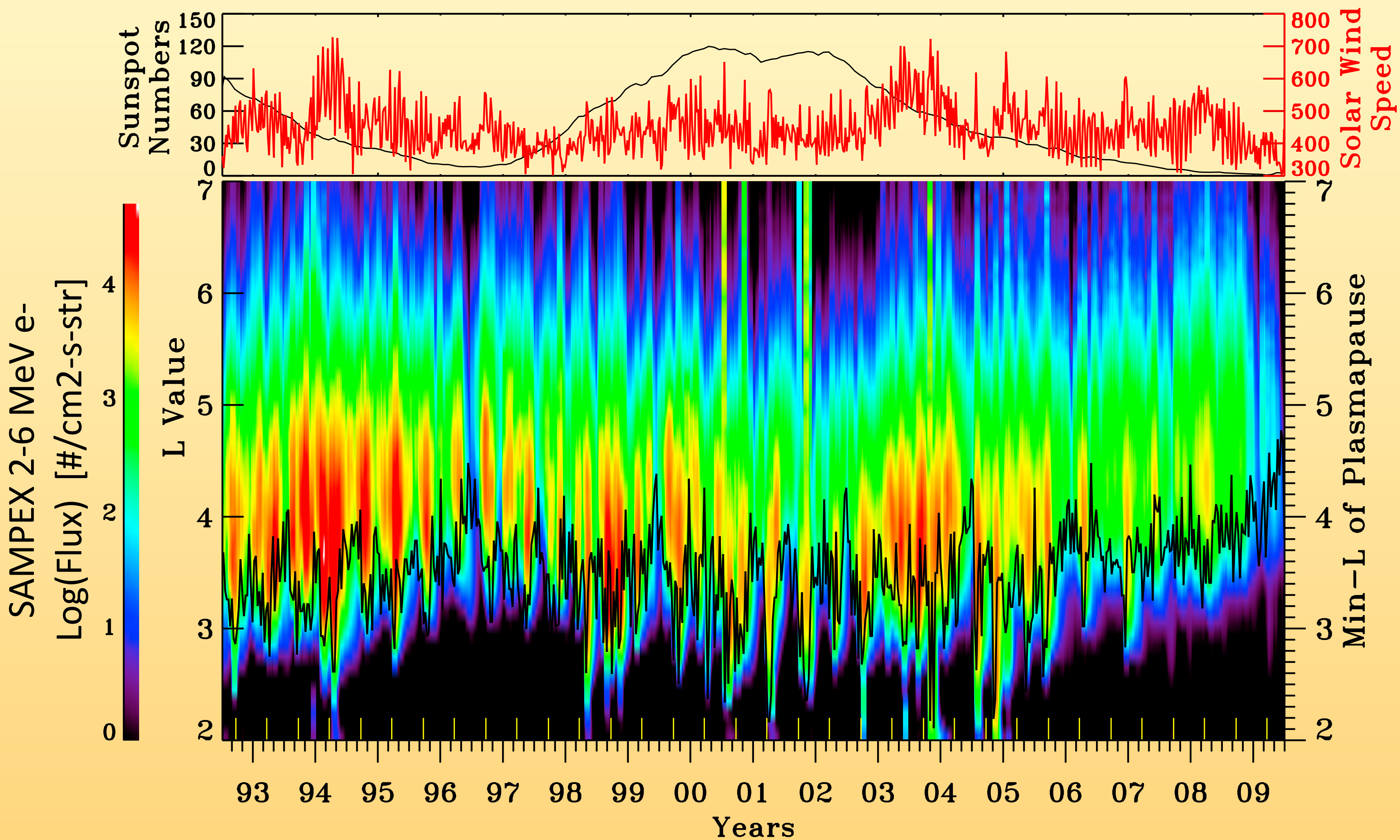
Rapid enhanced precipitation of radiation belt electrons: microbursts and precipitation bands

Lauren Blum and Xinlin Li

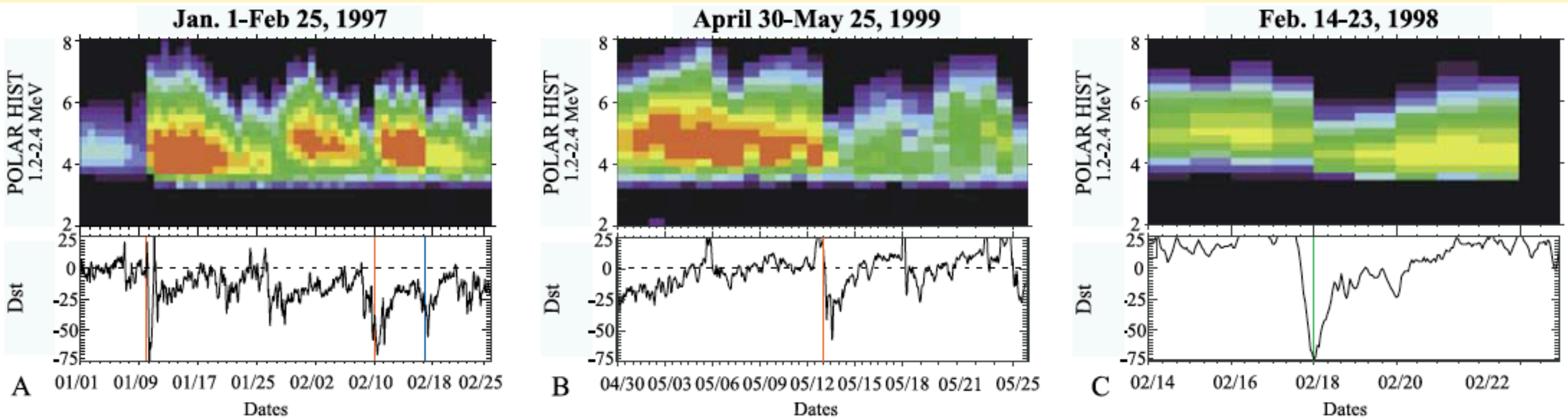
FOM Nov 6 2012

Outer Radiation Belt Dynamics



Li et al., 2011

Outer Radiation Belt Dynamics

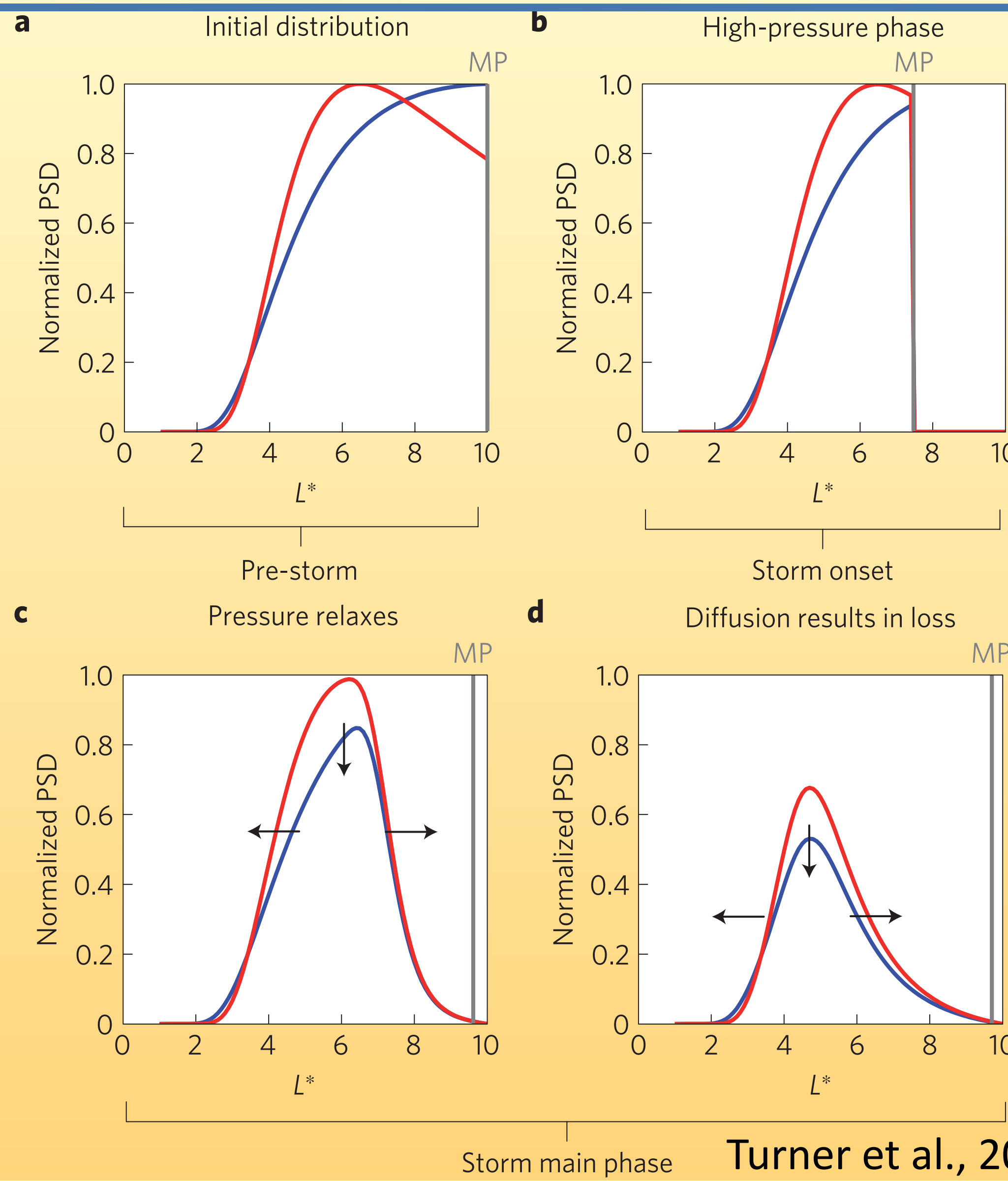


Reeves et al., 2003

- Variable responses depending on the storm -> depletions, enhancements, or no change post storm
- Balance of SOURCE and LOSS processes produce net radiation belt response
  - Need to understand LOSS mechanisms to understand acceleration and net radiation belt dynamics

