Whistler-mode chorus waves in the dayside outer magnetosphere: PENGUIn/AGO and THEMIS conjugate observations

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Introduction

We investigate **dayside chorus waves**:
- Whistler-mode chorus waves *on the dayside* (06h<MLT<18h)
- It has been reported that they frequently appear under weak geomagnetic conditions as well as active conditions.
- They have been observed *over a wider range of magnetic latitudes* (extending at least 25° off the magnetic equator)

**Comparison with nightside chorus**
- Night-side chorus is observed mostly under disturbed geomagnetic conditions and generated *around the magnetic equator*.

**Effects on the outer radiation belt**
- Whistler-mode chorus waves play an important role in *acceleration* of electrons up to relativistic energies and *loss* of relativistic electrons into the atmosphere.
Motivations

- What controls the generation of whistler-mode chorus waves on the dayside? Why are they often generated even during quiet times?
  - *Distortion of the dayside magnetospheric configuration* [e.g., Tsurutani et al., 2009; Spasojevic and Inan, 2010]
    - Drift shell splitting and bifurcation
    - Small dB/ds effects
  - *Modulation by ULF waves* [e.g., Li et al., 2011]
  - *Scattering followed by precipitation (leading to electron anisotropy)* [e.g., Tao et al., 2011]
  - *Sudden magnetospheric compression (leading to electron anisotropy)* [e.g., Gail et al., 1990]
- Where in MLAT and L are dayside chorus waves preferably generated? Why?
In this paper, we focus on quiet conditions.

✓ To understand why they are generated during quiet times as frequently as disturbed times.

✓ Dayside chorus waves can make an important contribution to generation and loss of outer radiation belt electrons under quiet conditions.
  – During quiet times, chorus wave events occur on the dayside more frequently than on the night side.
  – The outer radiation belt is active even under quiet solar wind and/or geomagnetic conditions.
Case Study: 26 July 2008

• In-situ observations: THEMIS
  – Magnetic field (FGM), wave fields (SCM, EFW; providing >4 kHz sampling)
  – Electrons (ESA; providing <3s full distributions)

• Ground-based observations: PENGUIn/AGO in Antarctica
  – -69.8° to -86.7° CGM latitude at 100 km reference
  – ELF/VLF receivers
Solar wind & AGO VLF data

Dst, AE, and solar wind data (from Wind)

Fig. 3

[0.5 – 1 kHz]

[1 – 2 kHz]

[2 – 4 kHz]

[4 – 8 kHz]
The diagram illustrates various aspects of THEMIS-A observations, including filter bank data, electron flux, minimum resonant energy, and anisotropy. The figures display spectral contents for different frequencies (Hz) and energies (eV), with color-coded representations indicating intensity and activity levels. Additional data tables are present, detailing specific parameters such as magnetic fields (nT) and electron flux (mV/m) over time. The diagram also includes other parameters such as magnetic field strength (B), ion density (n), and Earth's magnetic field inclination (inclination and declination). The edge in knowledge is highlighted to emphasize the advanced understanding gained from these observations.
Filter bank data (EFI, SCM) and electron flux: THEMIS-D and THEMIS-E
Spatial distributions of VLF wave intensification (mapped onto the magnetic equator using TS01)

THEMIS/EDC & AGO Wave Power (log)

THEMIS/SCM & AGO Wave Power (log)

THEMIS/EDC: 768 Hz
AGO: 0.5-1.0 kHz

THEMIS/SCM: 768 Hz
AGO: 0.5-1.0 kHz
Magnetic field configuration (TS01)

THEMIS-A
768 Hz

Magnetic Latitude [deg.]

IBI [nT, log]

[mV/ml]

[nT]

[nT]

[nT]

[nT]
Summary

On 26 July 2008, AGO in Antarctica and THEMIS were magnetically conjugated, when:

- Solar wind dynamic pressure was small and almost constant.
- VLF signals (0.5–1 kHz band) were enhanced at AGO AP2 and peaked around noon.
- Snapshots of power spectrograms indicate structureless chorus waves at ~0.5 kHz.
- THEMIS A, D, and E observed VLF wave intensification (0.3–1.2 kHz band) around noon in the outer magnetosphere.
- THEMIS A registered chorus waves with 0.5–0.7 kHz ~ 0.3–0.4 fce.
- Anisotropy is relatively higher above the estimated minimum resonant energy (~10 keV) than below it.

- Chorus waves were generated when field lines have small dB/ds with a wide range of magnetic latitude.
- Wave power was small when field lines have off-equatorial minimum B pockets.
Discussions

The conjugate observations showed:
• localized chorus intensification that persists for at least 1.5 hours under quiet conditions.

What causes quiet-time localized chorus waves?
✓ The distortion of the dayside magnetospheric configuration plays an important role. Small dB/ds in a wide range of MLAT (i.e., B uniform along B) seems responsible for the observed dayside chorus.
✓ A contribution from ULF waves is likely small.

Possible mechanisms
✓ Linear growth in a uniform (along B) field line. Resonant for a longer time?
✓ Non-linear growth due to long electron trapping?