Global Distribution of EMIC Waves – CRRES Results

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IMC III Workshop, UCLA 23rd - 27th March, 2015


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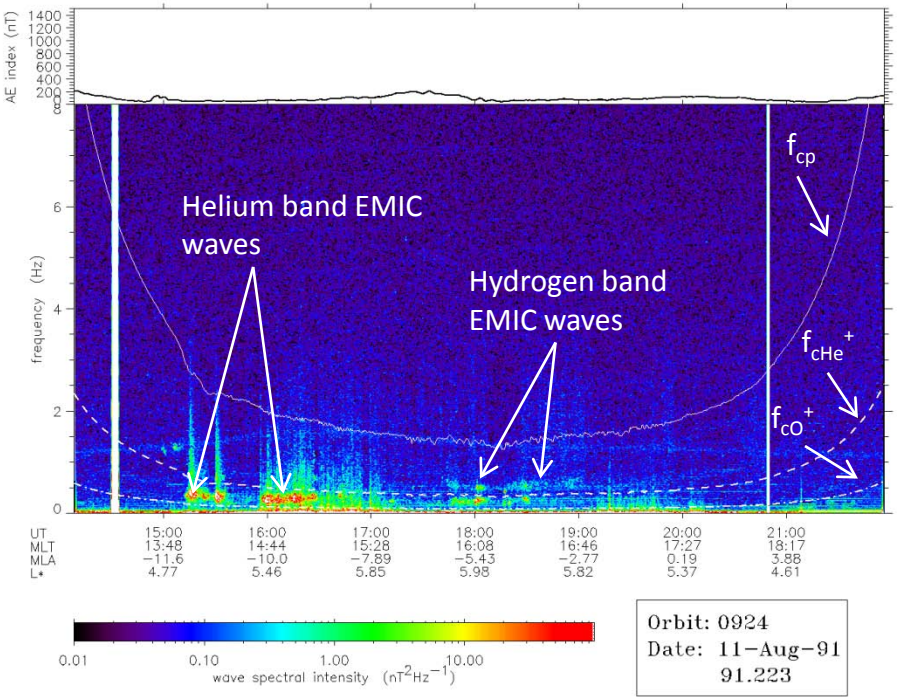
EMIC Waves

- EMIC waves are low frequency waves (0.1-5 Hz) which are mainly excited in two bands below the proton gyrofrequency:
  - hydrogen band waves
  - helium band waves
- These waves may be an important loss process for the radiation belts
- To assess their role in radiation belt dynamics we have produced a database of EMIC waves

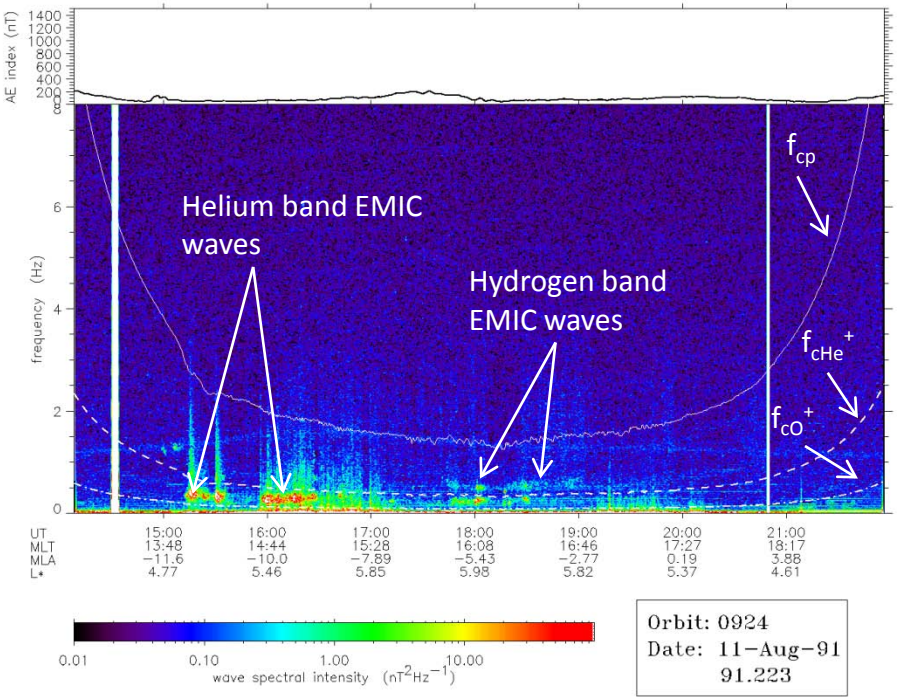


EMIC Waves

- Data on EMIC waves obtained from spectral analysis of measurements from the CRRES Fluxgate Magnetometer Instrument

- Wave spectrograms in the frequency range 0-8 Hz provided at a 25 s time resolution throughout the CRRES mission by Brian Fraser (U. Newcastle)

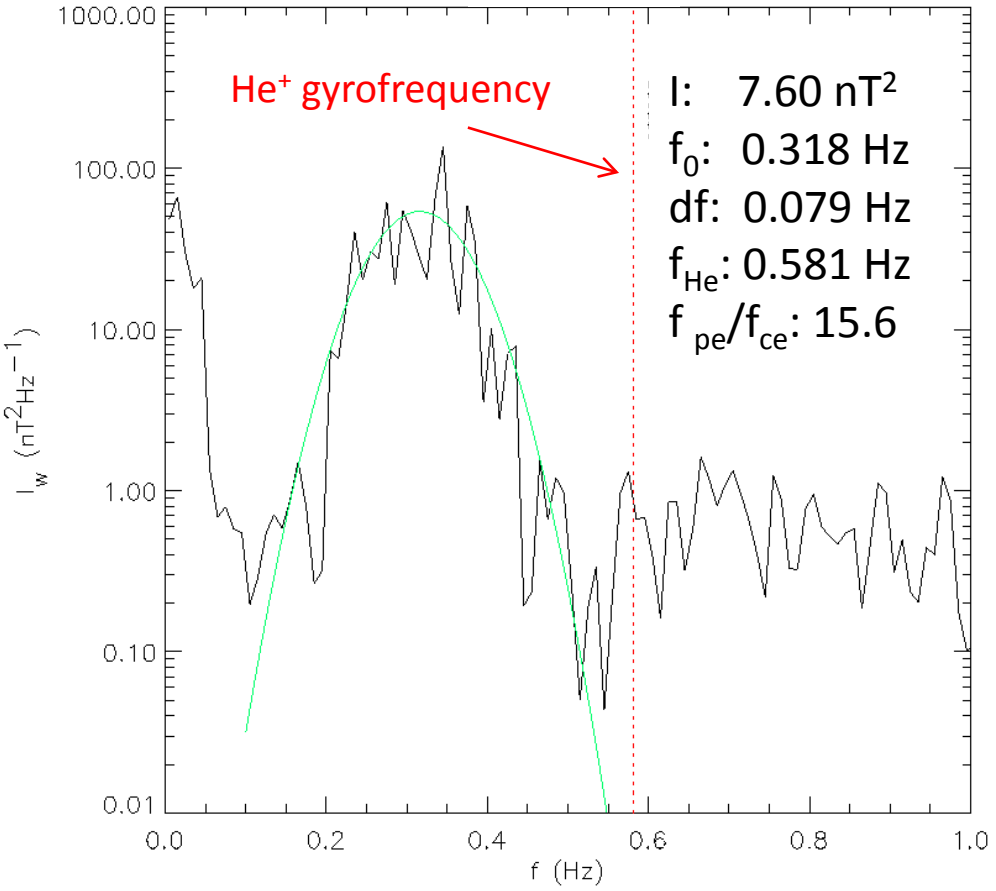
- Total of 796,523 useable spectral profiles



Gaussian Fits

- We fitted Gaussian profiles to the wave spectra in the hydrogen and helium bands
- To avoid fitting to spurious peaks we restricted the fitting to the 830 EMIC wave event intervals identified by Fraser and Nguyen [2001]
- The EMIC wave intervals covered 96 hours of the analysed 7248 hours, equivalent to 1.33 % of the total observations

