How Well do we Understand the Global Excitation of Magnetospheric Whistler-mode Chorus?

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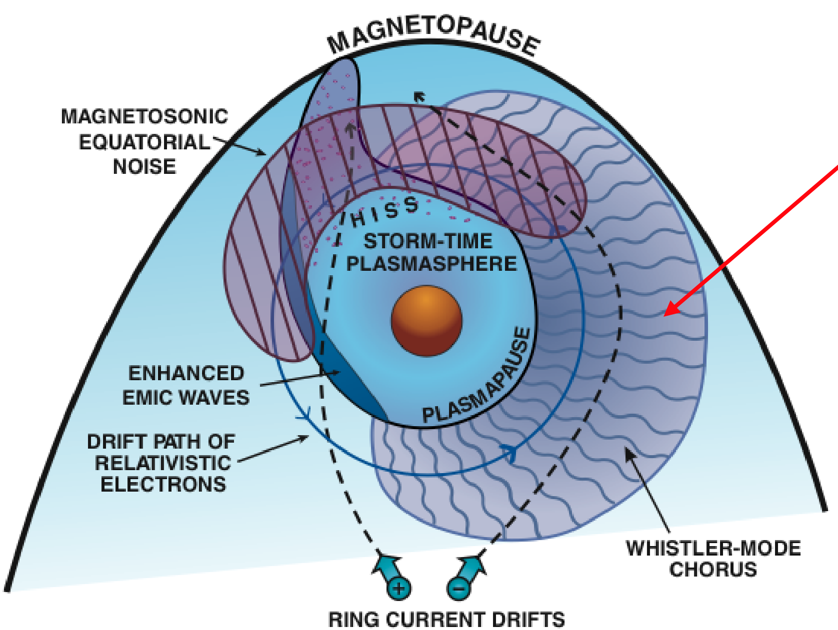
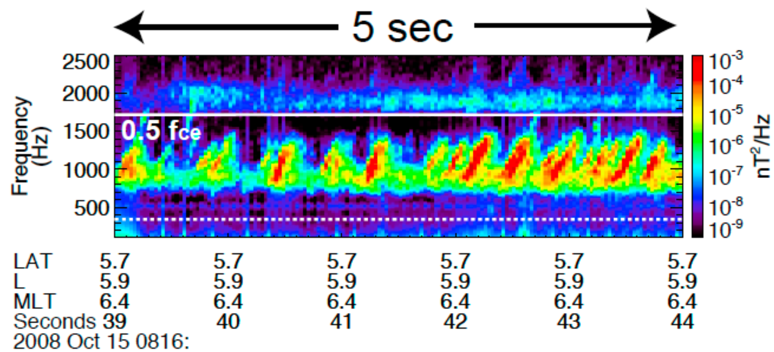




- Use THEMIS electron observations to evaluate linear wave growth rates.
- New simulation of role of chorus on the electron scattering in the outer radiation belt using the RAM-SCB code.

