Spatial distribution and properties of EMIC waves observed by Cluster

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Abstract:

Electromagnetic ion cyclotron (EMIC) waves are an important mechanism for energy transport and particle interactions inside the magnetosphere. In order to both test and drive models of these waves, detailed information about the wave normal angle, ellipticity, and Poynting vector direction distributions as well as the distribution of plasma conditions necessary for wave excitation is required. Previous statistical studies have used *in situ* data to investigate the distribution of these parameters in the the L-MLT frame within a limited MLAT range (i.e. [*Loto'aniu et al.*, 2005; *Min et al.*, 2012]). In this study, we present a statistical analysis of these wave parameters as well as the electron plasma/gyrofrequency ratio and a linear theory proxy for wave generation, using ten years (2001-2009) of data from Cluster totaling 2368 minutes of wave activity.

Motivation:

1. Investigate the distribution of various wave and plasma parameters in magnetic latitude.
2. Explore the effects of Shabansky orbits on off-equator EMIC wave generation [*Shabansky,* 1971].
3. Expand on previous statistical studies that had limited MLAT coverage (i.e. [*Loto'aniu et al.*, 2005; *Min et al.*, 2012]).

Electron plasma/gyrofrequency ratio:

The electron plasma/gyrofrequency ratio is a proxy for identifying a region with high n_e and low B, conditions which greatly increases the possibility of EMIC wave generation [*Kennel and Petschek*, 1966; *Summers et al.*, 2008; *Chen et al.*, 2009; 2010; *Zhang et al.*, 2011]. The ratio, which should be ≥ 10 to generate EMIC waves, is given by,

$$\frac{f_{pe}}{f_{ce}} = 321 \times n_e^{1/2} B^{-1}$$

Linear Theory:

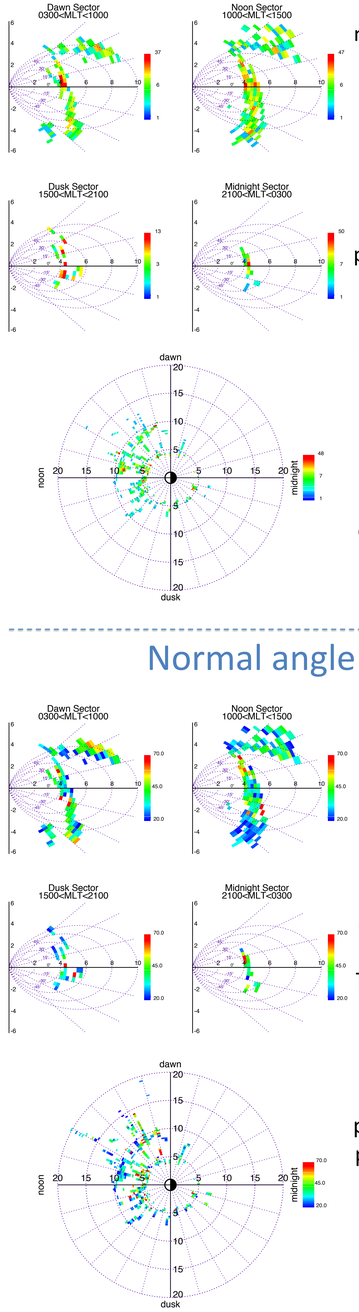
Linear Theory states that for an EMIC wave to occur, the wave growth parameter, Σ_h, must be larger than the instability threshold, S_h [*Gary et al.*, 1994]. Where,

$$\Sigma_h = \left(\frac{T_\perp}{T_\parallel} - 1\right)\beta_{\parallel h}^{\alpha_h} \qquad S_h = \sigma_0 + \sigma_1 \ln\left(\frac{n_{hp}}{n_e}\right) + \sigma_2\left[\ln\left(\frac{n_{hp}}{n_e}\right)\right]^2$$

$$\alpha_h = a_0 - a_1 \ln\left(\frac{n_{hp}}{n_e}\right) - a_2\left[\ln\left(\frac{n_{hp}}{n_e}\right)\right]^2$$

with $\sigma_0 = 0.429$, $\sigma_1 = 0.124$, $\sigma_2 = 0.0118$ and $\alpha_0 = 0.409$, $\alpha_1 = 0.0145$, and $\alpha_2 = 0.00028$ [*Blum et al.*, 2009].
Thus, by looking at $\Sigma_h - S_h$ during the events, we are able to see whether the observed waves are in a predicted source region.

Counts:



Log counts of minutes of wave activity in each spatial bin.