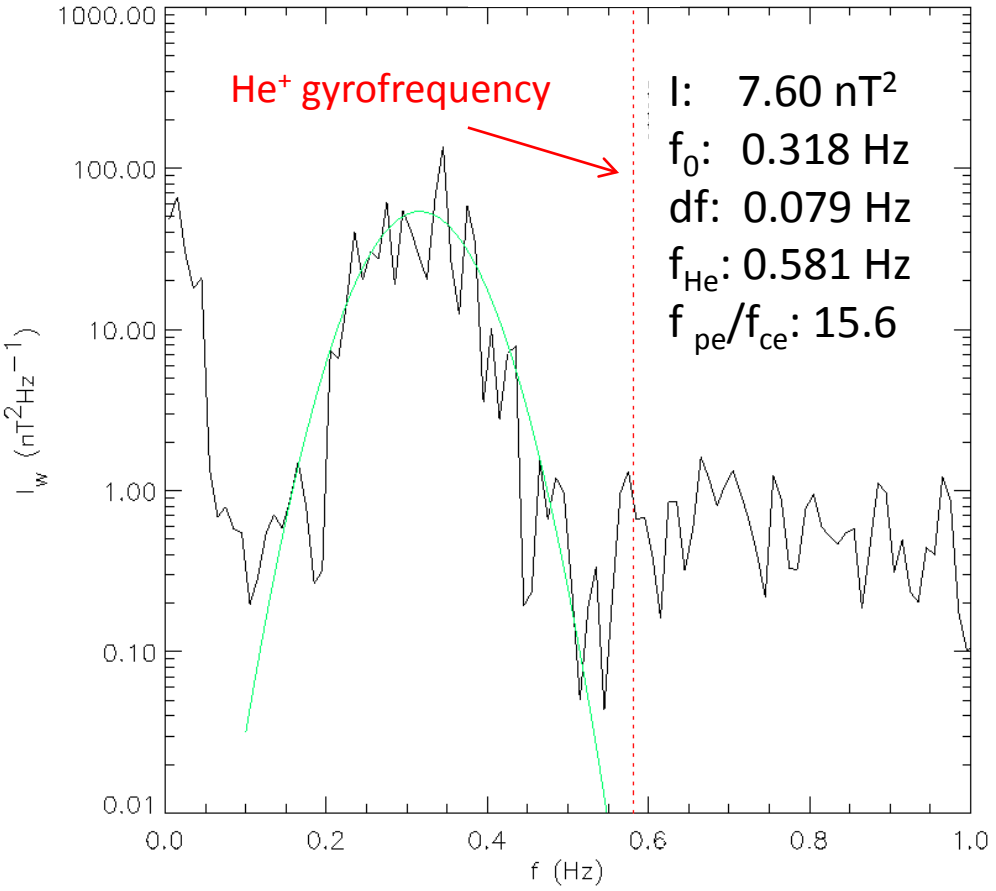
L*	UT	MLT	λ_m
5.17	15:30	14:17	-10.9



Gaussian Fits

L*	UT	MLT	λ_m
5.17	15:30	14:17	-10.9

- For each fit we recorded:
  - peak intensity I_0
  - peak frequency, f_0
  - spectral width, df
  - the integrated intensity, I, over the wave band



EMIC Wave Database

- We constructed two matrices, one for the helium and one for the hydrogen band waves.

- Each matrix contains the following information for each spectral profile:

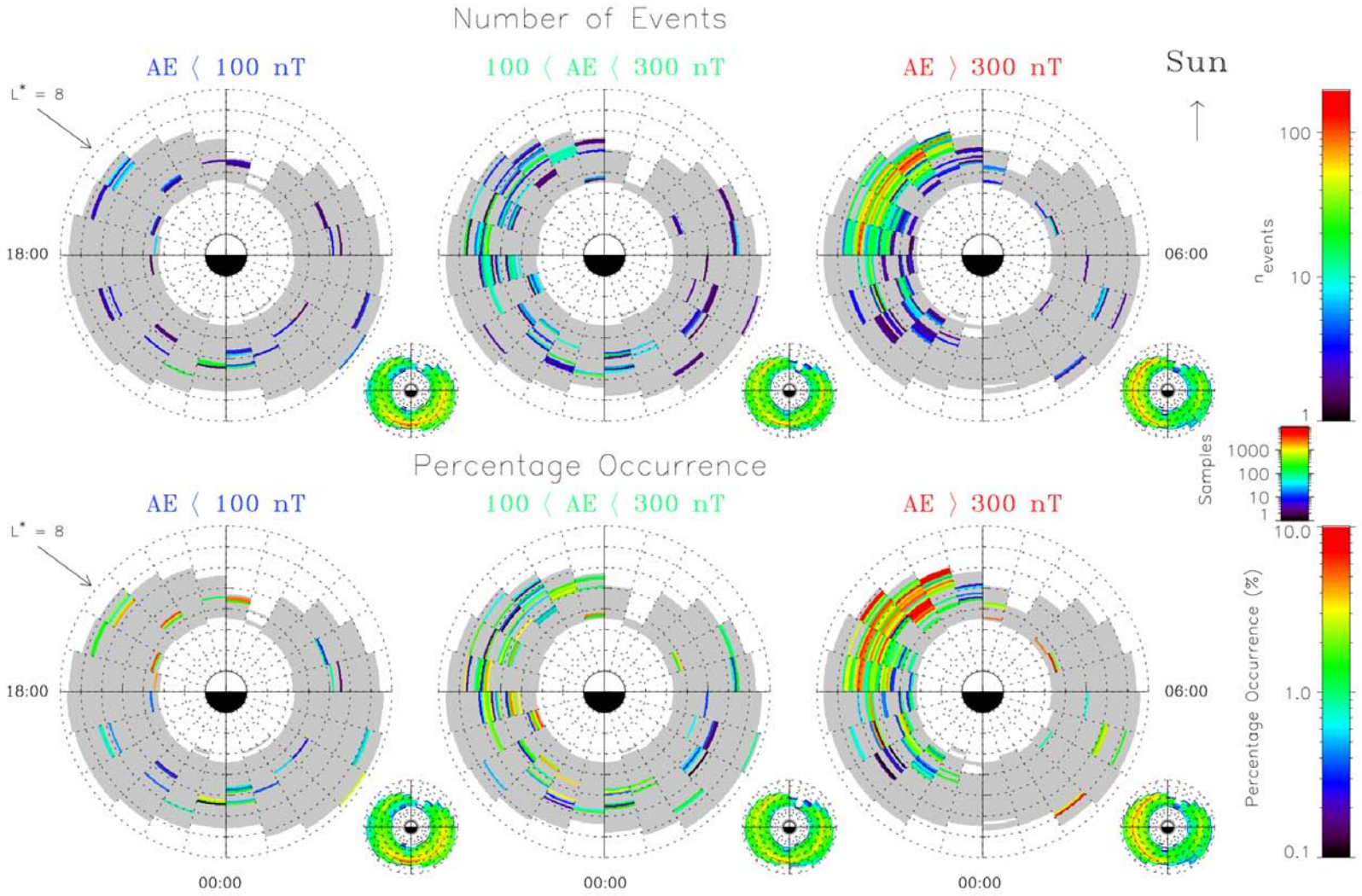
  - orbit number, UT
  - AE index, Dst index, & Kp index
  - L*, MLT, MLAT
  - plasma frequency
  - local and equatorial helium ion gyrofrequency
  - details of the Gaussian fit - I, I_0, f_0, df – when fit possible

Global Model

- We conducted a statistical analysis of the occurrence of helium and hydrogen band EMIC waves with intensities greater than 0.1 and 1 nT^2 as a function of spatial location and geomagnetic activity