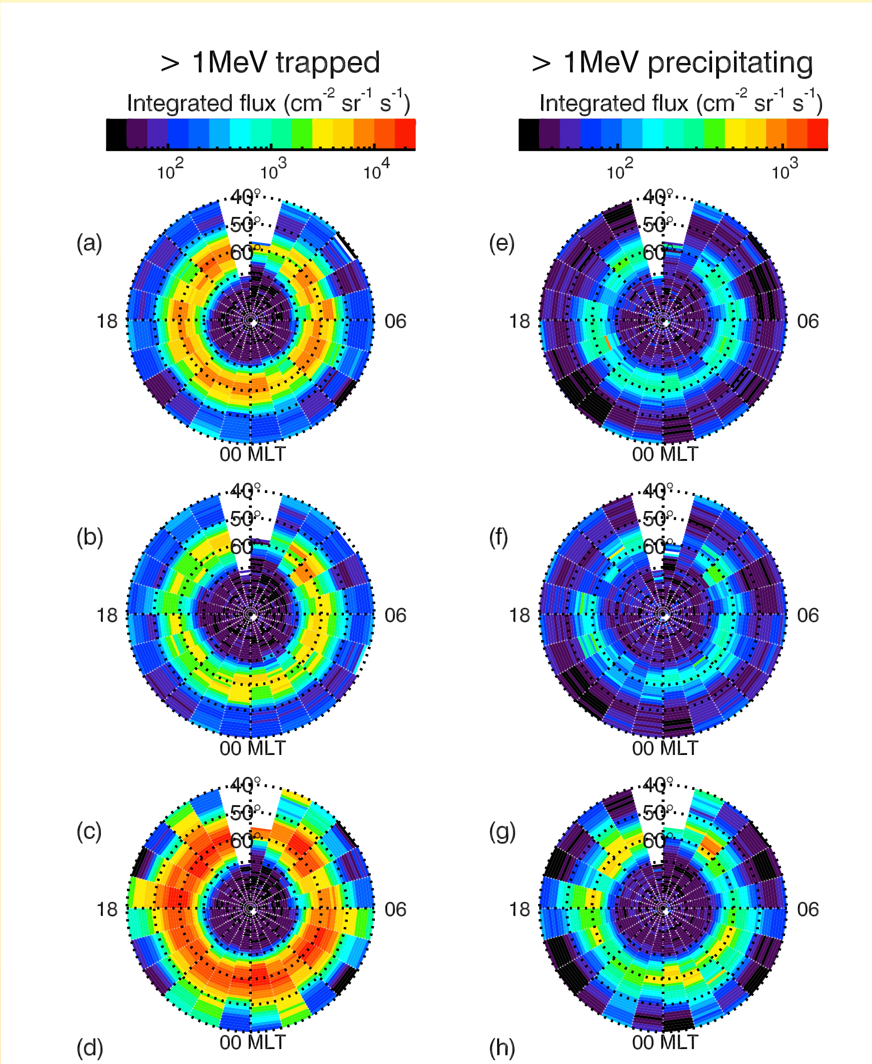
Radiation Belt Losses:

- Magnetopause shadowing
- Outward radial diffusion
- Precipitation

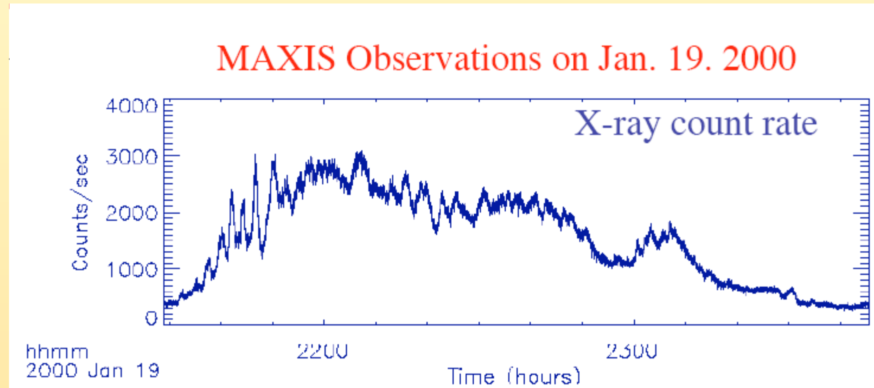


Turner et al., 2012

Precipitation

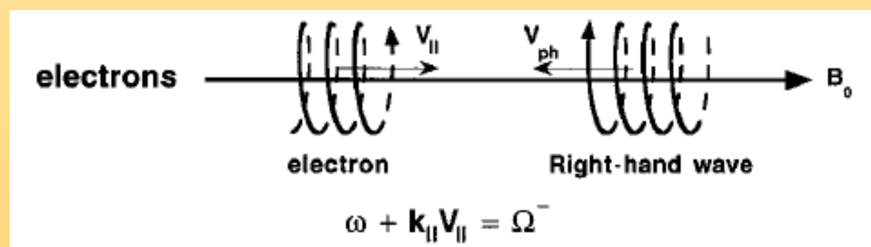


Horne et al., 2009



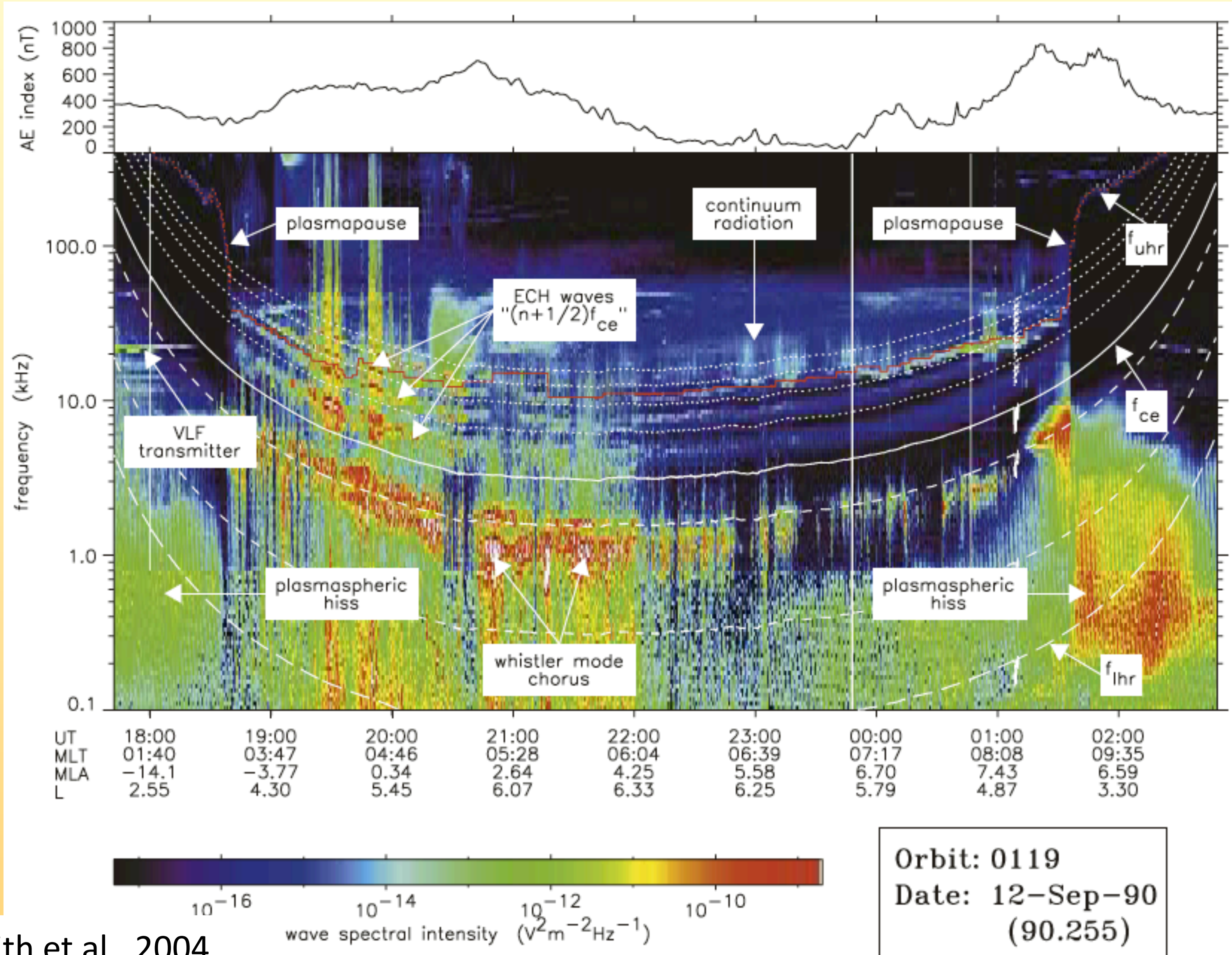
Millan et al., GRL, 2002

Wave-particle interactions, pitch angle scattering:



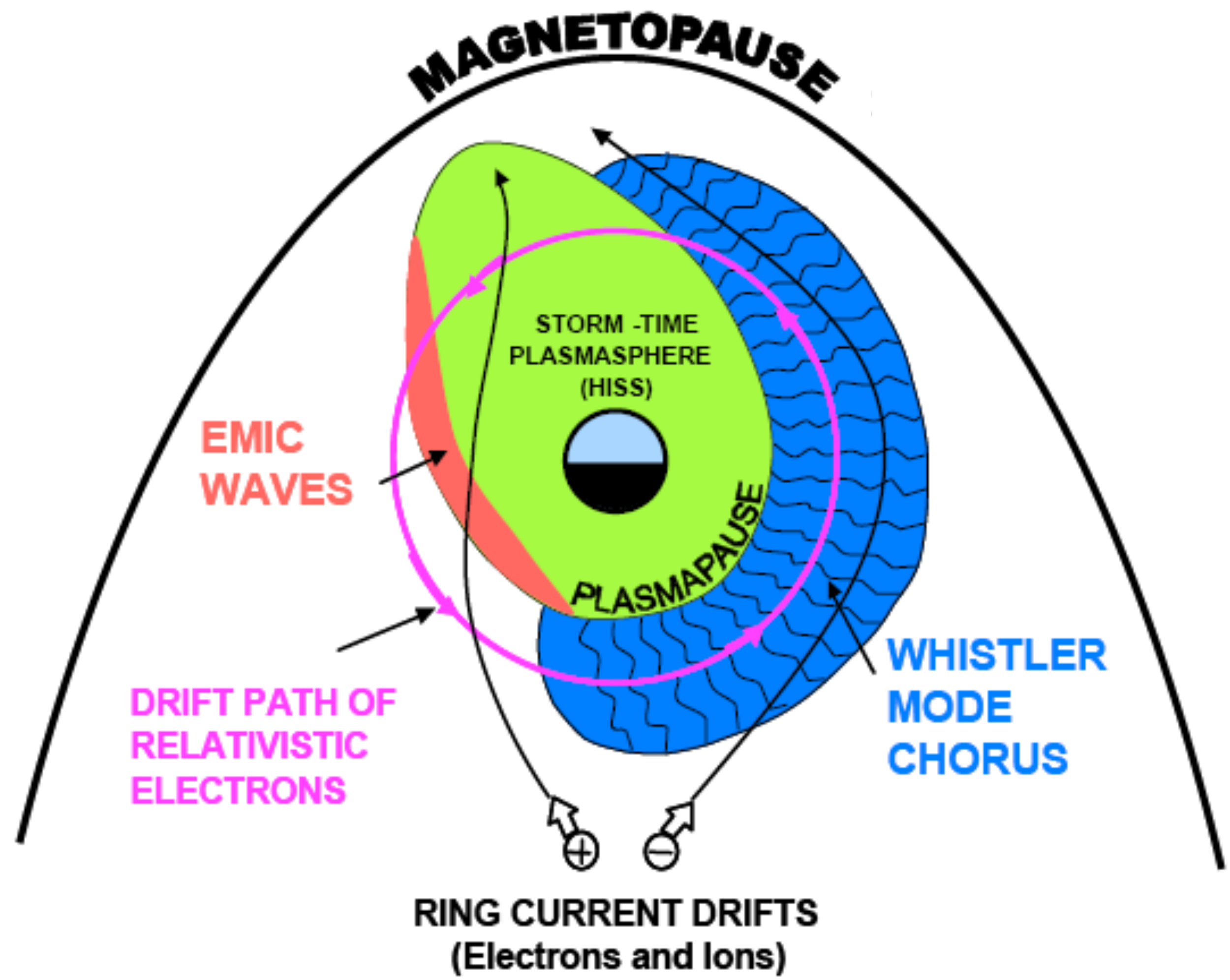
Tsurutani & Lakhina [1997]

