Radiation Belt Electron Precipitation and Associated Scattering Processes

- Recent progress on directly linking specific scattering mechanisms to precipitation events
- Remaining open questions regarding global distributions, precipitating energy spectra

Breneman and Blum [submitted]

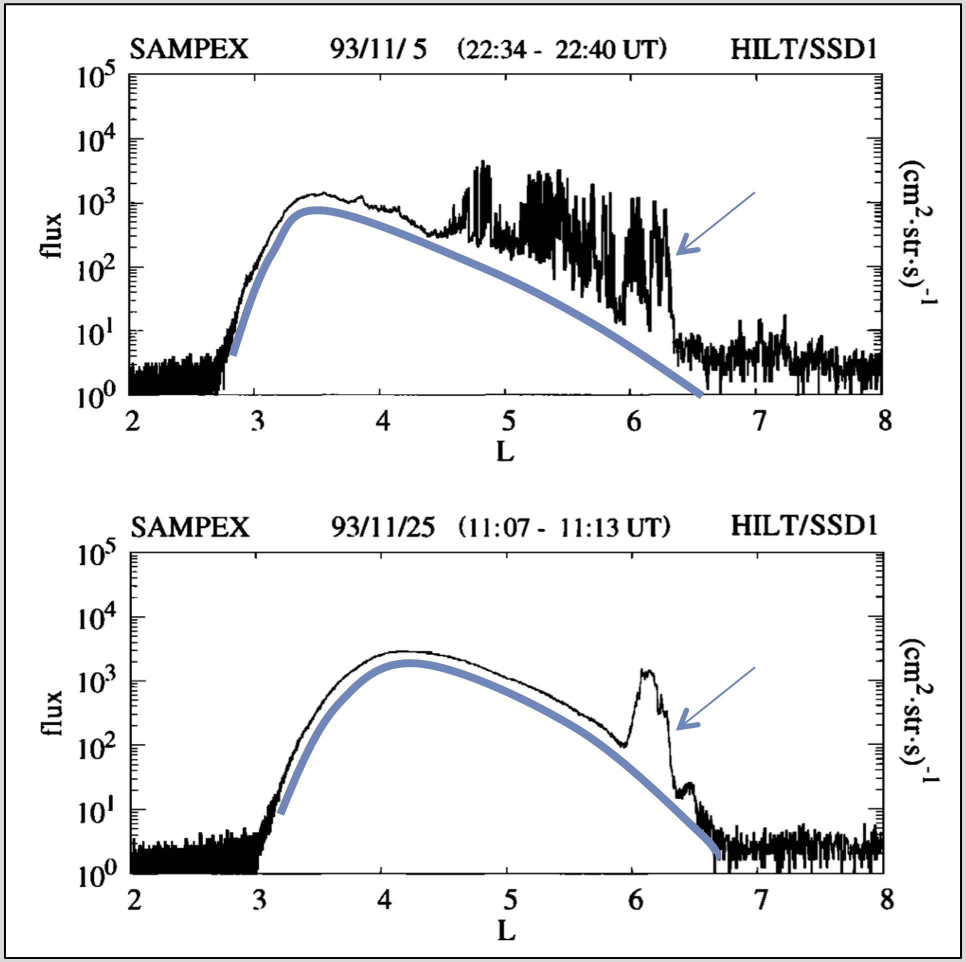
Lauren Blum
NASA/Goddard

Thanks to: A. Breneman, O. Agapitov, A. Artemyev, J. Bonnell, S. Kanekal, L. Kepko, X. Li, BARREL and Van Allen Probe teams

