Thursday Discussion

Wave-Particle Interactions Inside and Outside the Plasmasphere

Richard B. Horne and Jay Albert

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Invited talk, International Workshop on Energetic Particle Processes of the Near Earth Space (IWEPPNES), Paris, 18th May 2015.

1. On Wave Effects

- Which wave modes are the most important for electron acceleration?
- How important are they?
- And which ones are most important for loss, and how important are wave losses?
- How much do losses by wave-particle interactions contribute to electron flux drop-out events? So far we have focused on chorus, hiss and EMIC, but what about magnetosonic waves, Z mode waves, ECH waves, LO and RX mode waves, lower hybrid waves ...?
- Is low frequency hiss < 0.1 fce important? What about highly oblique waves?

2. On Wave Measurements and Models

- What information about the waves do we still require?
- Do we have the wave measurements and coverage we need in MLT, activity, wave normal angle, rate of occurrence...?
- Can we usefully model the waves by a small number of geomagnetic indices, and which ones are best?
- How accurate/detailed does the determination of L* for wave models need to be?
- Is using low-altitude particle data, e.g. from POES, to obtain the wave properties a better method?
- Can we usefully calculate the waves from growth rates from ring current and/or PIC codes?

3. On Plasma Density

- The ratio fpe/fce is crucial for the calculation of diffusion coefficients. We can estimate fpe quite well inside the plasmapause from measurements of fuhr and get fce from magnetometer measurements?
- But what about outside the plasmapause? Here fpe is largely estimated from the low frequency limit of the continuum radiation, which is regarded to have a cut-off at fpe. How reliable is this method? Can we assess it and can we do better?

4. Beyond Quasi-linear Theory

- Where does quasi-linear theory break down, and what replaces it?
- Is the use of time-averaged wave properties (e.g., power) equivalent to considering individual waves combined with repetition rate?
- Are analytical nonlinear results for large, idealized waves robust to complications like finite bandwidth, imperfect coherence, frequency sweep, subpacket structure?

5. On Flux Saturation

- Does the Kennel and Petschek type limit apply to high-energy flux?
- Is there new physics that sets limits?
- How do we model a severe event such as the Carrington event or equivalently a 1 in 100 year event?
- There may be more than one type of severe events, (fast solar wind, CME, ...)?
- How do we extend scaling of existing parameters?

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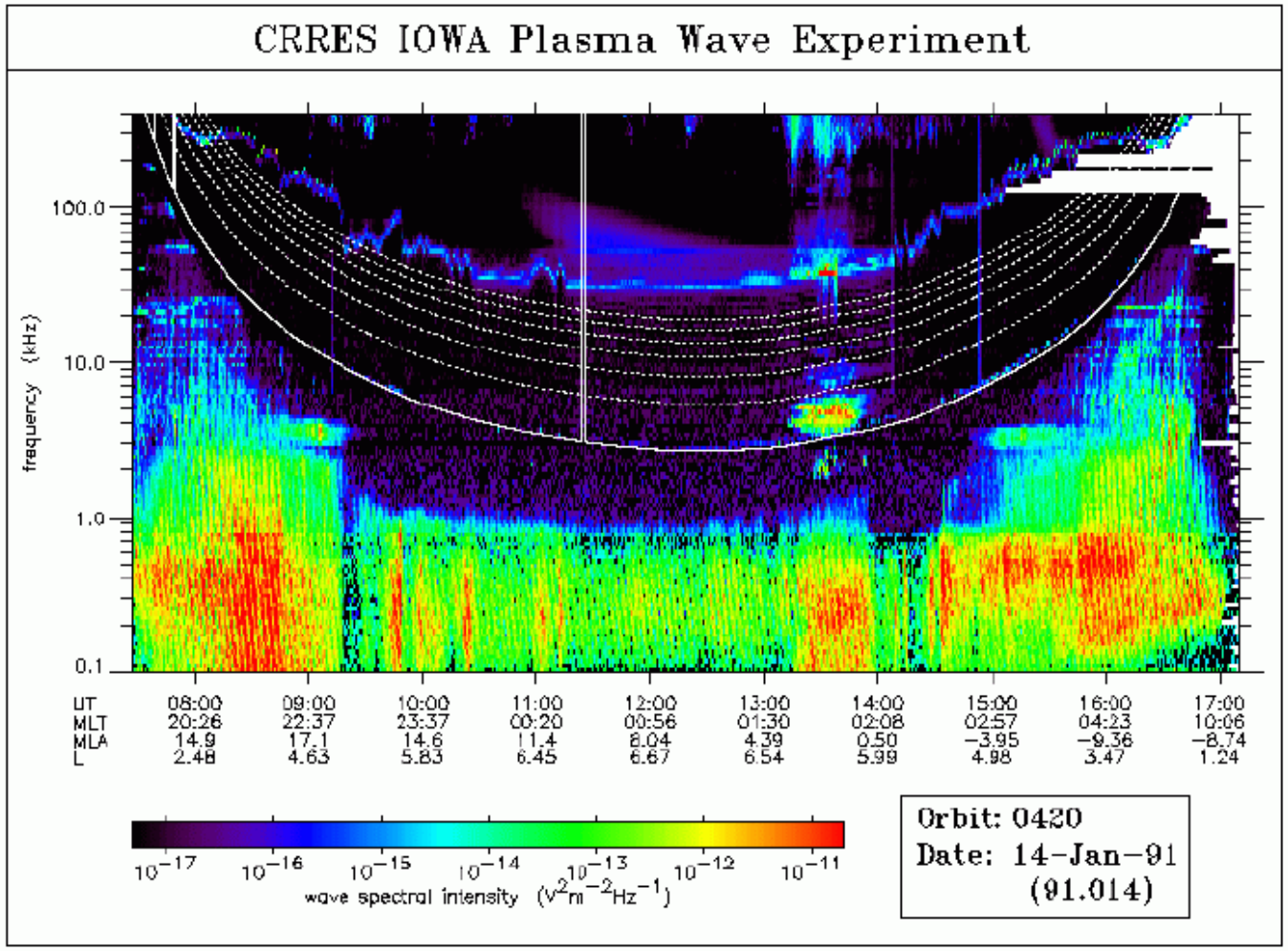
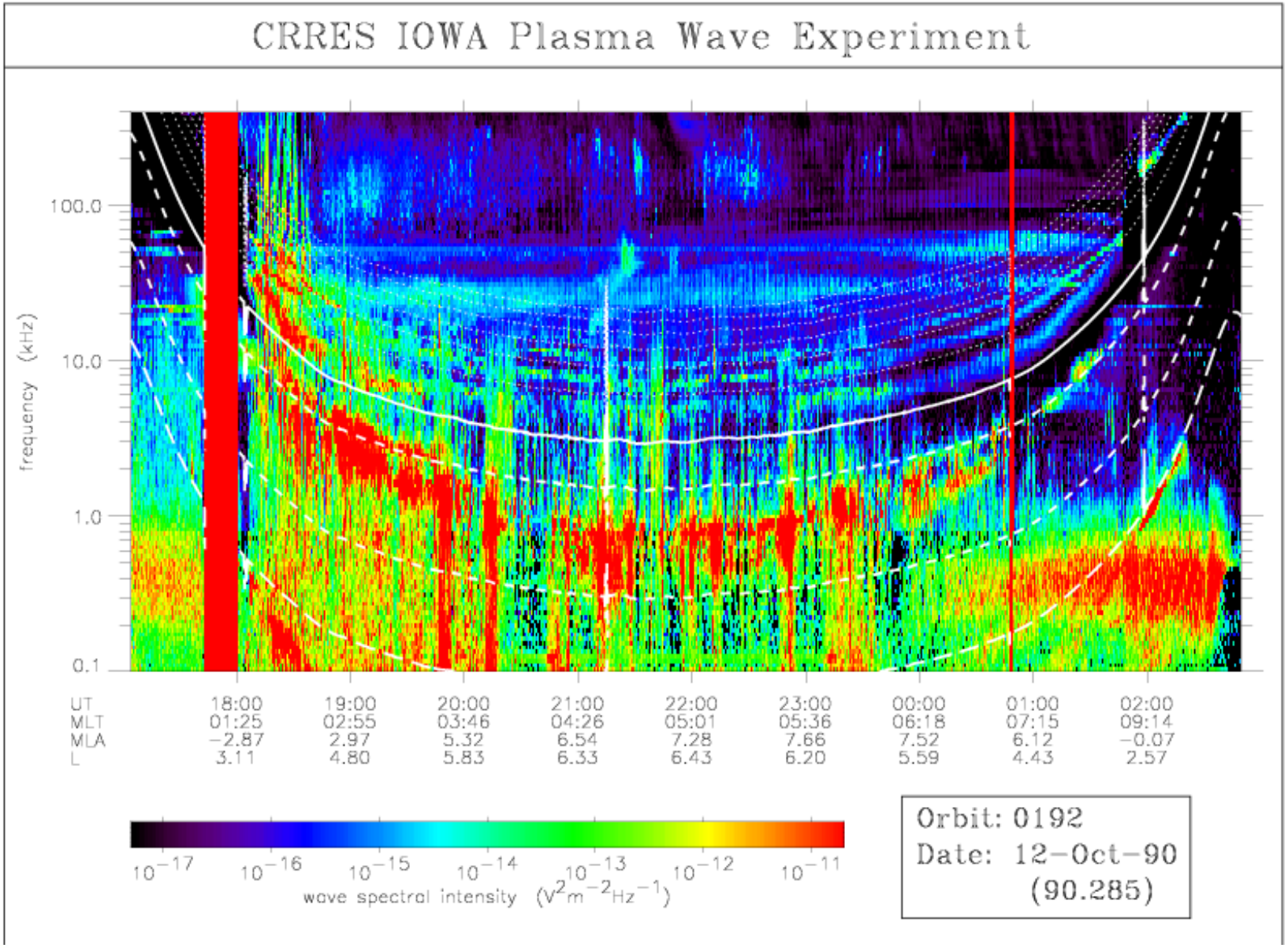
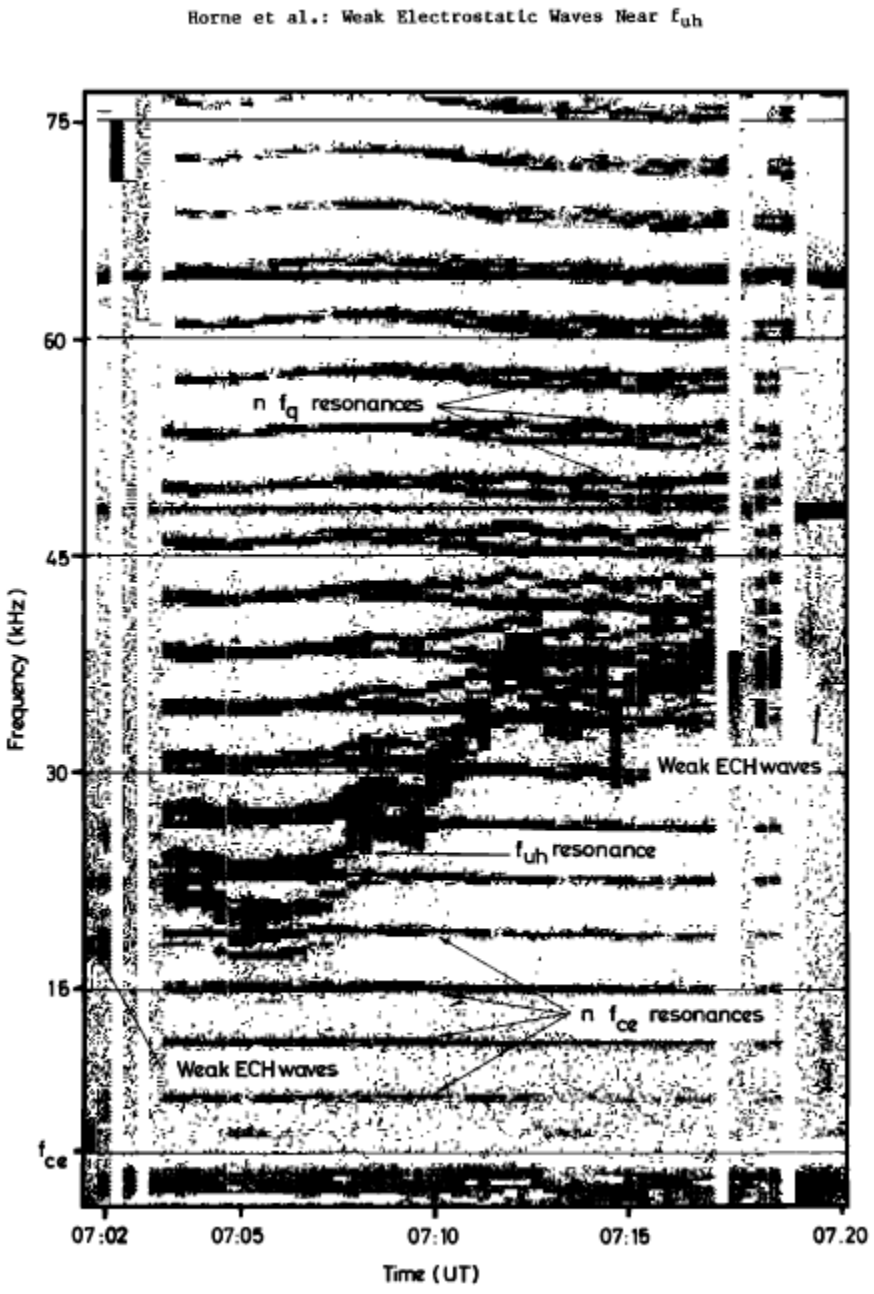
- Fpe from fUHR
- Fpe from lower cut-off of continuum radiation – LO cut-off
- Fpe from spacecraft potential – Wen Li