RBSP Meeting, APL, May, 2012

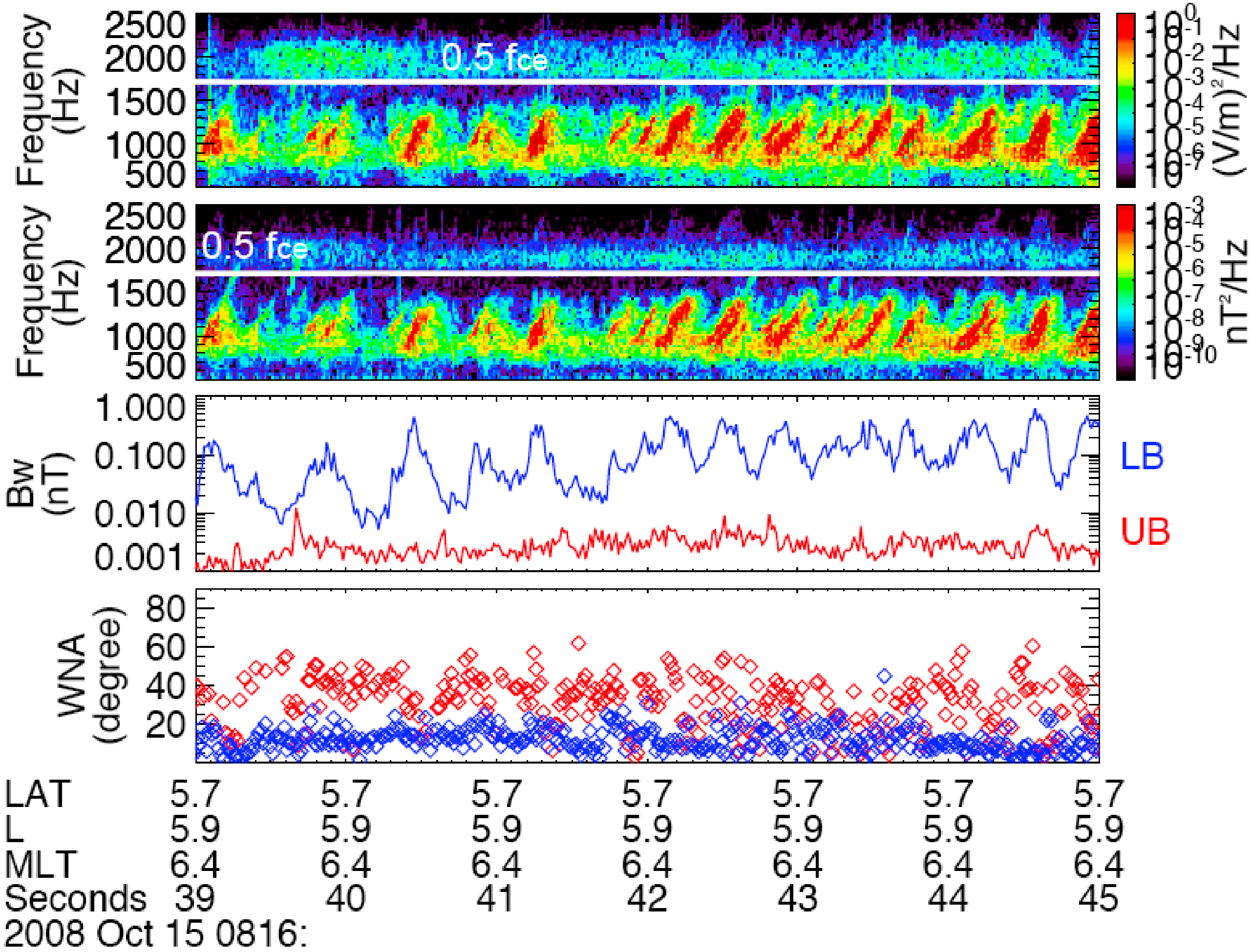
Typical Properties of Chorus Emissions

Wave E

Wave B

B_w

WNA



Lower-band

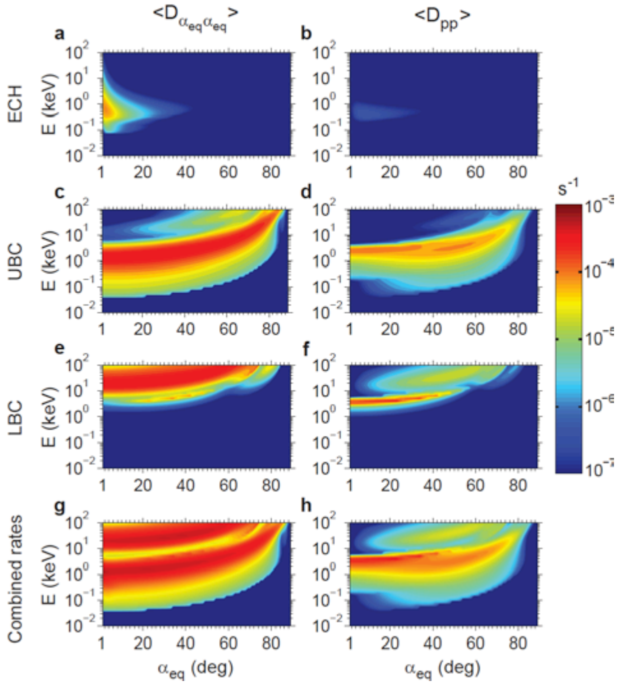
- ➢B_w reaches up to ~ 500 pT.
- ➢WNA < ~20° .

Upper-band

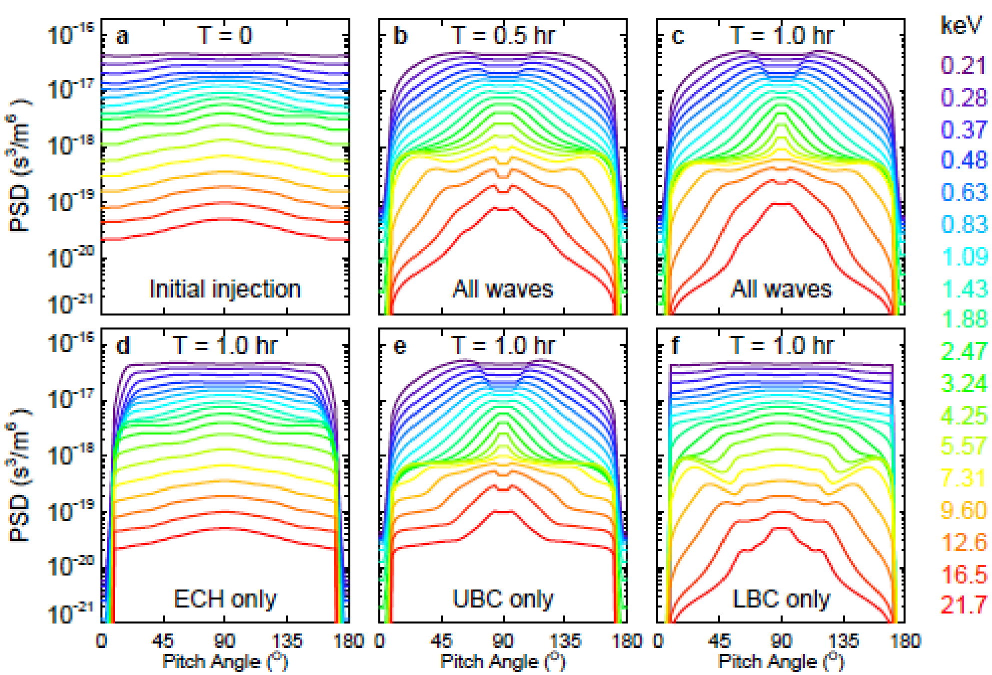
- ➢B_w is small (<10 pT).
- ➢WNA is very oblique.

Role of Chorus in Diffuse Auroral Precipitation

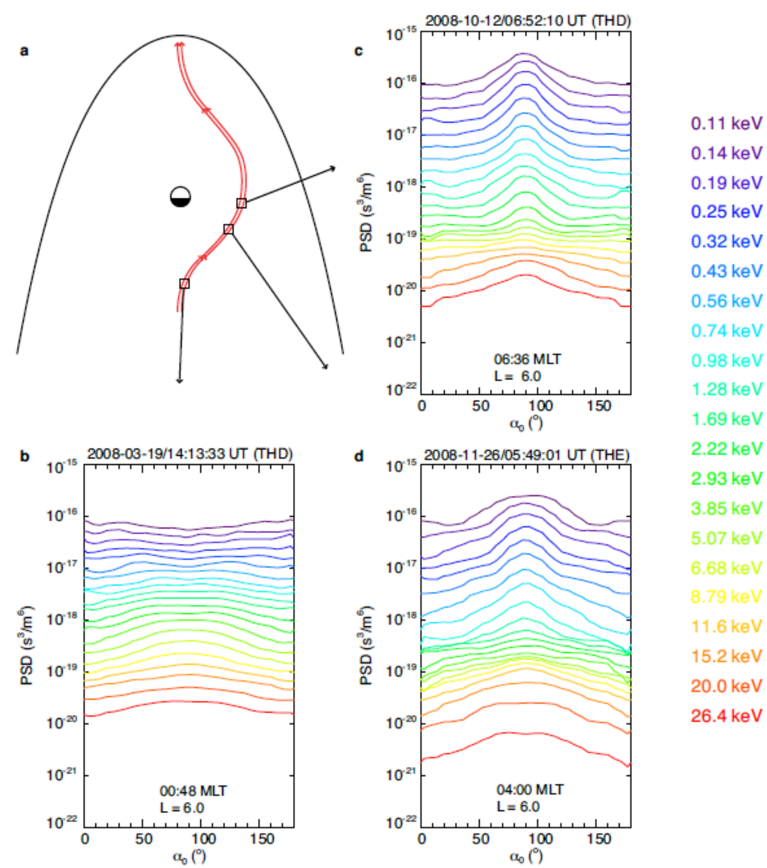
$$\frac{\partial f}{\partial t} = \frac{1}{Gp}\frac{\partial}{\partial \alpha} G\left(D_{\alpha\alpha}\frac{1}{p}\frac{\partial f}{\partial \alpha} + D_{\alpha p}\frac{\partial f}{\partial p}\right) + \frac{1}{G}\frac{\partial}{\partial p} G\left(D_{\alpha p}\frac{1}{p}\frac{\partial f}{\partial \alpha} + D_{pp}\frac{\partial f}{\partial p}\right),$$



Numerical Simulation:
Thorne et al., Nature 2010.
Tao et al.,JGR 2011.



