NONLINEAR DECAY OF LANGMUIR WAVES OBSERVED BY CLUSTER IN THE TERRESTRIAL FORESHOCK

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In this work we investigate the non-linear decay of Langmuir waves in the terrestrial foreshock. This region of solar wind upstream of the bow shock contains beams of energetic charged particles reflected and accelerated by the shock front. The electron beams are responsible for excitation of electrostatic waves close to the plasma frequency via a beam-plasma instability. Multiple processes can contribute to saturation of this wave growth. In the case of relatively low wave amplitudes, wave-particle interactions like particle trapping or quasilinear diffusion can provide sufficient damping to compensate the wave growth. Once the wave amplitude exceeds a certain threshold, these wave-particle processes cannot dissipate the wave energy anymore and a non-linear decay process sets in. This decay instability transfers the energy of the primary wave to two different waves. It gives rise to a positive growth rate for another Langmuir wave with a lower frequency and an ion-acoustic wave.

The solar wind plasma is known to contain a second electron population in addition to Maxwellian thermal electrons: the suprathermal electrons with a temperature 10 - 20 times higher than the cold population [4]. The presence of this suprathermal component modifies significantly the dispersion relation and allows for propagation of electron-acoustic waves, a wave mode unique to a two-temperature plasma. This property also opens a second channel for the decay instability, the Langmuir wave may now alternatively decay into an electron-acoustic wave and an ion-acoustic wave [2].

The existence and importance of the decay instability in the terrestrial foreshock has not been sufficiently assessed by previous works. We investigate this process by analysis of high-frequency electric field waveforms captured by the WBD instrument of CLUSTER [1]. The spectra observed in the foreshock often contain triplets of peaks corresponding to two waves close to plasma frequency and one low frequency wave in the range from 1 kHz to 5 kHz. Consistently with previous studies [3], we interpret these spectra as a signature of a parametric decay of Langmuir waves. By statistical analysis, we show that the frequencies of these wave triplets in many cases satisfy the resonance conditions required for the decay process. The relative number of spectra satisfying these conditions increases with the mean amplitude of the waves consistently with existence of an instability threshold. Another indication in favor of the decay scenario is a strong correlation of ion-acoustic wave activity observed by STAFF instrument with bursts of most intense Langmuir waves observed by WBD.

All the observed spectral peaks are significantly Doppler shifted in frequency by the solar wind flow. For some waveforms the observed Doppler shift of the secondary wave is larger than a theoretical maximum allowed by a dispersion relation of Langmuir waves. From this discrepancy we conclude, that at least in some cases the secondary wave produced by the decay is an electron-acoustic wave [5].

References

[1] D. A. Gurnett et al. The wide-band plasma wave investigation. *Space Sci. Rev.*, 79:195, 1997.

[2] A. Hanssen et al. Nonlinear wave interactions in two-electron-temperature plasmas. *J. Plasma Phys.*, 51 (3):423–432, 1994.

[3] P. J. Kellogg, K. Goetz, S. J. Monson, and S. D. Bale. Langmuir waves in a fluctuating solar wind. *J. Geophys. Res.*, 104(13):17069–17078, 1999.

[4] M. Maksimovic, S. P. Gary, and R. M. Skoug. Solar wind electron suprathermal strength and temperature gradients: Ulysses observations. *J. Geophys. Res.*, 105:18337–18350, 2000.

[5] J. Soucek, V. Krasnoselskikh, T. Dudok de Wit, J. S. Pickett, and C. .A. Kletzing. Nonlinear decay of foreshock langmuir waves in the presence of plasma inhomogeneities: Theory and cluster observations. *J. Geophys. Res.*, page in press, 2005. doi:10.1029/1999JA900021.