Rapid Precipitation Features

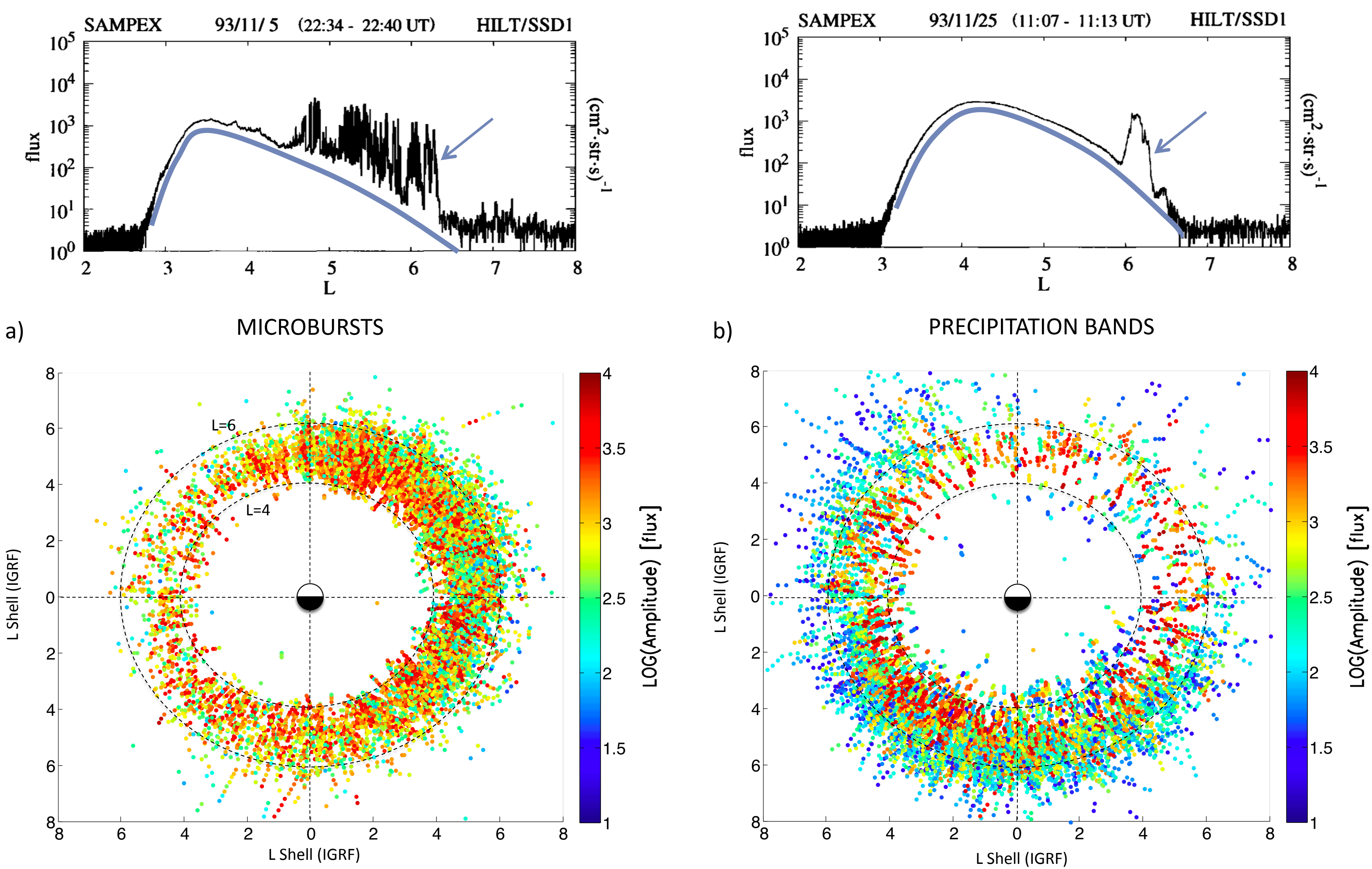
- **Microbursts:**
  <1 sec bursts of precipitation, seen primarily on the morning side

- **Longer duration REP:**
  ~5-30 sec sharp flux enhancements at LEO, seen on consecutive orbits and in conjugate hemispheres