THEMIS observations

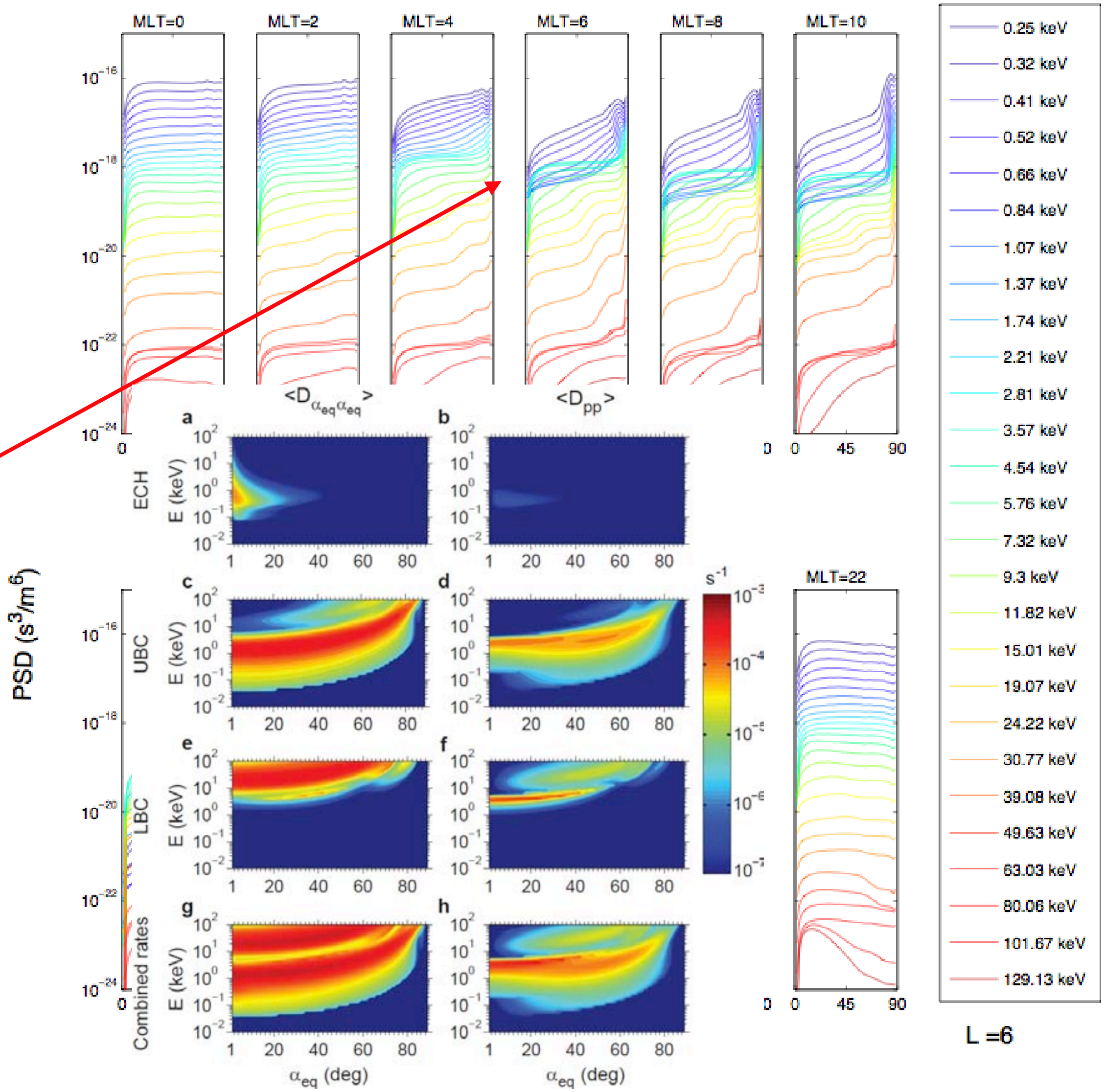


RAM-SCB Simulations of Electron PSD using Pitch-Angle Scattering Rates for Nightside Chorus

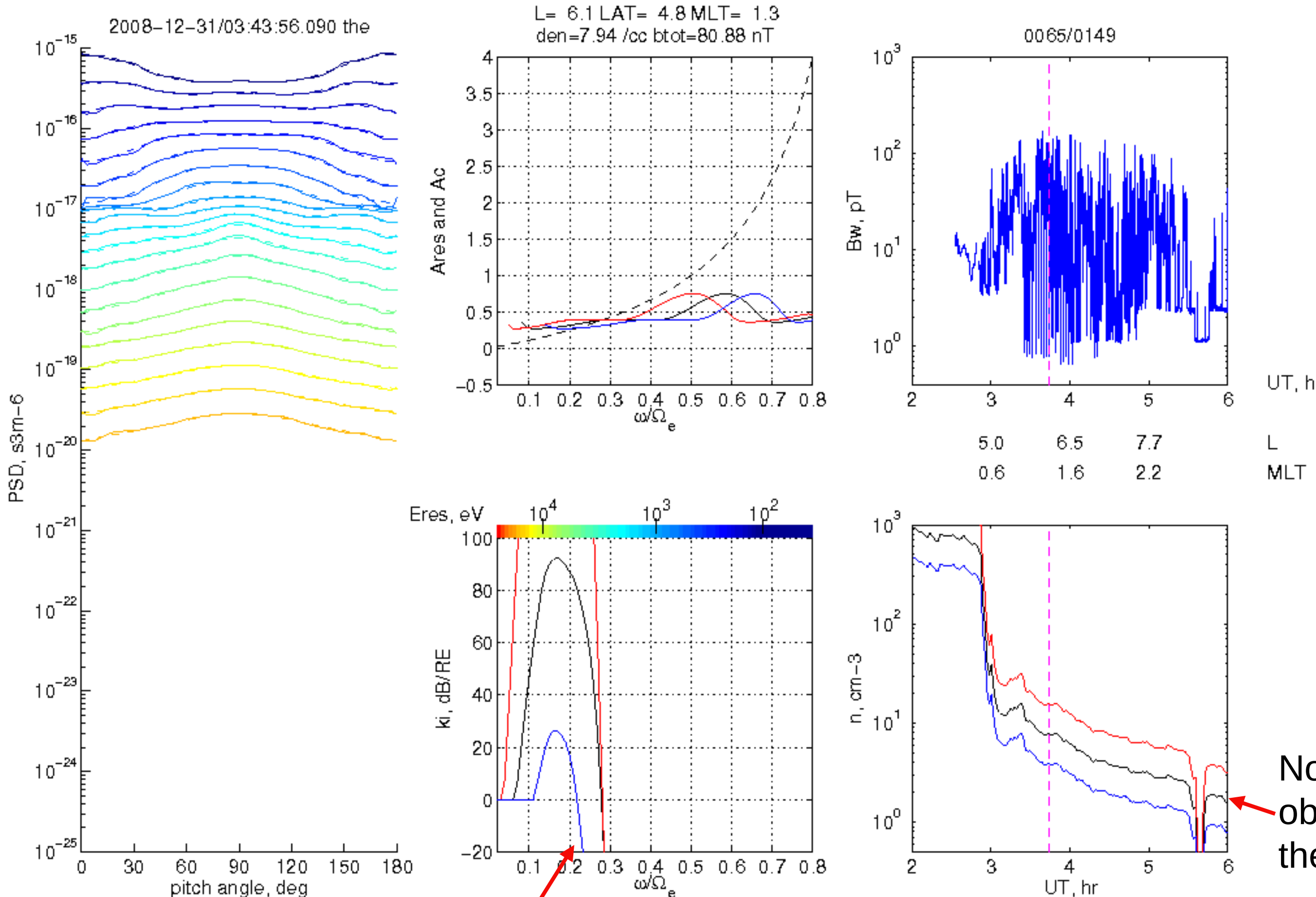
Isotropic electrons are injected along the nightside outer boundary at 6.6 Re.

