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Quasi-monochromatic ULF waves in the Venusian foreshock

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Abstract

There exist large amplitude ultralow frequency (ULF) waves in the ion foreshock of the Venusian bow shock. With the magnetic field observations from Venus Express between May 2006 and February 2012, an abundance of quasi-monochromatic ULF waves (with frequency below and far enough from the local proton cyclotron frequency) have been identified by an automatic survey. The transverse part of the power spectrum dominates the parallel part for these foreshock ULF waves. The periods found are in the range from 20 to 30 seconds and most of the waves display left-handed polarization in the spacecraft frame. Taking into account the Doppler-shift by the high speed solar wind, they may be right-hand polarized in the solar wind frame. These characteristics suggest that they are RH mode waves generated in the ion foreshock region by the field aligned beam protons reflected at the shock. One future objective will be to derive the relative occurrence of such foreshock waves and proton cyclotron waves associated to local pickup ions linked to exospheric hydrogen previously reported.

1. Data and observations

In a planetary foreshock, ULF waves are excited usually by field aligned beam ions reflected by the shock [1]. Many quasi-monochromatic ULF waves are identified in the Venusian foreshock by an automatic survey on 1 Hz magnetic field measurements from Venus Express (VEX). Figure 1 shows one case of foreshock ULF waves.

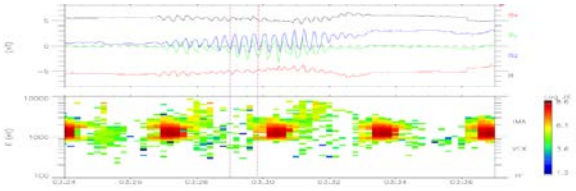

Figure 1: This is the example of ULF.

2. Wave analysis

The periods of the waves shown in Figure 1 is 18.1 ±1, while the local proton cyclotron periods is 12.1. Our automatic survey selects only cases displaying narrow power peaks showing that the waves are quasi-monochromatic (as in Figure 2). The transverse part always dominates the power spectrum. For more details of the ULF waves, minimum variance analysis is also used (in Figure 3) on the intervals marked by pink dashed lines in Figure 1. Figure 3 displays that the waves present left-handed polarization with respect to background field.

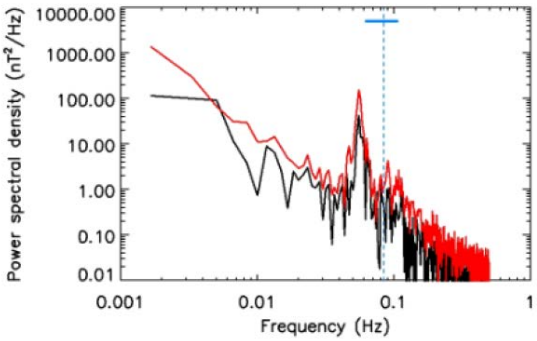

Figure 2: Transverse (red) and compressional (black) power spectrums of ULF waves for the case shown on Figure 1. Blue dashed lines show the local proton cyclotron frequency with error bars.

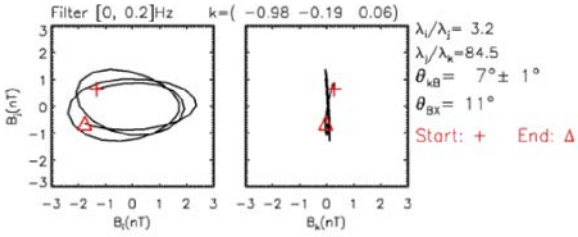

Figure 3: Hodograms of the wave magnetic field for selected intervals (marked by pink dashed lines in Figure 1) in principal axis coordinates.

3. Summary and Conclusions

In our study, quasi-monochromatic ULF waves in the ion foreshock of Venus are identified by an automatic survey. Their frequencies are low and far enough away from the local proton cyclotron frequency. Most of the waves have a period range from 20 to 30 seconds. When we analyze their power spectral density, the transverse part usually dominates. Moreover, MVA method is also utilized, and we find that most of the waves present nearly circular or slightly elliptical polarization. It should be noted that the results are similar when we select only cases with the ratio of intermediate to minimum eigenvalue larger than 10.

Propagation angles of the ULF waves are mainly less than 30 degrees, although they are few cases with values exceeding 50 degrees. Most of the waves propagate at small or moderate angles with respect to the background magnetic field. Thus, by comparison with results at Earth, it is suggested that those ULF waves are generated in the foreshock region by field aligned beam protons reflected at the Venusian bow shock. For the further study, the plasma particle data observed by VEX if available for each ULF wave case will be analysed. The next step, we will revisit the ULF waves boundary in the Venusian ion foreshock as was done recently at Saturn [2]. Another issue is the possible relation between the present foreshock waves and previously reported quasi-monochromatic ULF waves transmitting through a quasi-parallel shock [3].

References

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