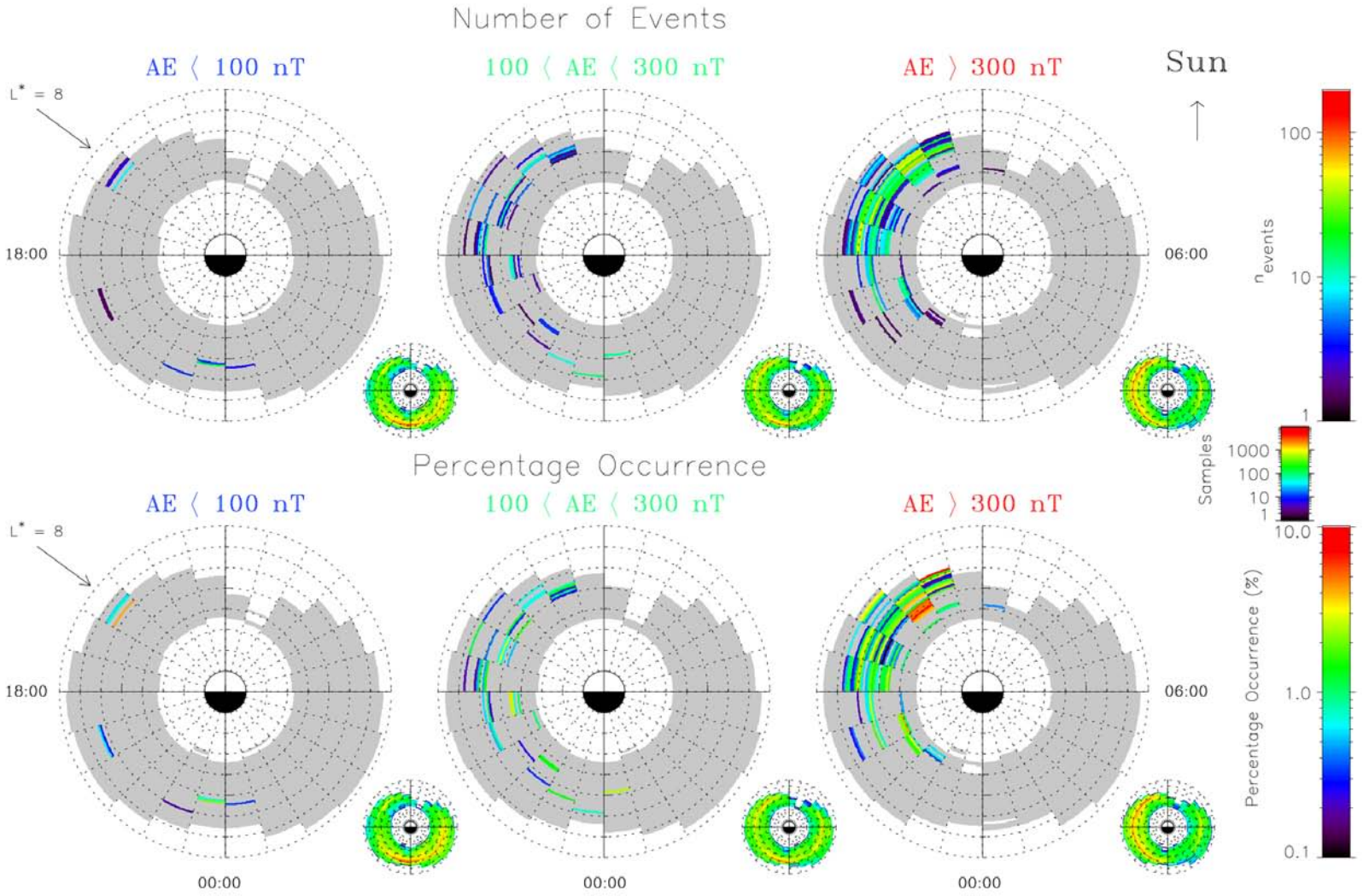
- We split the magnetic activity into three levels which we define as
  - **Quiet AE < 100 nT**
  - **Moderate 100 < AE < 300 nT**
  - **Active AE > 300 nT**

Helium Band EMIC Waves with $B_w^2 > 0.1\ nT^2$



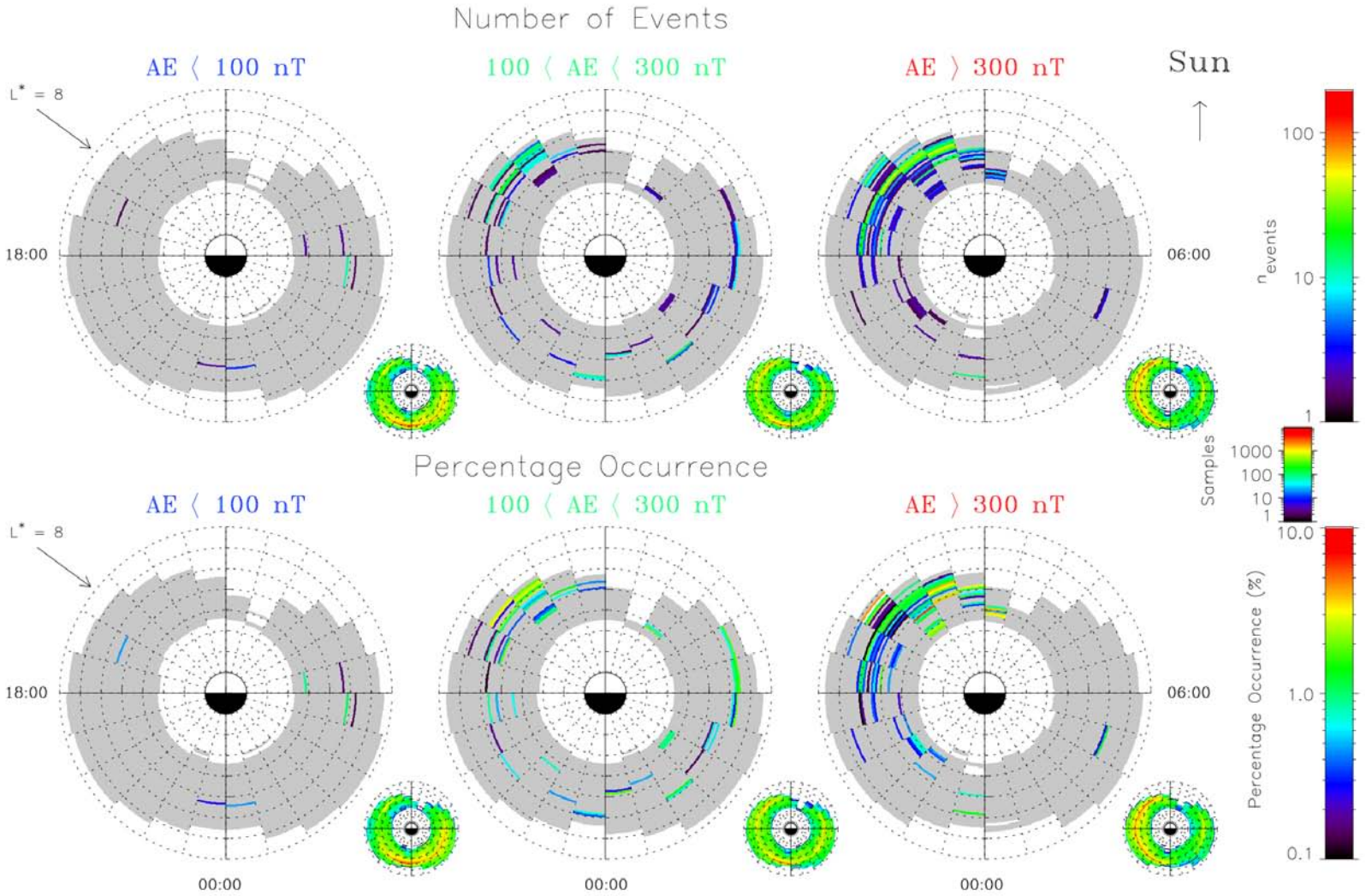
- Helium band EMIC waves most prevalent during active conditions in the afternoon sector from L*=4-7. Here intensities exceed 0.1 nT^2 for 2.6% of the time.