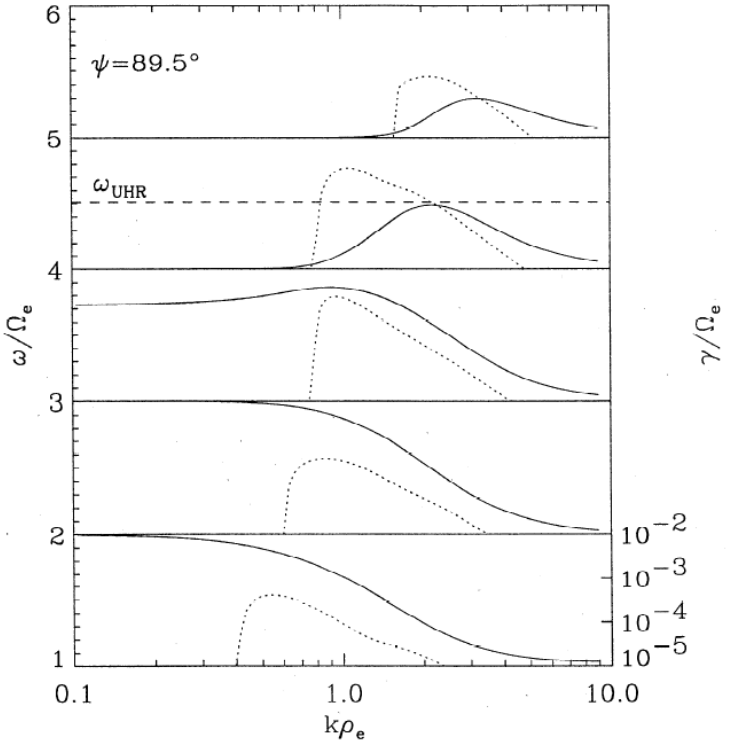
Where's the Upper Hybrid Frequency?

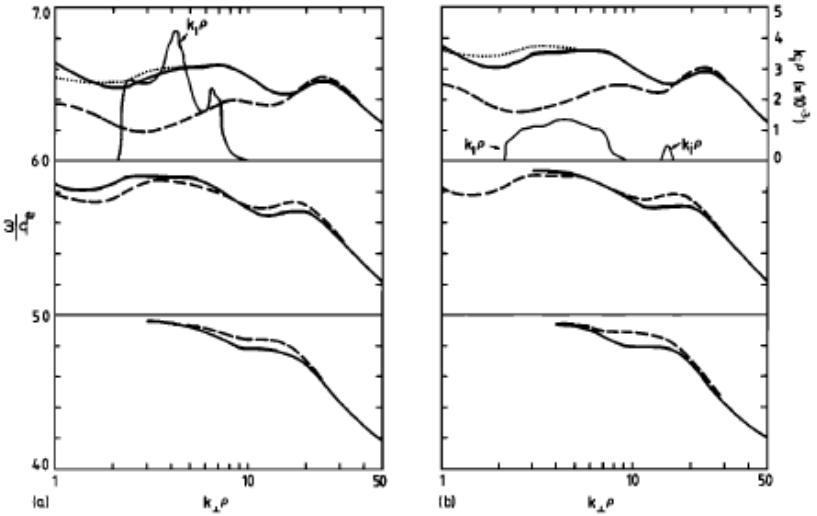


Wheres fUHR, Contiuum - overlaps ECH









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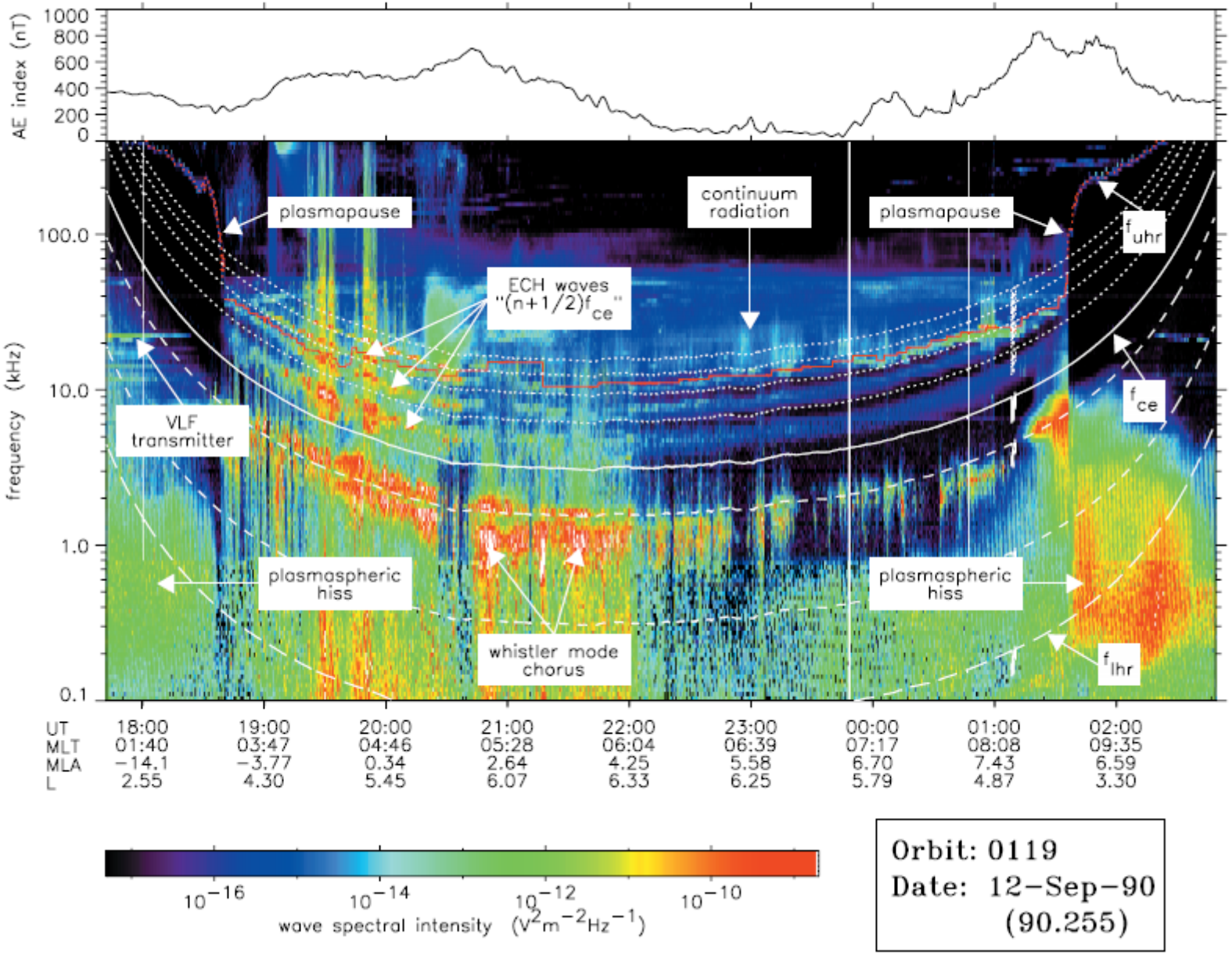

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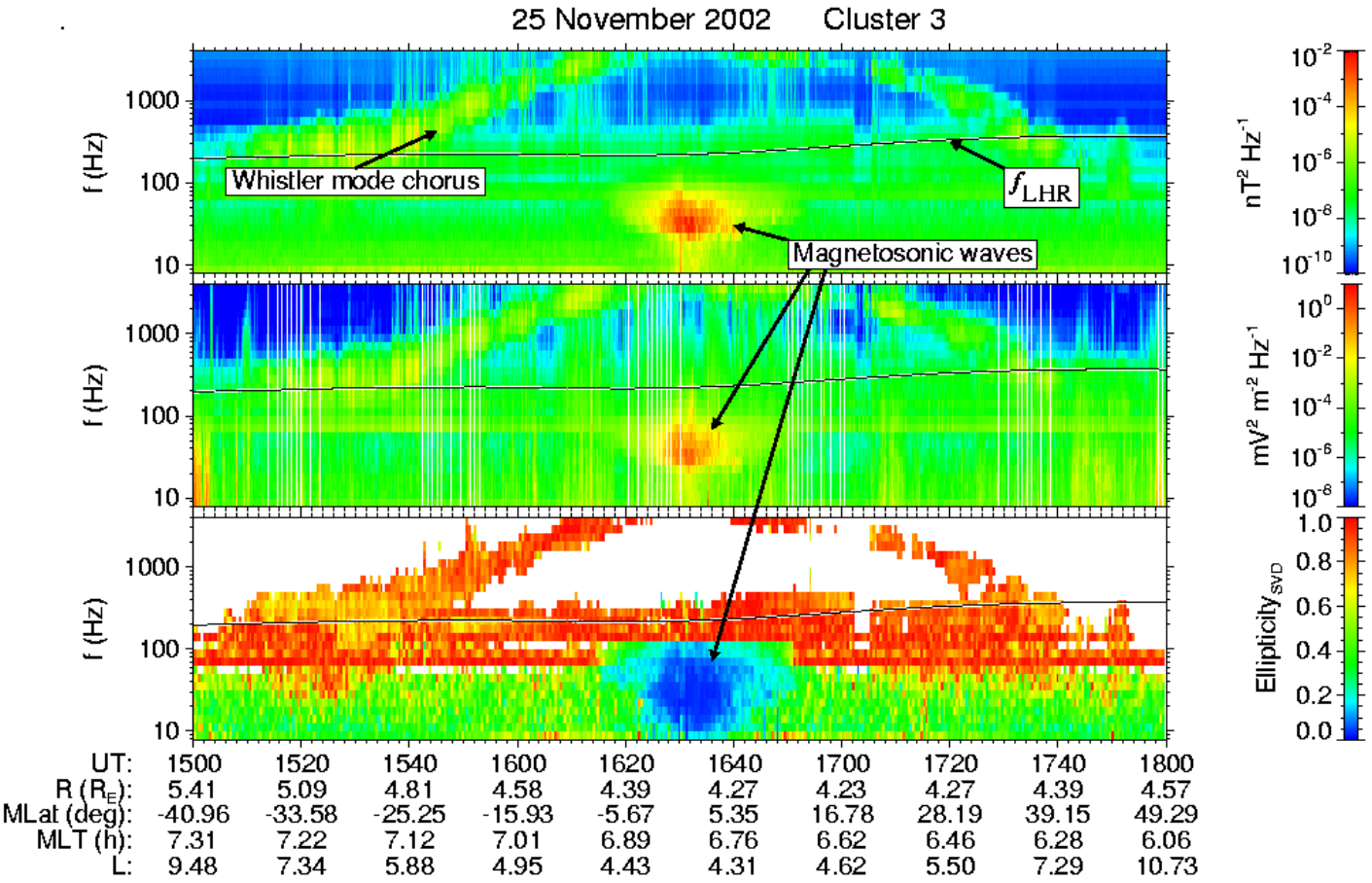
Magnetosonic Waves



- Magnetosonic waves propagate across Bo, fcH < f < fLHR
- Intense
- Generated by proton ring distributions [e.g., Boardsen et al. 1992]

