A SEARCH FOR LANGMUIR WAVE PRECURSORS OF THE TERMINATION SHOCK

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ABSTRACT

Kurth and Gurnett (1993) suggested that, like other collisionless shocks in the solar wind, the termination shock would likely be a source of Langmuir waves, also known as electron plasma oscillations. Furthermore, just as Langmuir waves often precede the crossing of a planetary bow shock, it was predicted that Langmuir waves might be observed several weeks prior to crossing the termination shock.

1. INTRODUCTION

Kurth and Gurnett identified the region just inside the termination shock as a likely location for Langmuir waves (see Figure 1) since that region is magnetically connected to the shock and, therefore, beams of electrons accelerated at the shock could be found. The electron beams form a bump-on-tail distribution which is unstable to the Langmuir waves. An important question is how durably the region is connected to the shock (because of meandering magnetic field lines) and how far the beams can propagate before they are dissipated. Beams generating type III solar bursts can propagate on the order of an AU and waves observed by Cassini upstream of Saturn's bow shock were observed a large fraction of an AU upstream.

Kurth and Gurnett also plotted the intensity of Langmuir waves as a function of heliocentric distance based on waves observed upstream of the bowshocks of Earth, Jupiter, Saturn, Uranus, and Neptune (see Figure 2). Further, they referred to a Helios result (Gurnett et al., 1978) that the intensity of Langmuir waves scale as the energy density in the solar wind plasma. Assuming that the termination

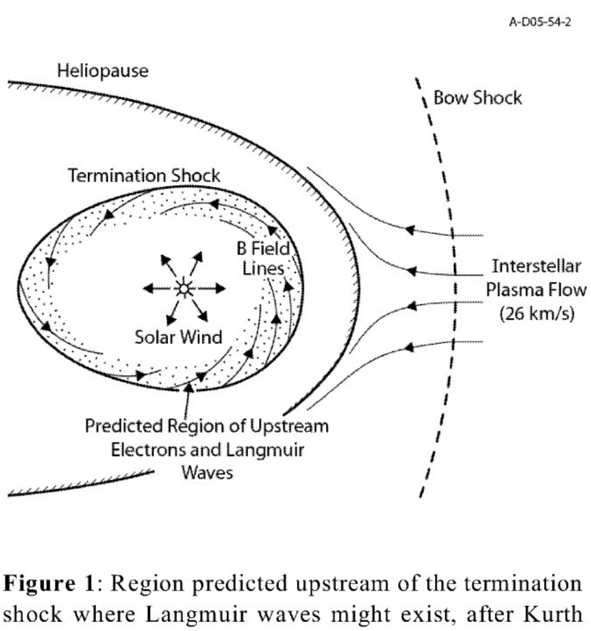

Figure 1: Region predicted upstream of the termination shock where Langmuir waves might exist, after Kurth and Gurnett (1993).

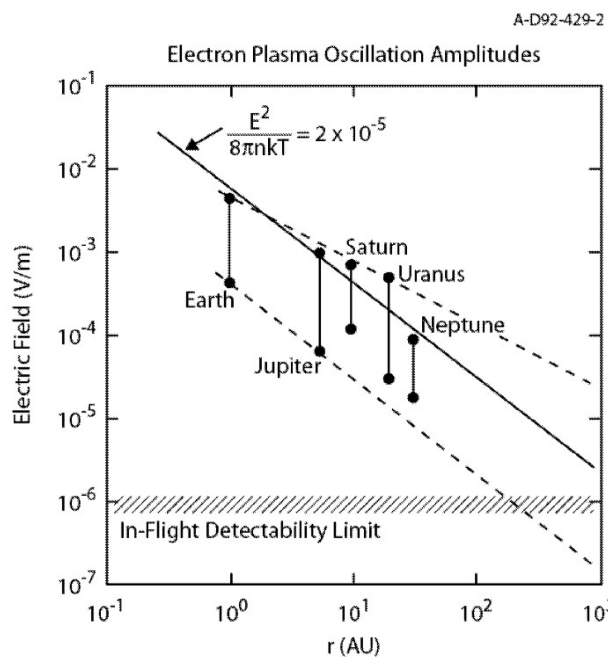

Figure 2: Predicted amplitude of Langmuir waves in outer heliosphere based on waves upstream of planetary bow shocks (Kurth and Gurnett, 1993).

