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Observations of amplitude-phase synchronization, current sheets and magnetic reconnections in CME source regions and ICME shocks

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Abstract. We apply nonlinear techniques to measure amplitude-phase synchronization due to multiscale interactions in the intermittent magnetic field turbulence in two solar events: 1) the solar active region AR 10950 before and after the X3.4 flare on 2006 December 13 and *in situ* detection of an ICME on 2006 December 14-16; 2) the solar active region AR 10720 on 2005 January 16 and *in situ* detection of an ICME on 2005 January 21-22. The first event is studied by Hinode solar magnetograms and STEREO-A data of ICME, and the second event is studied by SOHO MDI magnetograms and ACE/Cluster data of ICME. First, we compare the nonlinear dynamics of the solar active region with a solar quiet region for each event using the Hinode (SOHO MDI) magnetograms by computing kurtosis and the phase coherence index as a function of spatial scale r. We observe that the variation of kurtosis and the phase coherence index with r in the solar quiet regions is close to a Gaussian process with monofractal features. In contrast, the solar active regions exhibit multifractal features characterized by an increase of kurtosis and the phase coherence index as the spatial scale r decreases which is a signature of coherent magnetic structures resulting from amplitude-phase synchronization in an intermittent magnetic field turbulence. Next, we compare the nonlinear dynamics of the upstream and downstream regions of the ICME shocks of two events using the STEREO-A (ACE/Cluster) magnetometer time series by computing kurtosis and the phase coherence index as a function of time scale τ. In both events, the upstream and downstream regions indicate non-Gaussian features in the two-point difference statistics of amplitude and phase fluctuations, evidenced by a finite degree of amplitude and phase synchronization in a wide range of time scales. The level of intermittency for all scales computed by both kurtosis and the phase coherence index in the downstream region of the ICME shock is much higher than the upstream region. We show that the interplanetary magnetic field turbulence

in the downstream region of an ICME shock is closely correlated with the geomagnetic turbulence detected by the ground magnetometer. Finally, we apply single- and multi-spacecraft techniques to search for current sheets in an ICME shock using the Cluster magnetic field data of the second event. Two large-scale current sheets are detected at the leading boundary of the ICME ejecta using the single-spacecraft technique, which display physical characteristics typical of magnetic reconnection exhausts in the solar wind.

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