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



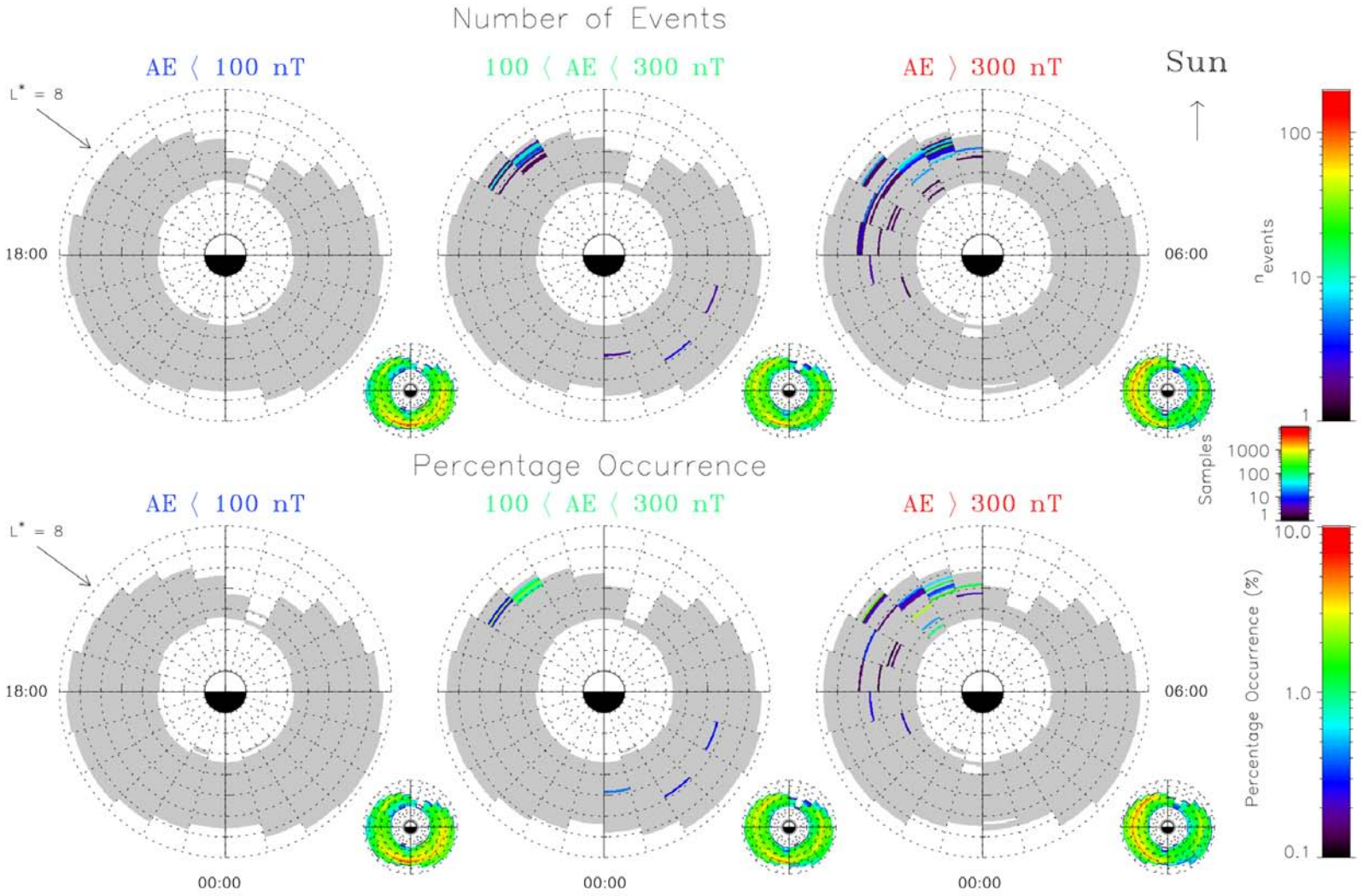
- Helium band EMIC waves exceed 1 nT^2 approximately 1% of the time in the afternoon sector from L* = 4-7 during active conditions

Hydrogen Band EMIC Waves with $B_w^2 > 0.1\ nT^2$



- Hydrogen band EMIC waves most prevalent during active conditions in the afternoon sector from L*=4-7. Here intensities exceed 0.1 nT^2 for 0.5% of the time

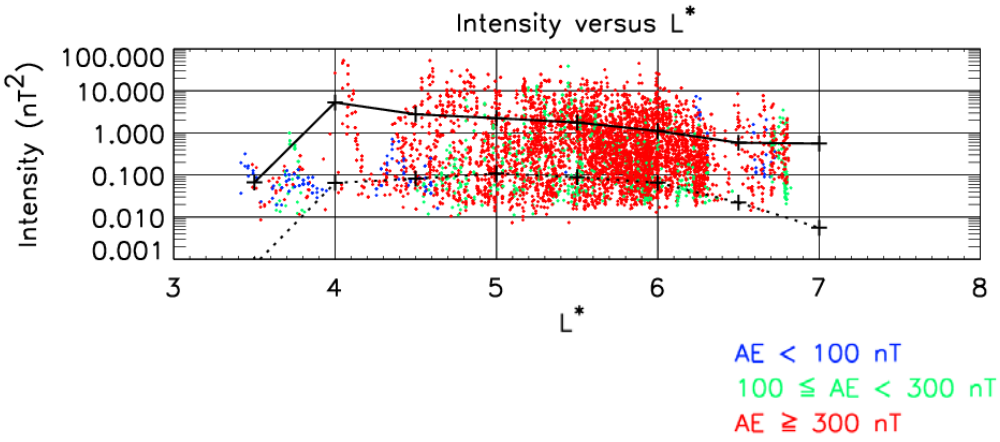
Hydrogen Band EMIC Waves with $B_w^2 > 1\ nT^2$



- Hydrogen band EMIC waves exceed 1 nT^2 approximately 0.1% of the time in the afternoon sector from L* = 4-7 during active conditions

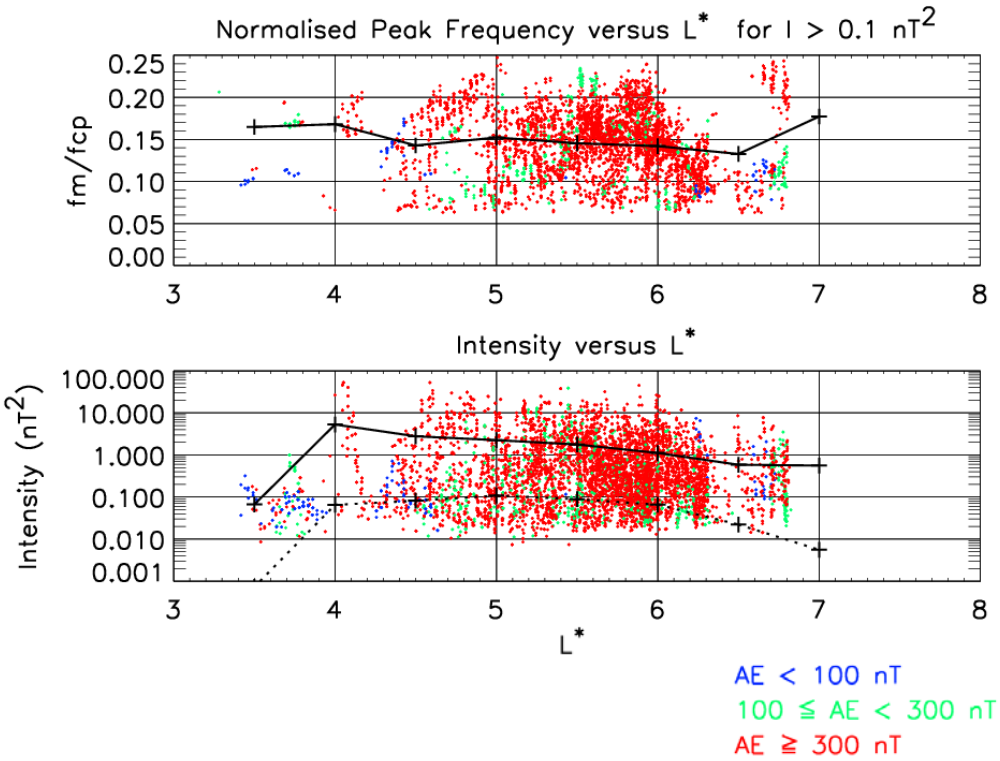
He Band Wave Parameters in the Afternoon Sector

- Intensities cover 4 orders of magnitude
- Average intensity of an EMIC wave event is of the order 1 nT^2
- Time averaged intensity is about a factor of 30 lower