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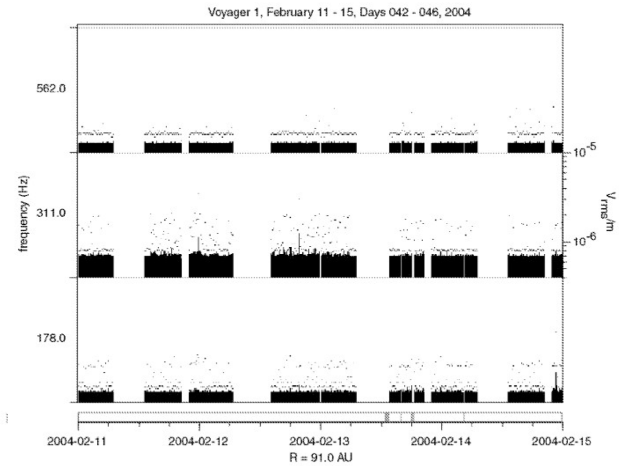

Figure 3: Langmuir waves seen at 311 Hz with amplitudes of order 1 μV/m at a distance of 91 AU.

shock is similar to planetary bow shocks in its acceleration of electrons, the Langmuir waves upstream of the termination shock should be above the Voyager in-flight detection limit for shock distances of about 100 AU and less.

In principle, it should be straightforward to search for the narrowband, bursty Langmuir wave emissions in the Voyager data set. However, extrapolating the frequency of these emissions out to 100 AU based on simple models of the solar wind density which vary as R^{-2}, leads to an electron plasma frequency of the order of 300 Hz. For reasons which are not fully understood, the Voyager plasma wave instruments are susceptable to interference from a large number of spacecraft activities in this same frequency range, including attitude control thruster activity, scan platform motion, tape recorder activities, and the gyroscopes sometimes used for attitude determination. Hence, these sources of interference normally appear as narrowband bursty emissions at about the right frequency for Langmuir waves in the outer heliosphere. A great deal of effort has gone into correlating such interference signals with various types of activities and using the spacecraft sequence to mark or filter out those times when such interference might take place. Since we do not have times for individual thruster firings, the above filtering can not eliminate the occasional individual bursts which occur when the thrusters fire to keep the spacecraft attitude from drifting out of its allowed 'deadband'. Therefore, to eliminate possible contamination from individual thruster bursts, we require a minimum of four consecutive samples to exceed a given threshold before considering them to be naturally occurring waves. Finally, the plasma instrument's modulator grids are driven by 400 Hz square waves, hence, these also provide a low level of interference. Since these emissions are synched with the spacecraft clock, they make a regular pattern which can be effectively filtered by eliminating the affected samples. When all of the above filtering is done, we are reasonably confident that any remaining narrowband, bursty emissions cannot be explained by spacecraft phenomena and must, therefore, be natural emissions.

2. OBSERVATIONS

We have closely examined recent Voyager 1 observations for bursty, narrowband emissions near the expected solar wind plasma frequency and have found a small number of intervals since early 2004 lasting from approximately one hour to a couple of days that appear to be Langmuir waves. Figure 3 shows an example from February, 2004. Most of the activity is found in the 311 Hz channel during February 11 - 13, but there is a brief burst at 178 Hz on February 14. The amplitudes for all the events found are quite small, of the order of 1 μV/m, and their frequencies range from 178 to 562 Hz, within the range expected for the electron plasma frequency at the 91 - 95 AU distance of Voyager 1 since early 2004. Krimigis et al. (2003) and McDonald et al., (2003) report Voyager 1 observations of elevated fluxes of energetic particles unlike those seen by Voyager 2 or elsewhere in the heliosphere, suggesting that Voyager 1 has entered a new region, likely influenced strongly by the termination shock. Given that these observations indicate that Voyager 1 is close to the termination shock, it is likely that the Langmuir waves observed in 2004 are upstream precursors of that boundary.

3. CONCLUSIONS

We have shown Langmuir waves that occur in a new region of the heliosphere strongly influenced by the termination shock and conclude that it is likely these emissions are upstream waves in a foreshock-like region associated with the shock. The amplitudes are somewhat weaker than expected from planetary bow shocks, suggesting that the termination shock is somewhat less efficient at generating the upstream waves. Also, the occurrence of the emissions is very spotty and extends over a longer interval of time than was expected, several months in 2004. This suggests that the magnetic field is tortuous and connection to the shock is highly variable.

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