

Irreversibility, Energy Cascade, and Detailed Balance Violation in Space Plasma Turbulence at Sub-Ion Scales

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A hallmark of space plasma turbulence is the emergence of an additional power-law spectral domain with a spectral exponent close to $8/3$, at scales near and below the ion-inertial length. While attributed to a distinct turbulent regime involving alternative wave modes and a novel cascade mechanism, its origin remains actively debated.

At the heart of this controversy lie some fundamental questions: 1) does energy transfer at sub-ion scales exhibit signatures of irreversibility, and 2) is there a fingerprint of a genuine turbulent cascade? In this talk, we discuss these questions directly by quantifying the violation of detailed balance in magnetic field fluctuations and investigating the presence of a cascade mechanism in energy transfer at sub-ion scales. In detail, we present a multi-faceted analysis of the irreversible features and the energy transfer at sub-ion scales by means of high-resolution magnetic field measurements from NASA-Parker Solar Probe and ESA-Cluster missions.

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