Waves…



Meredith et al., 2004

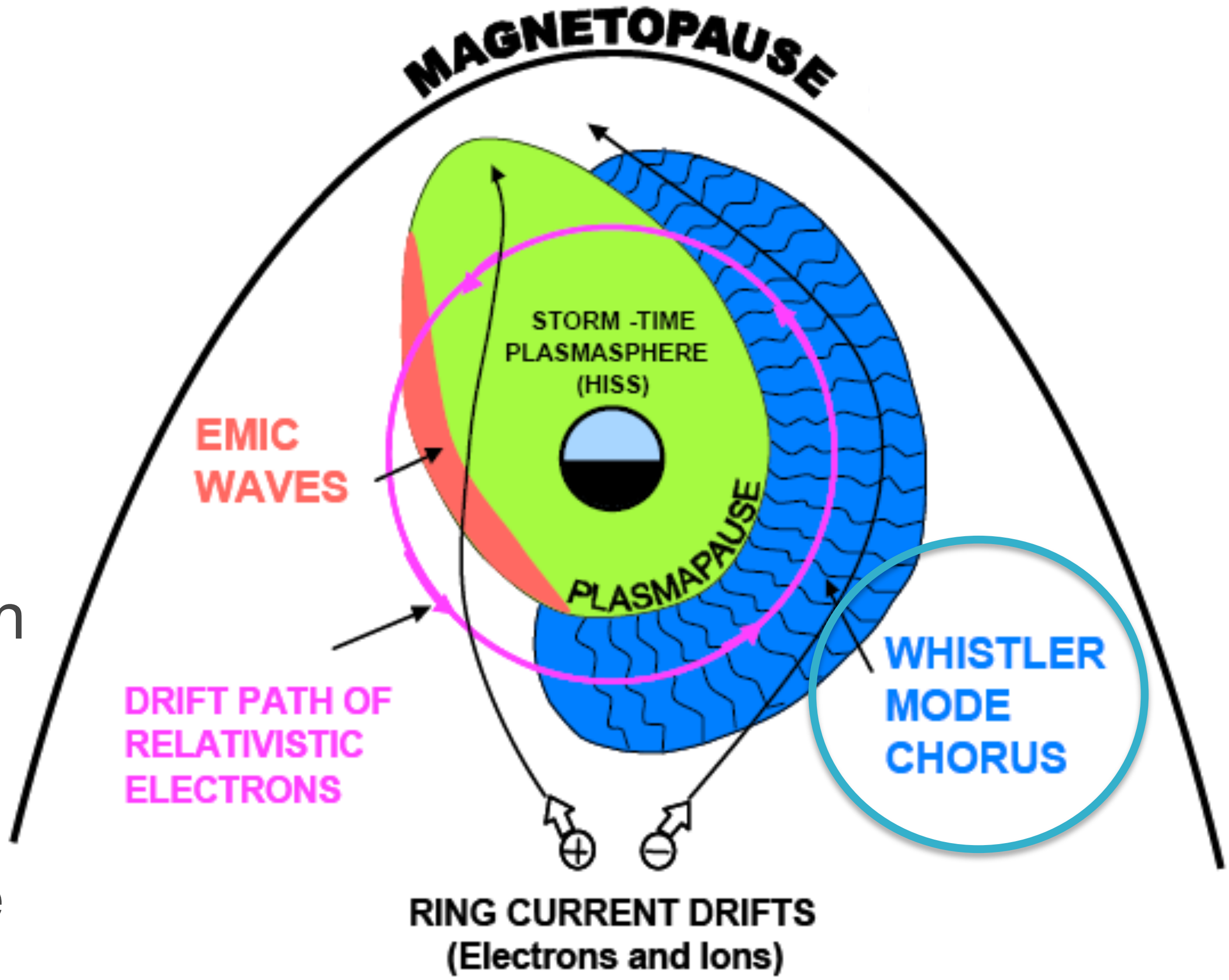
Wave-Particle Interactions



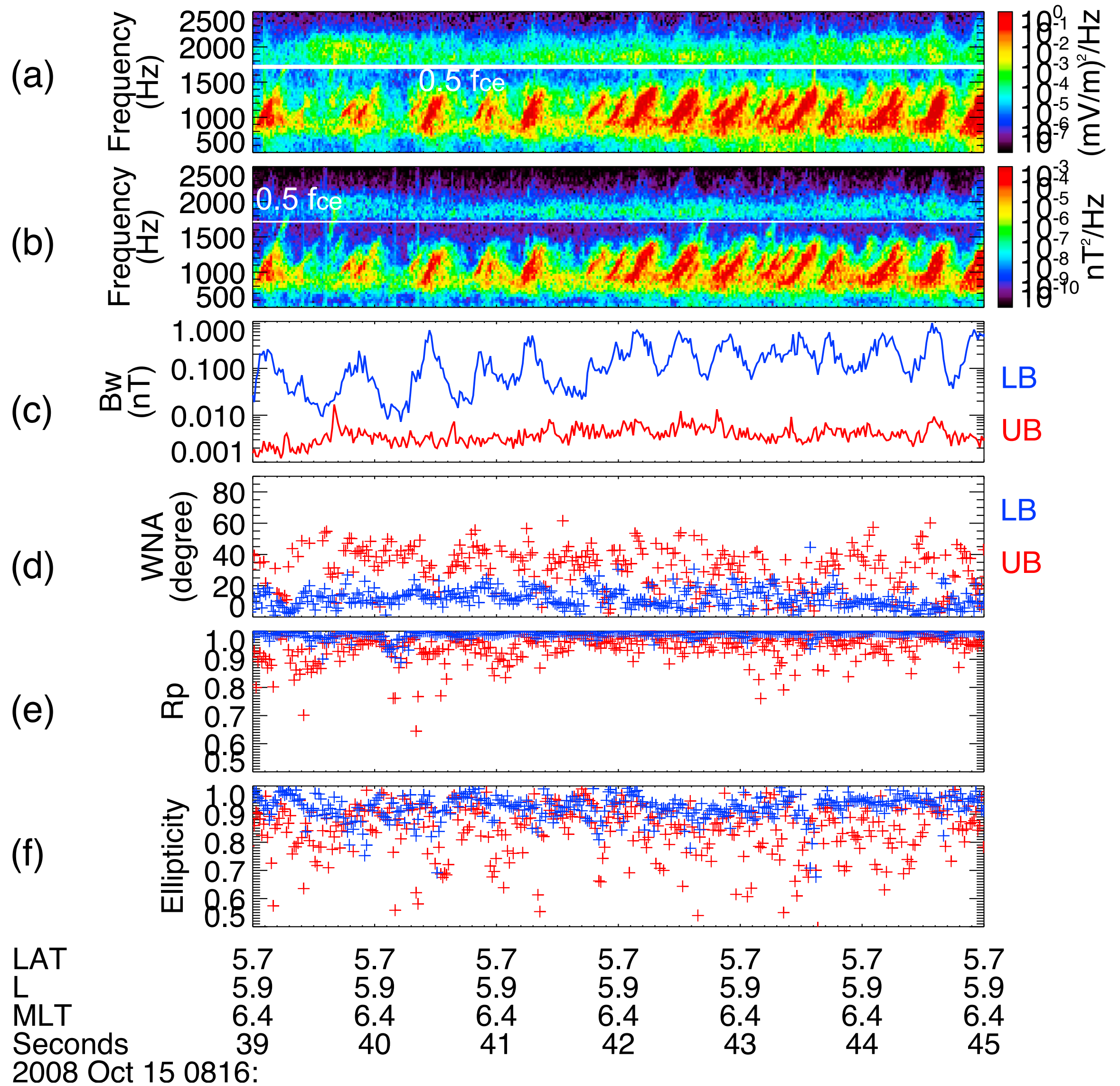
Summers et al., 1998

Chorus

- Generated by anisotropic keV electrons on the morning side
- Develop in the low density region outside the plasmapause
- Can cause electron loss and acceleration
- 0.1fce < f < 0.8fce