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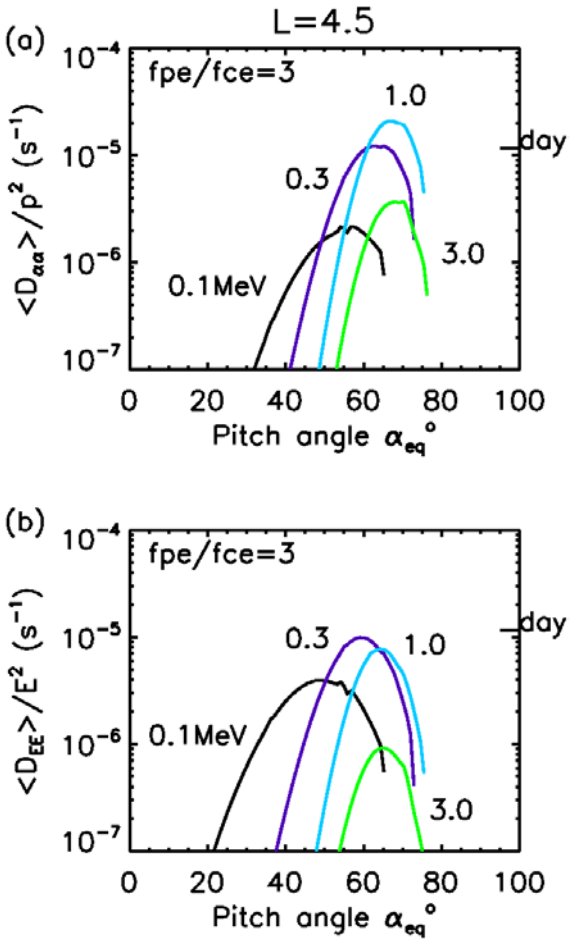
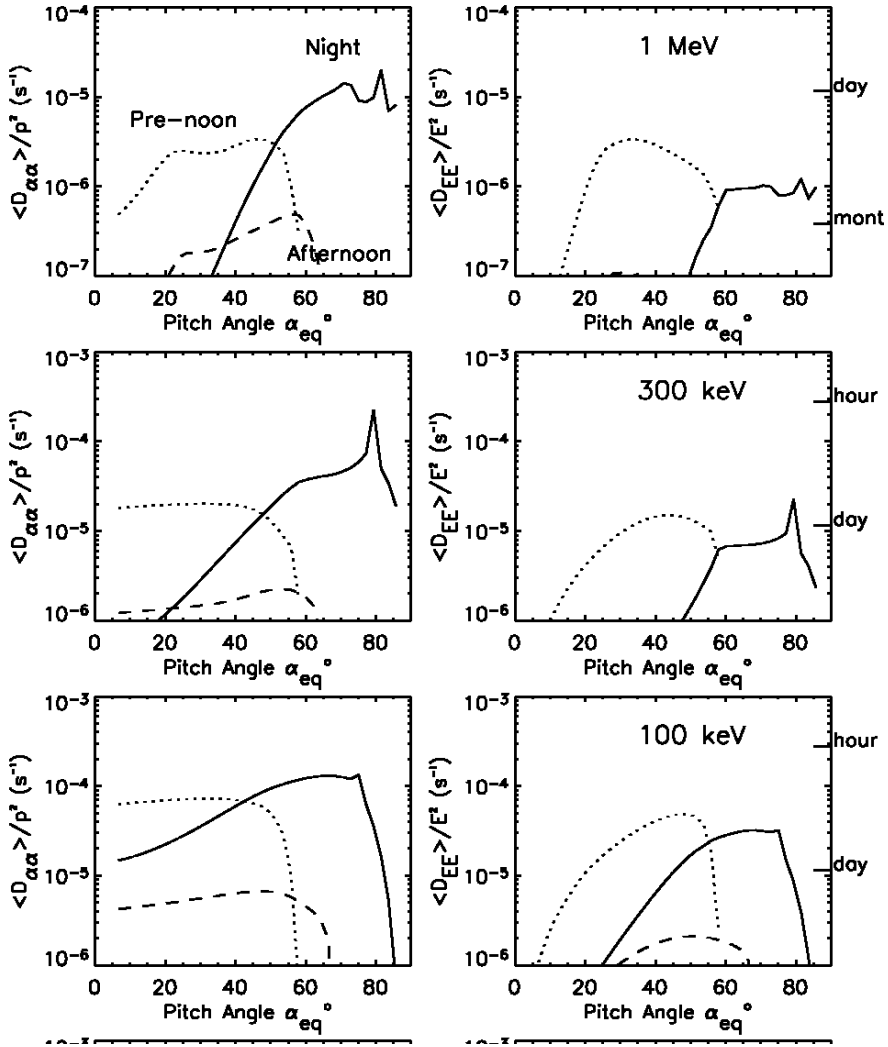
Chorus – Magnetosonic Comparison

- Magnetosonic waves, L=4.5
- x0.6 for bounce and drift average



Chorus, L=4.5, Bounce and drift averaged



Horne et al., JGR [2005]

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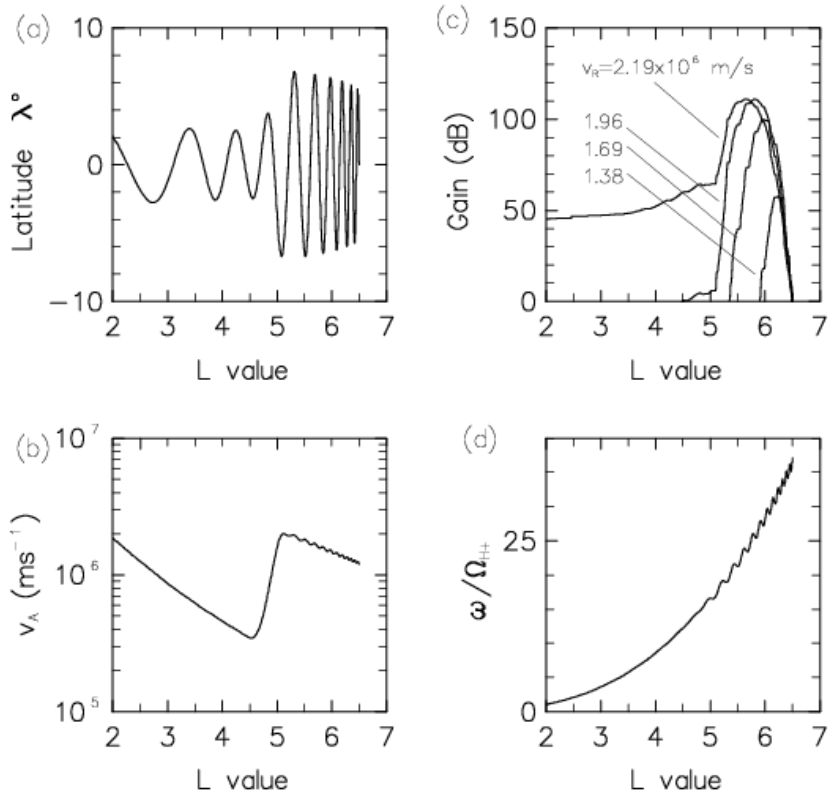
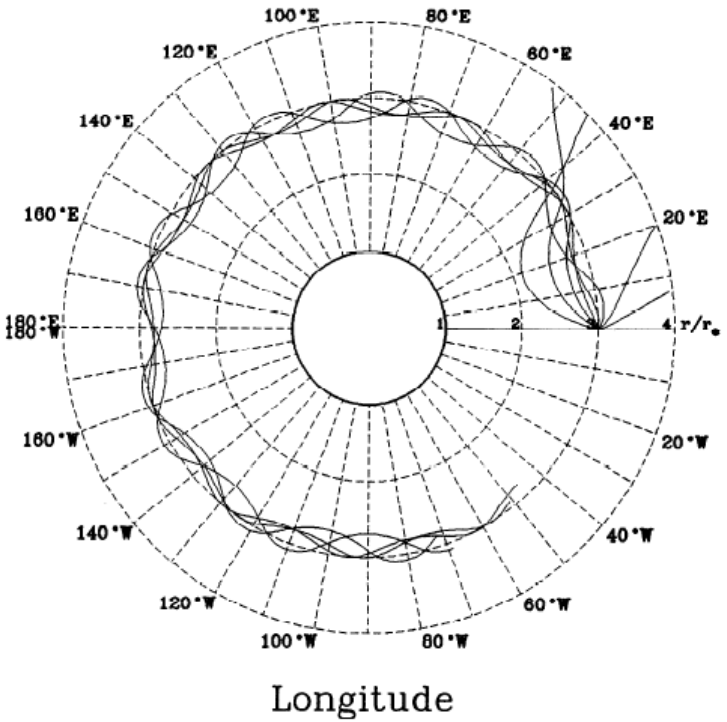
Confinement to the equator





- Horne et al., [2000]
- Wave normal angle – radial, azimuthal near plasmapause?

- Kasahara et al. [1992]

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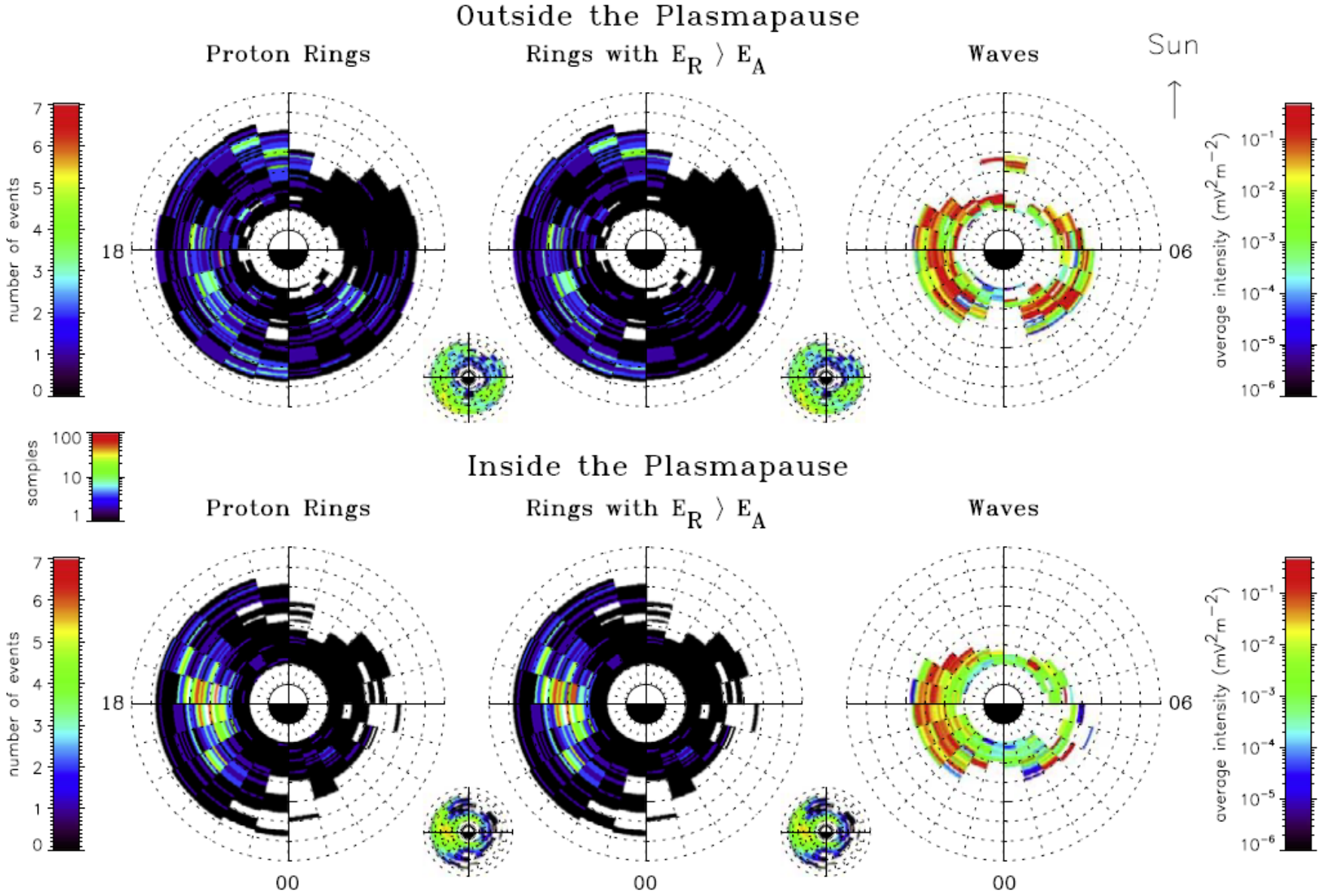
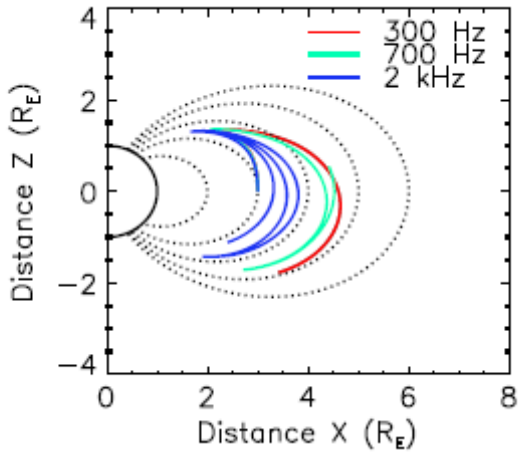
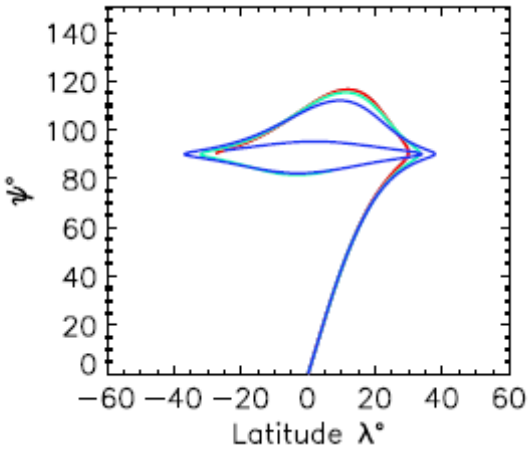
Magnetosonic waves



