Nature of Prominences and their role in Space Weather
Proceedings IAU Symposium No. 300, 2013
B. Schmieder, J.-M. Malherbe & S. T. Wu, eds.
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doi:10.1017/S1743921313011666

Characterization of intermittent structures in the solar wind

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Abstract. The solar wind (SW) is a suitable natural scenario to study the intermittent nature of magnetohydrodynamic (MHD) turbulence for systems with low dissipation rate. In particular, nonlinear wave-wave interactions can be characterized by the degree of phase correlation and by departures from Gaussianity of the magnetic field. In this work, we study *in situ* observations of magnetic field intensity from the spacecraft ACE, which is located near one astronomical unit from the Sun, in the SW near Earth. We compute the phase coherence index analyzing two sets of observations, each one consisting of approximately three months during 2008 and 2012, respectively. From these sets of data we characterize intermittent features of the magnetic field intensity corresponding to a solar maximum and a solar minimum.

Keywords. Solar Wind, Intermittency, Magnetohydrodynamic turbulence.

1. Introduction

Intermittent turbulence is characterized by fluctuations in different spatial scales. Such multiscale interactions are localized regions of plasma with phase synchronization giving place to the presence of phase-coherent intermittent structures which dominate fluctuations at small scales and show departures from Gaussianity. The solar wind (SW) is considered a natural laboratory for observing intermittent turbulence (Chian *et al.* (2009)), and the presence of these phase-coherent structures have been shown previously by Chian *et al.* (2009), Koga *et al.* (2007), Hada *et al.* (2003).

In this work, we study the intermittent fluctuations of the SW taking into account the proton to magnetic presure ratio ($\beta_p = P_{proton}/P_{mag}$) as a proxy for distinguishing between the usual SW and its transient component during two conditions of the solar cycle, namely, solar maximum and solar minimum. We aim at determining which condition leads to a more frequent ocurrence of phase syncronization by computing a phase coherence index obtained from first order structure functions.

2. Observations of solar wind at 1 AU and results

We study three months of magnetic field data with a temporal cadence of 1 second from ACE spacecraft for two different solar conditions: close to solar minimum (Jan-Mar 2008) and close to solar maximum (Jan-Mar 2012). We perform a daily analysis for both period of observations.

We characterize the spatial fluctuation of the magnetic field intensity ($B = |\vec{B}|$) by computing the structure function of first order $S(\tau) = \sum_{i=1}^{n} |B_{i+\tau} - B_i|$ for each temporal scale, τ, and over the n elements of the data series. In order to quantify the degree of phase syncronization we derive from $S(\tau)$ the phase coherence index as $C_\phi(\tau) = \frac{S_{prs}(\tau) - S_{org}(\tau)}{S_{prs}(\tau) - S_{pcs}(\tau)}$.

https://doi.org/10.1017/S1743921313011666 Published online by Cambridge University Press

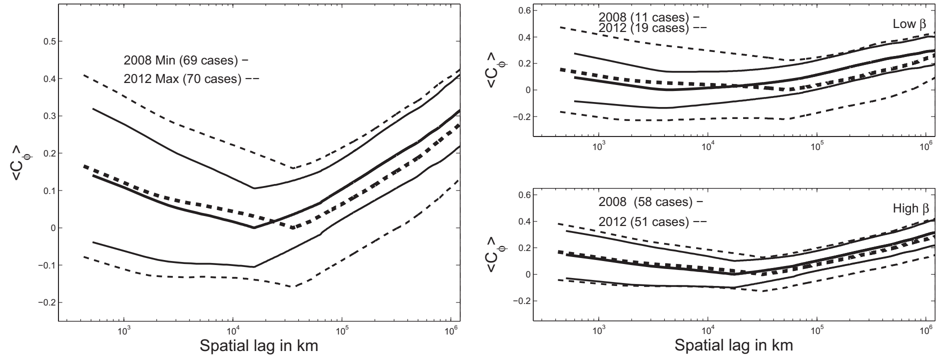

Figure 1. Left panel shows the mean variation of the coherence index $< C_\phi >$ and its standard deviation (σ in thinner lines) as a function of the spatial scale during solar minimum (full line) and solar maximum (dashed line). Right panels separate the cases shown in left panel for $\beta_p \leqslant 1.50$ (upper panel), and for $\beta_p \geqslant 1.50$ (lower panel).

Here org, prs, and pcs stand for the original data series, random phase series and constant phase series, respectively, each one obtained from the original series (Chian *et al.* (2009)). We present our analysis for solar maximum (2012) and solar minimum (2008), and we also consider $\beta_p = 1.50$ as a threshold value for separating low and high β_p regimes.

The left panel of Fig. 1 shows the mean coherence index $< C_\phi >$ and its standard deviation (σ) during both solar activity periods. Although the tendency is similar in both periods showing more coherence towards smaller spatial scales ($< C_\phi >\sim 0.2$ for $r < 10^3$ km), it is noticeable that during solar maximum the values of $< C_\phi >$ are more spread than during solar minimum, in particular, at smaller scales.

The right panels of Fig. 1 show $< C_\phi >$ during both solar activity periods but comparing high and low β_p regimes (lower and upper panels, respectively). In this case, the phase syncronization is slightly more enhanced during high β_p periods, indicating that phase syncronyzation would be not only more common in higher solar activity periods, but also in higher β_p regimes.

3. Discussion, preliminary results and future work

We study intermittency in the solar wind through the phase coherence comparing both regimes of solar activity for high β_p and low β_p cases using *in situ* observations at 1 AU in the ecliptic plane. We find that phase syncronization can be found more frequently during solar maximum. However, for $\beta_p < 1.5$, this feature is less noticeable. For $\beta_p > 1.5$, the values of $< C_\phi >$ are more spread being more coherent at smaller spatial scales indicating more cases with phase syncronization as a signature of intermittency.

Phase syncronization seems to be related to high solar activity, in agreement with the higher level of fluctuations, and with high β_p regimes, making β_p a parameter for ordering the fluctuations properties in the SW. However, further studies must be done.

Acknowledgments: This research has made used of NASA's Space Physics Data Facility (SPDF). We thank CONICET for finnancial support. We acknowledge support by UBACyT 20020120100220.

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https://doi.org/10.1017/S1743921313011666 Published online by Cambridge University Press