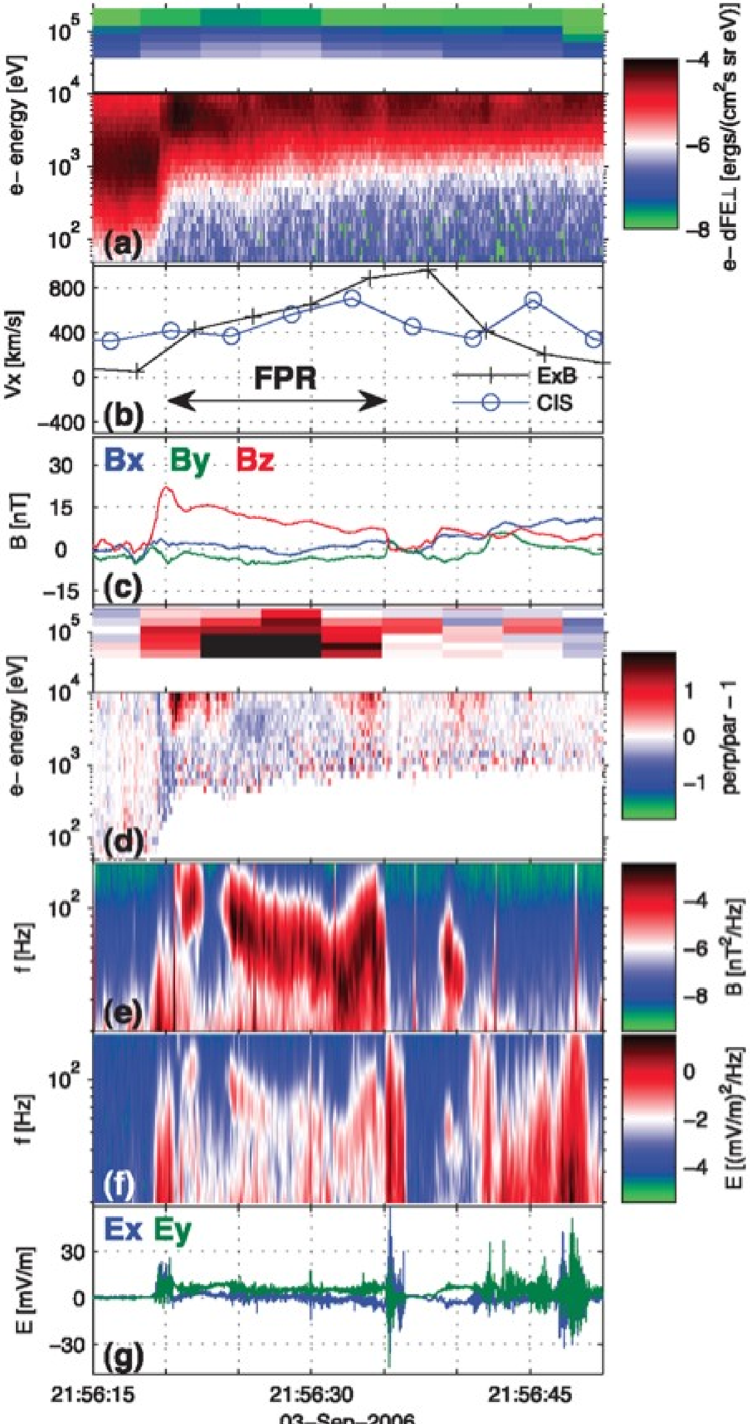
Active pileup!

Acceleration is adiabatic for energies >> Te, But not at low energies!

Fu et. al., GRL, Submitted, 2011

Waves at jet fronts

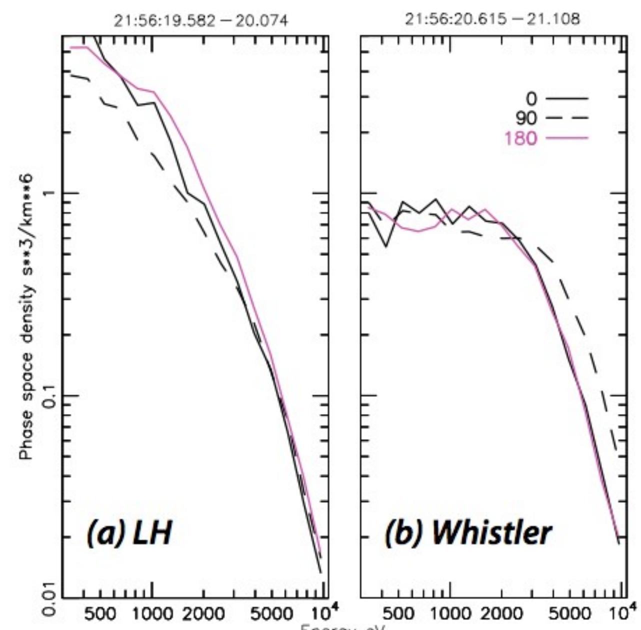
- ✔ Provide evidence for unstable electron distributions
- ✔ Wave-particle interactions make the braking process non-adiabatic
- ✔ Scattering by wave cause loss of energetic particles