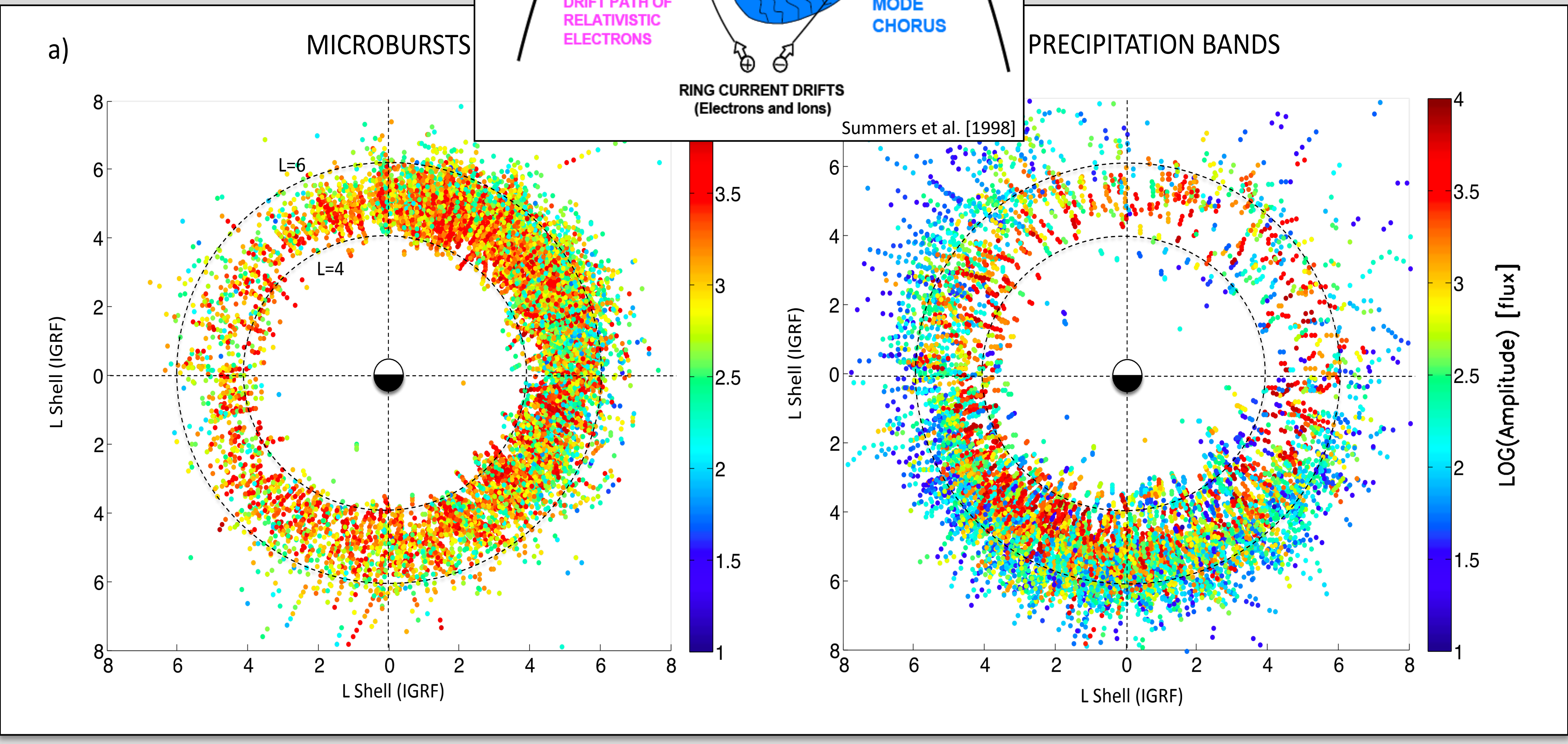


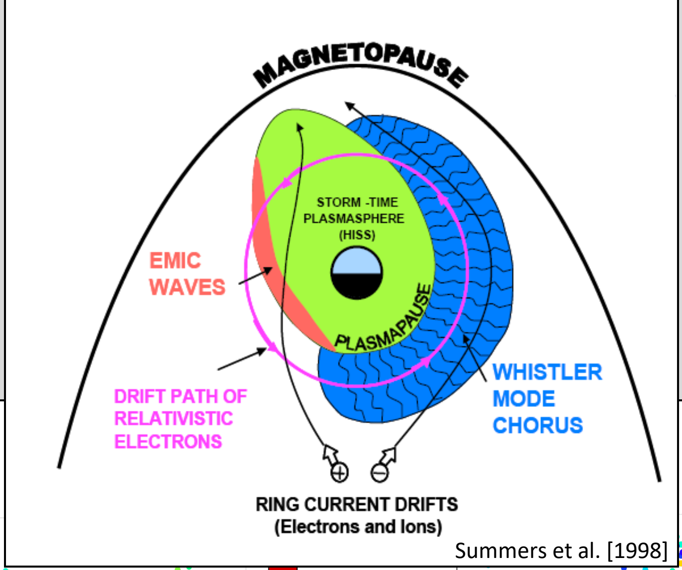
Nakamura et al. [2000]

Global Distributions



Blum et al. JGR [2015]