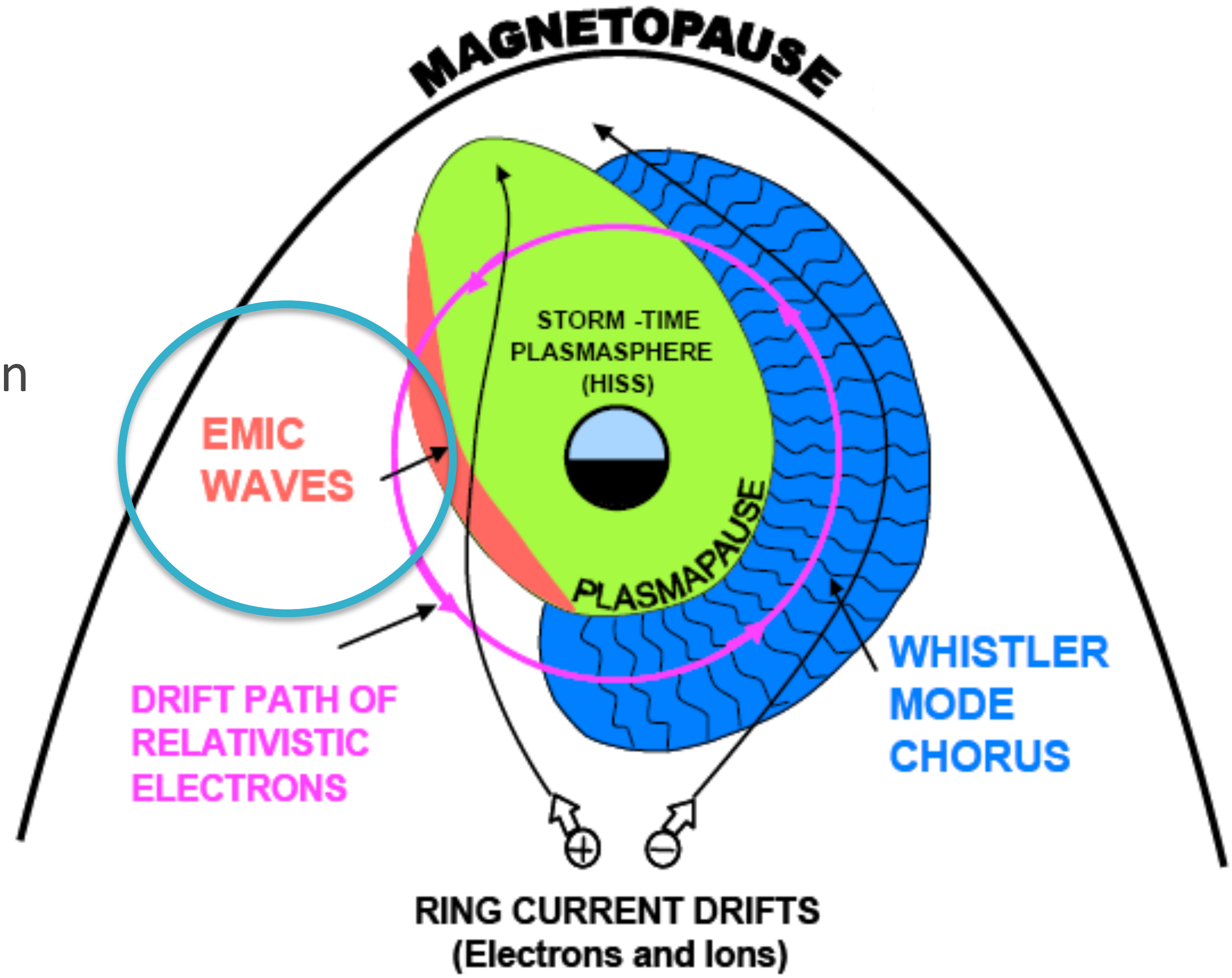
Chorus



Li et al., 2011

EMIC

- Generated by keV ring current ions injected during storms and substorms
- Low frequency waves (0.1-5 Hz) excited in bands below the proton gyrofrequency
- Able to resonate with and pitch angle scatter MeV electrons



EMIC

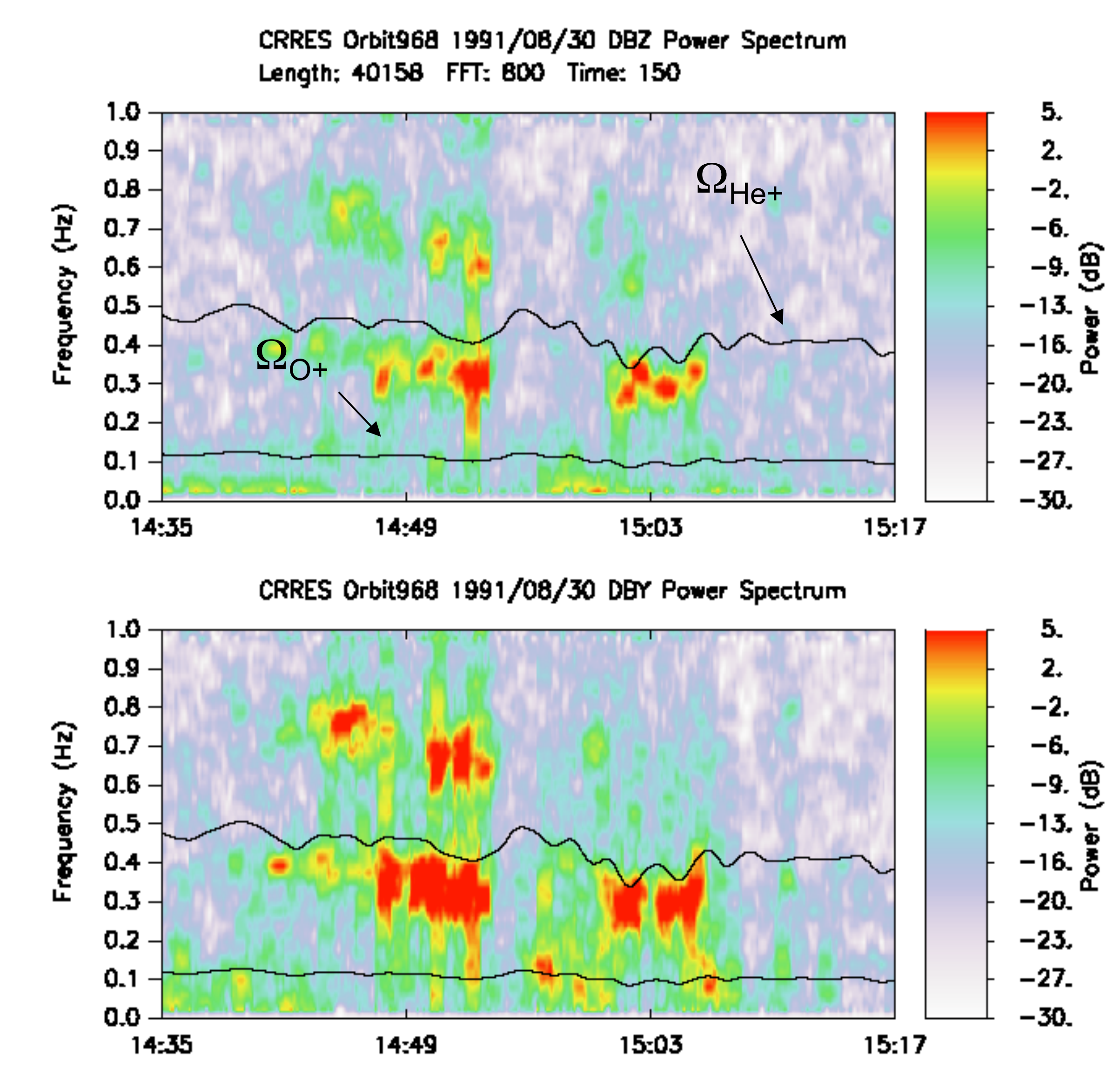


Figure courtesy of Brian Fraser

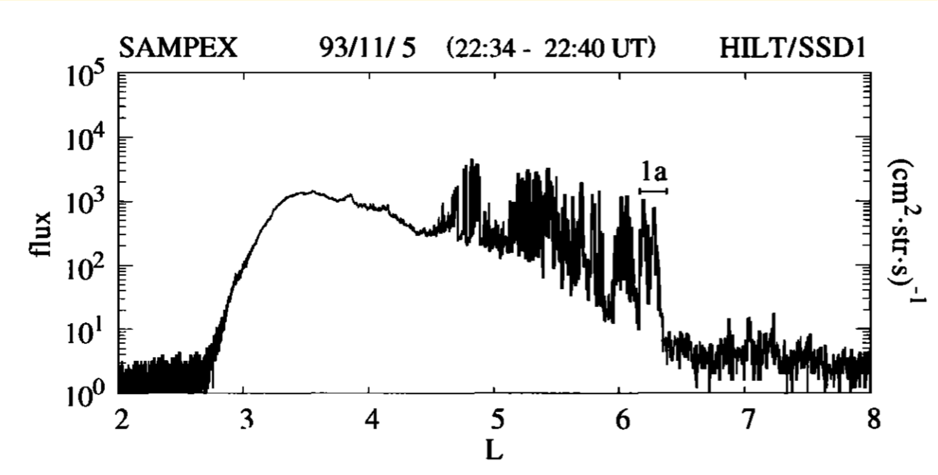
Microbursts and Precipitation Bands

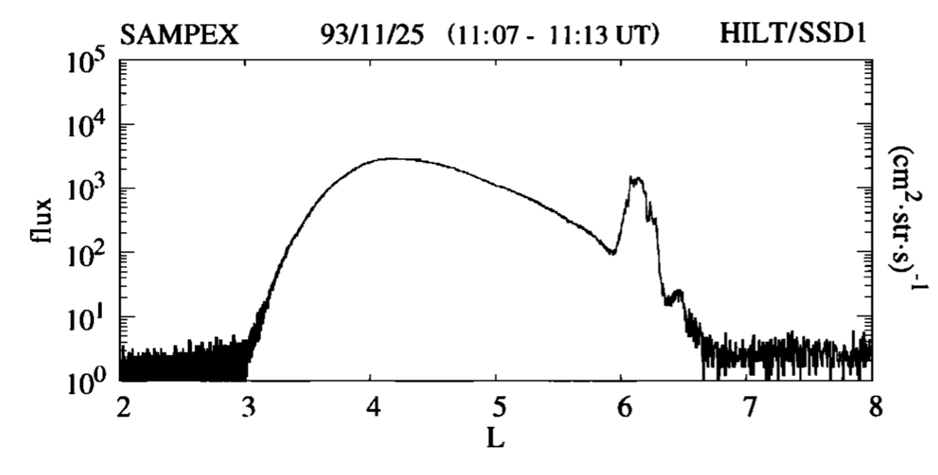
- Microbursts:

