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Observations of the balance between Alfvénic fluctuations and convected magnetic structures in different solar wind regimes

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The phenomenological view of magnetic and velocity fluctuations in the solar wind that considers two main contributors to heliospheric turbulence: dynamically and non-linearly interacting Alfvénic fluctuations on the one hand and advected magnetic structures on the other hand, provides a qualitative model that may lead to a more satisfactory description of solar wind turbulence. The nature of the fluctuations appears primarily to depend on the bi-modal nature of the solar wind, fast and slow, and the dynamic interaction between slow and fast streams. For highly Alfvénic flows, mainly in fast streams, velocity and magnetic fluctuations are highly correlated (or anti-correlated) as measured by the high (absolute) value of the normalised cross-helicity. Slow and mixed-speed streams have, by contrast, low ($\sim$0) values of cross helicity, often assumed to be the result of close to equal populations of Alfvén waves propagating away and towards the sun. However, observations seem to imply a generally dominant anti-sunward propagating wave population. Also, measuring the respective powers in the velocity and magnetic fluctuations has shown that magnetic fluctuations (nearly) always dominate, so that the residual energy (a measure of the powers respectively in magnetic and velocity fluctuations) is dominantly negative, while an equipartition of energy would give a zero value to this parameter. We have followed up previous studies (e.g. Bruno et al., Ann. Geophys., 25, 1913–1927, 2007) that had investigated possible reasons for this discrepancy by systematically distinguishing solar wind flow regimes, using the Ulysses observations at low and high heliolatitudes. A particularly important result is that the most Alfvénic regimes in the uniform high speed solar wind from the solar polar coronal holes have, as expected, a high (absolute) value of the cross-helicity, but a relatively constant negative value ($\sim$ -0.5) of the residual energy parameter. In other solar wind regimes, the cross-helicity behaves as expected, with generally fluctuating but low ($\sim$ 0) values, while the residual energy parameter (or, equivalently, the Alfvén ratio) shows a much more pronounced variability and burstiness, even though it remains much of the time negative. By comparing in detail the sample intervals from the different solar wind flow regimes, we probe the possibility of providing a measure for the respective contributions of magnetic structures and Alfvénic fluctuations. We find, qualitatively, that even in the uniform high speed solar wind the convected variations of the magnetic field (generally originating in the non-uniform coronal source field) lead to the higher magnetic fluctuation energy as recorded by spacecraft observations. In mixed speed streams, the interaction between the more variable velocity field and the more complex magnetic structures associated with the slow solar wind effectively form what may be regarded as an inhomogeneous (and interacting) mixture of fluctuations of different origins that leads to considerable challenges when described in terms of homogeneous and stationary turbulence.