Electrons are subject to pitch-angle scattering by nightside chorus and ECH

During transport to the dayside electrons are subject to loss to the atmosphere leading to pronounced pancake distributions at E < keV and increased anisotropy at E > 10 keV.



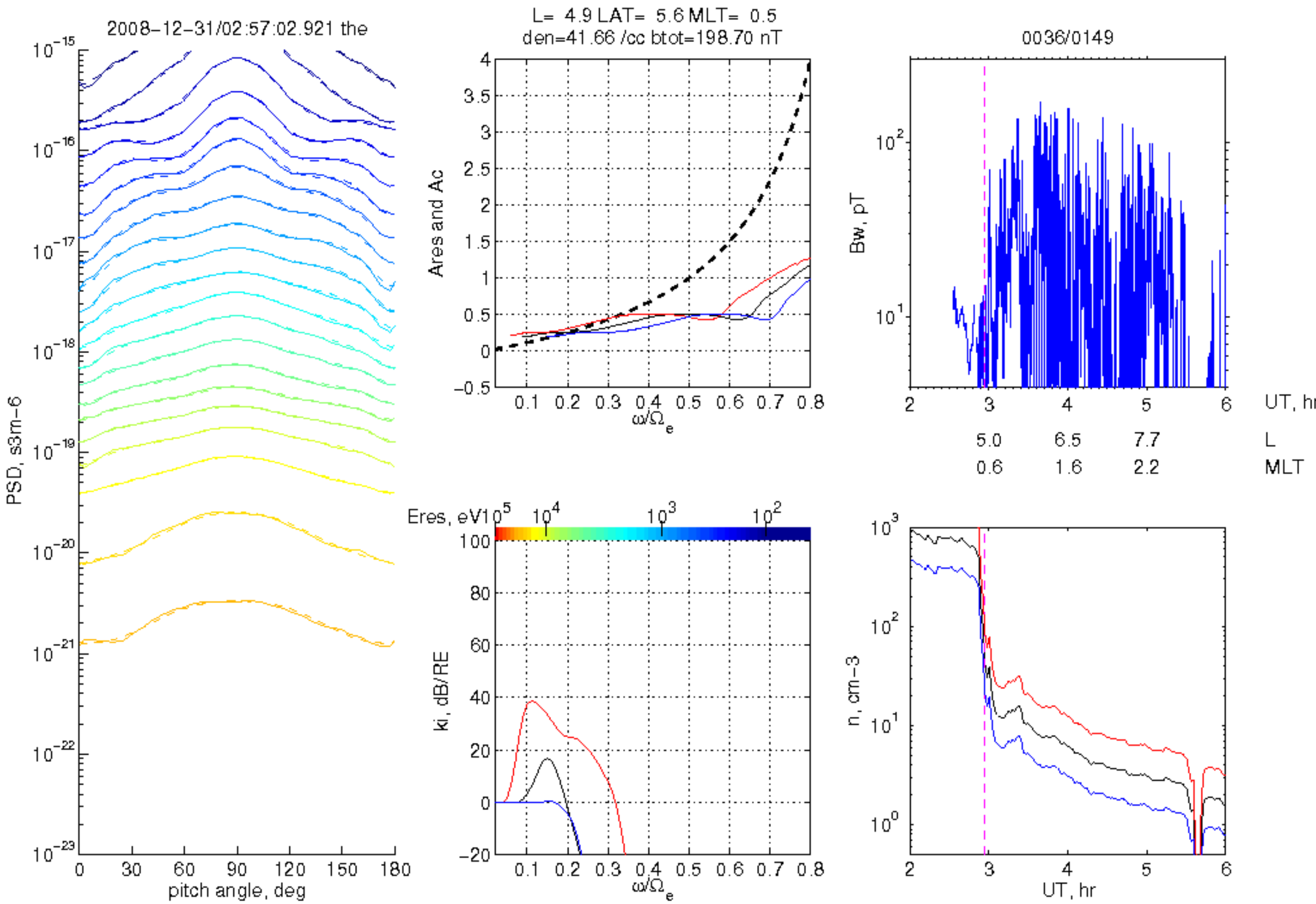
Chorus Excitation During Electron Injection on the Nightside



