15. SPACE PLASMA PHYSICS

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15.1. INTRODUCTION

The research work carried out by the Space Plasma Group in 2005 falls into the following main fields of investigation:

- Totem Pole emissions;
- Effects of large-amplitude waves on linear instabilities;
- Nonlinear wave equations: integrability and exact solutions.

15.2. TOTEM POLE EMISSIONS

15.2.1 Introduction[1]

Totem Pole emissions were first observed near the dayside magnetopause by the Geotail spacecraft in 1997. They are electrostatic electron Bernstein waves whose characteristics are not fully explained by the standard model invoked for the generation of this type of wave activity. In particular, the occurrence of harmonic branches above the upper hybrid frequency and the fine spectral structure of the lower frequency emissions could not be interpreted in the context of the model adopted to study Bernstein waves in the magnetosphere.

The classical paradigm associated with electron Bernstein emissions uses an admixture of cold and hot electron populations neutralized by a background of immobile ions, with the perpendicular velocity distribution of the hot species providing the free energy, and the emphasis placed on modes propagating slightly away from the perpendicular (with respect to the background magnetic field).

We adopted *an alternative source of free energy to stimulate electron Bernstein waves:* the almost *monoenergetic ion (AMI) beams* recently observed by the Interball 1 spacecraft. The success of this model led to its utilization in the context of the Totem Pole emissions where it was demonstrated that AMI beams could generate electron Bernstein emissions both below and above the upper hybrid frequency (as observed by the Geotail spacecraft) and provided a simple means of accounting for the fine spectral structure found in the lower harmonic bands (Figures 15.1 and 15.2).

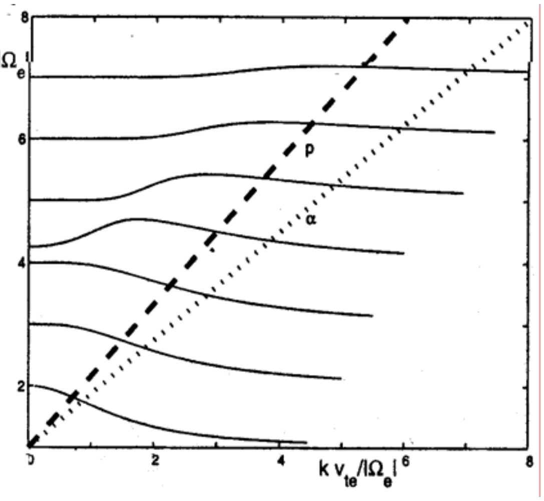

Figure 15.1 – Dispersion of the first seven electron Bernstein flute modes in a hydrogen maxwellian plasma with B_0=55 nT, T=30 eV and N_0=0.5 cm^{-3}. The straight lines indicate the perpendicular drift velocities of the proton (dashed) and alpha particle (dotted) beams.

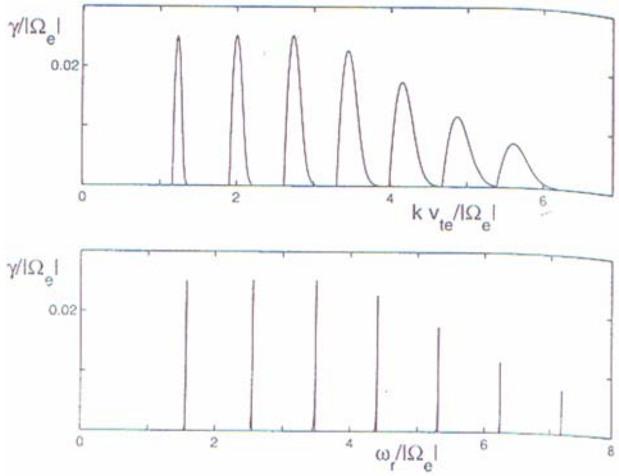

Figure 15.2 – Temporal growth rates of the first seven electron Bernstein flute modes stimulated by a perpendicular proton beam as a function of the wavenumber (upper panel) and the real frequency (lower panel).

15.2.2 Ongoing research

The previous work led to an original mechanism that offers a consistent interpretation of the main features encountered in the observations of Totem Pole emissions, relying on the properties of linear instabilities. Understanding of finer details displayed in the emissions spectrograms could benefit from the analysis of the nonlinear evolution of the

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[1] This research line has been carried out in collaboration with Prof. Luis Gomberoff, Physics Department, University of Chile at Santiago and partially funded by FONDECYT (Chilean Institute).

growth associated with the identified linear instabilities. To pursue this goal, we are assessing the possibility of adapting a numerical kinetic (particle in cell) code developed in Kyoto University (Kempo1) to simulate the proposed model underlying the emissions and thus follow the nonlinear regime of the instabilities.

15.3. LARGE AMPLITUDE WAVES AND INSTABILITIES

15.3.1. Introduction[2]

Electrostatic ion-acoustic instabilities have been observed in space environments (e.g., in the solar wind) where both the nature of the free energy source and the inexistence of the condition for small Landau damping (Te >> Tp) are not encountered and thus defy the standard theory of these instabilities.

15.3.2 Research results

To contribute to the interpretation of the above observations, we looked into the generation of electrostatic waves by *parametric decays of large-amplitude left-hand and right-hand waves propagating in the direction of the background magnetic field.* It is shown that the forward propagating ion acoustic waves involved in the parametric decay of the circularly polarized waves experience negligible Landau damping and can thus account for the puzzling observations of electrostatic ion-acoustic wave activity.

15.4. NONLINEAR WAVE EQUATIONS

15.4.1 Introduction

The study of nonlinear wave equations is a problem of considerable theoretical importance and with applications to several branches of Physics. In the case of Plasma Physics, it is relevant to the study of the interaction of pulsars and high power laser radiation with plasmas. It is the purpose of this research to give a contribution to the theoretical understanding of such waves. We address the question of integrability and the construction of exact solutions, in particular solitons, of certain nonlinear wave equations.

15.4.2 Ongoing research

We resort to the Painlevé method (for determining the type of movable singularities of the solutions) and the Hirota method (for determining if multisoliton solutions exist) to investigate the integrability of the following nonlinear equations: (i) the system of four partial differential equations that describe the evolution in time and one space dimension of the complex amplitudes of four waves constituting two resonant triplets; (ii) the partial differential equation in l+1 dimensions that appears in the analysis of the consistency error of the second-order Runge-Kutta method for the numerical integration of ordinary differential equations.

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[2] This research line has been carried out in collaboration with Prof. Luis Gomberoff, Physics Department, University of Chile at Santiago, and partially funded by FONDECYT (Chilean Institute).