  < 1 second bursts of electron precipitation

- Precipitation Bands:

  longer duration (~few sec-minutes) MeV electron enhancements





Nakamura et al., 2000

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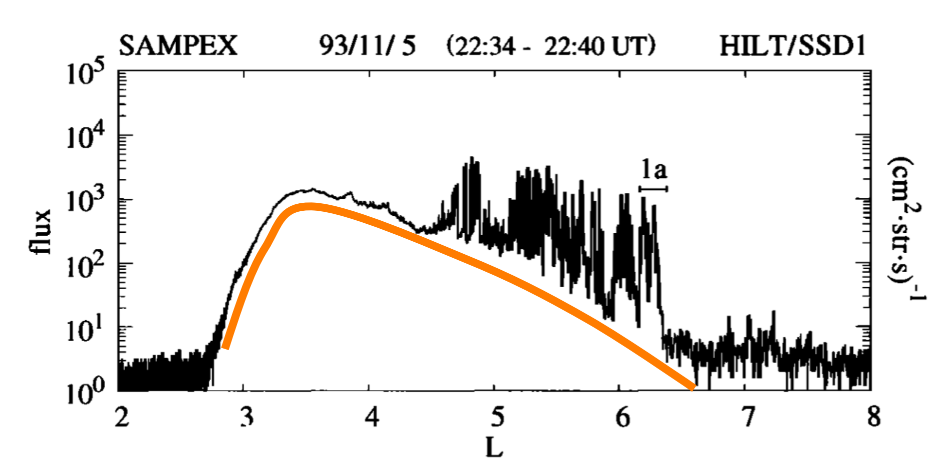
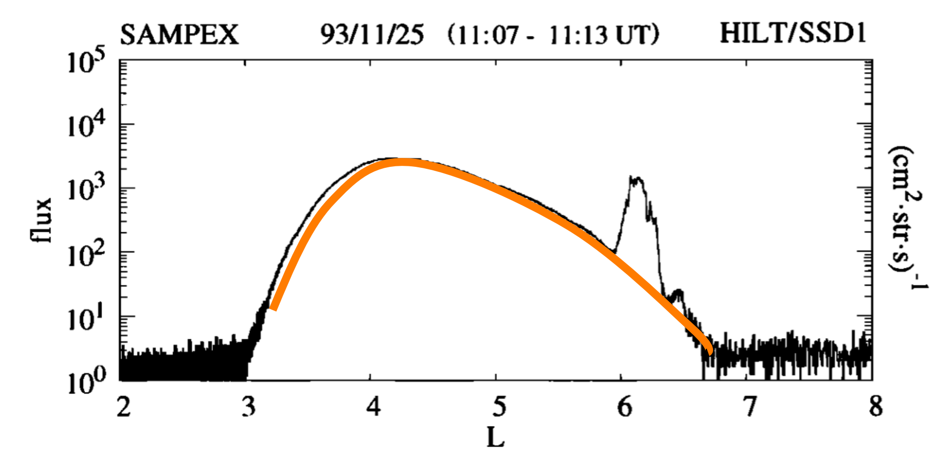




Nakamura et al., 2000

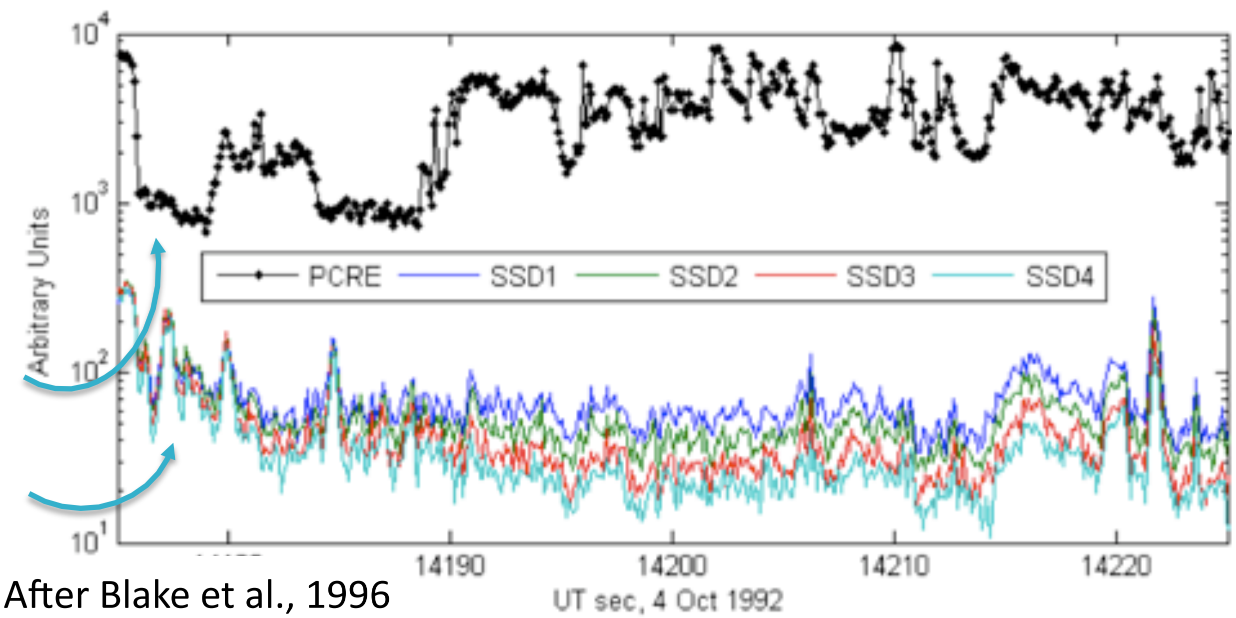
What are microbursts?

- < 1 second bursts of electron precipitation
- “soft” vs. relativistic microbursts:
  - Few 100s of keV e- precipitation bursts first detected by balloons in the 1960s and ‘70s (Anderson and Milton 1964; Parks, 1978)
  - Later MeV microbursts discovered by S81-1 spacecraft (Imhof et al., 1992)

-> a loose correspondence between the two types, but no 1-to-1 correlation

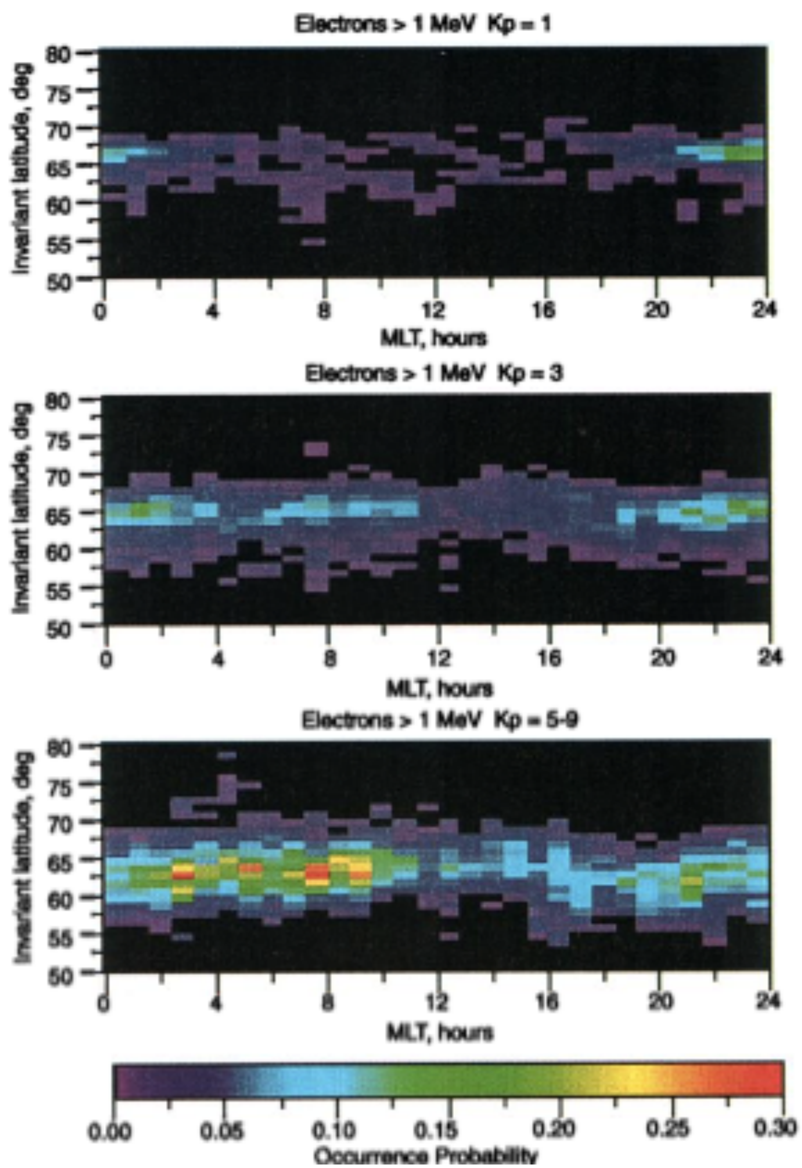
>150 keV

> 1 MeV



After Blake et al., 1996

Where are microbursts?



MeV microburst occurrences peak around midnight during quiet times

↓

Peak becomes enhanced and moves dawnward during active times

Lorentzen et al., 2001

Potential Causes of Microbursts

- keV microbursts:

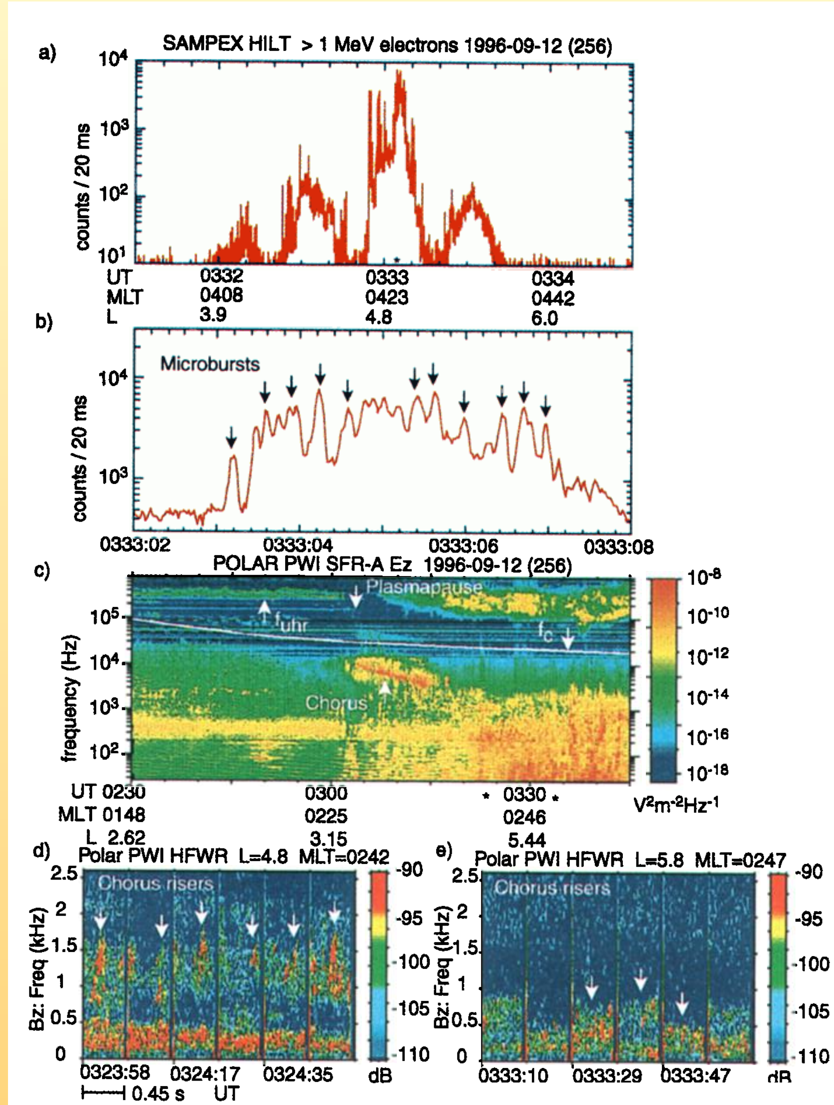
long associated with pitch-angle scattering by VLF chorus