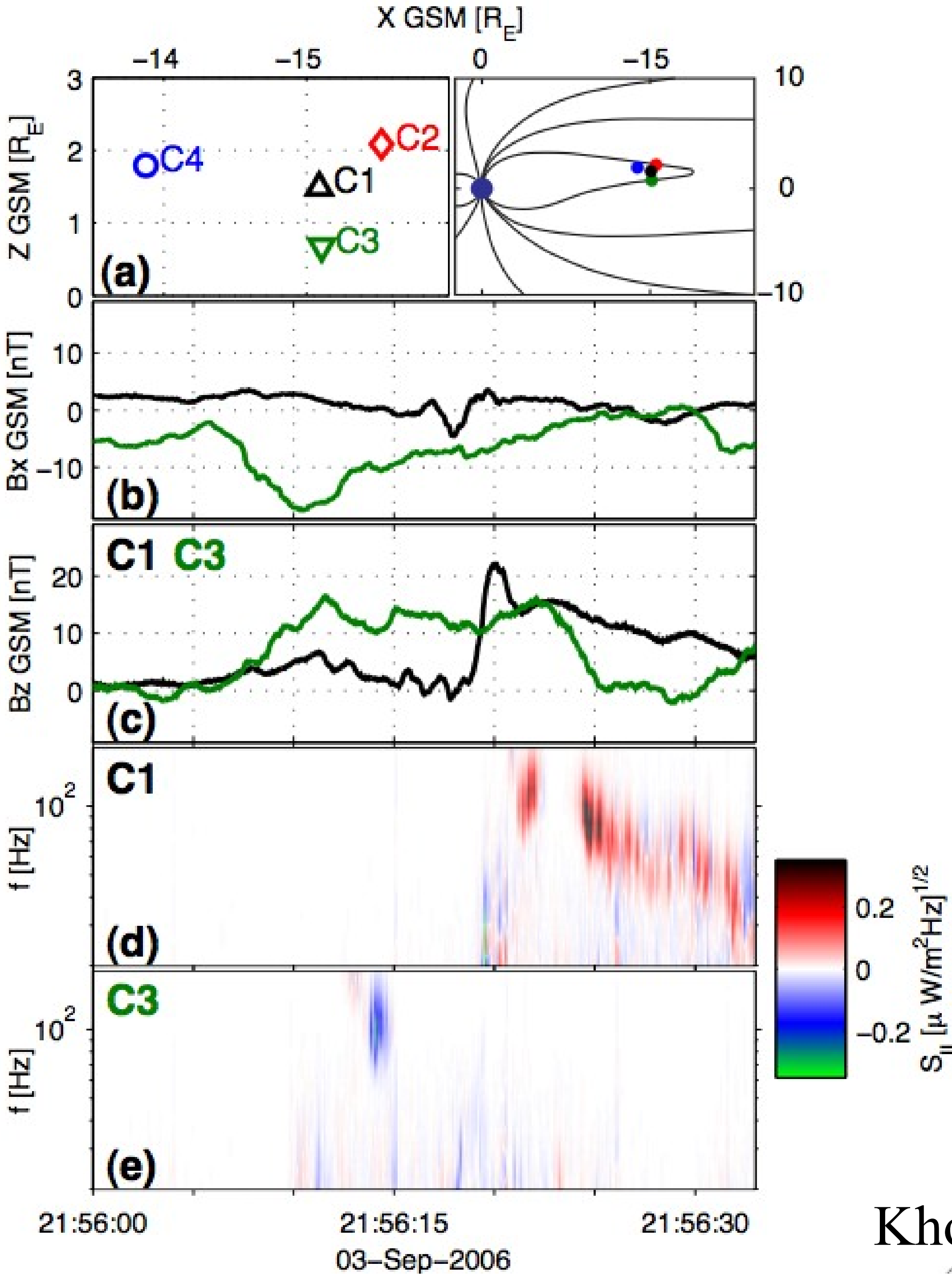
LHD Waves at the front

Whistler waves in the FPR:

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



Khotyaintsev et. al., PRL, 2011

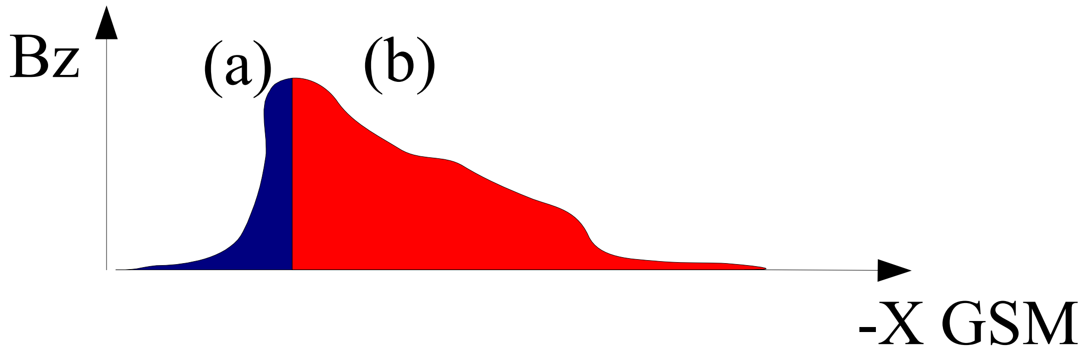


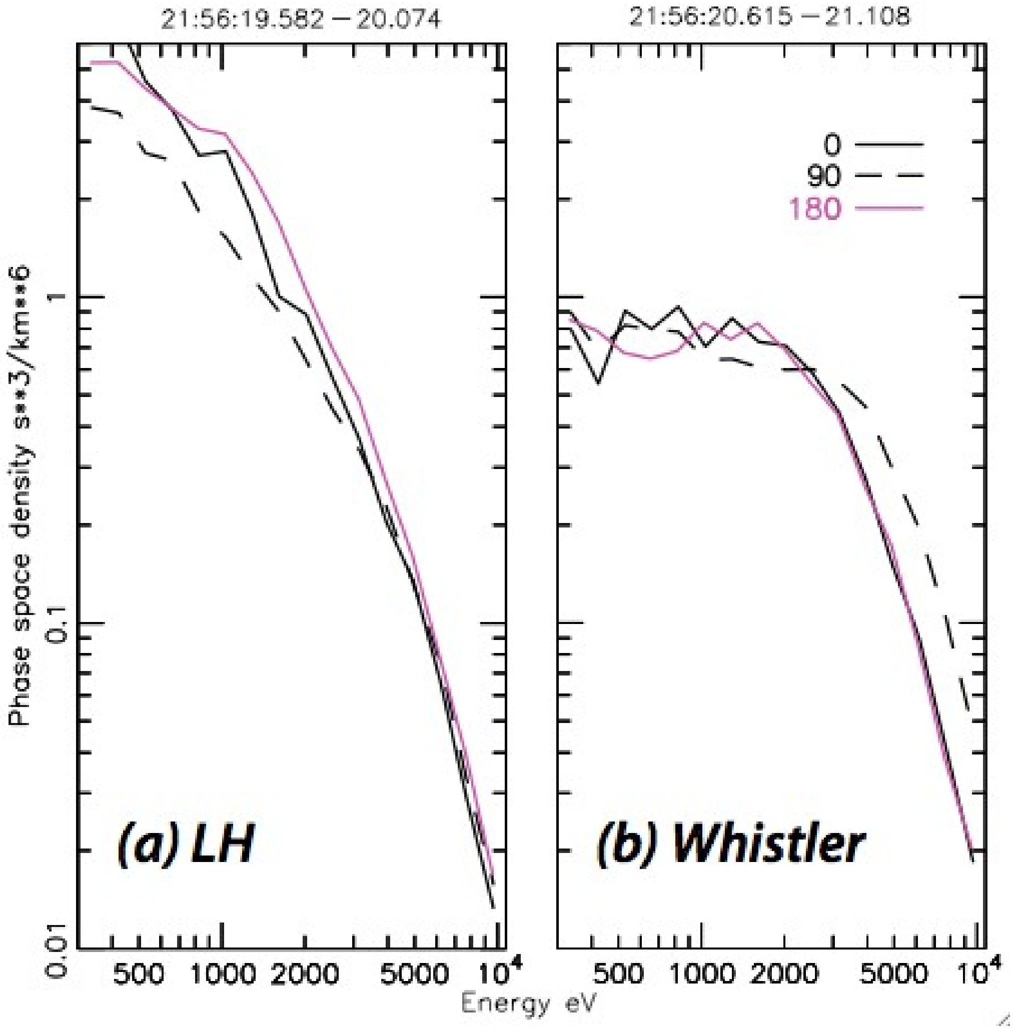
Generation at the neutral sheet:

C1: PF is upward

C3: PF is downward

Khotyaintsev et. al., PRL, 2011





Flat-tops are usually associated with reconnection outflow

Regions (a) and (b) are not connected, i.e. there is no plasma transport between them

Conclusions

- ✔ Inside the flux pileup region (FPR) we observe whistlers and an anisotropic distribution $T_{e\perp}/T_{e\parallel}>1$. The waves are locally generated close to the center of the current sheet and provide evidence for the betatron acceleration due to the magnetic flux pileup.
- ✔ The whistlers cause strong pitch-angle scattering of electrons, thus making the betatron acceleration non-adiabatic. Also can lead to loss of high energy electrons into the loss-cone.
- ✔ The wave-particle interaction limits the electron anisotropy due to the betatron acceleration at lower energies: the resulting distribution has limited anisotropy below 2 keV, and is more anisotropic at higher energies.
- ✔ Evolution of the electron distribution function indicates that the boundary between the front edge ($T_{e\perp}/T_{e\parallel}<1$) and the downstream FPR ($T_{e\perp}/T_{e\parallel}>1$) is tangential; i.e., all the electrons in the FPR come from the downstream region, and never encounter the dipolarization front.