The bin size in distance (top panel) and T01 L-shell (bottom panel) is 0.25 R_e. The bin size for MLAT (top panel) is 5° and the bin size for MLT (bottom panel) is 15 minutes.

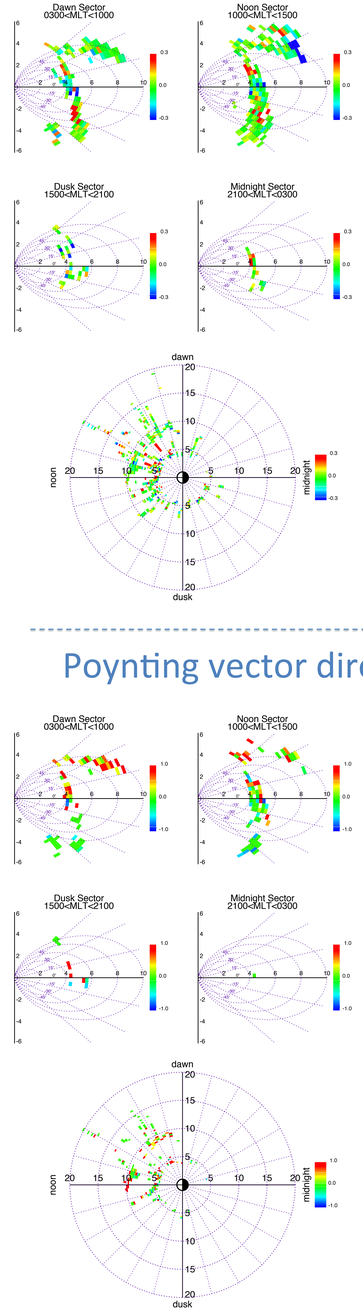
The higher counts near the equator is due to orbital effects.

Normal angle:

Angle between the phase velocity and background magnetic field calculated from Fast Fourier Transformation.

Due to ambiguity in the method, parallel vs. anti-parallel can not be distinguished.

Ellipticity:



A value of -1 indicates a purely left handed wave, +1 indicates a purely right handed wave, and 0 indicates a purely linear wave.

EMIC waves are largely expected to be left handed when generated and can change polarization during propagation.

Poynting vector direction:

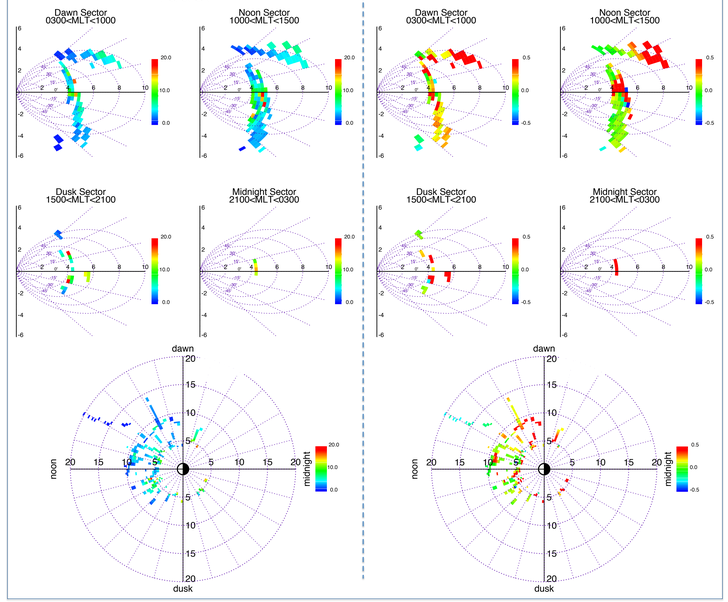
Normalized Poynting vector direction along the magnetic field.

A value of +1 (-1) indicates that all EMIC waves observed in bin were propagating parallel (anti-parallel) to the magnetic field. A value of 0 indicates equal number or parallel to anti-parallel propagating wave packets.

Wave generation proxies:

Electron plasma/gyrofrequency ratio:

Linear Theory:



Summary & Discussion:

Counts:	Predominantly on the dayside.
Ellipticity:	Mostly mixed polarization with inner mid-latitudes having more right handed to linear averages while the outer mid-latitudes and inner equatorial regions being more left handed to linear.
Normal angle:	Normal angles in the equatorial regions and outer mid to inner high magnetic latitudes are low with higher angles at the inner mid-latitudes.
Poynting vector direction:	The dominant direction in both hemispheres is away from the equator and towards the poles along field lines.
Wave generation proxies:	Both the electron plasma/gyrofrequency ratio and linear theory see evidence off equator source regions in the dawn and noon sectors. This is likely due to Shabansky orbits.

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