- MeV microbursts:

pitch-angle scattering by chorus at

- higher latitudes
- higher harmonics (Lorentzen et al., 2001)

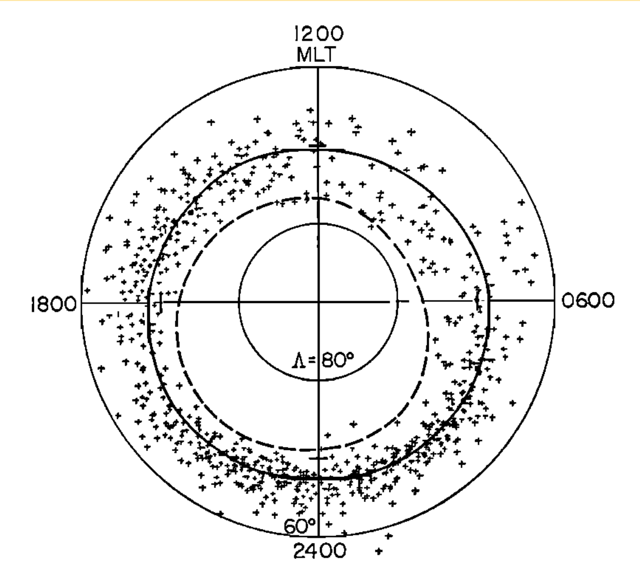
$$w + k\cos\theta \cdot v\cos\alpha = s\Omega_e/\gamma$$



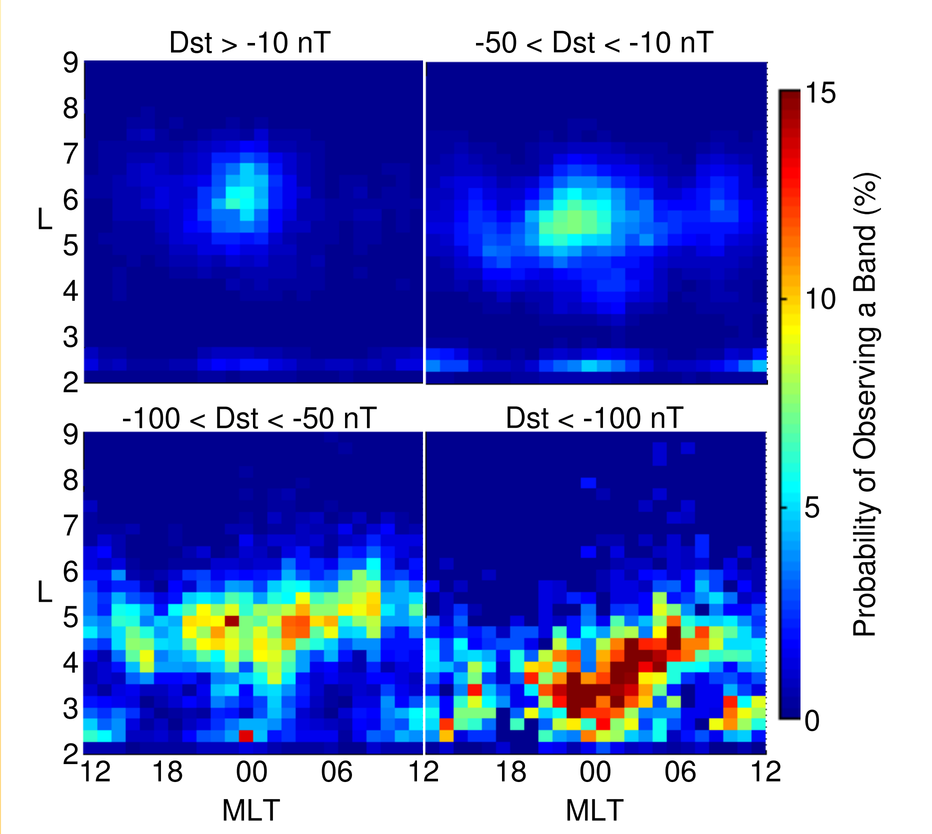
Lorentzen et al., 2001

What/Where are precipitation bands?

- ~10s of seconds, can persist for multiple orbits
- Predominantly across the night-side
- Occurrence increases with increasing geomagnetic activity



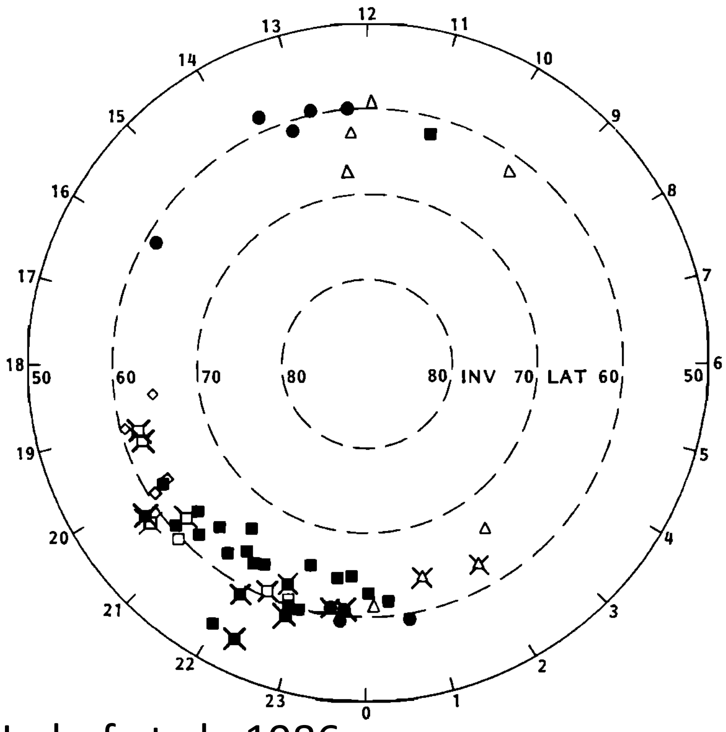
Brown and Stone, 1972



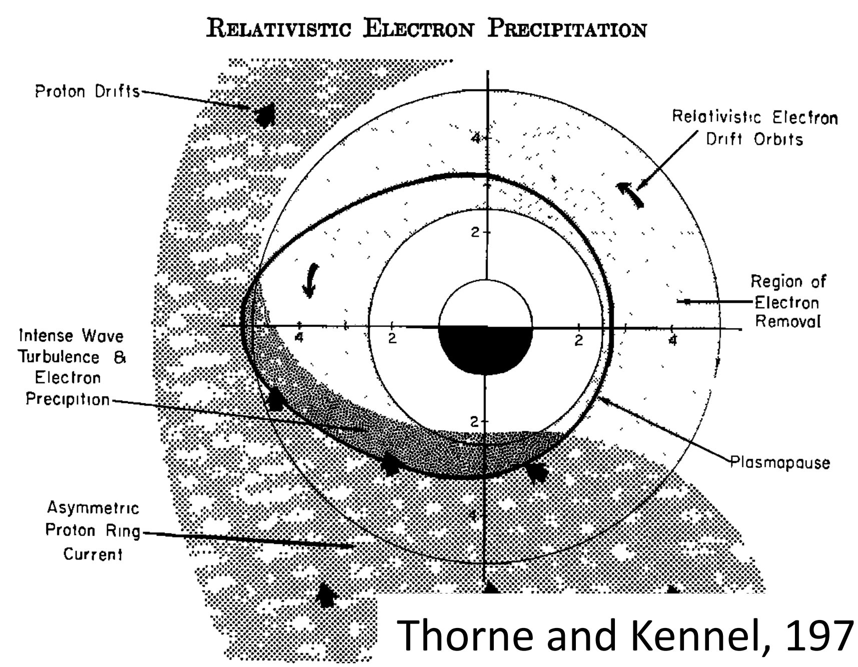
O'Brien et al., draft 2006

Potential Causes of Bands

- Potential source mechanisms include EMIC and electrostatic waves
  - Based on local time and L distribution, resonant energies



Imhof et al., 1986



Thorne and Kennel, 1971

Motivation

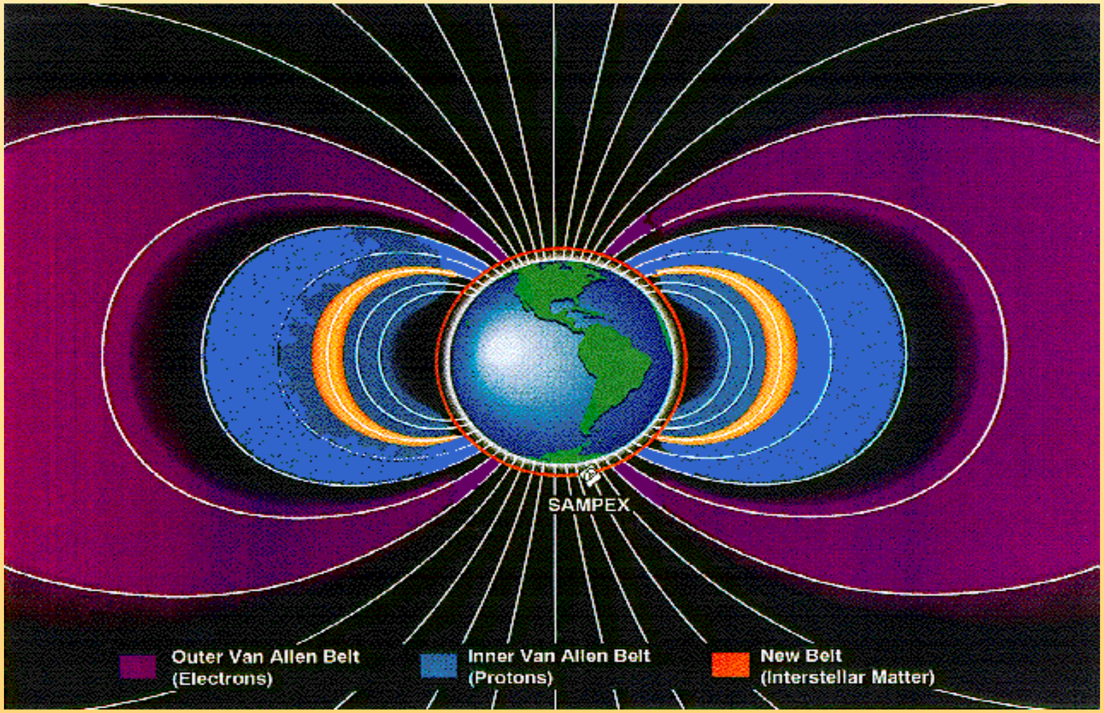
- Goal: to investigate these rapid enhancements of MeV electrons measured by SAMPEX/HILT
  - Characterize the distributions of precipitation bands and microbursts across storm phase and type
  - Quantify the relative contribution of each to radiation belt losses
  - Investigate the relation between EMIC waves and precipitation bands