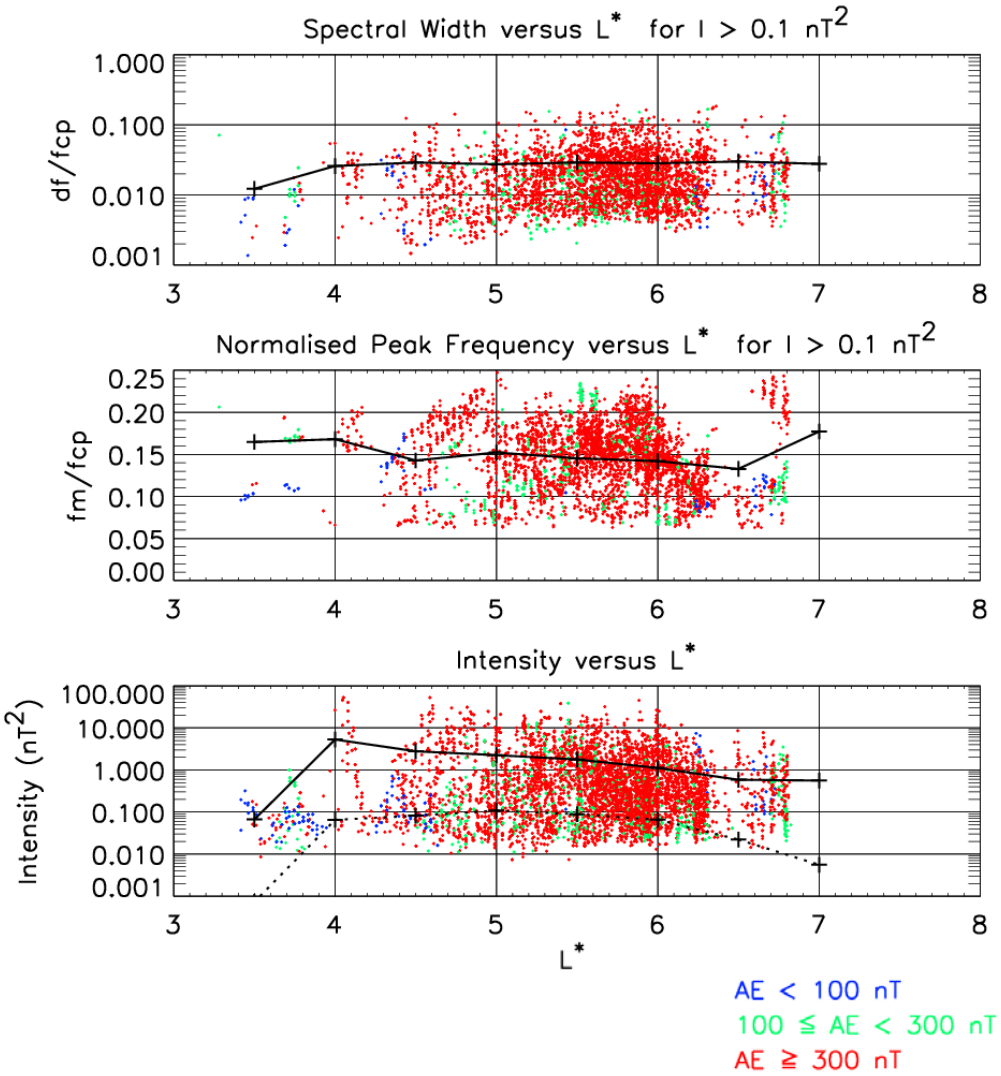
He Band Wave Parameters in the Afternoon Sector

- Bulk of events have peak frequencies between 0.1 and 0.2f_{cp}
- Average peak frequency is 0.15f_{cp} and doesn't vary significantly with L*



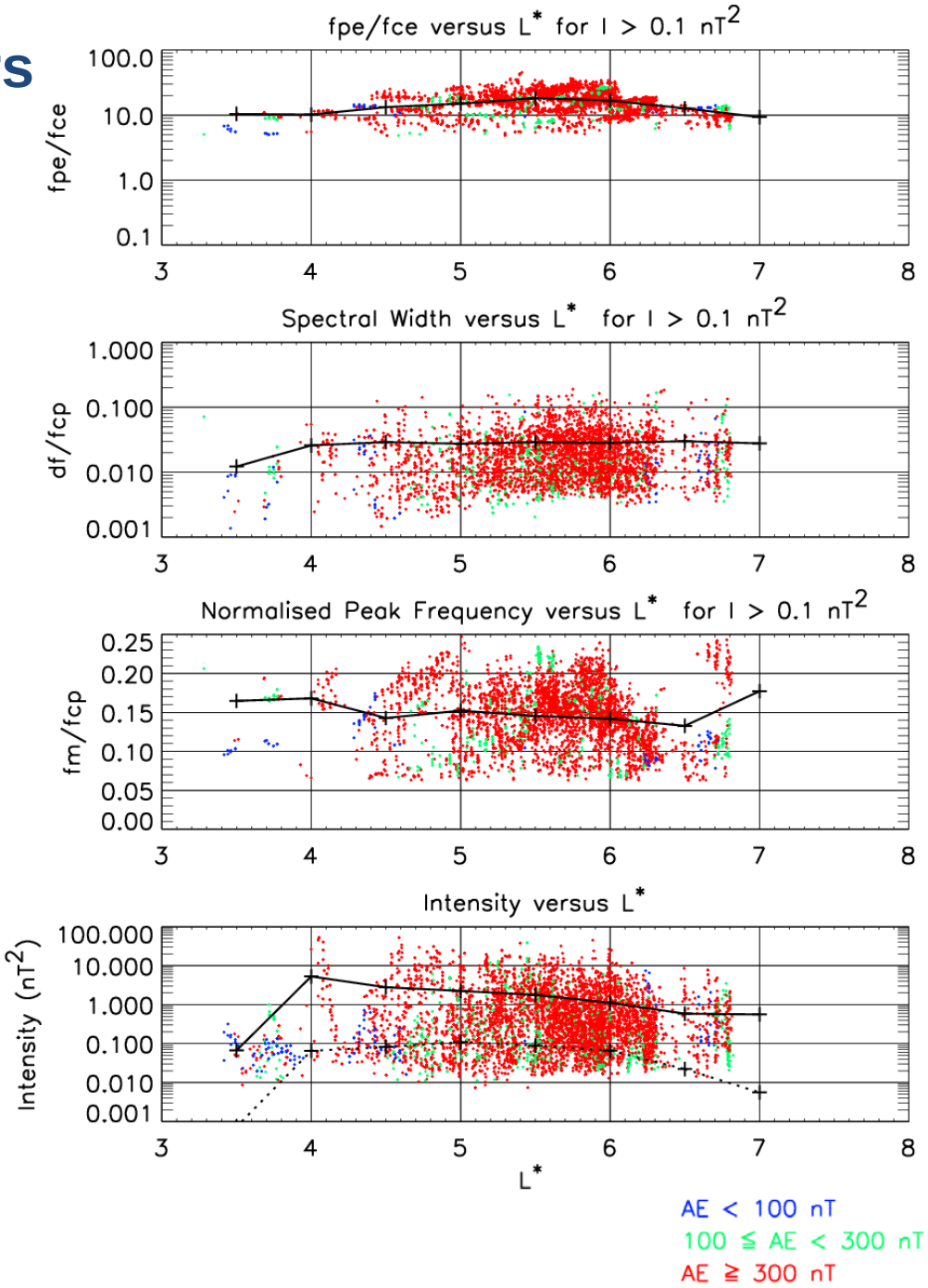
He Band Wave Parameters in the Afternoon Sector

- Bulk of events have spectral widths between 0.05 and 0.1 f_{cp}
- Average spectral width is $0.03f_{cp}$



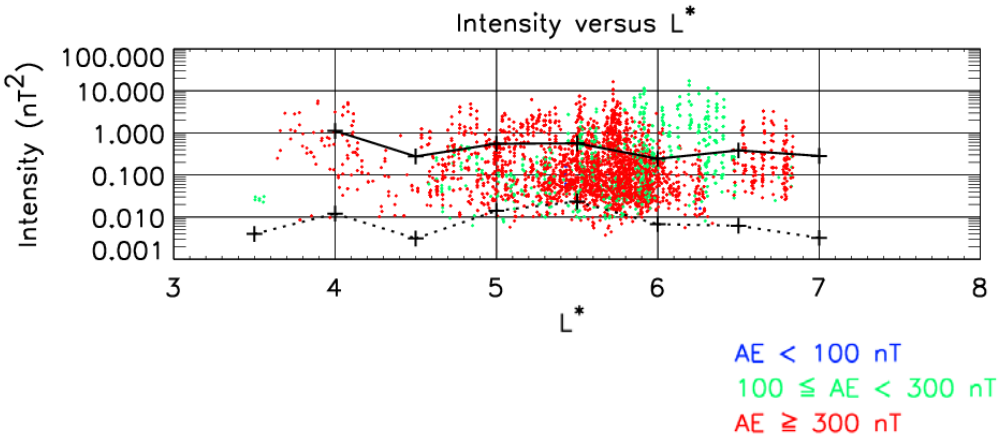
He Band Wave Parameters in the Afternoon Sector

