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SOLAR WIND SPECTRAL ANALYSIS IN HELIOSHEATH FROM VOYAGER 2 DATA

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Abstract:
The solar wind is a supersonic flow of magnetized plasma. It is time-dependent on all scales and expands with distance. The flow has fluctuations on a broad range of scales and frequencies. This fluctuations are not just convected outward but show energy cascades among the different scales. The solar wind turbulence peculiar phenomenology has been comprehensively reviewed by Tu and Marsch (1995) and Bruno and Carbone (2013). As the distance from the sun increases, the available data on plasma and magnetic field become increasingly scarce. At distance of the order of 1 astronomic unit (AU), several measurement have been performed by various crafts, but, nowadays, only the Voyager spacecrafts can measure data in the heliosheath, the outermost layer in heliosphere where the solar wind is slowed by the pressure of the interstellar gas, and only the Voyager 2 craft can measure both plasma and magnetic fields (Voyager 1 can measure only the magnetic field, and Pioneer 10 and 11 has ceased communications). Taken together, the Voyager 1 and 2 probes have collected over 11 year of data in the heliosheath. The Voyager plasma experiment observes plasma currents in the energy/charge range 10 – 5950 eV /q using four modulated-grid Faraday cup detectors [Bridge 1977]. The observed currents are fit to convected isotropic proton Maxwellian distributions to derive the parameters (velocity, density, and temperature) used in this work. Magnetic field and plasma data are taken the COHO web site and MIT Space Plasma Group repository. Several studies have been done in order to extend the existing models to make them consistent with the energetic particles and magnetic fields measured in the heliosheath, but so far an exhaustive explanation has not yet been obtained. In particular, the differences between the energetic particle intensity variations seen by the two crafts are unexplained. The electron intensity measured by Voyager 2 varies steeper by a factor of 10 in a single year, while the same quantity from Voyager 1 changes gradually over time [Hill et al 2014]. A possible explanation can be the presence of bubble of turbulence that travels in the heliosheat. Therefore, a characterization of turbulence and its intermittency is necessary to explain this phenomenology. The aim of this work is to provide the first spectral analysis of heliosheath solar wind, trying to characterize the plasma turbulence in that region by estimating the spectral slopes. A first result is that the low frequency spectral slope is lower when the electron intensity is low. In order to compute spectra, signal reconstruction techniques are mandatory: at distance over 80 AU, available data are very spotty. For the plasma velocity, there are 97% of missings due to unsteadiness in the signals the most important of which are: tracking gaps due to the V2 location and due to limited deep space network availability; interference from other instruments; possible errors in the measurement chain (from the Faraday cups up to the data acquisition system and the signal shipping to Earth); the temporal sequence of the nuclear propulsion used to control the Voyager trajectory and to assist in several critical repositionings of the craft. For data recovery, we mainly use two different methods. The first method used is based on the correlation computation [Matthaeus & Goldstein 1982] that allows to reconstruct correlations and use it to compute spectra. Better results can be achieved implementing the maximum likelihood reconstruction by Rybicki and Press (1992) based on a minimum-variance recovery with a stochastic component. The second methods comes from the Compress Sensing, a recent technique widely used in telecommunications, that provides the reconstruction of the signal from a sparse dataset (Donoho 1997), by using sparse Fourier matrices (Rauhut 2010). The methods used have been previously tested on 1979 data and on synthetic fluid turbulent fields. Results were in good agreement with the literature, and allows to compute largest spectra of solar wind at 5 AU, with frequencies ranging from 10^{-7} to 10^{-2} Hz [Fraternale et al (submitted), Gallana et al 2014].