EPSC Abstracts
Vol. 9, EPSC2014-557, 2014
European Planetary Science Congress 2014

Exploration of Kronian Magnetosheath Turbulence Using Cassini Data.

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Abstract

The power density spectra and the magnetic compressibility in Saturn's magnetosheath are investigated using in-situ measurements of the fields and particles from Cassini spacecraft mission. Two major results are found. 1) The absence of the $f^{-5/3}$ Kolmogorov-like inertial range: the averaged magnetic power spectral densities indicate that the spectra jump from a 1/f scaling at the large scales (typical for solar wind spectra, Leamon et al. 1999) directly into the ion scales with a slope of - 2.5 ,without forming any 5/3 inertial range. Furthermore 2) computing the magnetic compressibility we show the dominance of the compressible magnetosonic modes at the kinetic scales compared with Kinetic Alfven Waves (KAW) reported in the solar wind (Sahraoui et al 2009)

1. Introduction

The shocked solar wind plasma upstream of the bowshock, forms the magnetosheath. Through this region energy, mass and momentum are transported from the solar wind into the planet’s magnetosphere, playing a crucial role in the solar-planet interactions. Hence, the planets' magnetosheath present a high level of turbulence, embedded with nonlinear stochastic processes, and containing a rich variety of wave phenomena. Hereafter, the magnetic turbulence of the terrestrial magnetosheath has been extensively studied, however not so much has been done regarding the planets magnetosheaths.

1.1 Purpose of the study

In order to expand our knowledge on plasma turbulence and thanks to the cassini spacecraft mission, we decided to explore the characteristics of turbulence in the Kronian magnetosheath.

2. Data Set and Method

The analysis is based on data provided by the magnetic field and plasma particles experiments MAG and CAPS (Cassini Plasma Spectrometer) respectively on board Cassini spacecraft for 39 different time intervals which

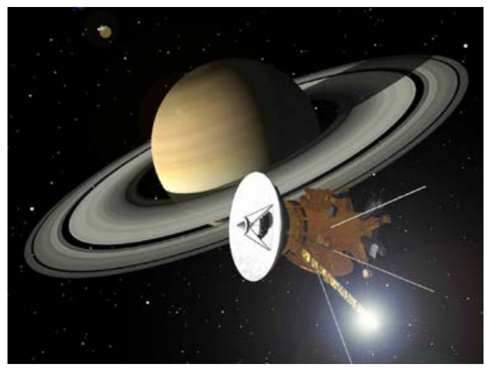

Figure 1: Cassini spacecraft at Saturn. (Jpl.nasa.gov)

correspond to the passage of Cassini in the magnetosheath of Saturn. One part of the data was taken from a list of 17 bow shock crossings (Dougherty et al. 2005) and another part was extracted from a set of 94 crossings made between 2005 and 2007 (Masters et al 2011). The Fluxgate Magnetometer sensor (FGM) of the Dual Technique Magnetometer (MAG) provided the DC measurements of the amplitude and the direction of the magnetic field with the highest resolution available (32 ms) a detailed description of the MAG experiment, with its different sensors, has been given by Dougherty et al. 2004 and Gurnett et al. 2004. Using the data collected by the Electron Spectrometer (ELS) and the Ion Mass Spectrometer (IMS) sensors of the CAPS (Young et al 2004) we have access to the electrons and protons moments respectively.
The power density spectra of the magnetic fluctuations are computed using the windowed Fast Fourier Transform (FFT) in the standard right-handed spherical coordinates, the Kronocentric Radial-Theta-Phi (KRTP), which is Saturn centered.

3. Observations & results

3.1 Power density spectra.

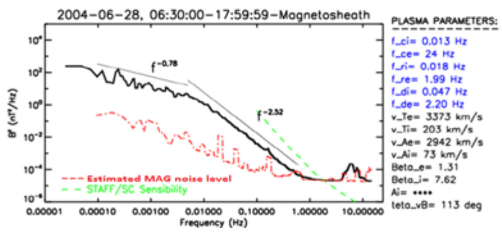

Figure 2: Magnetic power density spectra computed in Saturn's magnetosheath.

We first computed the power density spectra of the interplanetary magnetic fluctuations measured during several magnetosheath crossings as have been cited earlier. As we can see from figure 2, we found that the spectra are different from those measured in the solar wind: the MHD scales show a f^{-1} spectrum rather than the Kolmogorov scaling ~ $f^{-5/3.}$ And at the sub-ion (or kinetic) scales the spectra steepen to $f^{-2.5}$ similarly to previous observations in the terrestrial magnetosheath or the solar wind at 1AU [Sahraoui et al., ApJ, 2013].

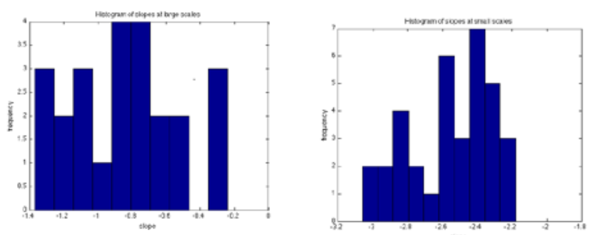

Figure 3: Histograms of the magnetic spectral slope computed at the large scales (a) and the ionic scales (b)

The histograms of Figure 3 show that for all the case studies, the slopes of the large scale zone f^{-1} (fig.3.a) vary between [~1.4-0.6] but are mainly concentrated around the value 0.8, and the slopes of the ionic scales (fig.3.b) ~$f^{-2.5}$ vary between [3-2.2] but mostly gathered around ~2.6.

3.2 Magnetic compressibility.

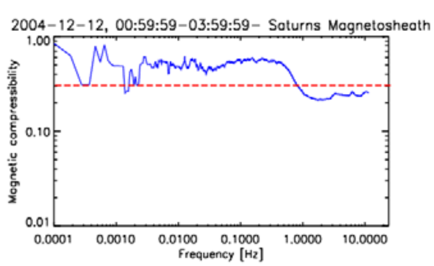

Figure 4: Magnetic compressibility for one case study

In order to characterize the nature of the propagation modes in the Kronian magnetosheath, we computed the magnetic compressibility defined as:

$$C = \frac{\delta B^2 para}{\delta B^2\ tot}$$

As we can see from figure 4, the magnetic compressibility is almost constant and higher than 1/3. This actually shows the highly compressible nature of the turbulence at MHD and kinetic scales contrary to the known results from solar wind turbulence [Kiyani et al., ApJ, 2013]

4. Summary and Conclusions

Throughout this work we have shown the absence of the Kolmogorov scaling ~ $f^{-5/3}$ at MHD scales, which scale as ~ f^{-1} suggesting the random-like nature of the fluctuations, contrary to known results on solar wind turbulence. The spectra steepen above the spectral break (near the ion scale r_i) to $f^{-2.5.}$

By studying the magnetic compressibility our results suggest that turbulence in the magnetosheath of Saturn are dominated by compressible magnetosonic modes whose nature (e.g. slow, mirror, fast) is currently being investigated.

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