Wave Normal Angle



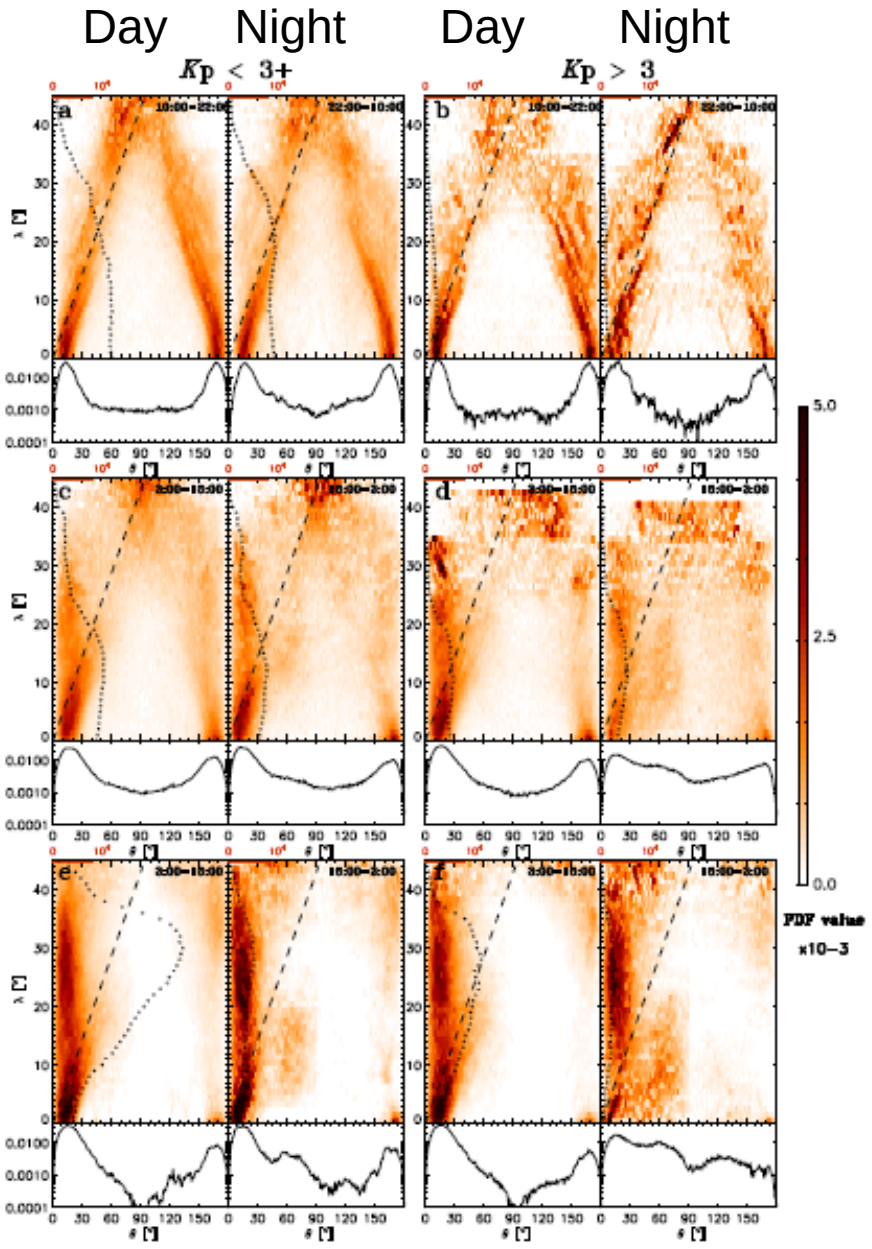
Hiss



Chorus
L=4-5.5

Chorus
L>5.5

- Glauert et al [2014]



- Agapitov et al [2013]

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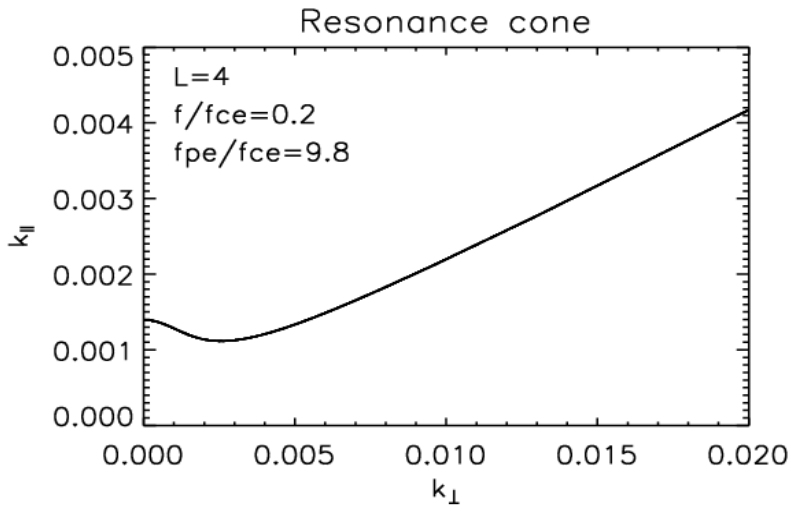
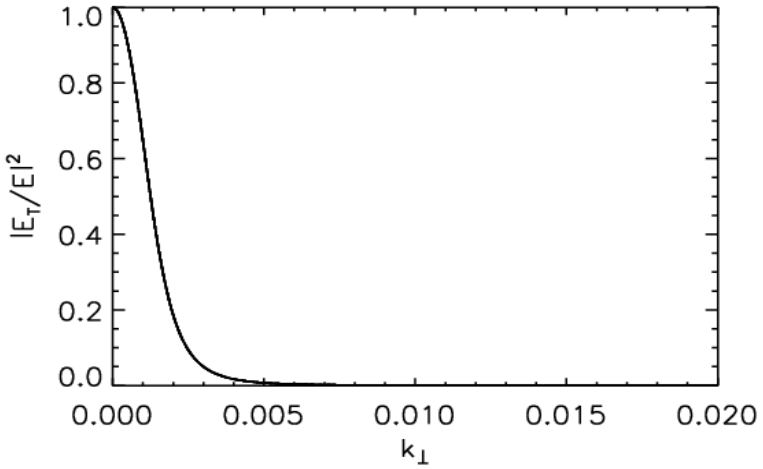
Wave Normal Angle – Hiss





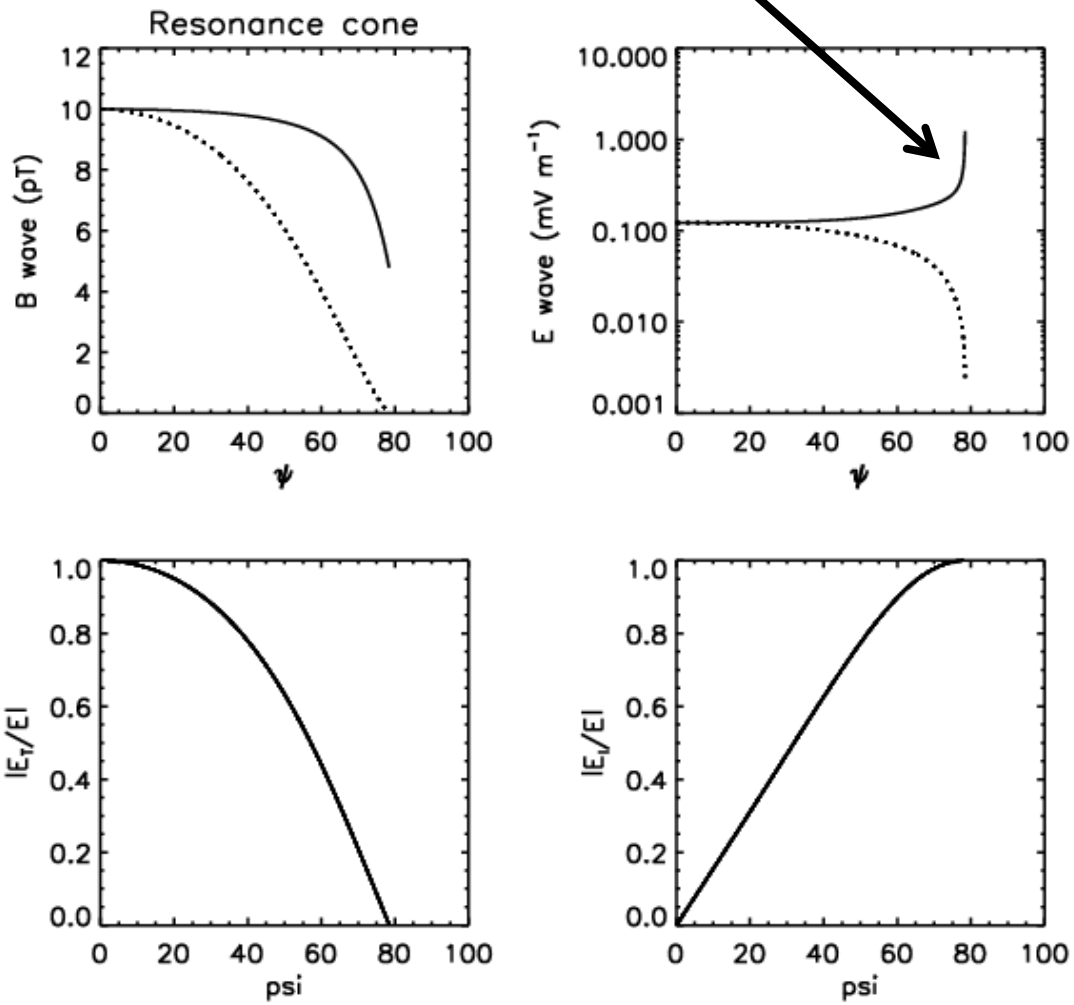
- $B^2(\omega) \sim |B_w|^2/\delta\omega \;\; g(X)$
- Constraint
  - $\Psi < \Psi res$
- How do we place the angular distribution?
- Diffusion rates are very sensitive to how close to the resonance cone we become
- Electrostatic component
- Cold cf hot plasma dispersion
- Landau damping
- We must set Bw such that E is constrained !!!!

