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Electron cyclotron harmonic emissions in Saturn's magnetosphere

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Abstract

Electron cyclotron harmonic emissions are ubiquitous in planetary magnetospheres. Their field strengths can be of order 1 mV/m which suggests they should be considered as contributors to the diffuse aurora at Earth. At Earth and Jupiter these emissions clearly cluster near the magnetic equator in the middle magnetosphere. However, at Saturn, their occurrence appears to be less organized. In this paper we examine the occurrence of intense electrostatic electron cyclotron harmonics in Saturn's magnetosphere to establish where conditions support their growth. We then consider the underlying electron distribution functions to understand how they control the occurrence of the emissions.

1. Introduction

Electron cyclotron harmonic (ECH) emissions are also known by a number of other terms, including (n + ½)f_{ce} (where f_{ce} is the electron cyclotron frequency) bands and Bernstein modes. As their various names imply, these emissions occur between harmonics of the electron cyclotron frequency up to and including that which spans the upper hybrid resonance frequency $f_{uh}^2 = f_{pe}^2 + f_{ce}^2$ where f_{pe} is the electron plasma frequency. Depending on the background plasma, such as the ratio of the cold to hot electron densities and the ratio of the cold to hot electron temperatures these emissions may occupy only the first band (sometimes referred to as the $3/2f_{ce}$ band), only the band at f_{uh}, or several bands from the first to higher harmonics. The ECH bands are driven by free energy in the electron distribution function, such as a positive slope in the perpendicular velocity distribution, a loss cone, or a temperature anisotropy.

There are thermal emissions which also appear between harmonics of f_{ce}, but this paper is not concerned with those.

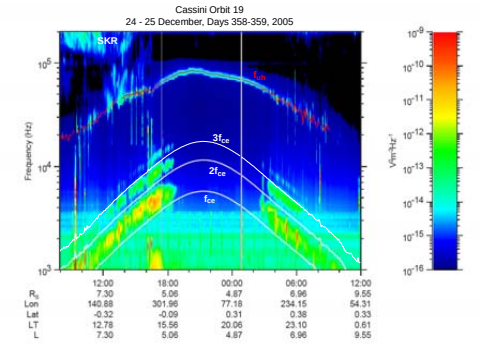

Figure 1: An example of ECH bands in Saturn's magnetosphere.

At Earth and Jupiter, the conditions for growth and the propagation of the emissions clearly favor intense emissions within a few degrees of the magnetic equator (minimum |B| surface). In fact, at Jupiter, it is usually possible to identify the magnetic equator simply by noting the location of the ECH bands. However, at Saturn, a clear pattern of occurrence is elusive. This paper seeks to find such a pattern and explain why the bands grow where they do.

One complicating factor at Saturn is that 'injections' or inward moving 'empty' flux tubes driven by the interchange instability are often locations of multi-harmonic ECH bands because of a lack of cold electrons and an unstable population of superthermal

electrons. We suspect that another complicating factor in Saturn's magnetosphere is the large neutral population in the magnetosphere and the presence of the E-ring dust.

2. Work to be presented

This paper examines the occurrence of ECH instabilities not associated with injection events. We show the results of a manual review of the plasma wave data from Cassini and then move to a more statistical approach. Preliminary results do show some tendency for ECH waves to cluster near Saturn's magnetic equator, even showing the slight northward offset commensurate with the north-south asymmetry in the magnetic moment of the planet. However, there also appears to be a preference for the multi-harmonic emissions to favor the radial distance range from 5 to 9 R_S, probably due to the predominance of cold plasma inside of 5 R_S.

Upon establishing the regions of occurrence of the ECH bands, we will then examine the characteristics of the electron distributions in the regions favored and avoided by the emissions to understand what aspects of the distribution favor the wave growth and how those distributions may have evolved.