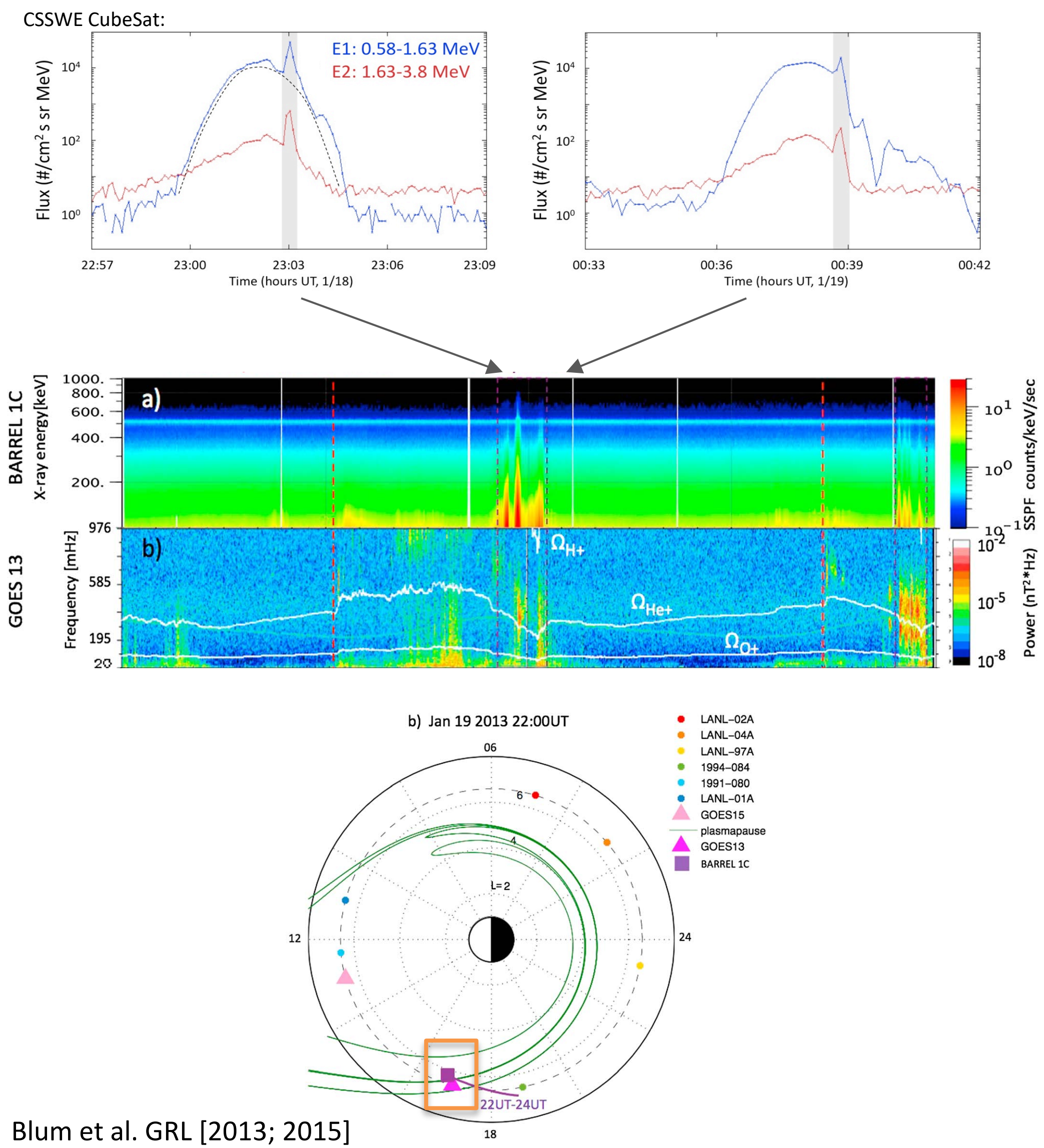




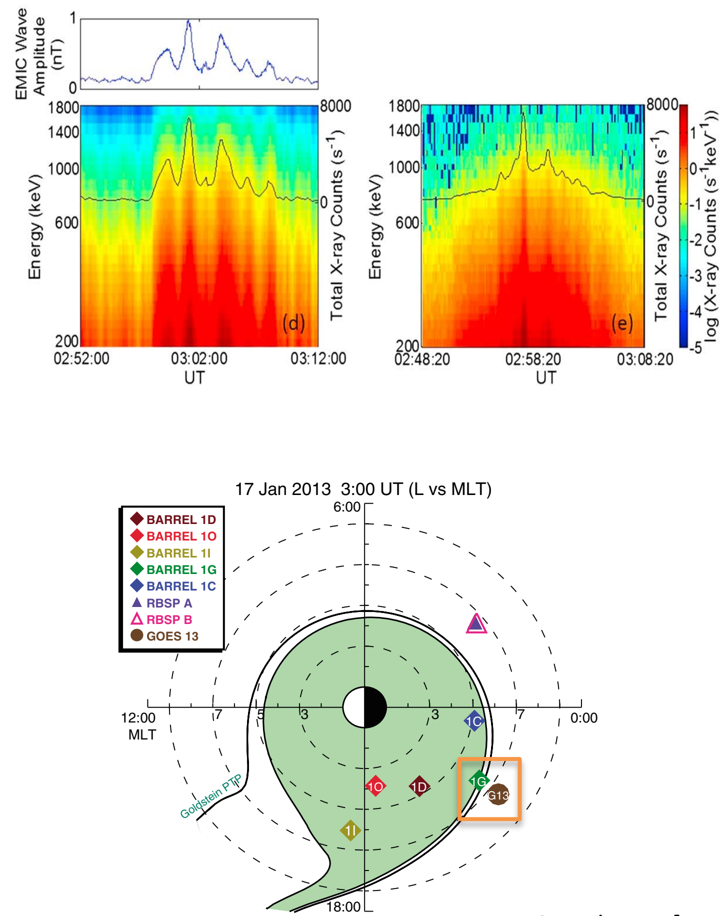
Clear radial and local time differences support different wave modes as scattering mechanisms

EMIC-Driven Precipitation

Magnetically conjugate multipoint measurements directly linking waves and precipitation [e.g. Miyoshi et al. 2008; Rodger et al. 2008, 2015; Clilverd et al. 2015; Hendry et al. 2016]

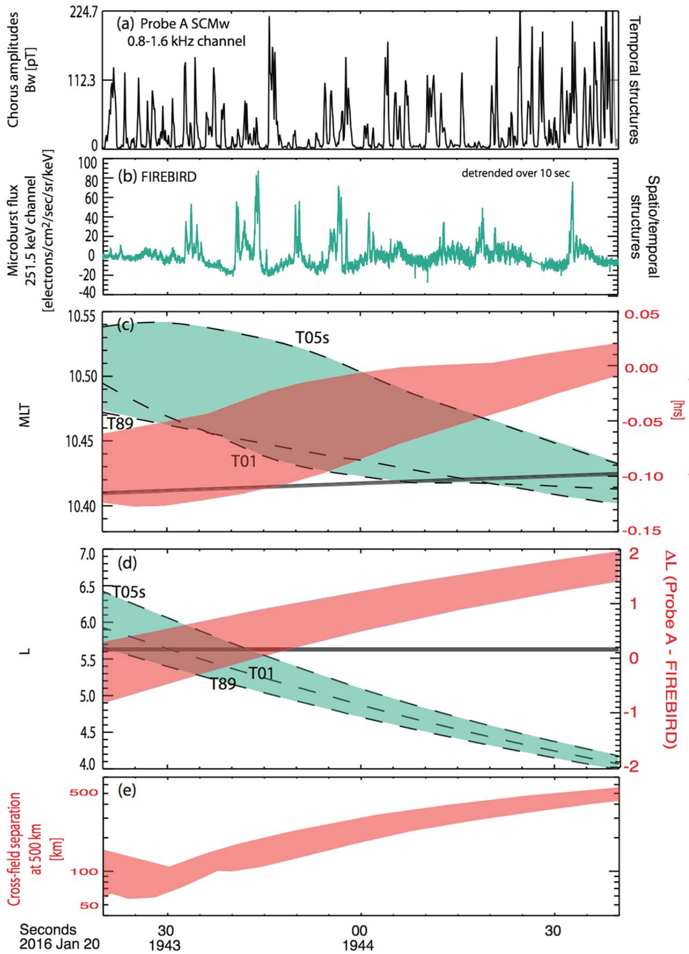


Blum et al. GRL [2013; 2015]