Wave Normal Angle

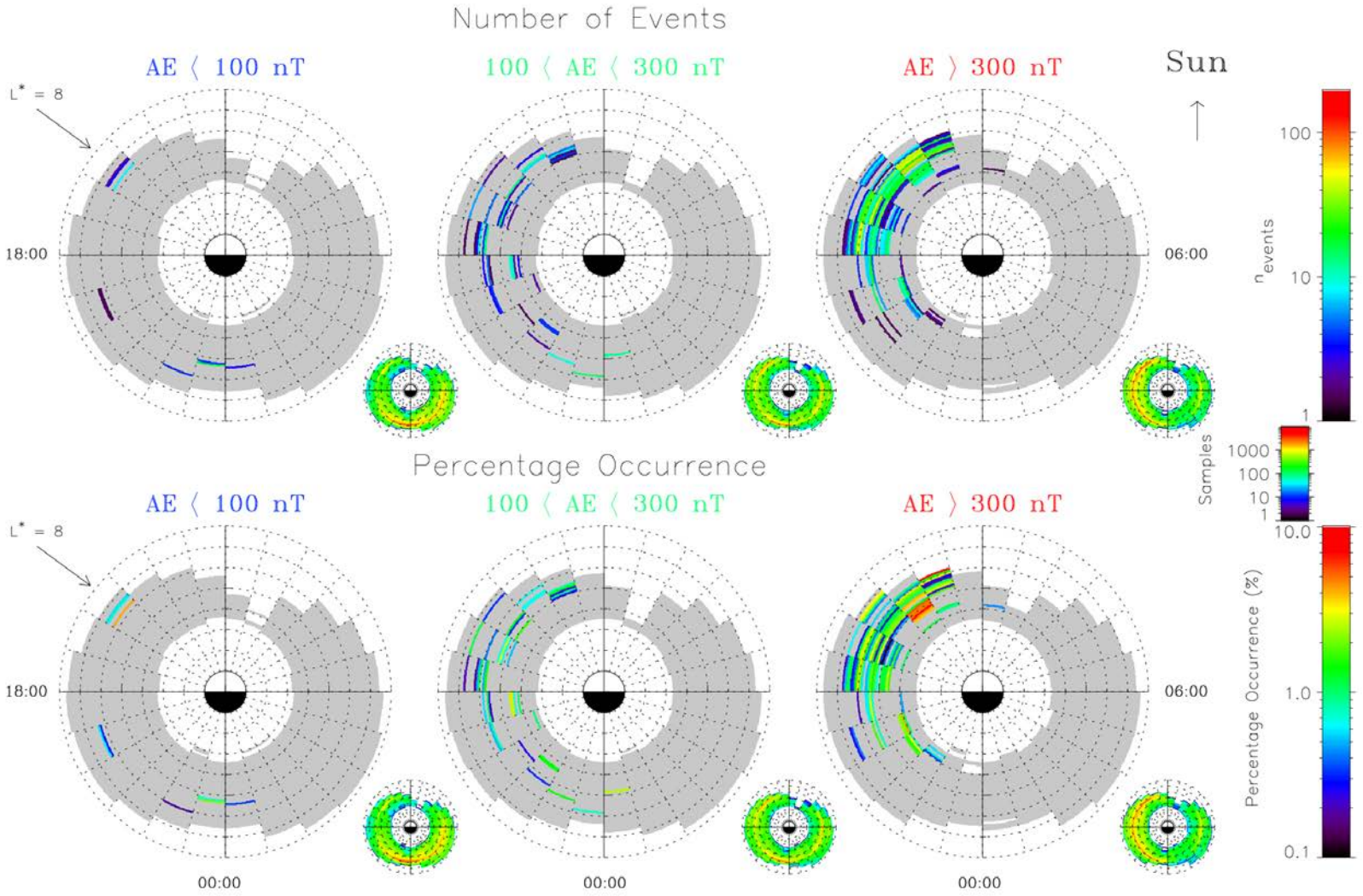
- $B^2(\omega) \sim |B_w|^2/\delta\omega \;\; g(X)$
- Spread of 80

- Our implementation
- Since $B^2(\omega) \sim E^2(\omega)$
- Use $B^2(\omega)\ |E_t/E|^2$
- Omits electrostatic component
- So how important is the ES component?

Transformed E field is too large

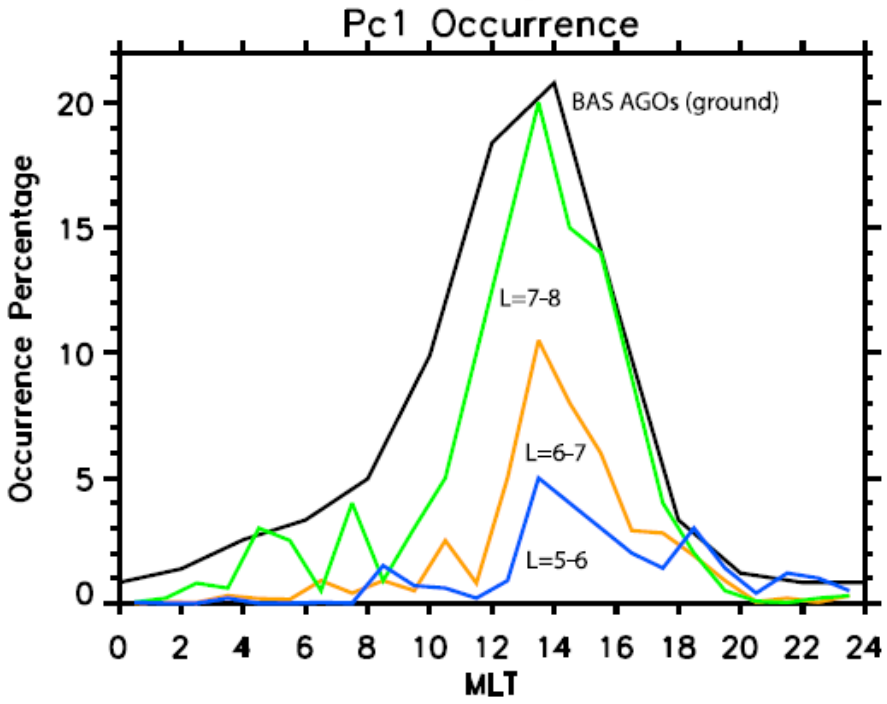


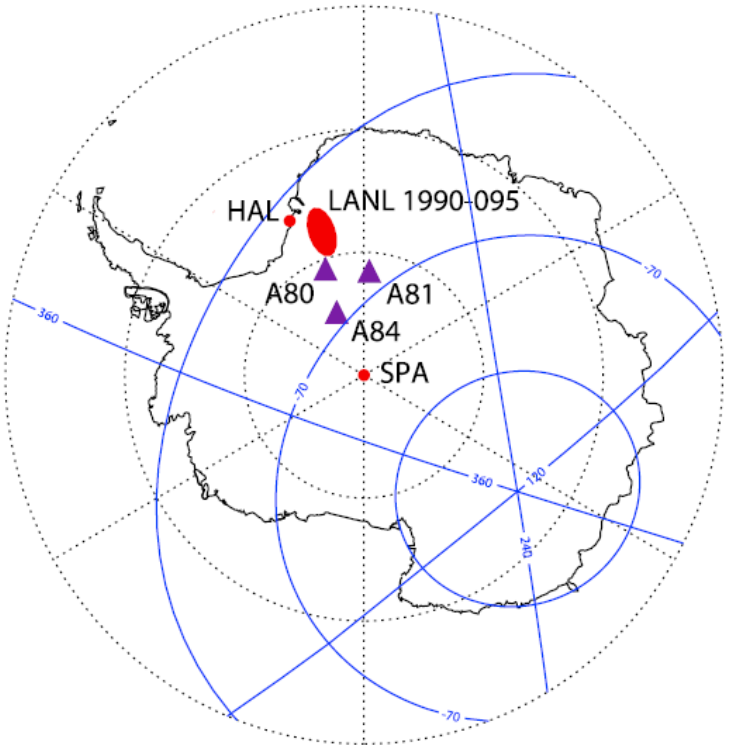
Helium Band EMIC Waves with $B_w^2 > 1\ nT^2$



- Helium band EMIC waves exceed 1 nT^2 approximately 1% of the time in the afternoon sector from L* = 4-7 during active conditions

EMIC – Ground and Space





Posch et al [2010]

- BAS data L > 6.28
- Weak correspondence with plumes – but MLT agrees with AMPTE/CCE
- Comparison with CRRES? Distribution at lower L < 3 ?

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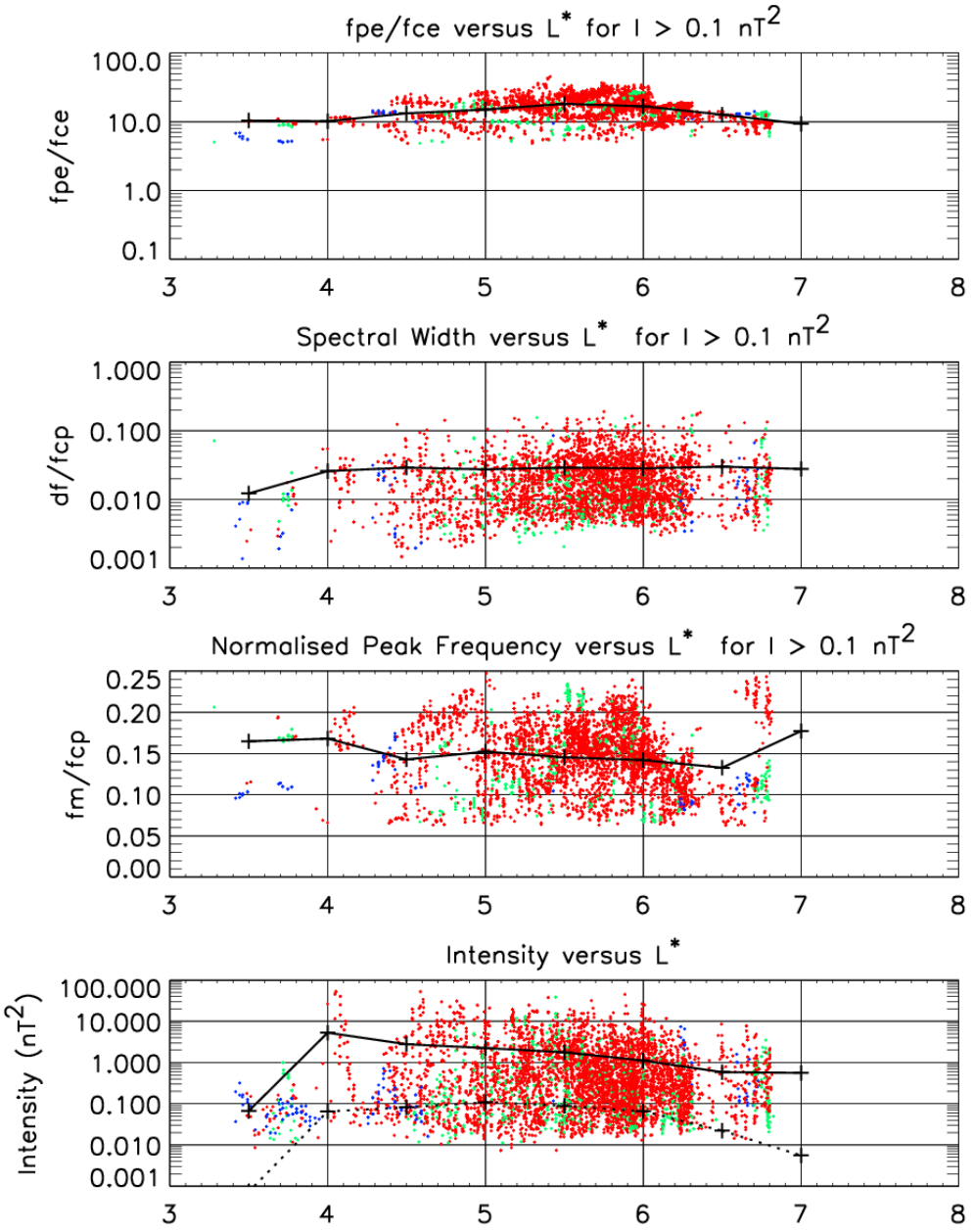
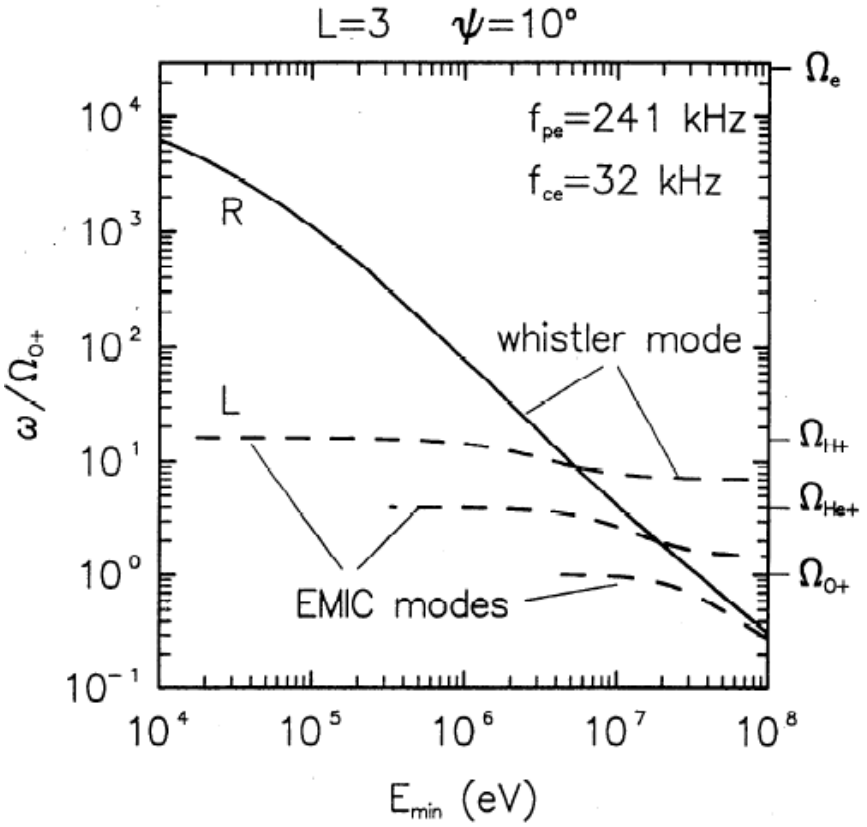
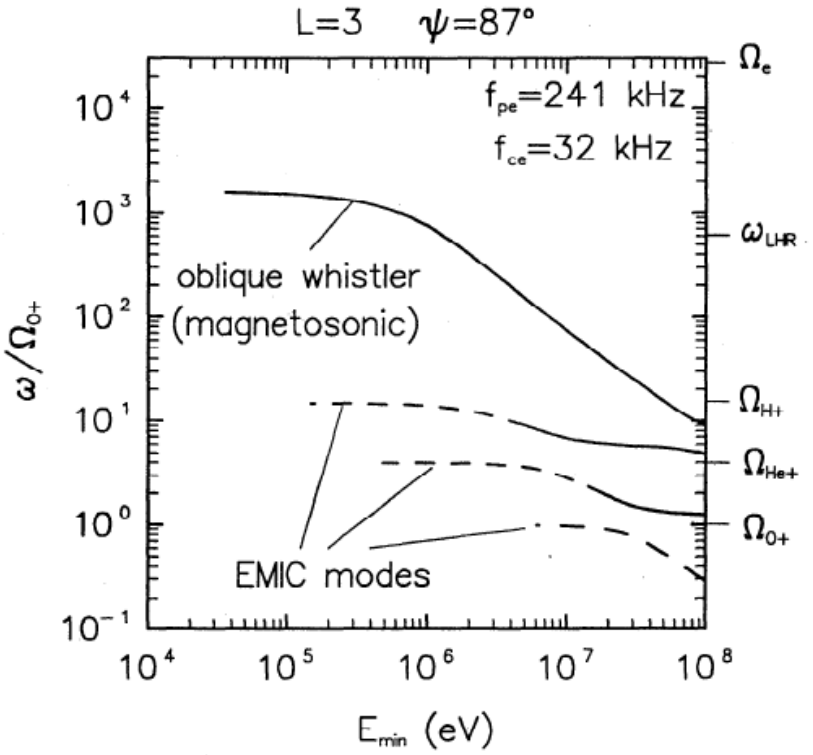
EMIC Variability

