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# ULF oscillations at discrete frequencies: a comparison between ground, magnetospheric and interplanetary measurements

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**Abstract.** The occurrence of ULF oscillations at discrete frequencies in the power spectra of the geomagnetic field components ($\sim$ 1.3, 1.9, 2.6, 3.4 mHz) has been reported in several works. Possible sources for such fluctuations are the solar wind pressure pulses impinging on the magnetopause and producing a multi-harmonic cavity and/or waveguide compressional modes. However, in recent years, several works presented a number of events in which the power spectra in both the magnetospheric field and the solar wind density show peaks at the same discrete frequencies. Then, it was suggested that these pulsations might be directly driven also by density oscillations of the external solar wind. In the present study we carefully investigate this aspect.

**Key words.** Magnetospheric fluctuations – Selected frequencies

## 1. Introduction

An interesting aspect of the geomagnetic field observations at low latitudes is represented by the occurrence of low frequency spectral peaks at discrete frequencies in the Pc5 range ($\sim 1.2-1.4, 1.8-2.0, 2.4-2.6, 3.2-3.4$ mHz) (Ziesolleck and Chamalaun 1993; Francia and Villante 1997; Villante et al. 2001). These spectral enhancements were originally identified at higher latitudes (Samson et al. 1991). According to theoretical models (Radoski 1974; Kivelson and Southwood 1985, 1986; Samson et al. 1992) these fluctuations may be interpreted in terms of ground signatures of magnetospheric cavity and/or waveguide compressional modes driven by solar wind (SW) pressure pulses. On the other hand recent works (Kepko et al. 2002; Kepko and Spence 2003) presented some events in which the power spectra in both the SW pressure and the magnetospheric field magnitude contain peaks at the same discrete frequencies. Then, it was suggested that, at least occasionally, discrete oscillations of the magnetospheric field can be directly driven by fluctuations of the external SW parameters and not related to a possible cavity or waveguide modes. In the present paper we investigate these aspects focusing attention on few remarkable events selected in the geomagnetic field observations and comparing ground observations with those obtained in the magnetosphere and in the near-Earth interplanetary medium.

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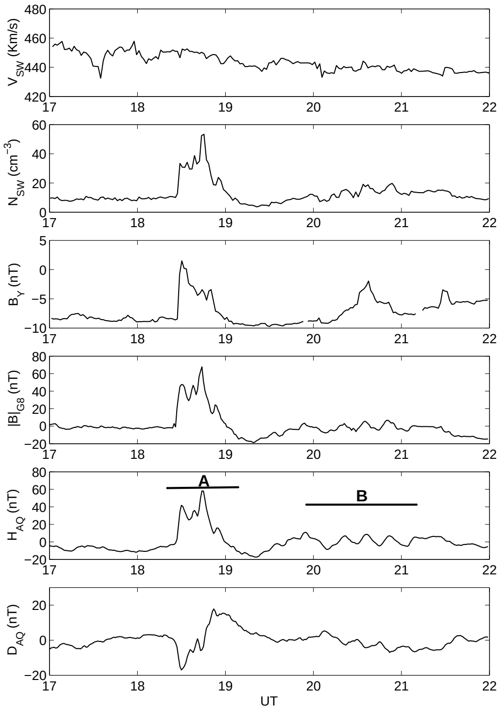


**Fig. 1.** A comparison between SW and IMF data from WIND (at $X_{GSE} \sim 85R_E$), GOES-8 and ground measurements on August 1, 1998, corresponding to the time interval 17:00 – 22:00 UT. From the top: the SW velocity and number density, the azimuthal IMF component, the magnetospheric field magnitude and the ground magnetic field.

## 2. Data analysis and experimental results

Data presented in this work are from WIND, GOES-8 and GOES-10 geosynchronous orbit satellites (MLT = UT-5:00 and MLT = UT-9:00 respectively, MLT being the magnetic local time) and from a low latitude ground station (L'Aquila, AQU, $\Lambda \sim 36°$, MLT = UT+1:37). By means of an algorithm that provides an automatic selection, we identified the most significant events (i.e. those characterized by sharp and distinct spectral peaks) in ground measurements at AQU in a five years interval (1998-2002).

Fig. 1 shows the SW and interplanetary magnetic field (IMF) from WIND (located at $X_{GSE} \sim 85R_E$), GOES-8 and ground measurements on August 1, 1998 (17:00 – 22:00 UT). WIND data have been plotted with a time shift of +21 min to take into account the propagation delay. Two events corresponding to different conditions were selected in this time interval: the first one (A) is characterized by a large amplitude variation of the geomagnetic field lasting about 40 minutes; the second one (B) is characterized by quasi-periodic regular oscillations. As can be seen, in both cases the geomagnetic and magnetospheric field observations closely reflect the SW density variations.