Nominal density obtained from the SS potential

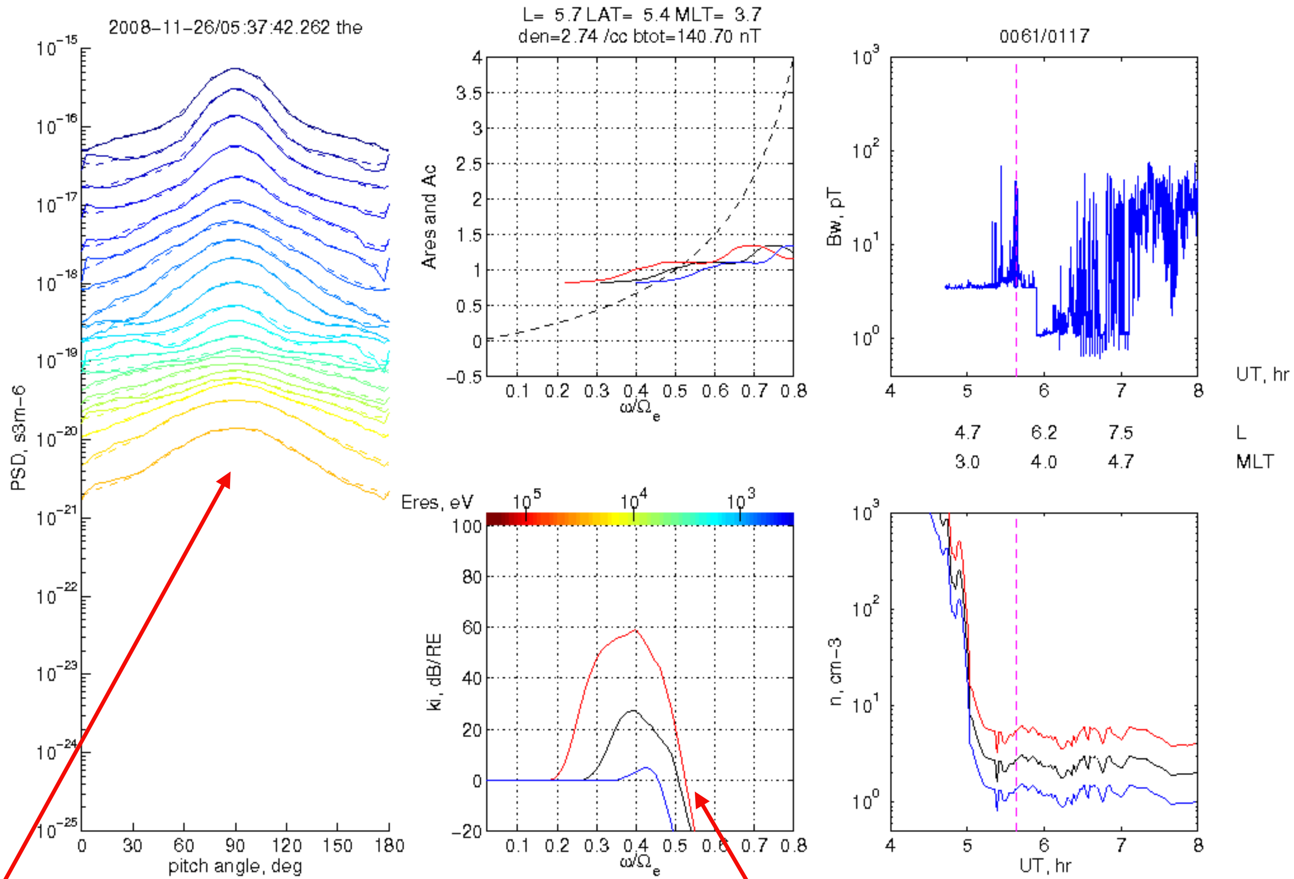
Extremely strong wave amplification in the lower band (< fce/2) by cyclotron resonant instability with anisotropic ~ few- 10’s keV electrons. Non-linear processes [e.g., Omura et al., 2008] should lead to rising frequency elements, which could extend into the upper band.

Movie of Chorus Excitation on the Nightside



Anisotropic plasma sheet electrons between a few keV -30 keV provide a source for strong cyclotron resonant instability of lower band chorus for 5<L<8, but there is insufficient anisotropy at energies less than a keV to excite upper band waves.

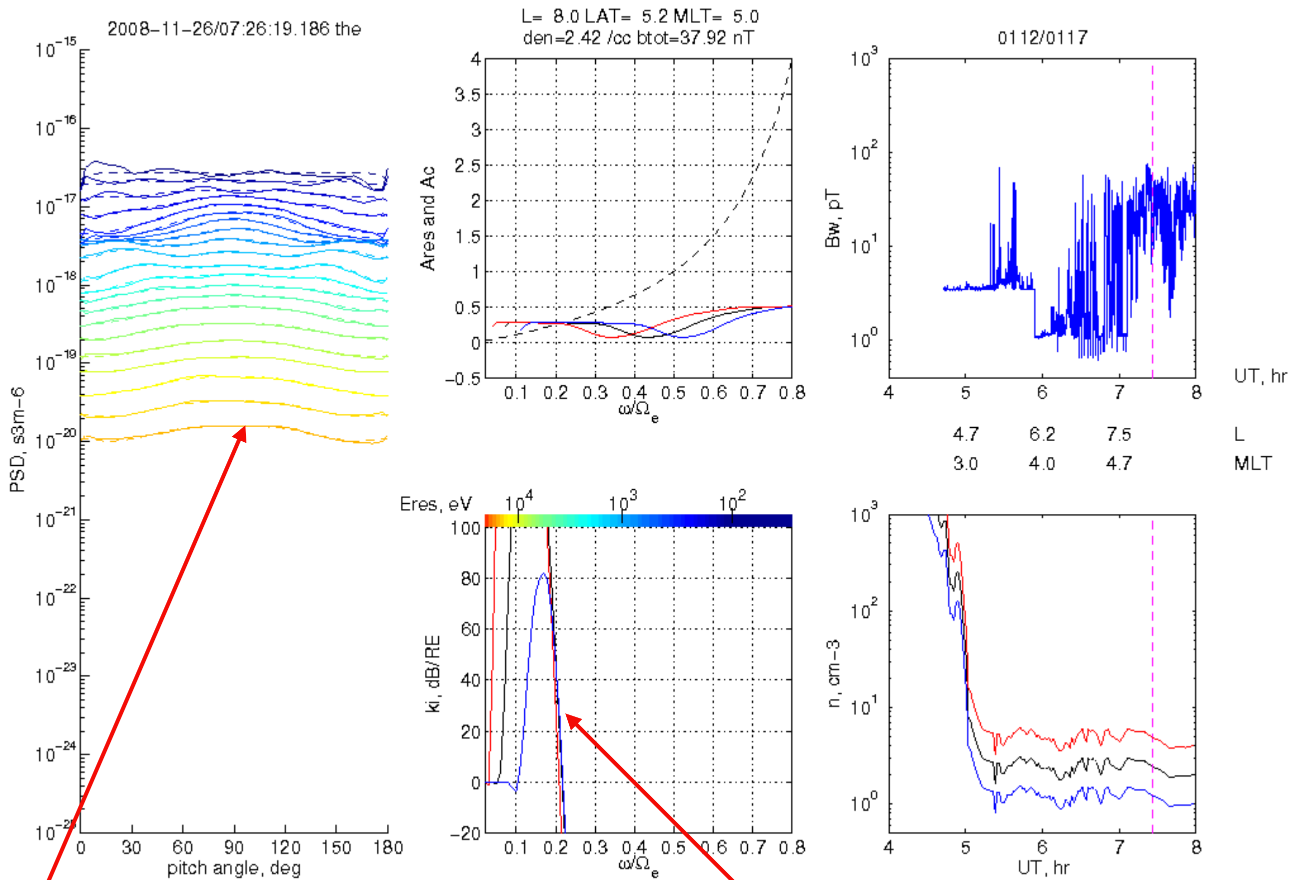
Chorus Excitation Near Dawn at low L



Evolution of highly anisotropic electron distributions due to the combined scattering by upper and lower band chorus.

Moderate convective gain in the lower band for frequencies up to fce/2.

Chorus Excitation Near Dawn at High L



Electron distributions similar to those seen during injection events near midnight.