- How close to fcHe?



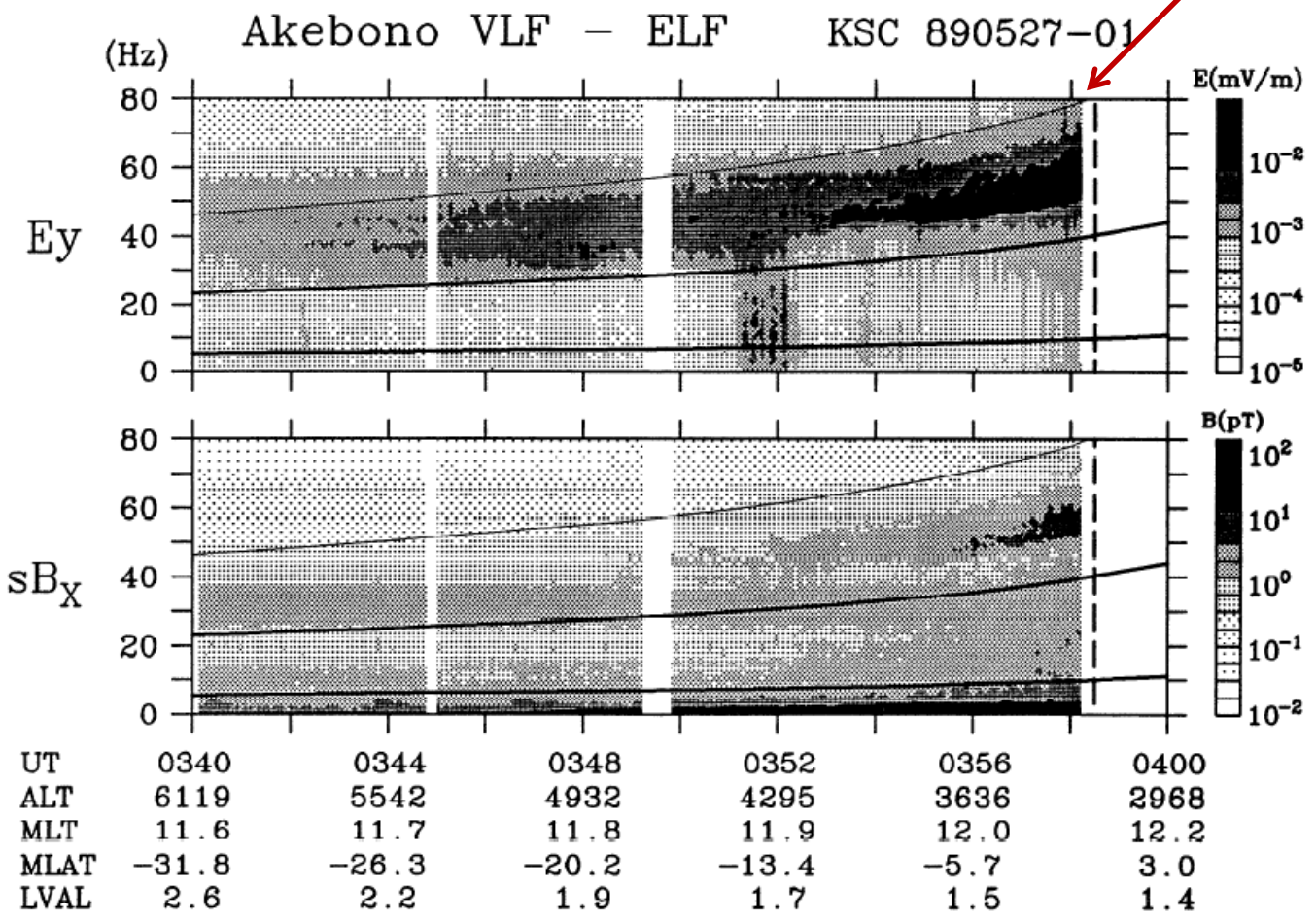
EMIC – Resonant Energy





- For EMIC – f closer to fcHe, lower Eres

EMIC at L = 1.7 – RBSP?
And how can you generate them?



- Kasahara et al. [1994]
- Akebono

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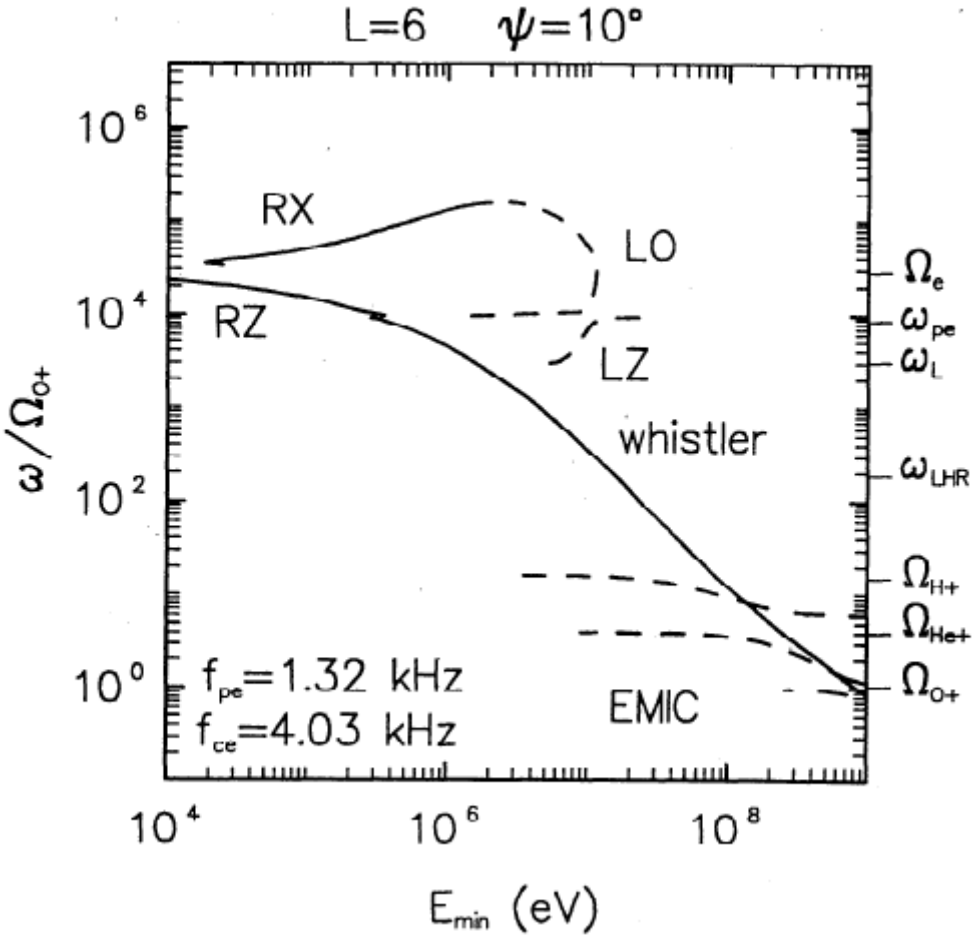
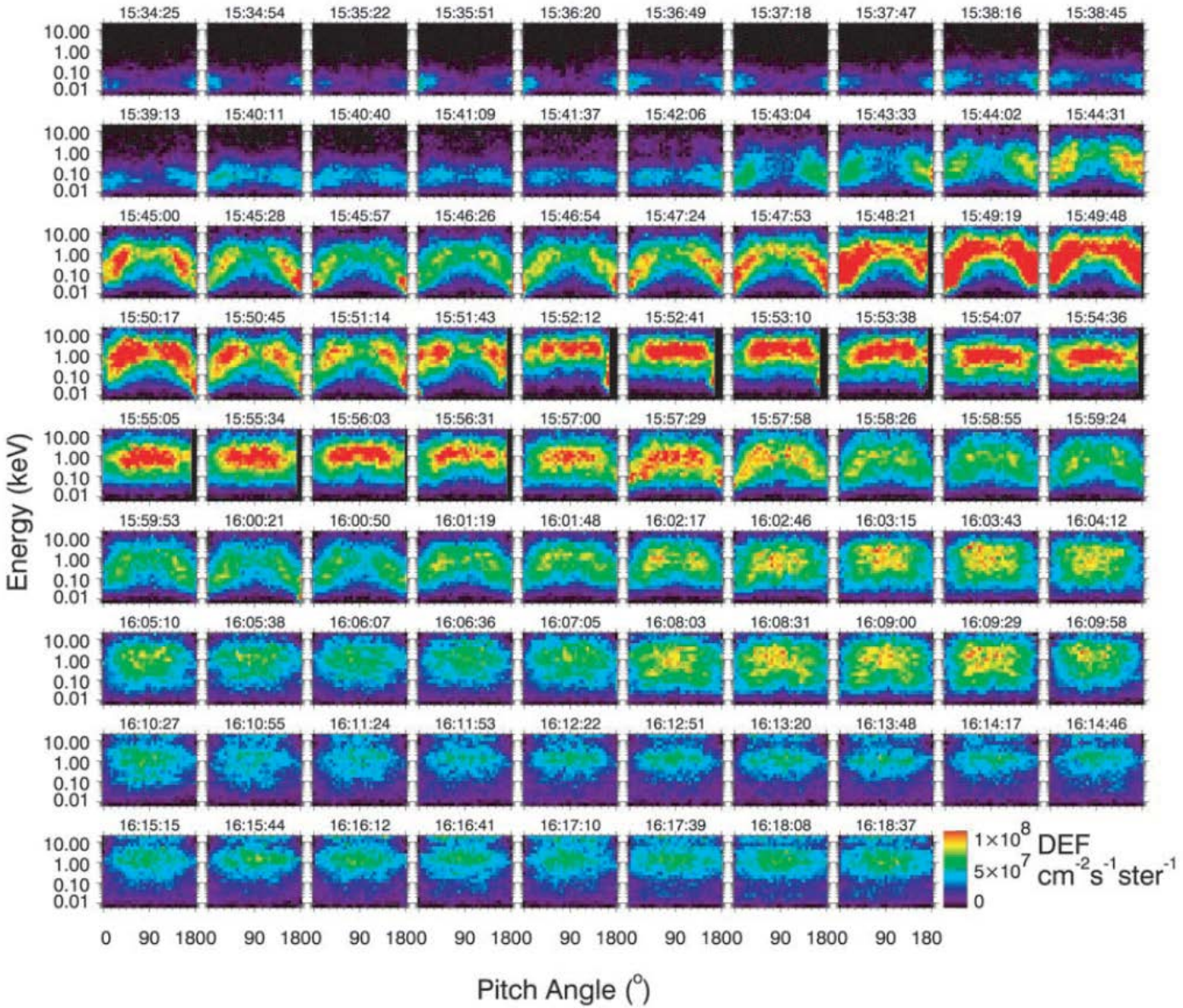
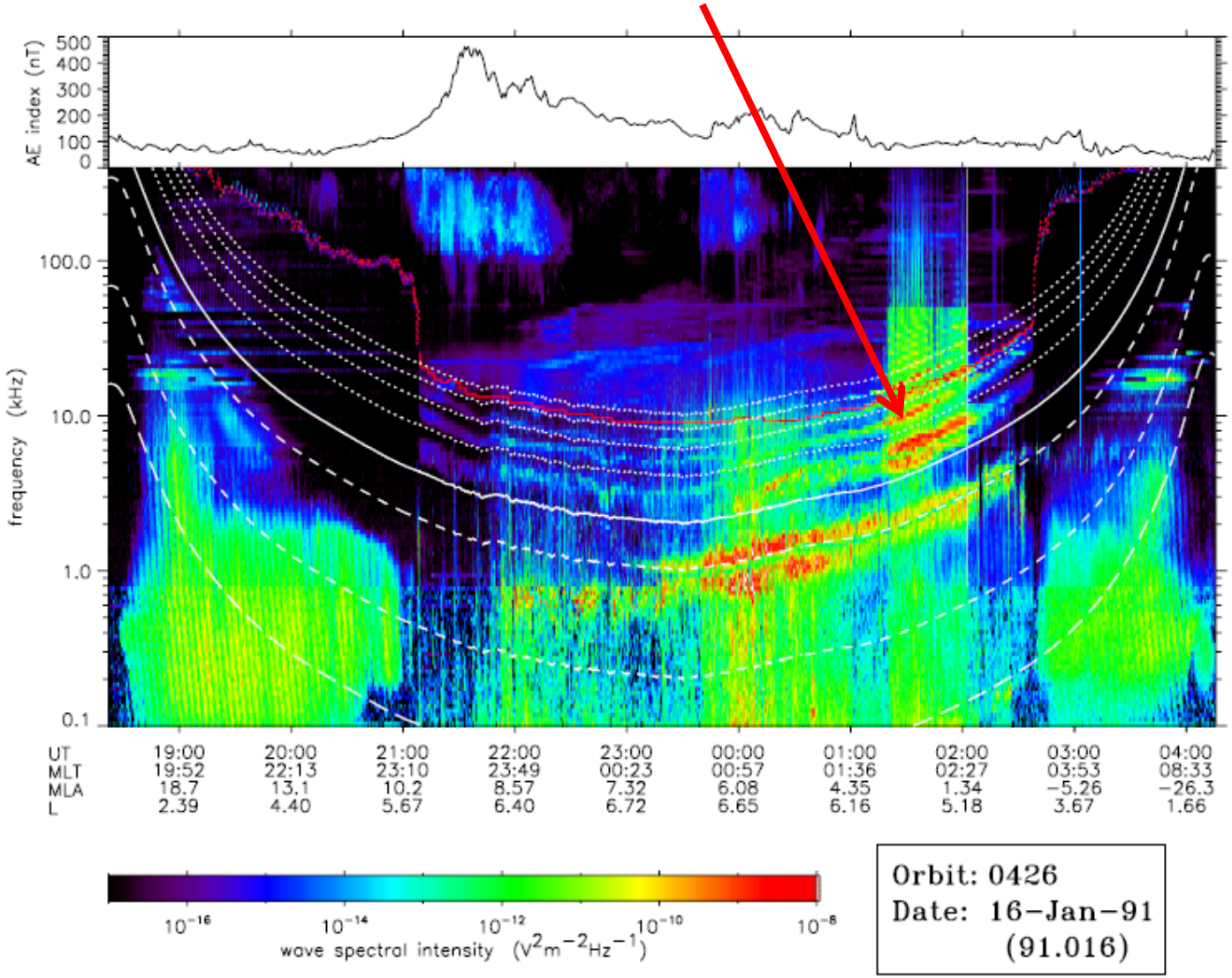
Other Wave modes?



