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Dispersive Signals in the Venus Ionosphere

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Abstract

The Venus Express mission carries a dual tri-axial magnetometer that allows the correction of the observations for the time-varying spacecraft contribution to the measurements. We have used the measurements from the dual sensors to correct for the spacecraft signals and find two contributions from the Venus environment. A low-frequency contribution below about 10 Hz is produced by the solar wind interaction with the ionosphere and can cross the magnetic field lines at these low frequencies to be observed even at lowest altitudes. This ULF signal is linearly polarized. A higher frequency ELF signal is often found propagating along the magnetic field in the right-handed whistler mode. These signals are observed when there is a significant radial component of the field that permits vertically propagating electromagnetic waves from atmospheric sources to reach the spacecraft. These signals have all the properties expected for electromagnetic waves generated by electric discharges in the clouds of Venus.

1. Observations of Dispersion

Figure 1 shows filtered waveforms of these signals and Figure 2 shows dynamic power spectra of these signals.

A blow-up of the dynamic spectrum shows the impulsive nature of the waves and evolution of the spectra expected from the dispersion of the whistler waves in Figure 3. This is the behavior expected if these signals were produced by lightning in the nearby atmosphere beneath the spacecraft. A second way to measure dispersion is to use overlapped power spectra. Such an analysis is shown in Figure 4. It is consistent with the dispersion shown in the dynamic spectra. A third technique to detect dispersion is simply to convert the signals to an audio frequency and listen to the signals. The ear is a very sophisticated sound detector and with the brain can detect even subtle changes in tone. These signals also pass the audio test.

2. Cleaning the Signals

The Venus Express spacecraft is a noisy environment for a magnetometer and our progress has been slowed by our need to clean the data. We have now optimized our cleaning algorithms.

With our improved cleaning techniques we continue to analyze the measurements returned from the 128 Hz sampling of the magnetometer and map its occurrence in the high-latitude band around the north pole, where Venus Express' periapsis lies. We expect soon to complete the cleaning of the data to the end of 2012.

3. Schumann Resonances or Solar Wind Interaction Signatures?

At low frequencies, after about 20 Hz and lower, there are strong, linearly polarized signals. When they are Fourier analyzed, the waves exhibit a banded structure reminiscent of Schumann resonances. These waves appear to be generated in the solar wind interaction, but it is unclear why they have this banded appearance. Figure 5 shows an example of such waves.

Figures

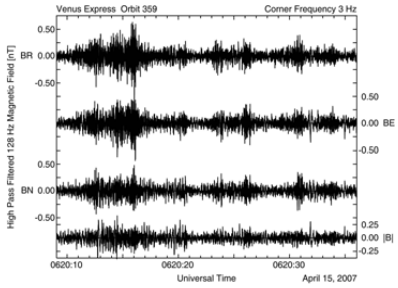

Figure 1: Band-pass filtered magnetic field in radial, east, north coordinates showing the ELF signals present on April 15, 2007, from 0620:09 to 0620:35. High-pass corner frequency is 20 Hz.

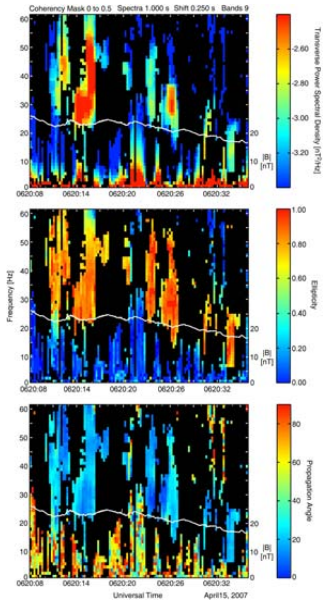

Figure 2: Dynamic spectra showing the transverse power the ellipticity of the waves and the direction of propagation in the band above 20 Hz on April 15, 2007.

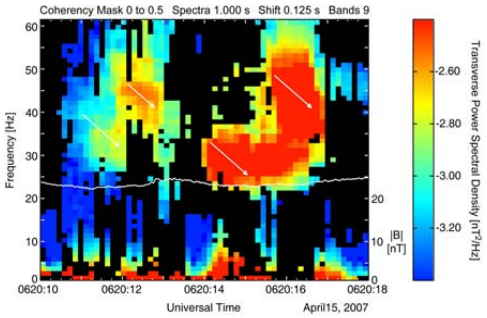

Figure 3: Higher-resolution analysis of Figure 2 showing the expected dispersion and the time evolution of the spectra that is consistent with this expected dispersion.

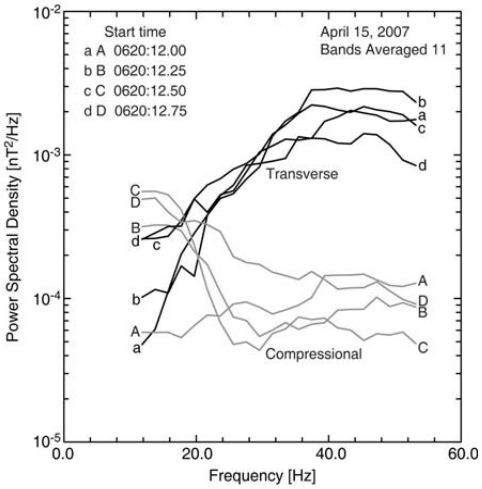

Figure 4: Time series and overlapped power spectra illustrating the dispersive signals.

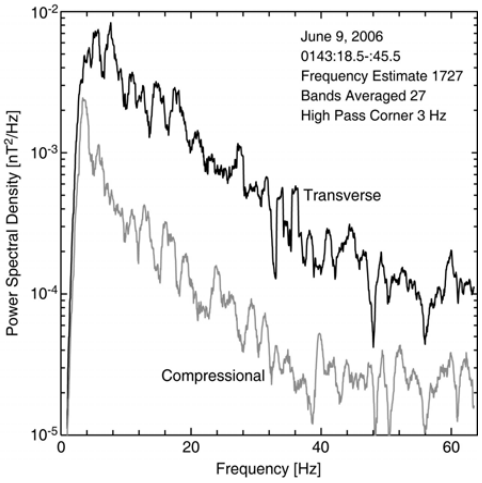

Figure 5: Power spectrum on June 9 shows linearly polarized waves that have a series of bands in the frequency domain.