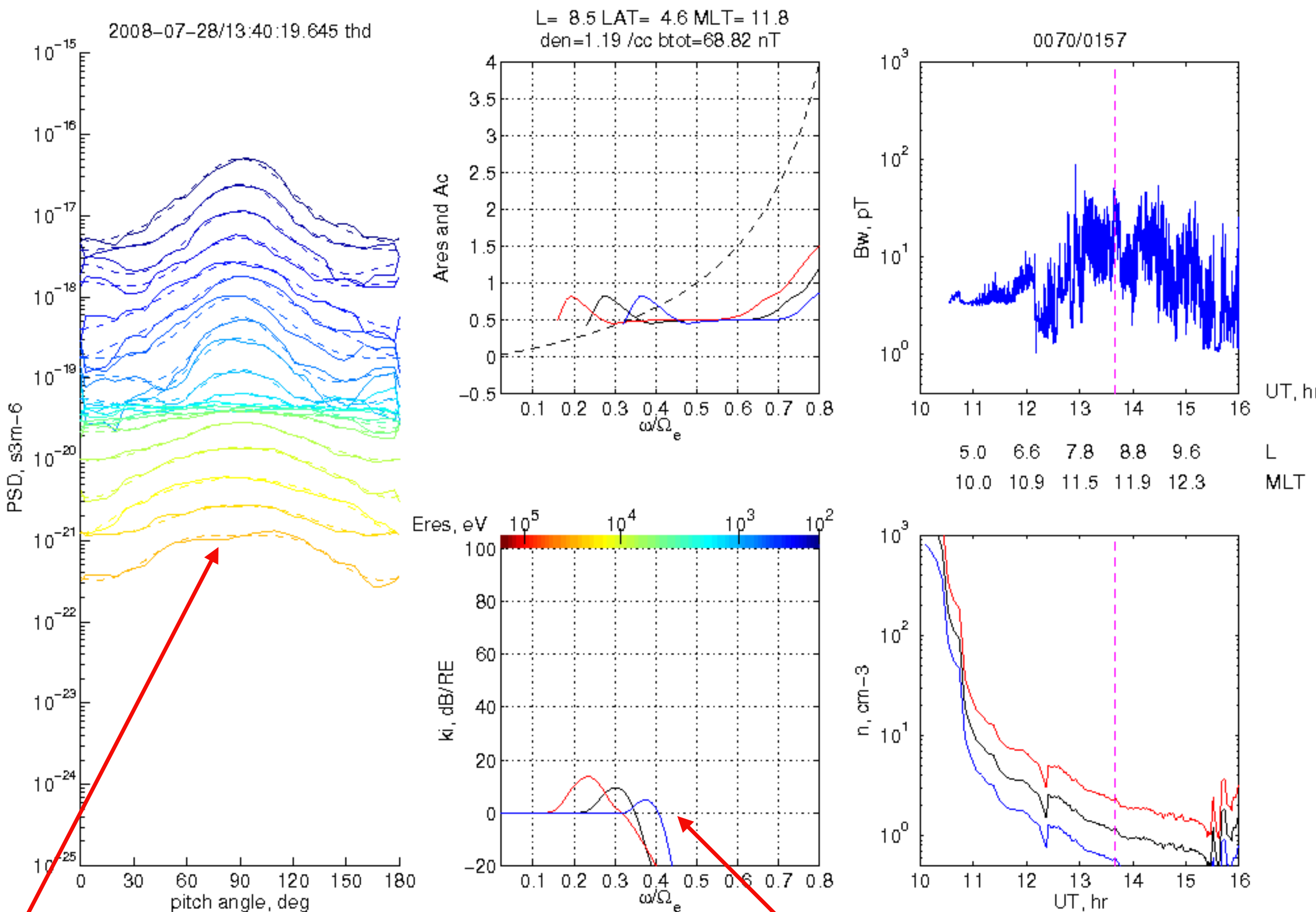
Very strong convective growth in the lower band at higher L.

Movie of Chorus Excitation Near Dawn

QuickTime™ and a
Animation decompressor
are needed to see this picture.

Notice the changing electron distribution as THEMIS moves outwards to higher L: with the highly anisotropic distributions anticipated from rapid upper band chorus scattering at L< 6, and the increased flux of mildly anisotropic high energy electrons at L > 7.