- The ratio f_{pe}/f_{ce} is large and typically greater than 10



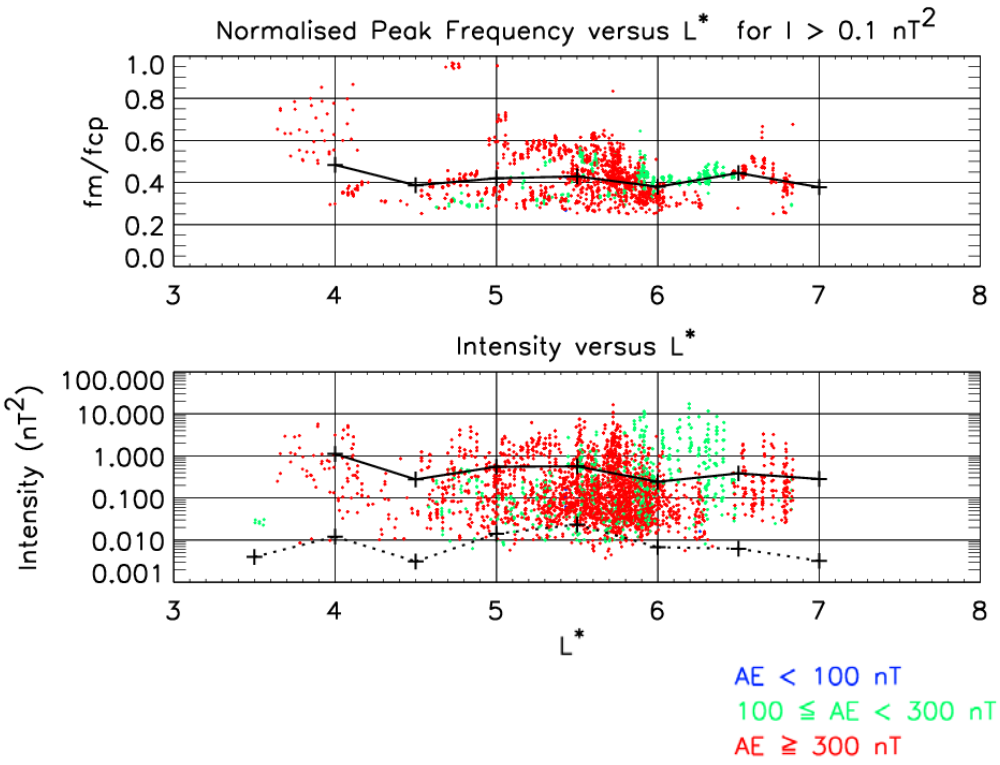
H Band Wave Parameters in the Afternoon Sector

- Intensities cover 3 orders of magnitude
- Average intensity of an EMIC wave event is of the order 0.5 nT^2
- Time averaged intensity is about a factor of 50 lower



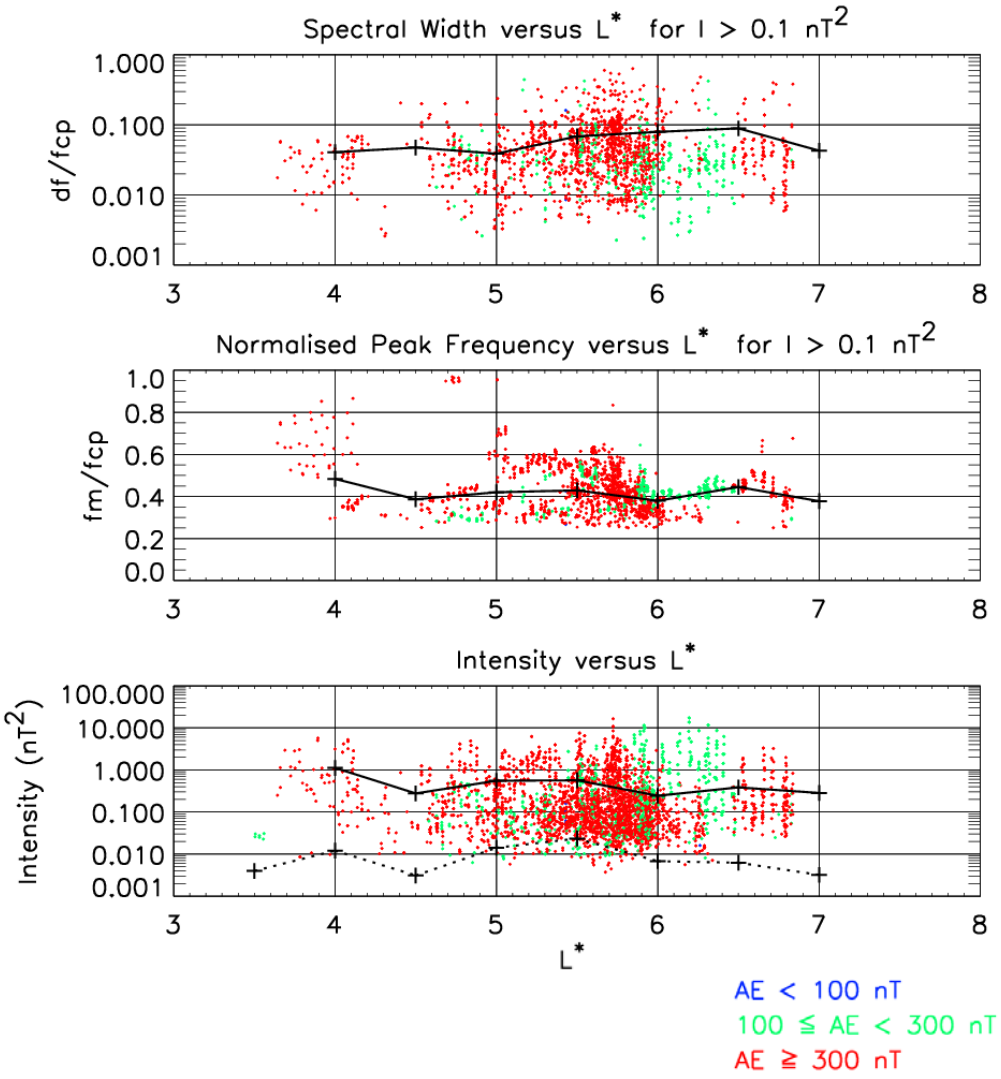
H Band Wave Parameters in the Afternoon Sector

- Bulk of events have peak frequencies between 0.3 and 0.6f_{cp}
- Average peak frequency is 0.4f_{cp} and doesn't vary significantly with L*



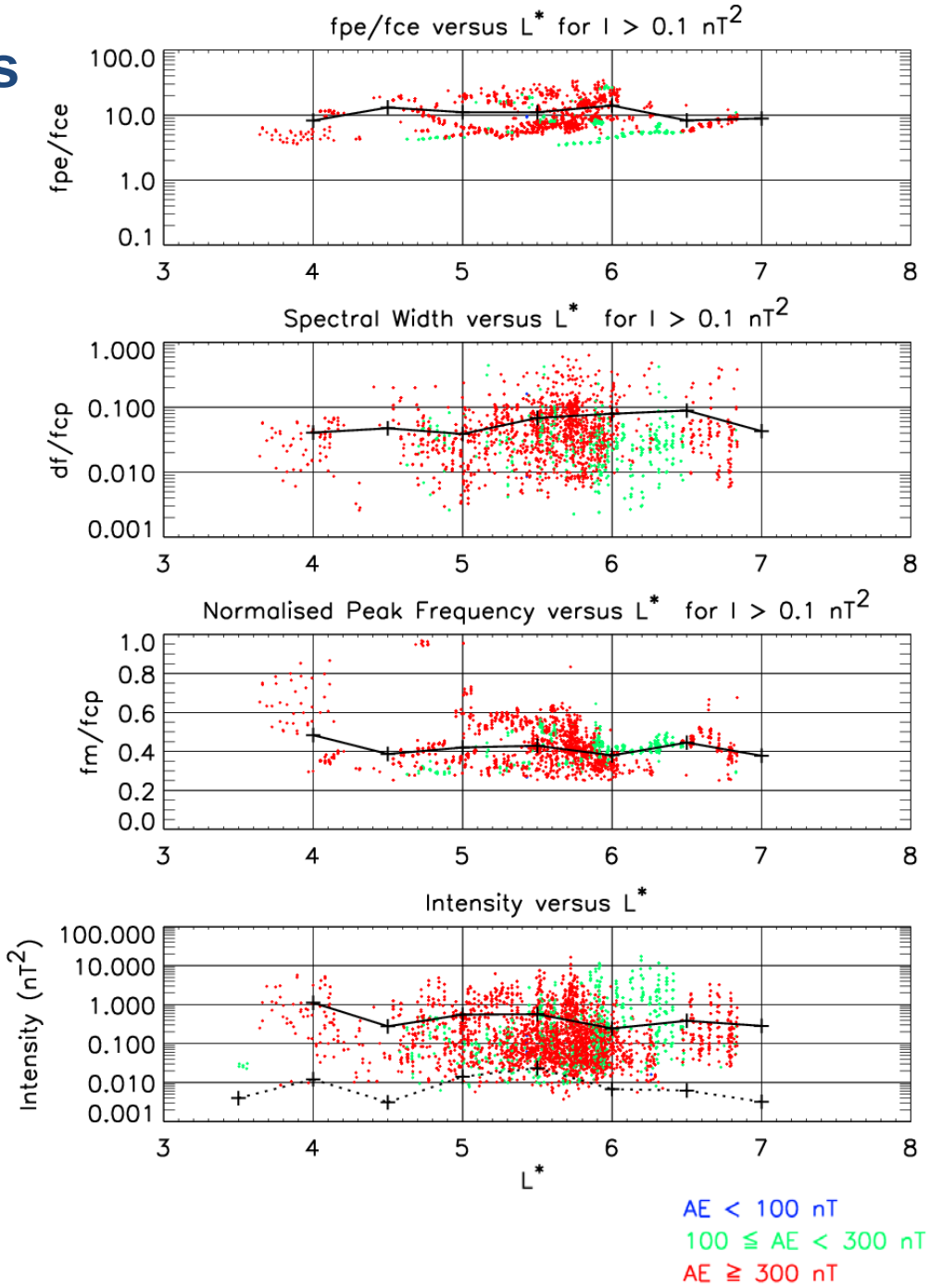
H Band Wave Parameters in the Afternoon Sector

- Bulk of events have spectral widths between 0.01 and 0.5 f_{cp}
- Average spectral width is $0.05f_{cp}$



H Band Wave Parameters in the Afternoon Sector

- The ratio f_{pe}/f_{ce} is large and typically greater than 10



Conclusions

- Helium band EMIC waves with intensities greater than 0.1 nT^2 are most prevalent during active conditions from L* = 4-7 in the afternoon sector with an average occurrence rate of 2.6%.