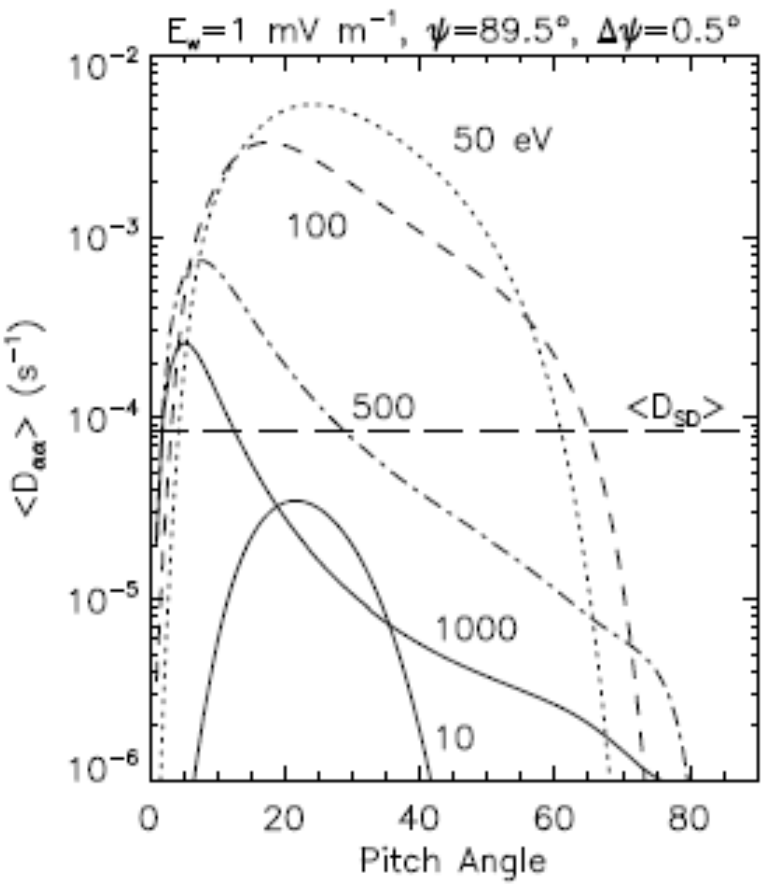
Abel et al. JGR [2002] L=6.8 0705 MLT
Spin Averaged, 30s between plots AE > 468 nT

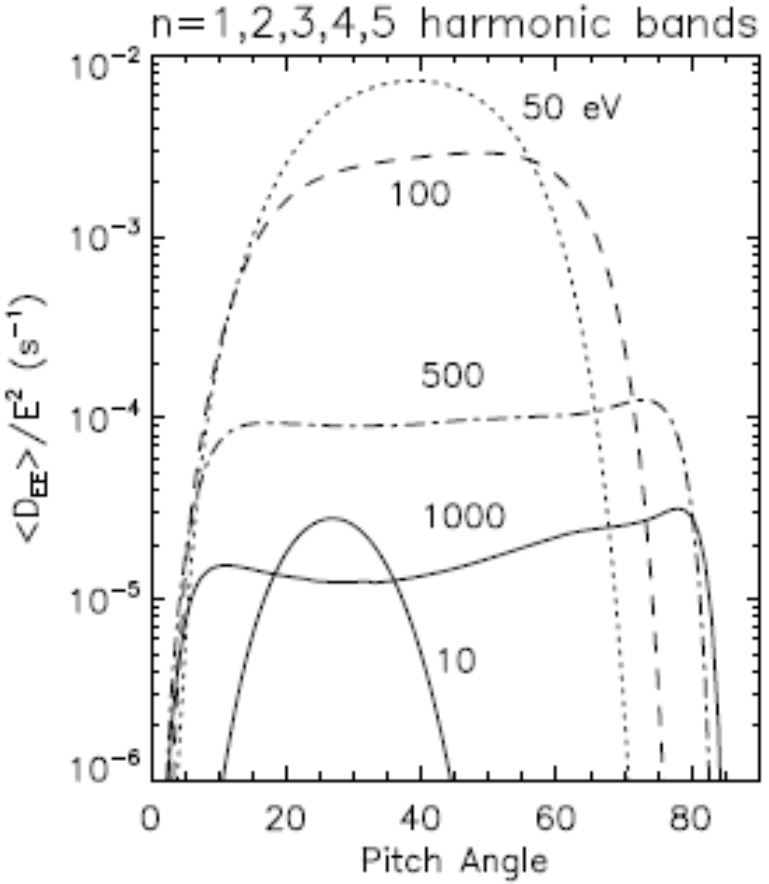


ECH Waves at the Equator



Electron diffusion by ECH waves at the Equator





- Horne GRL [2015]
- Hope data?

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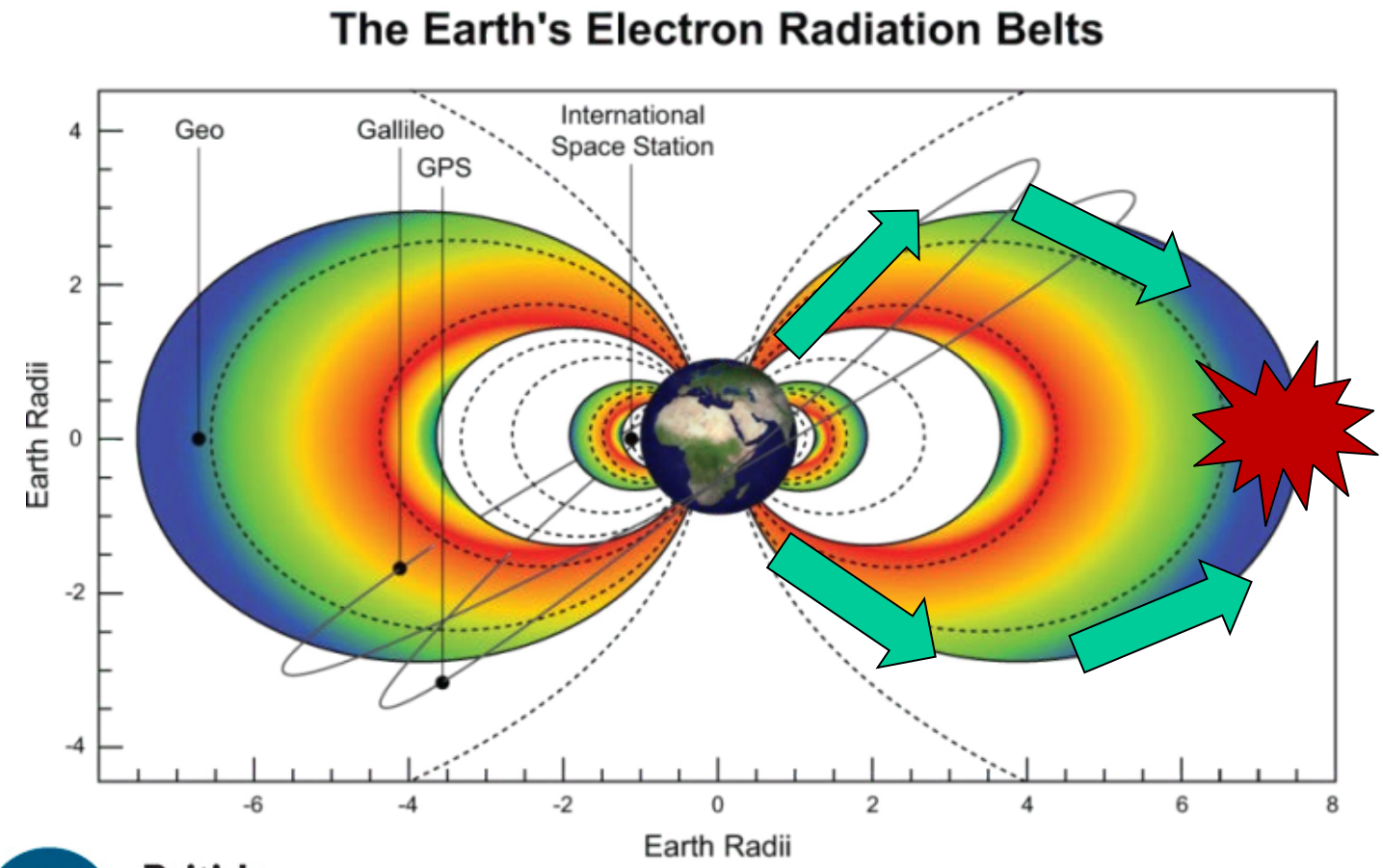
Concept