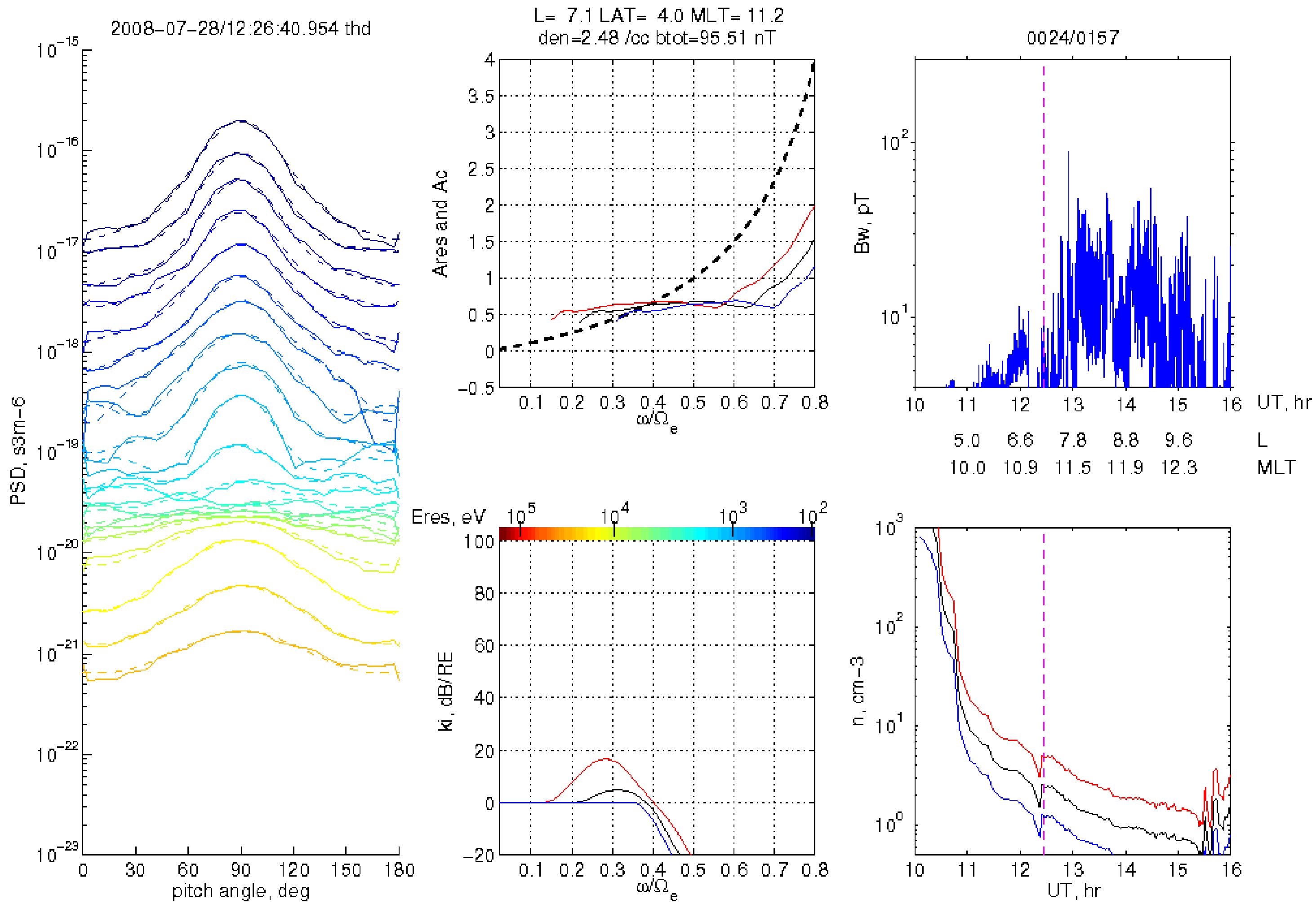
Chorus Excitation on the Dayside



Depleted electron flux exhibiting characteristic PSD distributions anticipated from scattering by lower and upper band chorus. [Tao et al., JGR 2011]

Very modest wave growth from electron distributions close to marginal stability.

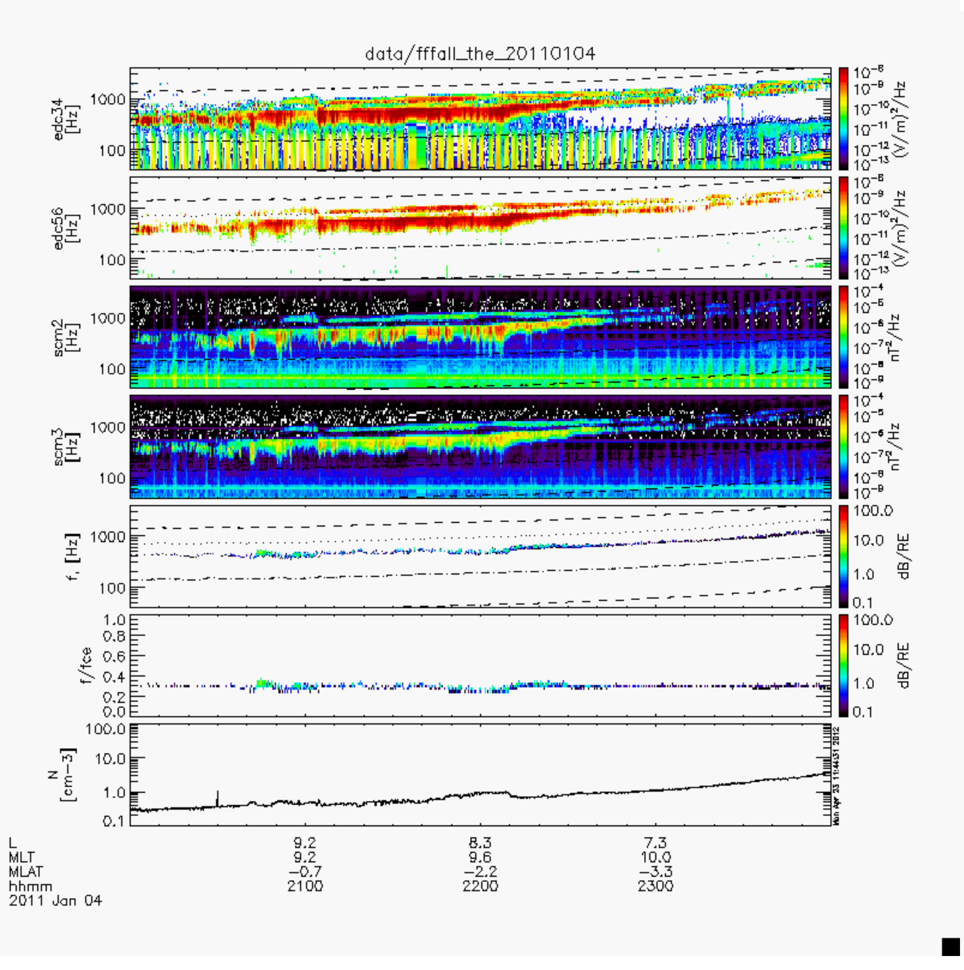
Movie of Chorus Excitation on the Dayside



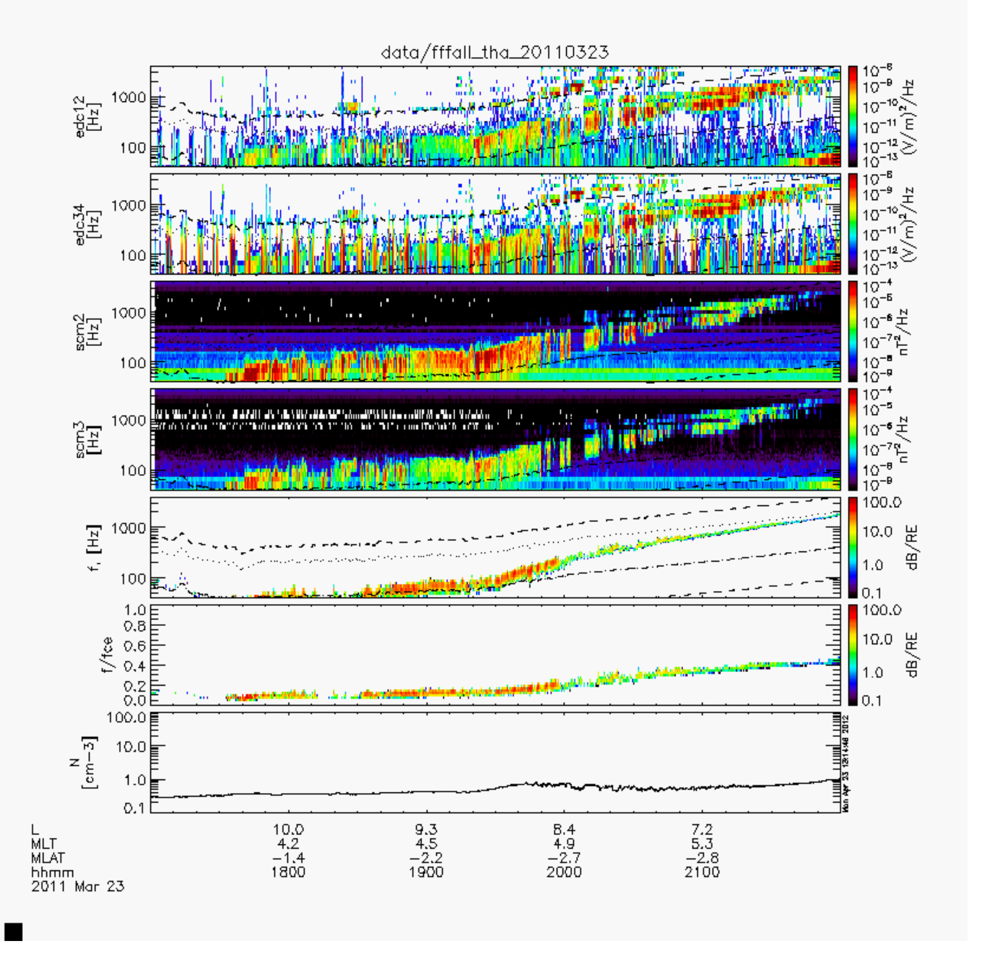
The depleted but highly anisotropic higher energy electron flux present throughout the dayside appears to be close to marginal stability, but the measured lower energy pancake distributions have insufficient anisotropy to lead to linear wave growth of upper band chorus.