- The average intensity of a helium band EMIC wave event is of the order 1 nT^2 but the time-averaged intensity is a factor of 30 lower.

- The average peak frequency and width of he moderate and strong helium band EMIC waves ($I > 0.1\ nT^2$) in the afternoon sector is $0.15f_{cp}$ and $0.03f_{cp}$ respectively

Conclusions

- Hydrogen band EMIC waves with intensities greater than 0.1 nT^2 are most prevalent during active conditions from L* = 4-7 in the afternoon sector with an average occurrence rate of 1%.

- The average intensity of a hydrogen band EMIC wave event is of the order 0.5 nT^2 but the time-averaged intensity is a factor of 50 lower.

- The average peak frequency and width of he moderate and strong helium band EMIC waves ($I > 0.1\ nT^2$) in the afternoon sector is $0.4f_{cp}$ and $0.06f_{cp}$ respectively

Acknowledgements

- The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreements numbers 262468 (SPACECAST), 284520 (MAARBLE) and 606716 (SPACESTORM) and is also supported in part by the UK Natural Environment Research Council

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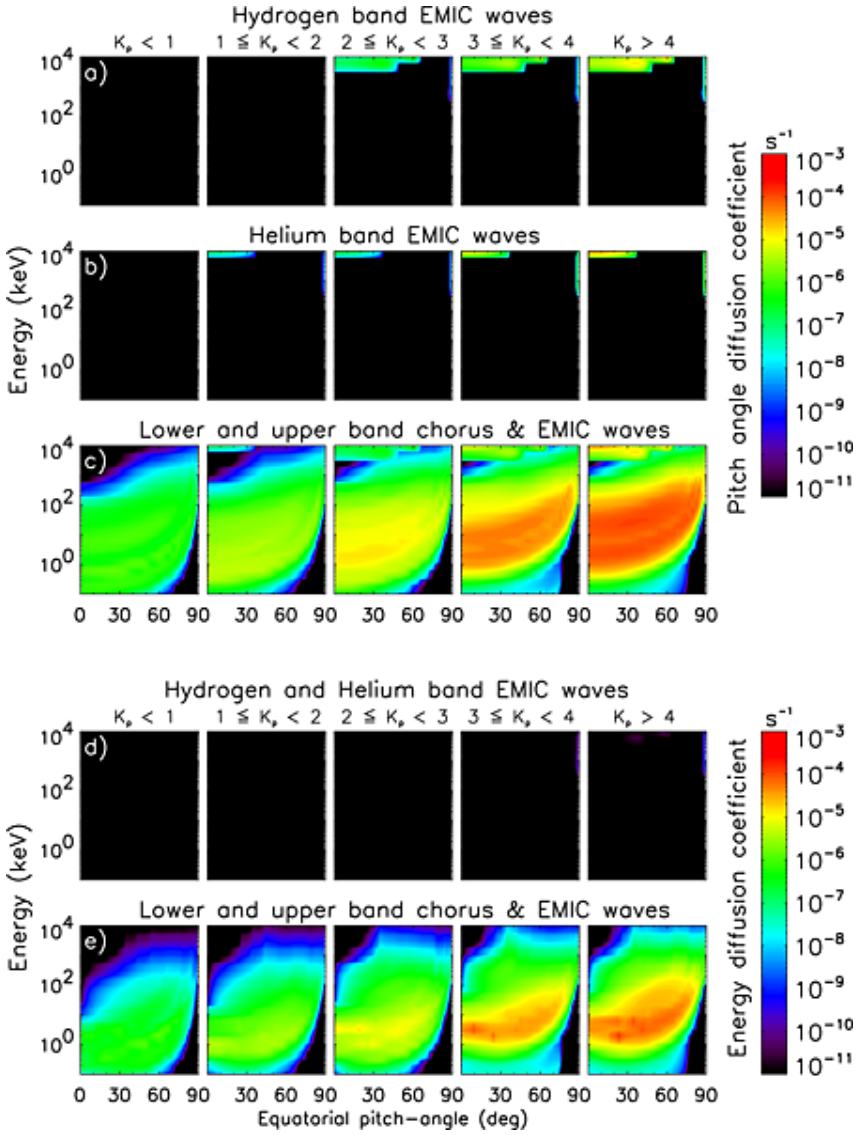
Diffusion Rates

- Calculated diffusion matrices for hydrogen and helium band EMIC waves
- Pitch angle diffusion becomes significant only at high energies (E > 2 MeV) and low pitch angles ($\alpha < \sim 60^{o}$)
- Energy diffusion is insignificant at all energies and pitch angles

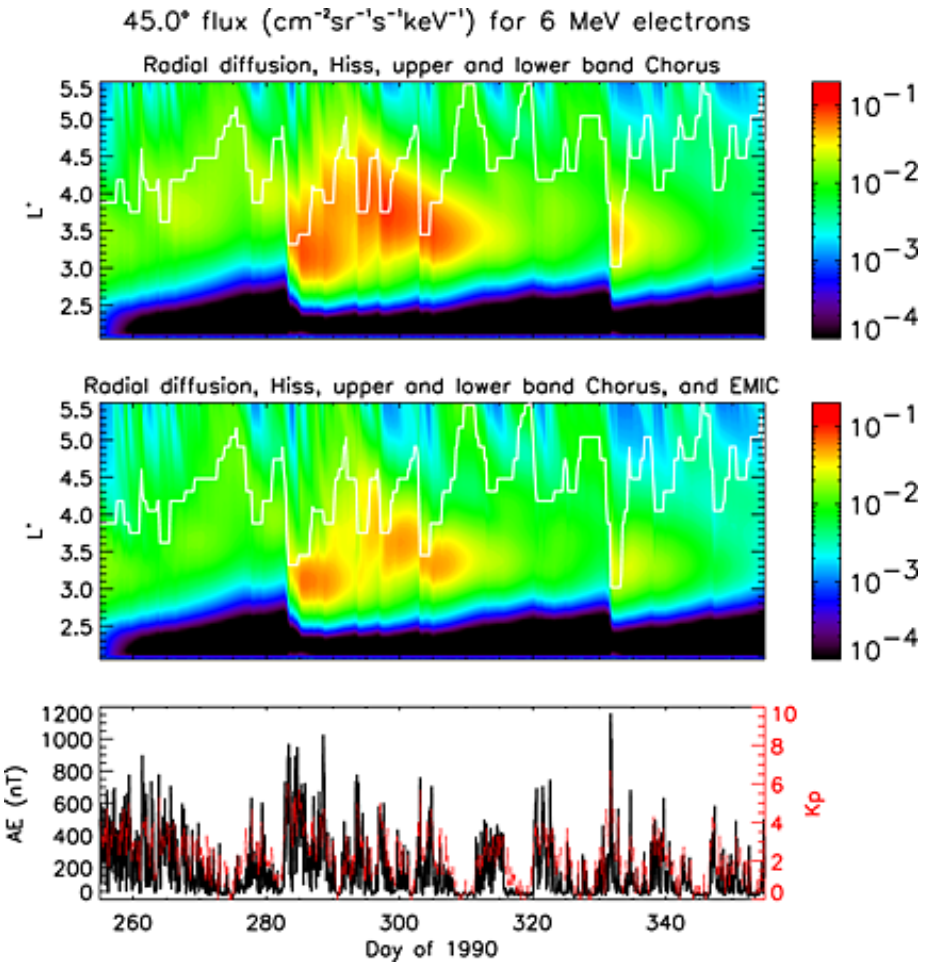


Kersten *et al*., 2004

Global Simulations

- The diffusion matrix has been included into the BAS Radiation Belt Model and the model run for a 100 day period in 1990 during the CRRES mission