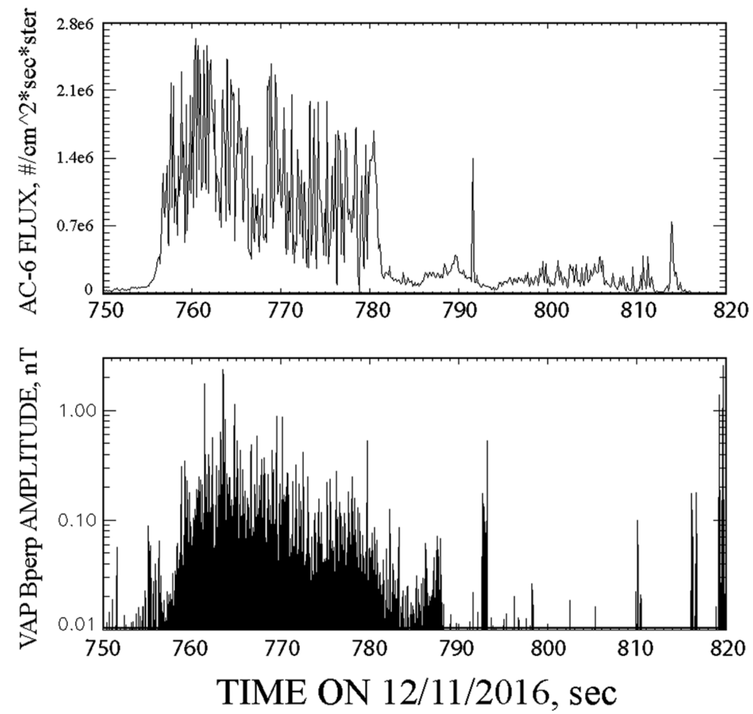


Li et al. GRL [2014]

Chorus-Driven Microburst Precipitation

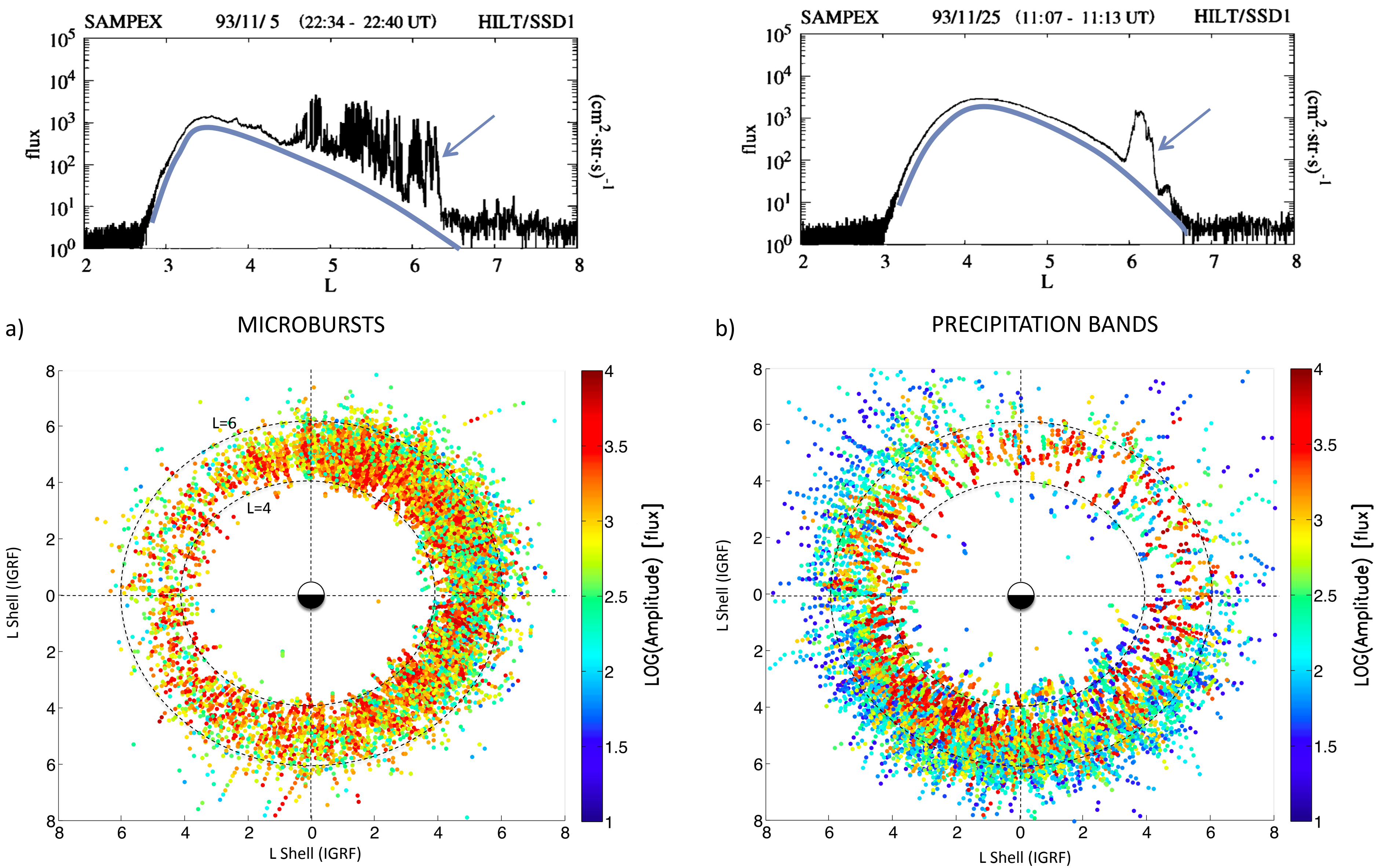


Breneman et al. [2017]



