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Final Technical Report on  
**Energization of Radiation Belt Electrons and Loss of Ring  
Current Ions**

AFOSR Grant F49620-93-1-0333

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Ph.D. students Marc Lessard and Jerry Goldstein received support from the above grant. Lessard will finish his Ph.D. in December, with three Journal of Geophysical Research papers under submission, titles and abstracts attached. Goldstein will finish within a year, and has submitted a paper to Geophysical Research Letters, title and abstract attached. These four papers constitute the technical summary of an impressive body of Ph.D. thesis research performed by these outstanding students, who have presented preliminary versions at AGU and GEM workshops.

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## Simultaneous satellite and ground-based observations of a discretely driven field line resonance

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**Abstract.** An analysis is presented of a toroidal field line resonance observed on the ground by CANOPUS magnetometers and scanning auroral photometers on 13 December, 1990, following a substorm onset at 0750 UT and intensification at 0850 UT. Magnetic and electric field data from the CRRES satellite provides evidence that the resonance was also observed in the magnetosphere. A spectral peak at 2.1 mHz is present in all data sets at approximately the same latitude and universal time, indicating that CANOPUS and CRRES are observing the same resonance. Peaks are also present at 1.4 and 1.7 mHz in the ground based magnetometer and CRRES data, although their presence in the photometer data is not clear. While the elliptical orbit of CRRES with apogee of  $6.3 R_E$  provides an excellent platform for observing the toroidal nature of such resonances, the short orbital period precludes extended observations of the compressional signal that is probably responsible for excitation of the resonance. However, data from GOES 6 and 7, located at nearly the same magnetic local time as the CANOPUS stations, indicates that power at 2.1 mHz was present at varying levels in the compressional component of the magnetic field as of approximately 1900 UT on the preceding day. An increase in the  $D_s t$  index to 35 nT followed by a decrease to -40 nT at that time suggests that the compressional power was associated with a moderate storm. Because the GOES satellites are in geosynchronous orbits, their observations of the compressional signal over such an extended interval requires that the signal be global in nature, suggesting the presence of a cavity mode structure.

### 1. Introduction

*Dungey* [1963, 1968] investigated the possibility that ULF pulsations might result from standing waves in the magnetosphere. In his analysis, he studied the characteristics of waves in a cold plasma using a cylindrical geometry. Whether a cylindrical geometry or a dipolar geometry is used [*Radoski et al.*, 1966], the system of equations decouples in two limits. The large scale limit ( $m \rightarrow 0$ ) is usually associated with global phenomena,

while the small scale limit ( $m \rightarrow \infty$ ) is relevant for local disturbances with scale size a small fraction of the magnetosphere. For the purposes of this paper, we concentrate on the  $m \rightarrow 0$  limit. In this case, the equations decouple to reveal the possibility of two types of waves. One type, often called the toroidal mode, refers to waves where velocity and magnetic field perturbations are azimuthal, while electric field perturbations are radial, corresponding to a transverse Alfvén wave. The other possibility is for the presence of a global scale fast mode

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## A statistical study of Pc 3-5 magnetic pulsations observed by the AMPTE/IRM satellite

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**Abstract.** Magnetic field data from the AMPTE/IRM satellite is used to complete a statistical study yielding occurrence rates of a number of different types of pulsations. Two hour panels of dynamic spectra and detrended line plots were inspected to determine occurrence rates over all local times from  $L = 6$  to  $L = 20$ . Event types include fundamental field line resonances, harmonic resonances, storm time pulsations and signatures of bursty bulk flows and fast flows. However, we also include observations of Pc 3 compressional pulsations and note their association with harmonic events. Likewise, we include high frequency events (40 mHz to 70 mHz) and show a relation to storm time pulsations. Based on the occurrence distributions, we are able to make a number of conclusions. We determine that the excitation source of fundamental resonances is likely band limited from 3 mHz to 10 mHz and that harmonic resonances are least sometimes associated with compressional Pc 3 pulsations. Storm time pulsations, compressional in nature, sometimes are associated with relatively high frequency transverse events and often occur in regions very close to the magnetopause. Based on other works that associate these pulsations with instabilities in the partial ring current, we suggest that the partial ring current may extend to the magnetopause during storms and substorms. Finally, we note that bursty bulk flows and fast flows in general have a magnetic signature that is predominantly compressional and discuss the relevance this may have regarding substorm dipolarization.

### 1. Introduction

A number of statistical studies of the magnetosphere using both ground based and satellite data have been completed which have proven to be very useful in understanding generation mechanisms of various types of pulsations. In this work, we report results of a statistical survey of occurrence rates of signals with periods in the Pc 3-5 range (10-600s) observed by the Active Magnetospheric Particle Tracer Explorer/Ion Release Module (AMPTE/IRM) satellite. We consider events of various types (and, presumably, different excitation

mechanisms) and define these types based on previous reports of observations and theory. While some events such as fundamental and harmonic resonances appear to be very well understood, other activity such as that associated with bursty bulk flows has been studied much less. Not all of the events we include are necessarily coherent pulsations. For example, signals with compressional oscillations that may be associated bursty bulk flows do not appear to result from wave activity. These are included in this study because their occurrence distribution may be helpful in understanding their origins even if they are not wave related.

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## Observations of radially polarized pulsation bursts with variable frequencies in the nightside magnetosphere

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EXCITATION OF CAVITY MODES IN THE PLASMASPHERE:  
NUMERICAL SIMULATION OF THE JANUARY 1997 MAGNETIC CLOUD EVENT

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*Abstract.* Data from the Plasma Wave Instrument (PWI) on the Polar satellite is used to construct an electron number density for the plasmasphere of January 11, 1997. This density profile is incorporated into a dynamic numerical simulation of a cold, ideal MHD plasmasphere on a dipole grid, with a broad-band excitation applied at the plasmapause. In the simulated plasmasphere, this impulsive perturbation produces a discrete spectrum of fast magnetosonic cavity modes, coupled to field line resonances (FLRs) at various harmonics. The simulated frequency spectrum is compared with recent observations of Pc 3 pulsations in the plasmasphere, as well as previous theoretical results. Direct comparison with Polar wave data for the January event is underway.

### Introduction

It has been proposed that the magnetosphere, bounded by the magnetopause and the ionosphere, and separated into the inner magnetosphere (i.e., the plasmasphere) and outer magnetosphere, can act as a resonant cavity for ultra-low frequency (ULF) magnetosonic waves [Kivelson et al., 1984; Allan et al., 1986b; Zhu and Kivelson, 1988, 1989; Lee and Lysak, 1989; Kouznetsov and Lotko, 1995; Lee, 1996]. If this cavity mode hypothesis is correct, the magnetosphere should possess an intrinsic discrete spectrum of fast magnetosonic standing waves; furthermore, unless the wave fields are completely axisymmetric, individual cavity modes will be coupled to one or more standing toroidal Alfvén mode oscillations. This coupling is strongest at the field line resonance (FLR), where the frequency of the cavity mode matches the toroidal eigenfrequency of the local