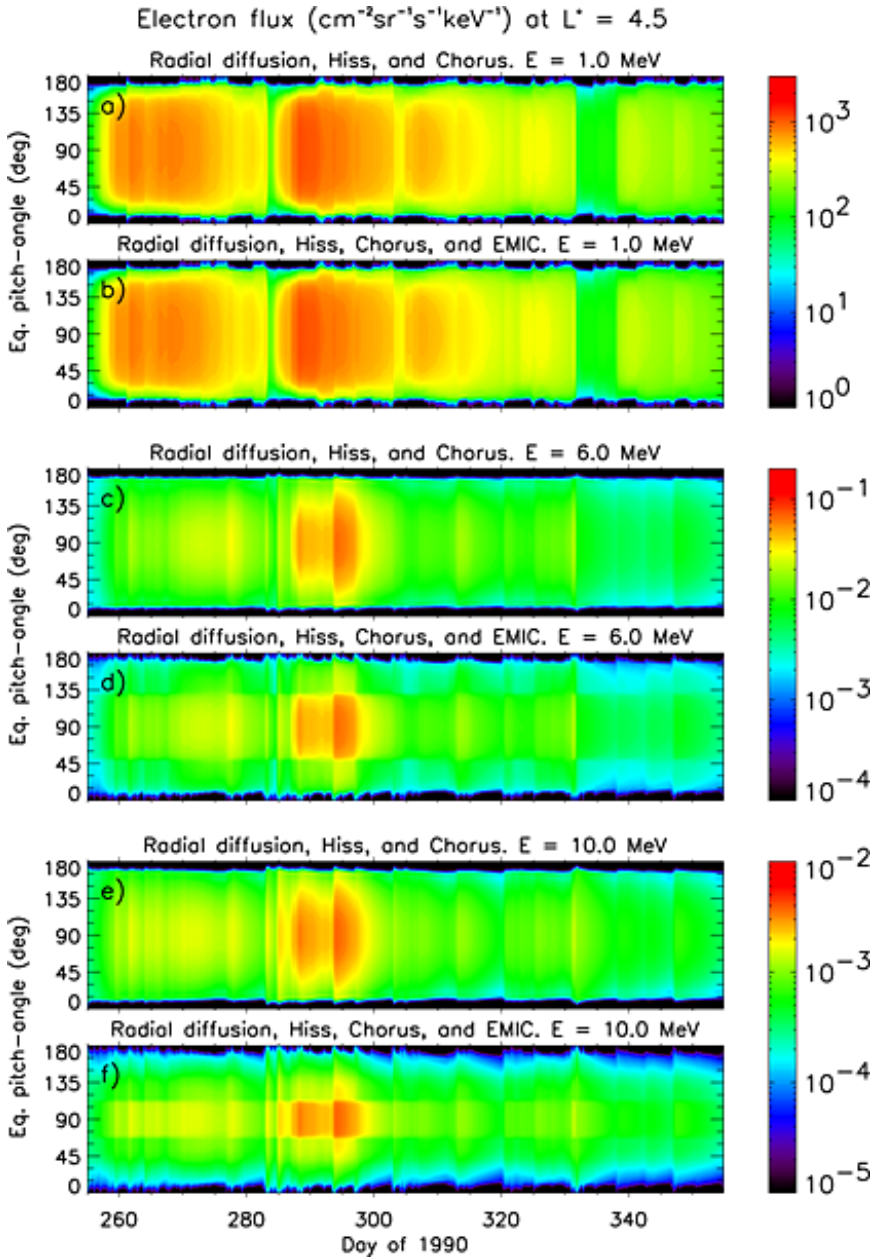
- When EMIC waves are included the 6 MeV electron flux at a pitch angle of 45^{o} is reduced, particularly during DOY 285-310



Kersten *et al*., 2004

Pitch Angle Distributions

- We ran the model to examine the structure of the pitch angle distribution left behind in space
- The results show that the pitch angle distribution is peaked near 90^{o} and that the width of the distribution varies with energy.
- In general higher energies of 6 and 10 MeV have an increasingly narrow distribution, consistent with observations [Usanova *et al*., 2014]

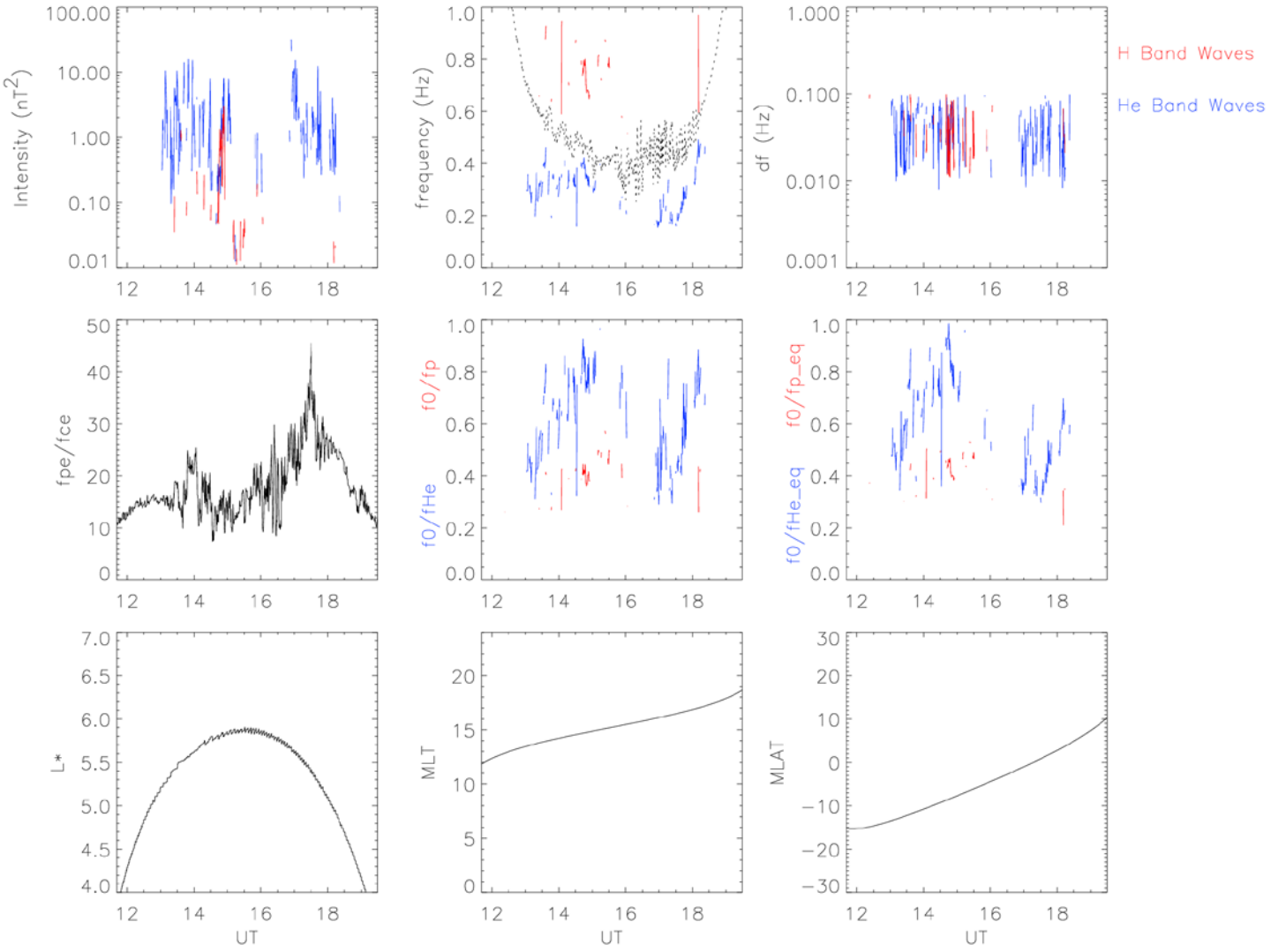


Kersten *et al*., 2004

Conclusions

- EMIC waves are effective at scattering electrons for E > 2MeV
- There is no significant energy diffusion
- EMIC waves lead to significant losses at pitch-angles < 60° (for L* > 3.5)
- EMIC waves will result in a peaked particle distribution for 70° < α < 90°

Sample Orbit



- Note wide range of variability in intensity covering three orders of magnitude