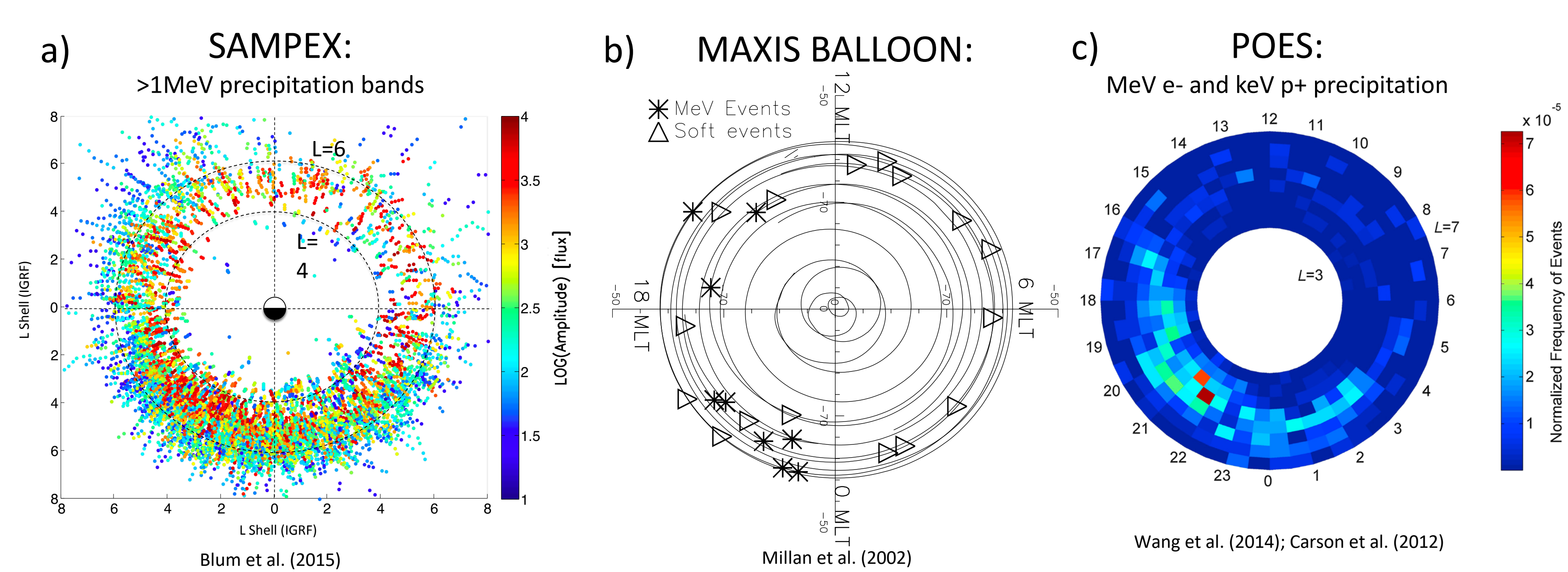
Mozer et al. [2018]

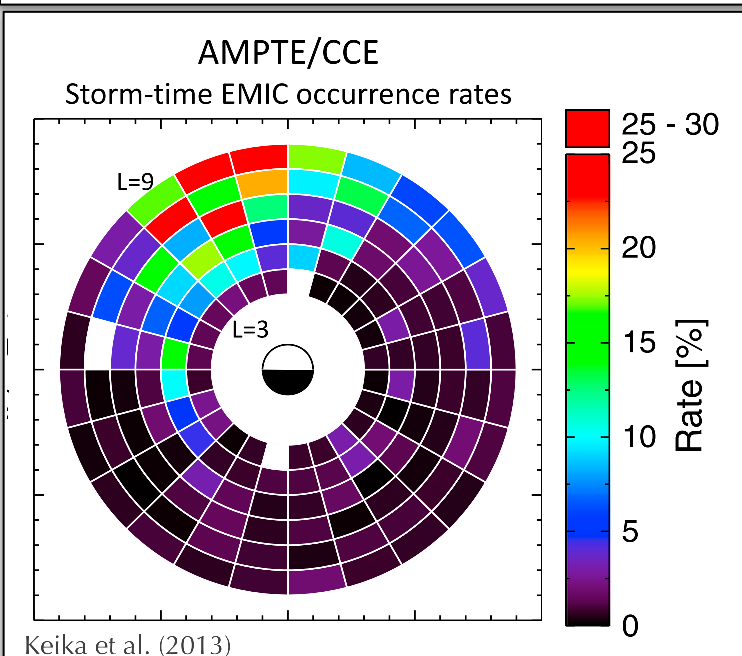
Remaining Questions



Blum et al. JGR [2015]

