Alfvénicity and non-Maxwellian features in solar wind streams: insights from Solar Orbiter

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Alfvénic fluctuations are a pervasive feature of the solar wind, spanning both fast streams and intervals of slow wind with enhanced Alfvénicity. Their presence is closely associated with departures from thermodynamic equilibrium and is thought to play an important role in generating non-Maxwellian features, such as ion beams and temperature anisotropies. This points to an active role of wave–particle interactions in shaping ion velocity distribution functions.

The ESA/NASA Solar Orbiter mission enables a detailed investigation of how these fluctuations evolve with heliocentric distance and how they relate to the kinetic properties of the plasma. This work leverages measurements from both the cruise and nominal mission phases to examine the coupling between turbulence and particle dynamics. The analysis combines spectral characterization of magnetic and velocity fluctuations with an in-depth investigation of proton and alpha particle velocity distribution functions. A clustering technique commonly used in machine learning is applied to identify the main ion populations, with the aim of clarifying the processes leading to non-Maxwellian features across different solar wind regimes.