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Langmuir waves observed in planetary foreshocks by Cassini: From the beginning to the Grand Finale

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Abstract

We present a review of Langmuir wave observations across planetary foreshocks obtained by the Cassini spacecraft. During its seven year journey to Saturn, Cassini made flybys of Venus (April 1988 and June 1999), Earth (August 1999), and Jupiter (December 2000). The spacecraft arrived to Saturn in July 2004. Since then Cassini orbits Saturn with many foreshock visits. Almost 20-year-long mission provides an unique opportunity to study and compare Langmuir wave properties across the solar system. Using the Radio and Plasma Wave Science (RPWS) instrument, we examine measurements from a foreshock of each of four visited planets. The Langmuir wave observations are compared and peak electric field amplitudes are estimated. The Langmuir wave properties as a function of the foreshock position for each of flybys are also discussed.

1 Introduction

Langmuir waves are a typical emission observed in a region ahead of planetary shocks. Solar wind electrons accelerated at the shock front are reflected back into the solar wind forming electron beams, which stream along the solar wind magnetic field lines. In regions with electron beams, usually called the electron foreshock, the electron distribution is unstable and electrostatic Langmuir and beam-mode waves are generated via the beam instability (e.g., [1]). The processes of generation and evolution of electrostatic waves depend strongly on the solar wind plasma conditions and on the position inside the foreshock. In a relatively narrow region behind the sunward foreshock boundary, Langmuir waves are the most intense and they are usually observed as the narrowband emission with single peak spectra at a frequency close to the electron plasma frequency (Fig. 1). More complex waves exhibiting a wide frequency spread are often observed deeper downstream (e.g. [3]).

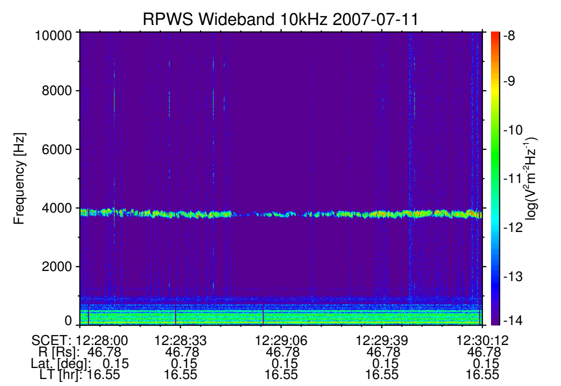

Figure 1: Time-frequency spectrogram for the RPWS/WBR electric component with the Langmuir wave emission observed inside Saturn's foreshock.

2 Instrumentation

For the purpose of this review data from the Radio and Plasma Wave Science (RPWS) and the Magnetometer (MAG) instruments on board the Cassini spacecraft were used. The RPWS instrument consists of three electric antennas, a triaxial search coil magnetometer, and five specialized receivers (for more details see [2]). The receivers cover a range from 1 Hz to 16 MHz for the electric fields and up to 12 kHz for the magnetic fields. Because the Langmuir wave peak frequency is different at each of four planet, the high frequency receiver (HFR) data are used for the Venus and Earth flybys, and the medium frequency receiver (MFR) data are used at Jupiter and Saturn. For a long-term survey inside the Saturnian foreshock, the Wideband receiver (WBR) data are also taken. The HFR A-C subbands cover a frequency range from 3.5 to 319 kHz. MFR provides intensity measurements from a single selected antenna over a frequency range from 24 Hz to 12 kHz. The WBR lowband covers the same frequency range, but provides irregular waveform snapshots. The strength and direction of the interplanetary magnetic field were obtained from the triaxial fluxgate magnetometer which is a part of the MAG instrument.

3 Observations

Due to instrumental settings there are no Langmuir wave observations during the first Venus flyby (April 1998). During the second Venus flyby (June 1999), the RPWS observed the intense Langmuir wave emission with an estimate amplitude on the order of $\mathrm{mVm^{-1}}$, which is similar to the peak amplitude detected by Pioneer Venus and Galileo.

Cassini performed one gravity assist flyby of Earth in August 1999. During this flyby, RPWS observed the intense Langmuir waves at frequencies below 20 kHz in the vicinity of the bow shock. Further from the bow shock less intense emission at the same frequencies was also detected. The largest Langmuir wave electric field detected by Cassini during this flyby was below $\mathrm{mVm^{-1}}$. This amplitude is smaller as compared to measurements of other spacecraft
(e.g. $> 10^2\,\mathrm{mVm^{-1}}$ as measured by STEREO).

In December 2000, Cassini had a flyby of Jupiter. RPWS measured the narrowband emission at frequency of about 2 kHz. The amplitude of the Langmuir waves at this frequency band was on order of $10^{-1}\,\mathrm{mVm^{-1}}$.

After the Saturn Orbit Insertion in July 2004, Cassini spent more than 500 days in front of Saturn's bow shock. Using the RPWS/Wideband receiver, almost 10^6 waveform snapshots (Fig. 2) with the intense Langmuir wave emission were identified. Typical Langmuir wave amplitudes were observed in the range from 10^{-2} to $1\,\mathrm{mVm^{-1}}$ with the median wave amplitude of $8 \times 10^{-2}\,\mathrm{mVm^{-1}}$ [4]. The most intense waves were observed in the vicinity of the foreshock sunward boundary. The amplitudes then fall off with increasing depth in the downstream region.

4 Summary

Langmuir waves have been detected by the Cassini/RPWS instrument upstream of the bow shock of each planet Cassini visited. The characteristics of the Langmuir waves are similar at each planet, with the main difference being the frequency of the waves due to the decrease in the solar wind density with distance from the Sun. The Langmuir waves have similar spectral characteristics at each planet. Near the sunward foreshock boundary crossings, the Langmuir waves are found to be intense, narrowband emissions near the electron plasma frequency. The Langmuir waves often show spectra that are up- and/or down-shifted in frequency from the plasma frequency deeper in the foreshock, very similar to previous observations by other spacecraft.

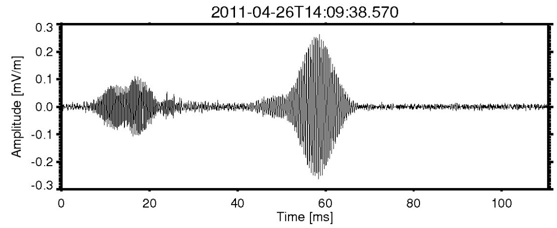

Figure 2: Example of the RPWS/WBR waveform snapshot with typical Langmuir wave packets observed inside Saturn's foreshock.

Acknowledgements

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References

[1] Scarf, F. L., R. W. Fredricks, L. A. Frank, and M. Neugebauer (1971), Nonthermal electrons and high-frequency waves in the upstream solar wind, 1. Observations, J. Geophys. Res., 76, 5162–5171

[2] Gurnett, D., et al. (2004), The Cassini radio and plasma wave investigation, Space Sci. Rev., 114 (1-4), 395–463

[3] Píša, D., O. Santolík, G. B. Hospodarsky, W. S. Kurth, D. A. Gurnett, and J. Souček (2016), Spatial distribution of Langmuir waves observed upstream of Saturn's bow shock by Cassini, J. Geophys. Res. Space Physics, 121, 7771–7784,

[4] Píša, D., G. B. Hospodarsky, W. S. Kurth, O. Santolík, J. Souček, D. A. Gurnett, A. Masters, and M. E. Hill (2015), Statistics of Langmuir wave amplitudes observed inside Saturn's foreshock by the Cassini spacecraft, J. Geophys. Res. Space Physics, 120