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Two-dimensional hybrid simulations of Alfvénic fluctuations in the expanding solar wind

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The supersonic expansion of the solar wind and wave particle interactions which characterize the ion evolution are investigated using a hybrid expanding box model. We present 2D simulations of the interaction between Alfvénic like fluctuations using two different geometries: an in-plane mean magnetic field and an out-of-plane mean magnetic field. The initial conditions for the Alfvénic spectrum are a) a mixed parallel and oblique propagating modes (in-plane) and b) purely perpendicular wavevectors (out-of-plane). For both geometries we consider 2 kinds of initial conditions.
1) the imbalanced case with Alfvén waves propagating in one direction along the guide field, that is an initial condition with maximal correlation between u and b (maximal cross helicity and null residual energy)
2) the balanced case with counter-propagating Alfvén waves and with an initial magnetic energy dominating over kinetic energy (null cross helicity and maximal residual energy).
Such characteristics are the most frequently observed in the solar wind.

We investigate parallel and perpendicular proton heating properties of the turbulent spectra in the simulations and the influence of the expansion on the evolution of turbulence and its decay. As suggested by solar wind observations, the perpendicular heating and parallel cooling is not strong enough to overcome the expansion-driven anisotropic cooling. Once the expansion drives the system unstable with respect to the fire-hose instability driven by the proton temperature anisotropy, electromagnetic fluctuations are generated. These waves scatter protons and reduce their temperature anisotropy. Consequently, this mechanism constrains the temperature anisotropy and the system evolves along a marginal instability path.