- Ionospheric source of low energy electrons – how important?
- ECH waves play a role in the M-I current system



Wave-particle interactions trap the electrons in space

Electrons also accelerated from < 100 eV to few keV and form a source for further acceleration

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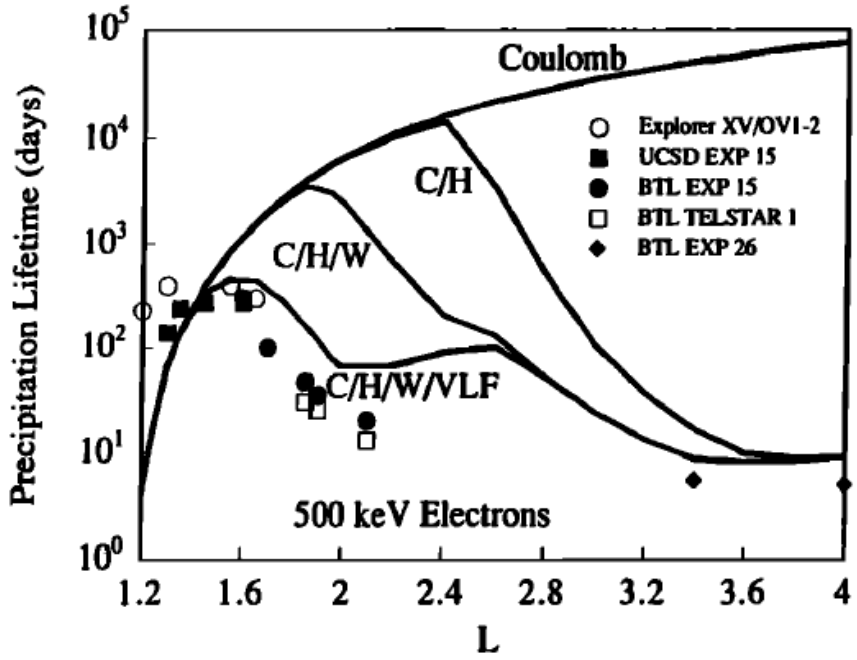
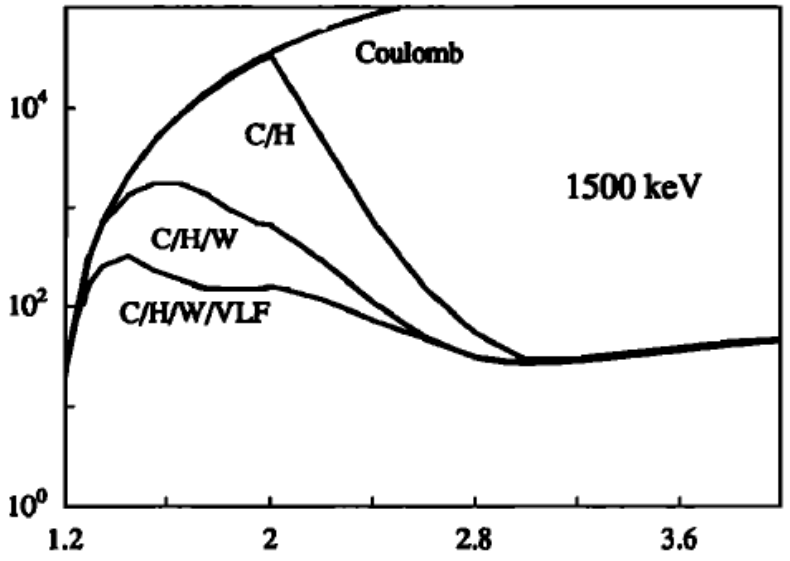
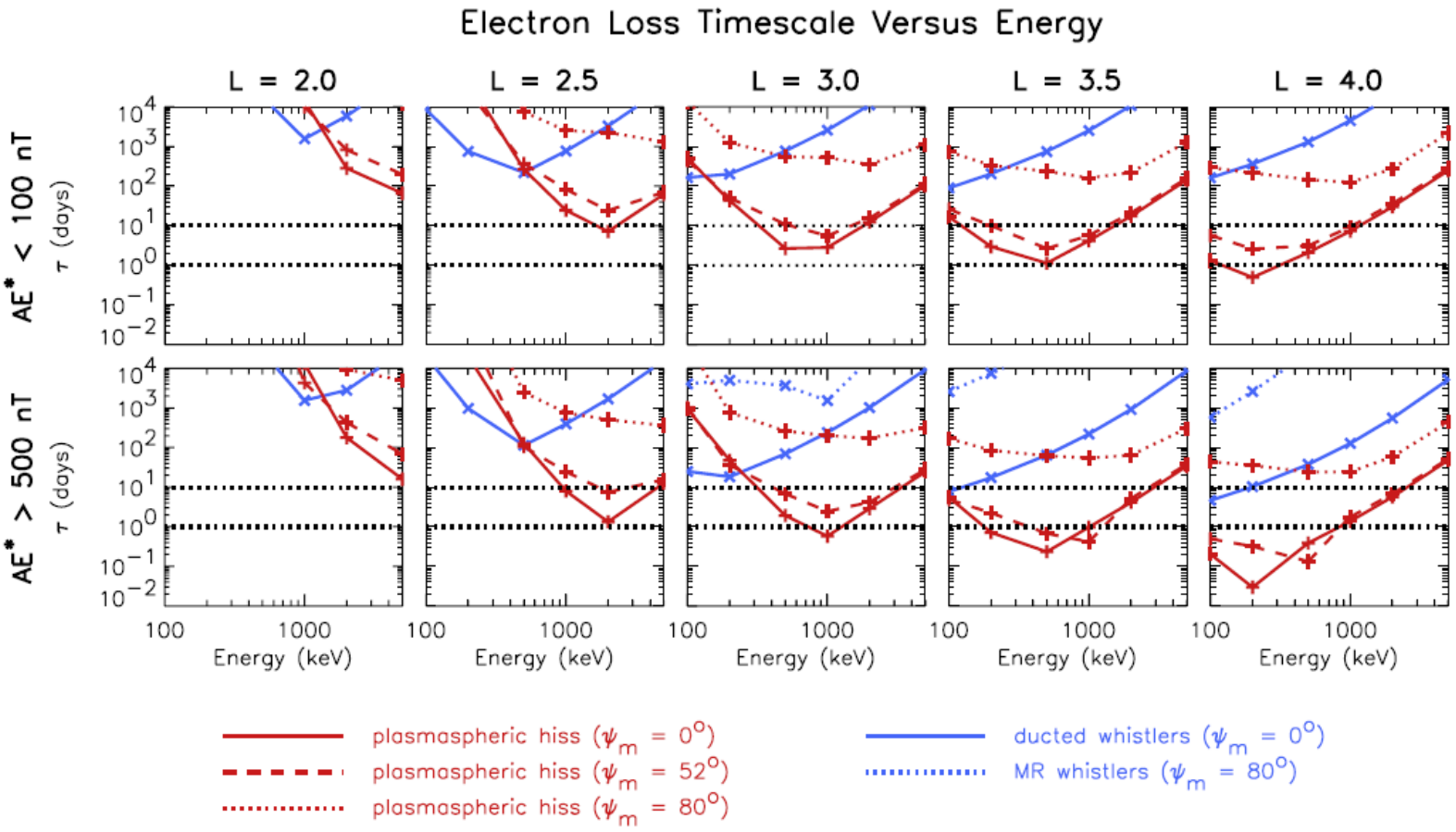
- Abel and Thorne JGR [1998]



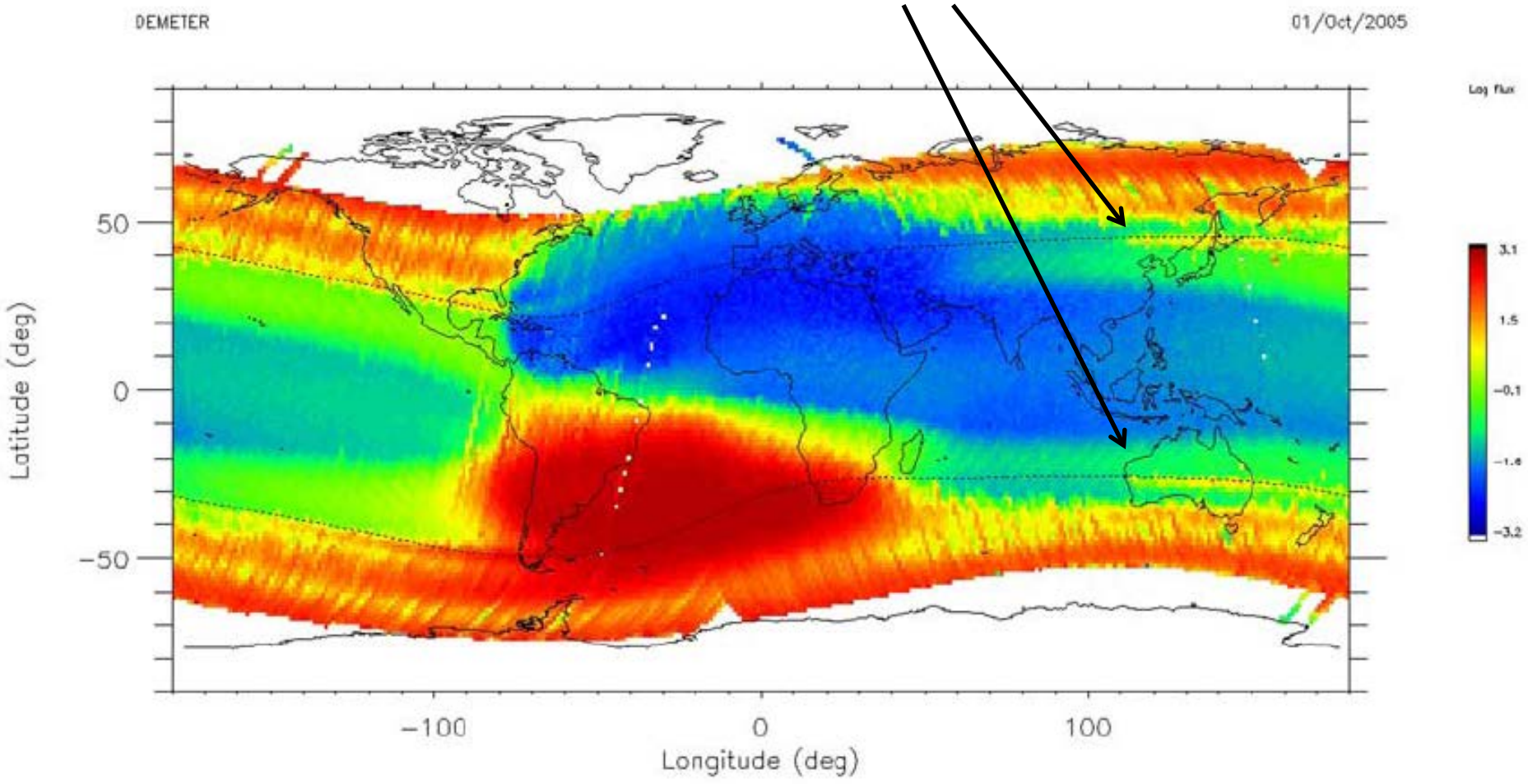


Hiss Matrix - Slot Region losses



- Meredith et al [2007]

Electron Precipitation due to NWW Transmitter



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- Sauvaud et al. [2008]
- Rodger et al. [2009]

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