Convective Growth Rates Determined by Local Electron Distributions

Dayside chorus



Nightside chorus



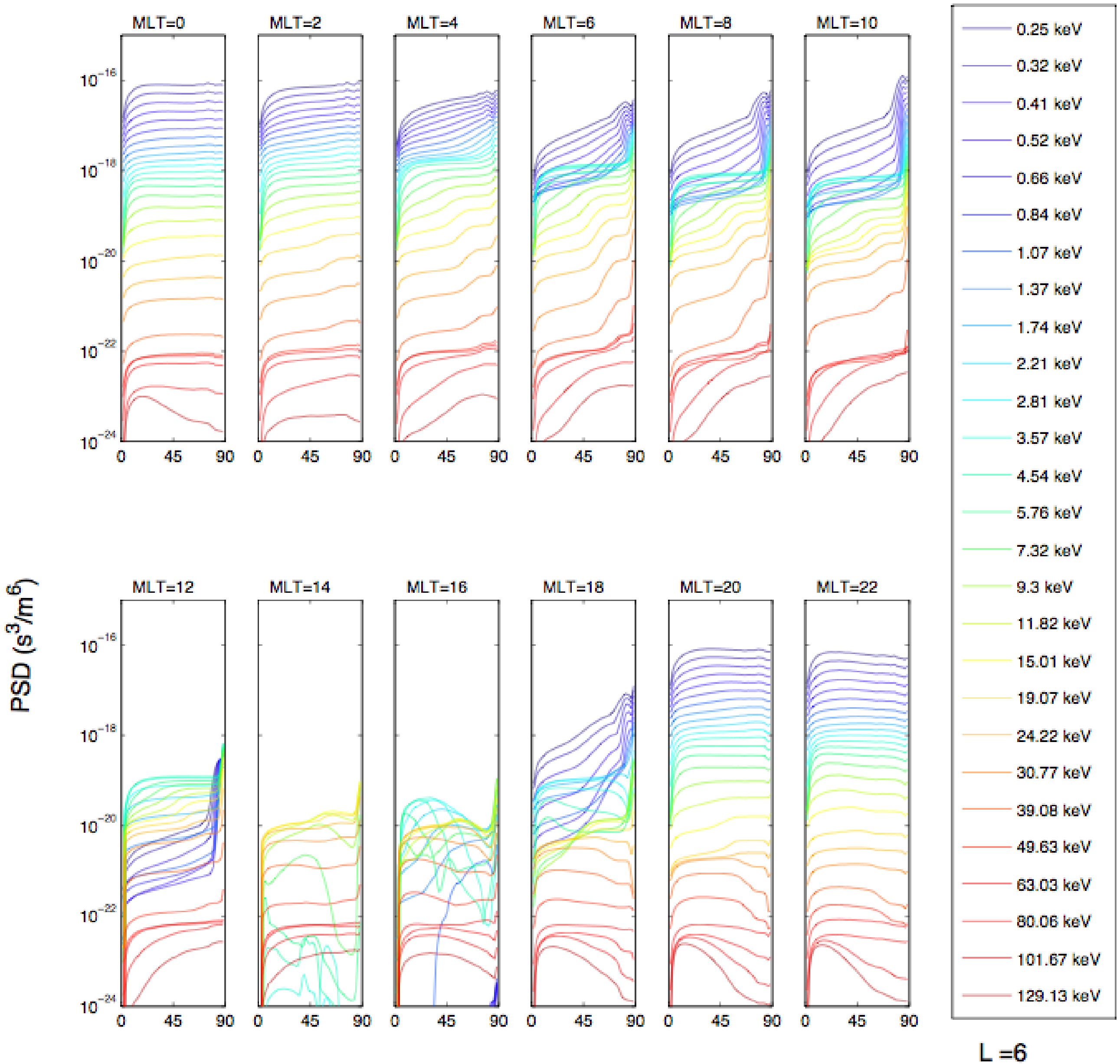
What is the Excitation Mechanism for Upper band Chorus?

Upper band waves are observed with little anisotropy at low energies. Consequently we suggest that the upper band waves are probably a consequence of non-linear processes; namely rising chorus elements.

QuickTime™ and a
Animation decompressor
are needed to see this picture.

Conclusions

- Linear wave growth calculations indicate that measured electrons distributions injected into the nightside magnetosphere are capable of producing rapid wave amplification at frequencies below fce/2 leading to the onset of non-linear processes.
- On the dayside the electron fluxes are depleted but remain close to marginal instability due to strong anisotropy resulting both from rapid night-side chorus scattering and drift shell splitting.
- A consequence of the marginal stable electron distributions is the triggering of instability by macroscopic changes in the plasma (density or B variations).
- There is little evidence for linear instability above fce/2, suggesting that upper band chorus is a result of non-linear processes, e.g. rising elements together with enhanced Landau damping near fce/2.
- RAM-SCB simulations of the transport of electrons from the nightside to the dayside including the scattering by a statistical distribution of chorus emissions, shows the characteristic development of extremely anisotropic pitch-angle distributions but will we be able to measure these?



MLT=0
MLT=2
MLT=4
MLT=6
MLT=8
MLT=10
MLT=12
MLT=14
MLT=16
MLT=18
MLT=20
MLT=22
PSD (s^3/m^6)
10^{-16}
10^{-18}
10^{-20}
10^{-22}
10^{-24}
0
45
90
0.25 keV
0.32 keV
0.41 keV
0.52 keV
0.66 keV
0.84 keV
1.07 keV
1.37 keV
1.74 keV
2.21 keV
2.81 keV
3.57 keV
4.54 keV
5.76 keV
7.32 keV
9.3 keV
11.82 keV
15.01 keV
19.07 keV
24.22 keV
30.77 keV
39.08 keV
49.63 keV
63.03 keV
80.06 keV
101.67 keV
129.13 keV
L =6