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Global and Local Characterization of Turbulent and Chaotic Structures in a Dipole-Confined Plasma[1]

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When the plasma density increases sufficiently, plasma confined by a strong dipole magnetic field exhibit a dramatic transition to a confined state with complex turbulent behaviors. Recent experiments using the Collisionless Terrella Experiment (CTX) used statistical tools and fast imaging to understand this turbulent state with respect to both local and global paradigms. Locally, multi-point and multiple-time autocorrelation and bispectral analyses are computed and used to estimate the linear dispersion and nonlinear structure coupling of a broad band of interacting fluctuations. Globally, the whole-plasma dynamics is observed using a unique high-speed imaging diagnostic that views the time-varying spatial structure of the polar current density. The bi-orthogonal decomposition for multiple space-time points is used to decompose the measured plasma dynamics into spatial and temporal mode functions. The dominant spatial modes are found to be long wavelength and radially broad; however, the amplitudes of these global modes are chaotic and impulsive. In all cases, the fluctuations appear to be interchange-like and consistent with a model for two-dimensional electrostatic interchange mixing. To the best of our knowledge, this is the first time when both local and global dynamics of turbulent structures have been simultaneously measured and compared in hot magnetized plasma. Our measurements are sufficient to compare and contrast two competing paradigms of plasma turbulence: (i) a nonlinear mode-mode structure coupling and cascade derived from a statistical treatment of measurements from closely-spaced probes, and (ii) a chaotic evolution of a few dominant and relatively long-wavelength modes that generate an equivalent local spectrum due to the impulsive amplitudes and time-varying frequencies of the global modes.

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