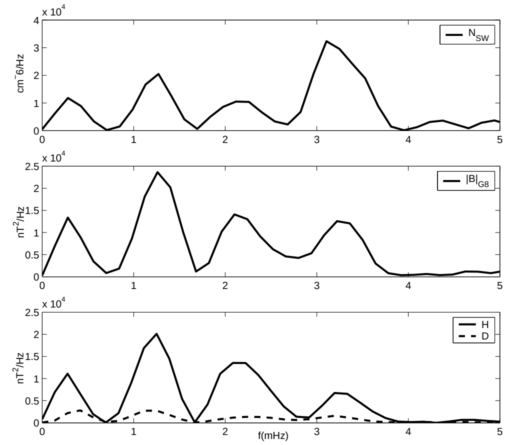


**Fig. 2.** Spectral analysis of A event, August 1, 1998, relative to the time interval 17:30 – 19:30 UT. From the top: SW number density, magnetospheric and geomagnetic field.

The spectral analysis of A event shows (fig. 2) four spectral peaks ($\sim$ 0.3, 1.3, 2.2 and 3.1 mHz) in the SW density, in the magnetospheric and in the geomagnetic field. As can be seen, the experimental measurements show a spectacular correspondence between ground, magnetospheric, and SW observations. The same conclusion holds for event B which shows (fig. 3) a monochromatic dominant peak at $\sim$ 1.0 mHz in all parameters.

Fig. 4 shows the SW and IMF data from WIND (located at $X_{GSE} \sim 40R_E$), GOES-8, GOES-10 and ground measurements for C event (June 8, 2000). WIND observations have been delayed by 6 minutes. As can be seen, a macroscopic fluctuation in the SW density lasting about 50 minutes is observed by WIND:

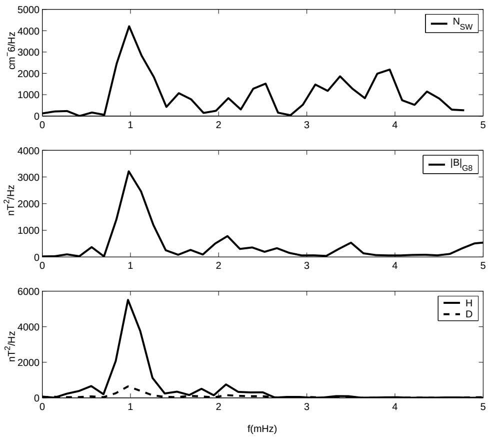


**Fig. 3.** The same as in fig. 1 for August 1, 1998, corresponding to the time interval 19:30 – 21:30 UT.

it finds a clear correspondence in the magnetospheric and geomagnetic field observations. The spectral analysis shows (fig. 5) that spectral peaks at ∼ 1.9, 2.6 and 3.6 mHz are observed in the SW density and in the magnetospheric field (less clearly in GOES-10, which is located in the early morning sector). Similar power enhancements are detected in ground measurements where the more prominent peak occurs at ∼ 3.6 mHz.

Fig. 6 shows the SW and IMF data from WIND (located at $X_{GSE} \sim 80R_E$), the magnetospheric field data and ground measurements for D event (September 18, 2001). WIND observations have been delayed by 15 minutes. A macroscopic variation in the SW density lasting about 50 minutes is observed also in this case: it finds a clear correspondence in the magnetospheric and geomagnetic field. The spectral analysis shows (fig. 7) that spectral peaks at ∼ 0.5, 0.9 and 1.4 mHz are observed in ground measurements and in the magnetospheric field. In this case, except a clear peak occurring at ∼ 0.5 mHz, similar power enhancements are not detected in the SW density.

## 3. Conclusions

In the present study we analyzed four selected events and compared geomagnetic and mag-