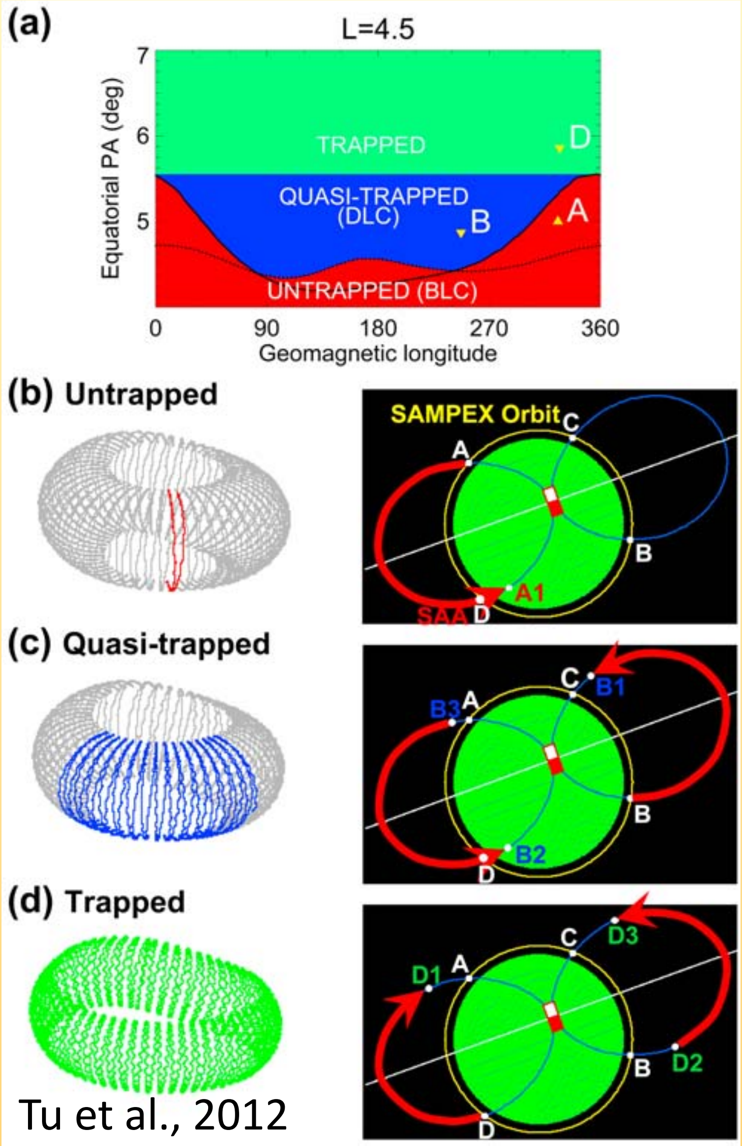
SAMPEX

- Orbit:

520 x 670 km, 82° inclination

- Operation: 1992 - current

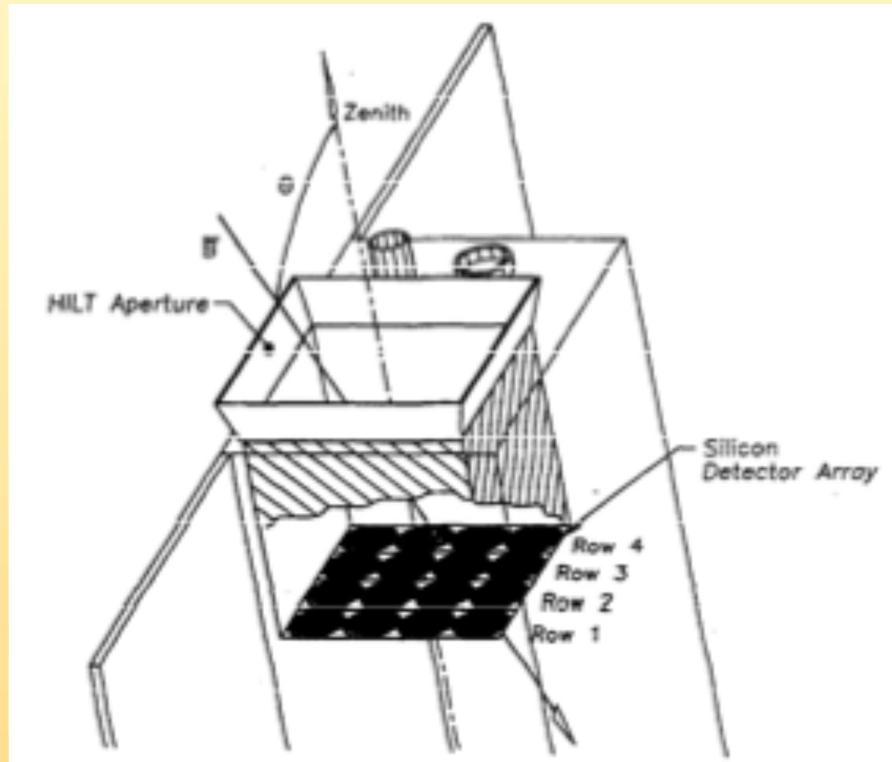




Tu et al., 2012

SAMPEX HILT Instrument

- Array of 16 solid state SiLi detectors grouped into 4 rows of 4 detectors: SSD1, SSD2, SSD3, SSD4
- 20 – 100 ms time resolution
- Sensitive to electrons > 1MeV
- Pulse height analysis also possible, to get rough energy spectrum
- Ratio of counts in each row provides qualitative pitch angle information



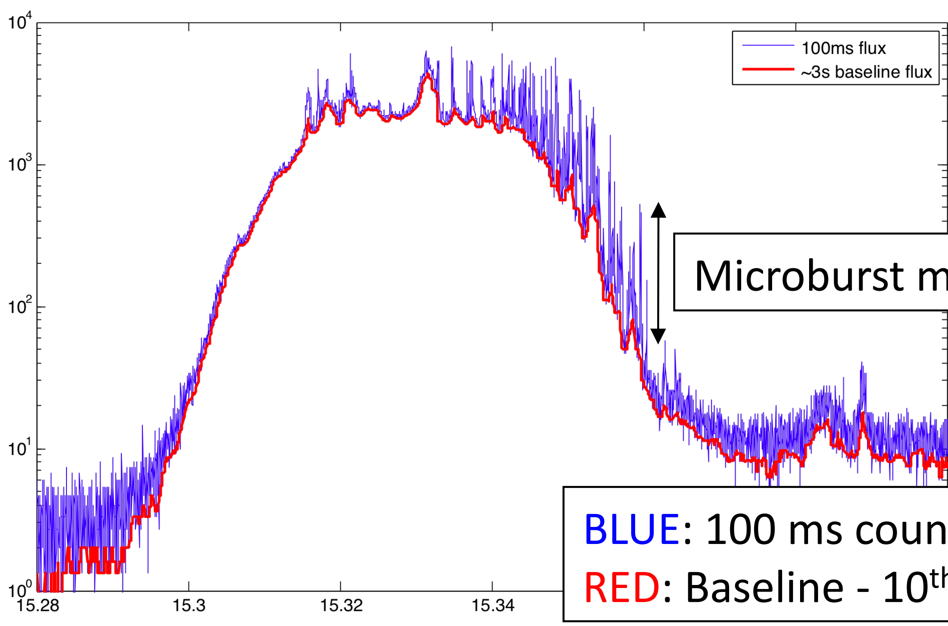
Blake et al., 1996

Automated Microburst Detection

O'Brien et al. (2003) microburst criteria:

$$\frac{N - N_{ave}}{\sqrt{1 + N_{ave}}} > 10$$

For N_{ave} = 500 ms running average, N = 100 ms count rate



Microburst magnitude = BLUE – RED

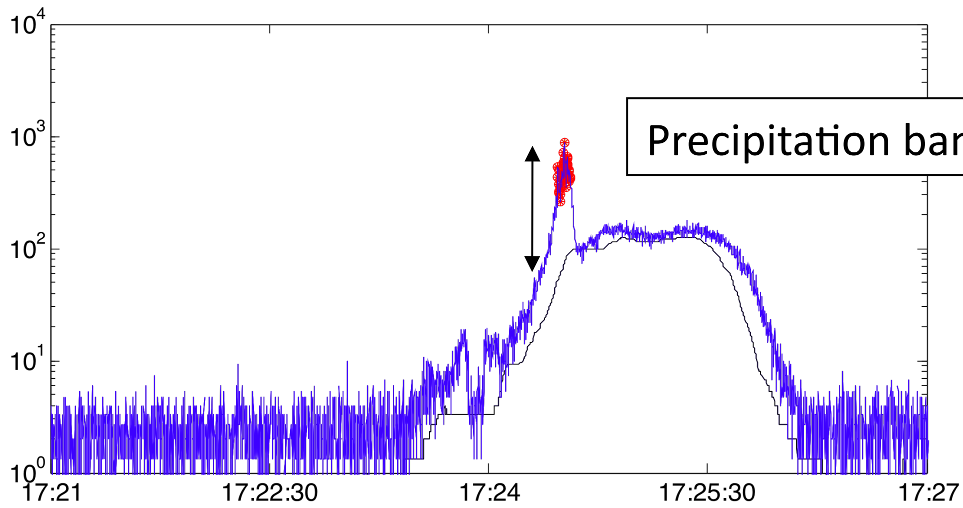
BLUE: 100 ms count rate

RED: Baseline - 10th percentile of 3 sec bins

Automated Band Detection

Precipitation band criteria:

- N_{100} > 4x baseline for ≥5 sec
- 10 second linear correlation coefficient between N_{100} and baseline < .955

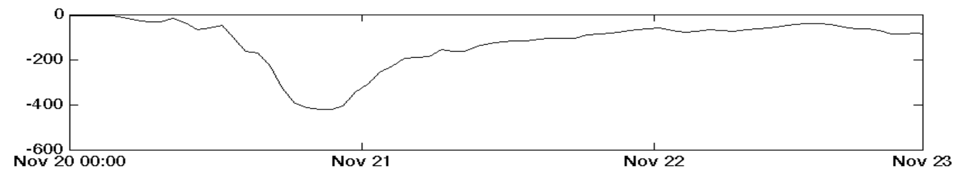


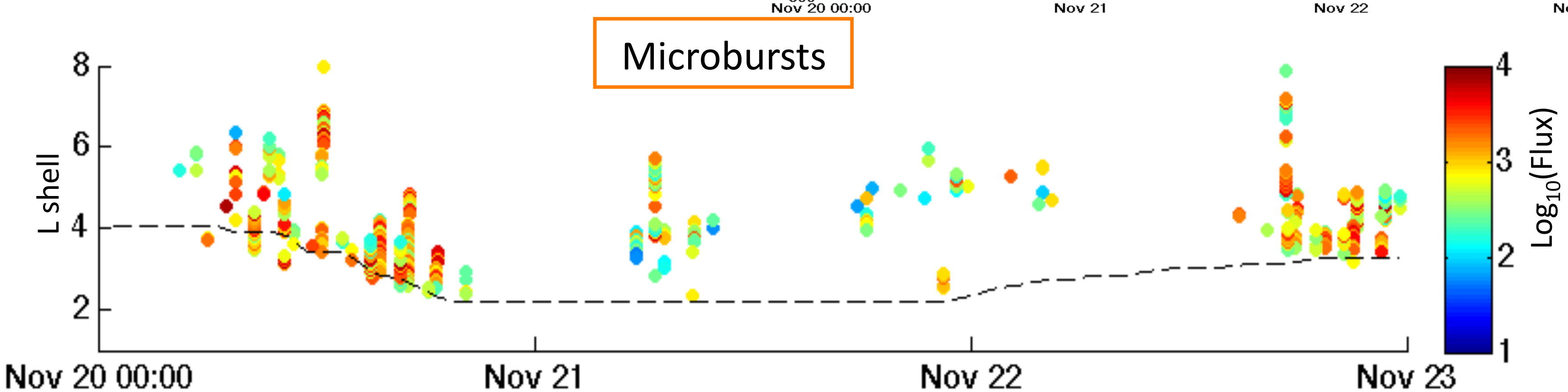
Precipitation band magnitude = BLUE – BLACK

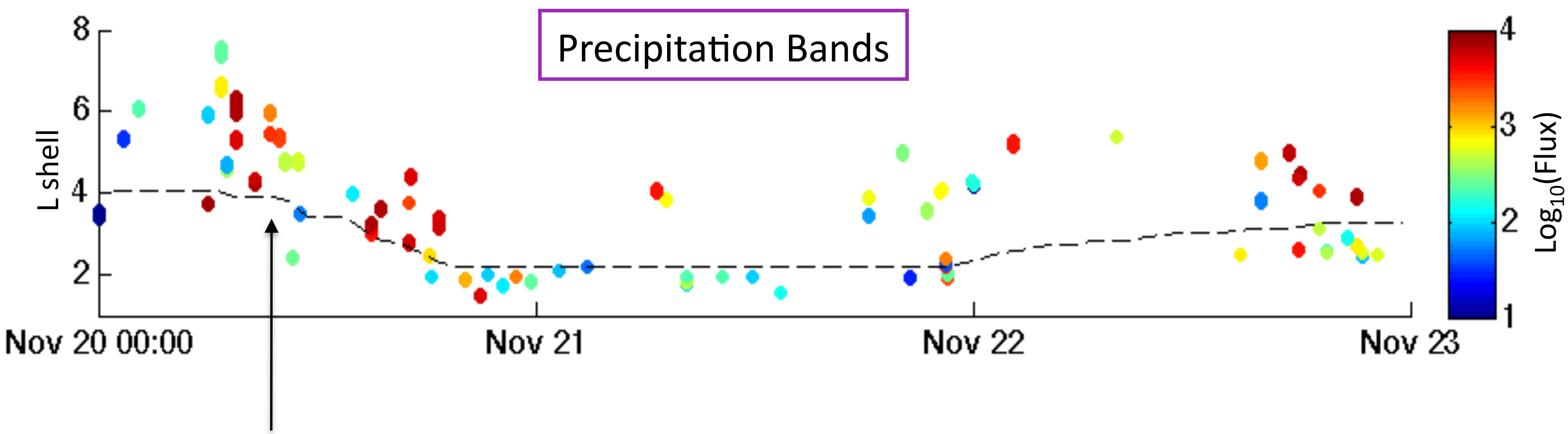
BLUE: 100 ms count rate
RED: Band detections
BLACK: Baseline - 10th percentile of 20 sec bins

Microburst and Band distributions during Nov 2003 storm

Nov 20-23 2003, Dst_{min}=~-450 nT



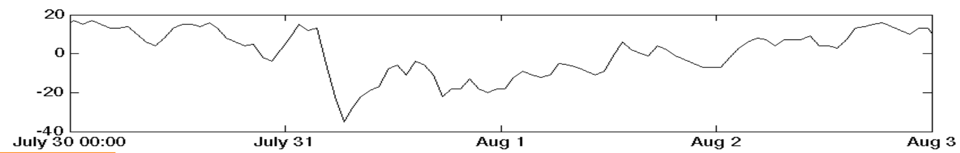


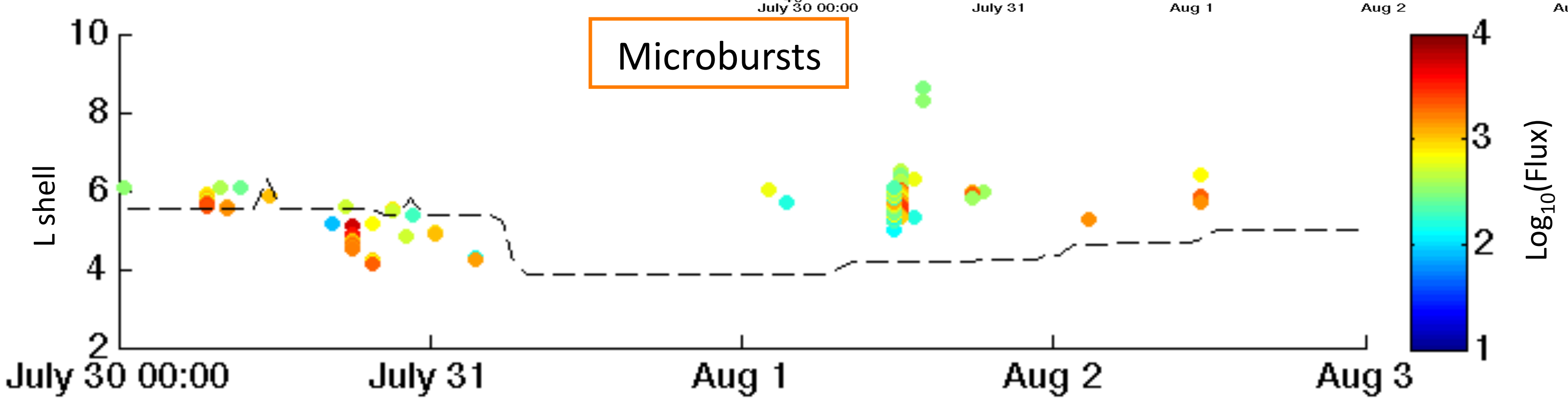


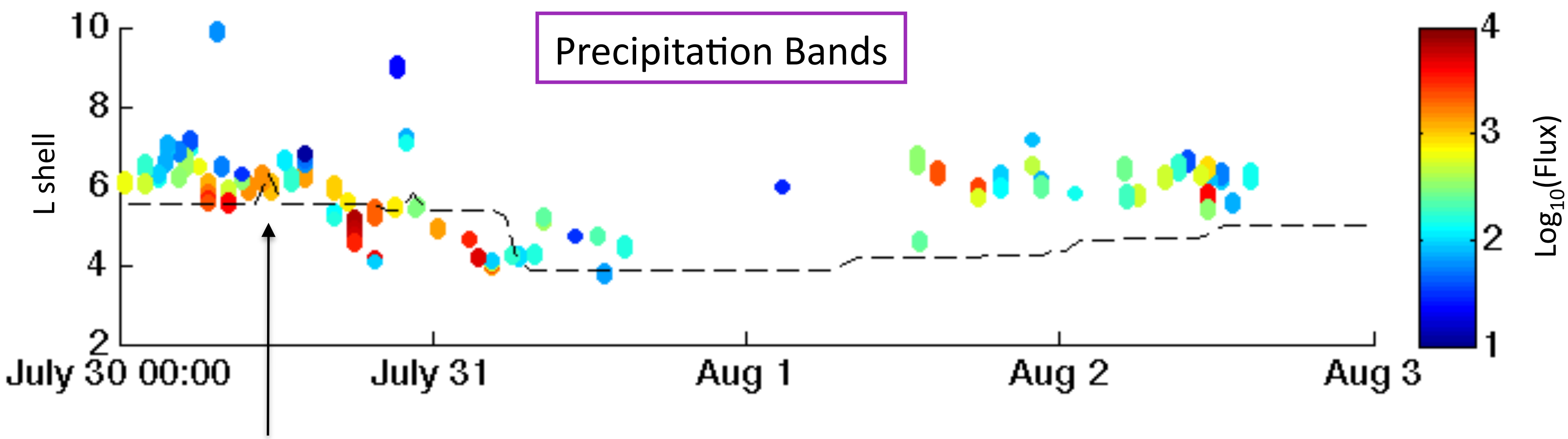
$L_{pp} = -1.57 * \log_{10}(Dst_{min,\ 24hr}) + 6.3$ (O'Brien and Moldwin '03)

Microburst and Band distributions during July 2001 storm

July 30-Aug 3 2001, Dst_{min}=~-40 nT







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