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Foreshock electron beam energies estimated from Langmuir waves observed by Cluster

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Abstract

One of characteristic observable signatures of the foreshock region upstream of planetary bow shocks is the continuous presence of electrostatic wave activity close to the local electron plasma frequency. These waves are known to be generated by electron beams in the range from 100 eV to several keV originating from the shock. Due to the low intensity and intermittent nature of the electron beams, direct observations with particle instruments are very difficult and rare. Foreshock waves, on the other hand, provide a very good indication of the presence of the beam and their properties (namely the Doppler shift) allow for the indirect measurement of the beam energy. We present the measurement technique and the statistics of the beam energy as a function of the location within the foreshock.

Introduction and Context

The electron foreshock is a region of the solar wind magnetically connected to the bow shock. The plasma of this region differs from the free solar wind by the presence of beams of energetic electrons reflected by the shock and streaming along the field lines against the solar wind flow (*Fitzenreiter et al.*, 1990). These beams render the electron distribution unstable and give rise to electrostatic waves close to the electron plasma frequency via the beam-plasma instability (*Filbert and Kellogg*, 1979).

Foreshock electron beams are in general weak and transient which makes direct observations by particle instruments difficult and rare. Such observations were published by *Fitzenreiter et al.* (1984) and *Fitzenreiter et al.* (1996) who demonstrate unstable distributions with bump on tail features at energies below 500 eV. Another study (*Bale et al.*, 2000) has revealed electron beams at much higher energies (up to 10 keV) close to the foreshock edge. All the above publications present case studies of a small number of individual observations and suffer from a high degree of uncertainty in the beam energy identification. No statistical results were presented.

Summary of results

Unlike the beams themselves, the Langmuir waves generated by the beams can be easily measured by spacecraft electric field wave instruments. In particular the Wide Band Data instrument of Cluster (*Gurnett et al.*, 1997) provided large datasets of high resolution waveform observations of foreshock plasma waves, which we are have used in our study.

Observations show (*Kellogg et al.* (1999); *Hospodarsky et al.* (1991) and many others) that foreshock wavepackets frequently contain beating signatures of two waves resulting in two-peaked spectra, such as the example in Figure 1. The origin of such spectra is a subject of debate, but it is assumed that the second peak is generated from the first one by reflection or nonlinear wave decay.

The energy of the beam associated with a Langmuir wave can be estimated from the Doppler shift of the wave by simple resonance condition. For wavepackets containing double peak signature, this Doppler can be estimated from the separation of the two peaks. This technique was applied to a large number of Cluster foreshock wave observations and statistics of the beam energy as a function of spacecraft location within the foreshock is presented.

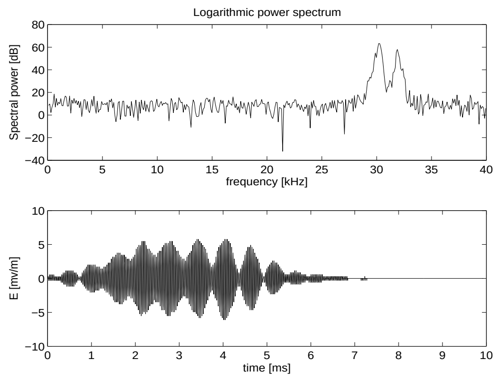

Figure 1: An example of a foreshock wavepacket showing two Doppler shifted spectral peaks (Cluster WBD instrument).

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