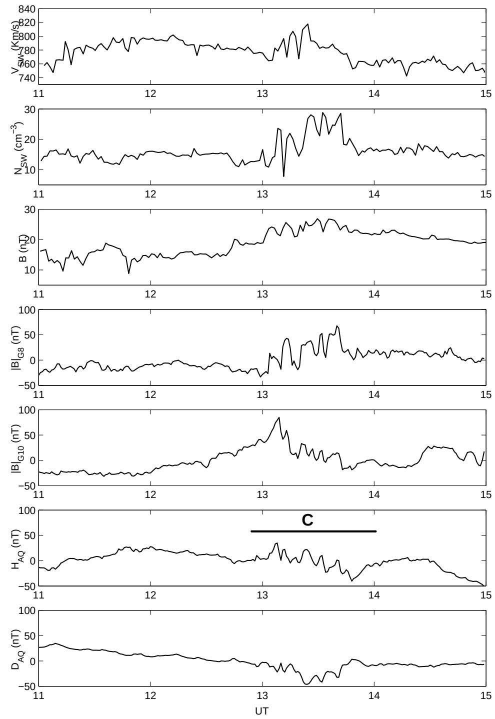


**Fig. 4.** A comparison between SW and IMF data from WIND (at $X_{GSE} \sim 40R_E$), GOES-8, Geos-10 and ground measurements on June 8, 2000, 11:00 – 15:00 UT. From the top: the SW velocity and number density, IMF magnitude, magnetospheric field magnitude from GOES 8 and GOES 10 and ground observations.

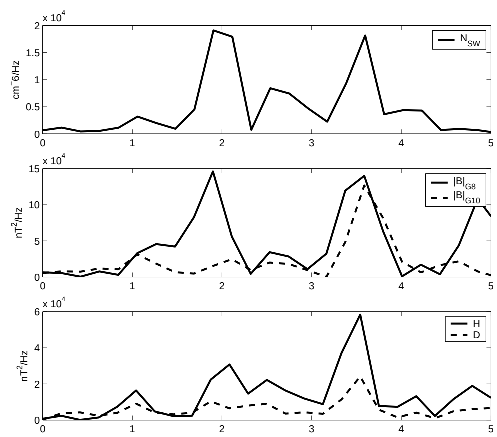


**Fig. 5.** The same as in fig.1 for June 8, 2000, relative to the time interval 12:40 – 14:00 UT.

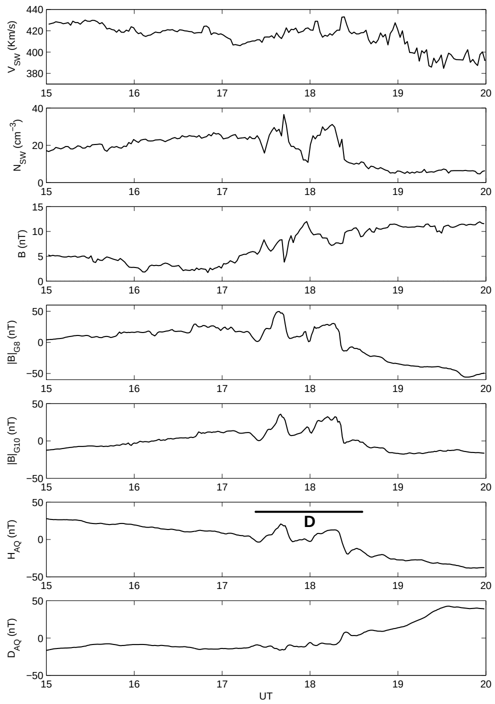


**Fig. 6.** The same as in fig.4 for September 18, 2001, 15:00 – 20:00 UT.

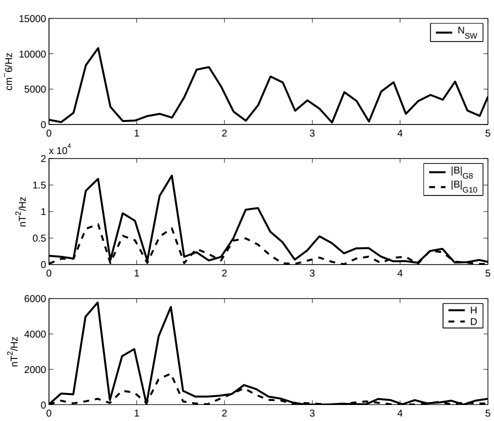


**Fig. 7.** The same as in fig.1 for September 18, 2001, relative to the time interval 17:00 – 19:00 UT.

netospheric field data with IMF and SW data. All of these events are characterized by a clear correspondence between variations observed in the SW number density and oscillations of magnetospheric and geomagnetic field. For three of these events, the spectral analysis shows that pulsations at selected frequencies in the Pc5 frequency range (1-5 mHz) and below find a clear correspondence with SW density and magnetospheric field fluctuations. It suggests SW density fluctuations as candidates for the onset of global magnetospheric modes. The spectral analysis of the last event shows peaks observed at ground station and in magnetosphere not simultaneously observed at the same frequencies in the SW density. In this event the magnetospheric and geomagnetic field fluctuations are not directly driven by SW density variations.

A worldwide analysis of the geomagnetic field observations and a more careful comparison with other external parameters also for other events is presently in progress.

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