

Fluctuation Relation in MHD Turbulence: Entropy Production and Time-Reversal Asymmetry in the Inertial Range

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Fluctuation Relations (FRs) provide a rigorous statistical framework for quantifying irreversibility and entropy production in non-equilibrium systems, extending the second law of thermodynamics to mesoscale fluctuations. While their validity has been established in hydrodynamic turbulence, their extension to magnetohydrodynamic (MHD) turbulence remains unexplored. Here, we present preliminary results on the validity of the Fluctuation Relation (FR) and the Integral Fluctuation Theorem (IFT) in 3D incompressible MHD turbulence, using MHD DNS simulations. Following the framework of Yao et al. (2023), we define a local entropy production rate proxy Ψ_ℓ based on the energy cascade flux at inertial-range scale ℓ . The probability distribution of Ψ_ℓ is asymmetric, consistent with a positive mean entropy production. The FR is only partially satisfied likely due to the quasi-Eulerian nature of the analysis. These results parallel analogous findings in fluid turbulence, pointing to the role of correlations in modifying the canonical FR, and motivate a Lagrangian extension of the analysis.