Global Precipitation Distributions

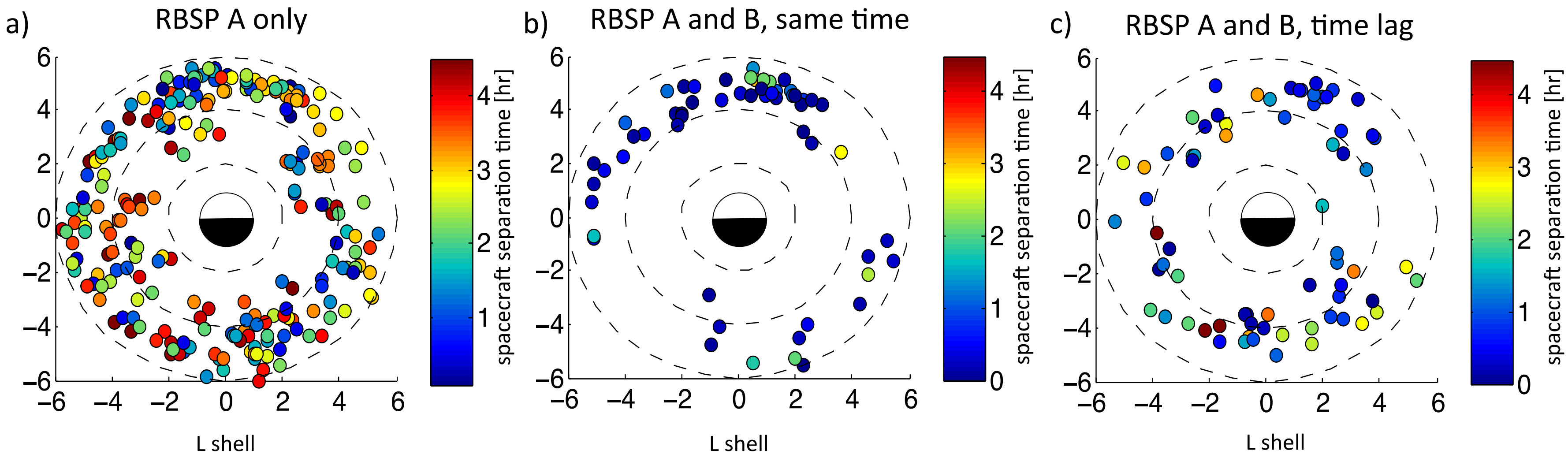




- What fraction of EMIC waves are driving electron precipitation?
  - What are the key wave or plasma properties determining this?

- What fraction of precipitation is caused by EMIC waves?
  - Are field line curvature scattering or other wave modes contributing (e.g. Smith et al. JGR 2015)

EMIC wave spatial scales



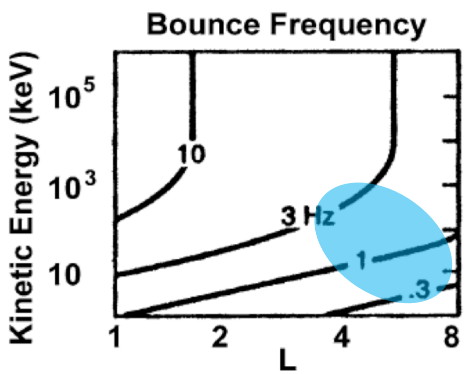
Full range of MLTs, lag times, even some very small spacecraft separations	Mostly outside L=4, primarily dayside, spacecraft time lag < 3 hrs	Full range of MLT, lag times, L shells; slightly longer lag times on nightside (ave 1.6 hrs vs 1.2 on day)

- Dayside, H+ band waves more often span larger areas, while He+ band and nightside waves are more localized (but often persistent)
- Looking into MLT dependent wave and plasma properties may help us understand the pre-midnight prevalence of precipitation events

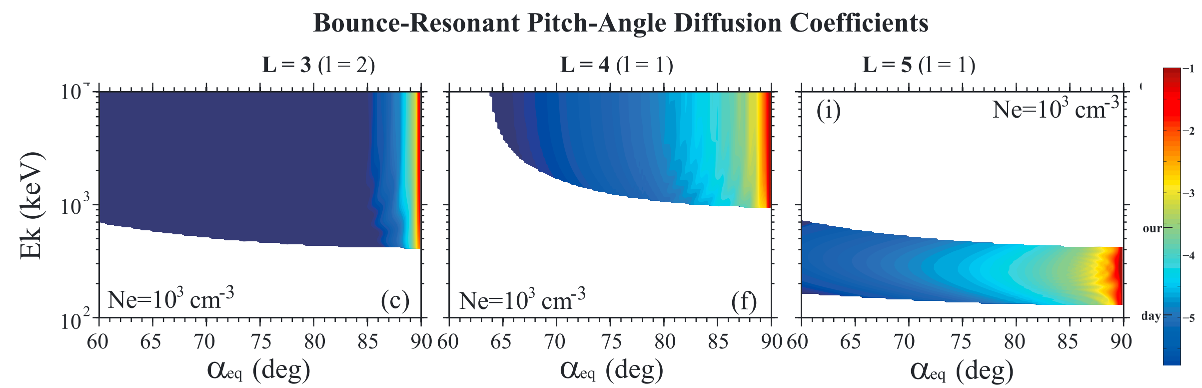
Blum et al. GRL [2017]

Energy Dependence of Precipitation

EMIC-driven precipitation



Schulz and Lanzerotti [1974]



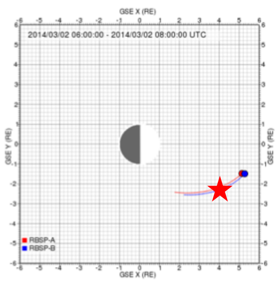
Cao et al. [2017]

- In addition to gyroresonance with MeV electrons, EMIC waves are also of the right frequency (~few Hz) to resonate with the bounce motion of 10s-100s keV electrons
- Bounce-resonance and violation of the second adiabatic invariant can be effective for near-equatorially mirroring electrons, which are unable to be scattered through cyclotron resonance with whistler mode chorus and hiss waves, e.g. Cao et al. [2017]
- Parameter study by Cao et al. [2017] shows diffusion can be significant at pitch angles ~90, but very sensitive to L shell, wave normal angle, and wave frequency

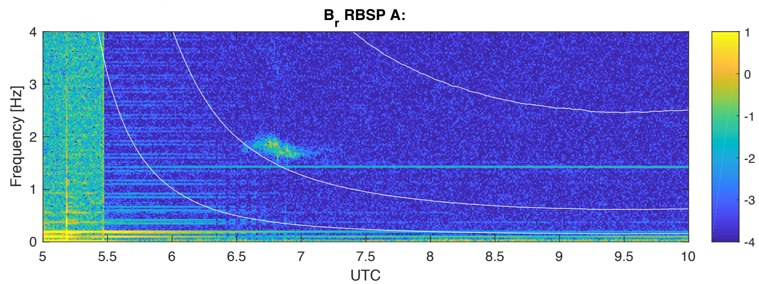
Bounce Resonance

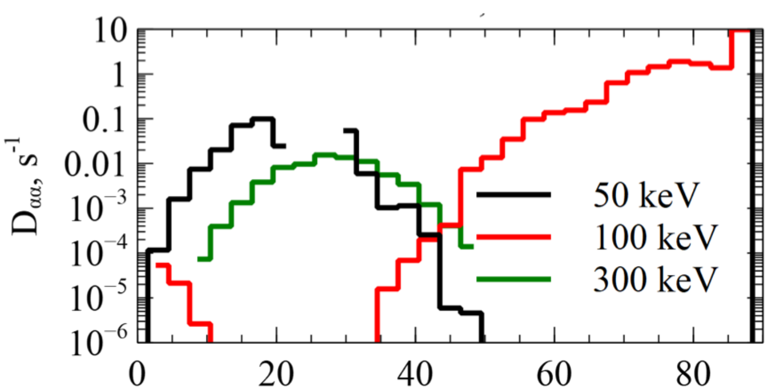
Here, we evaluate bounce resonance diffusion coefficients for realistic wave and plasma parameters

02 March 2014, H band, day

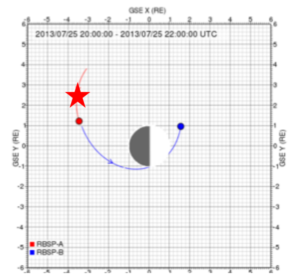


n: 10-15 cc
wpe/wce: 3
n_{O+}/n_e=5%
n_{He+}/n_e=5%

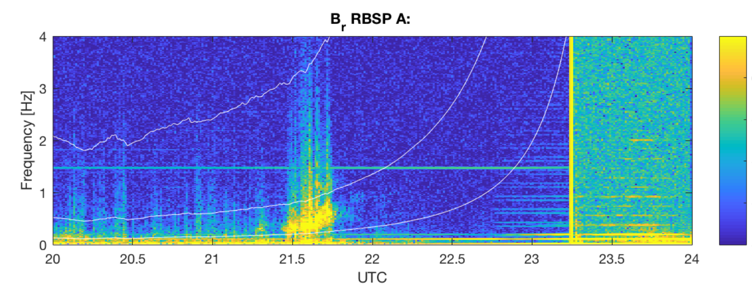


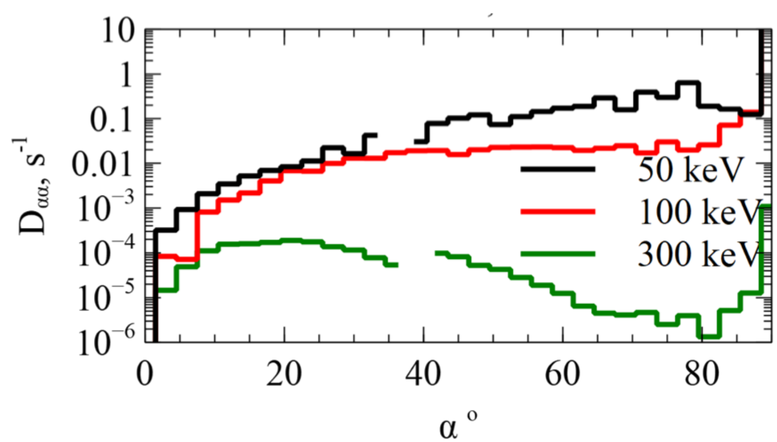


25 Jul 2013, He+ band, dusk



n: 290 cc
wpe/wce: 20
n_{O+}/n_e=5%
n_{He+}/n_e=15%





Courtesy of A. Artemyev, in prep.

Preliminary Findings

- For realistic wave spectra, we obtain electron scattering at intermediate pitch-angles, not just at large pitch angles
- Lower energy electrons (10s-100s keV) can be scattered effectively even by fairly field-aligned waves
- Diffusion rates are comparable to (or larger than) rates for these electrons interacting with hiss/chorus waves

-> Preliminary calculations show bounce resonant interactions with EMIC waves could play an important role in ~10s-100s keV electron dynamics (not just MeV electrons)

Energetic Electron Precipitation and Associated Scattering Processes

- Recent event studies of conjugate multipoint observations help confirm associations between various wave modes and types of precipitation
- Still need to understand:
  - What fraction of precipitation events are caused by what wave modes (and vice versa)
  - Detailed precipitating energy spectrum and nature of wave-particle interaction

GTOSat

- Recently selected HTIDS, launch ~2021 into geosynchronous transfer orbit (GTO)
- GTOSat team: L. Blum, L. Kepko, S. Kanekal, D. Turner, A. Jaynes
- Measure pitch angle resolved ~200keV-2MeV electrons
  - PSD profiles to distinguish between various loss and acceleration mechanisms
- Radiation belt monitor in the post Van Allen Probes era
  - Pathfinder for reliable, capable CubeSats beyond LEO and affordable magnetospheric constellation missions