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Nonlinear instabilities driven by coherent phase-space structures

MAXIME LESUR, Itoh Research Center for Plasma Turbulence, Kyushu University

Coherent phase-space (PS) structures are an important feature of plasma turbulence. They can drive nonlinear instabilities [1], intermittency in drift-wave turbulence [2], and transport [3]. We aim at a comprehensive understanding of turbulence, not just as an ensemble of waves, as quasilinear theory implies, but as a mixture of coupled waves and localized structures. This work, which focuses on isolated PS structures, is a fundamental advance in this direction. We analyze the effects of self-binding negative fluctuations (PS holes) on stability, intermittency and anomalous resistivity, both analytically and numerically. We present a new theory which describes the growth of a hole or clump [4]. We find that PS holes grow nonlinearly, independently of linear stability. Numerical simulations clarify the physics of nonlinear instabilities in both subcritical and supercritical conditions. When many resonances are unstable, several holes can coalesce into one main macro-scale structure, which survives much longer than a quasilinear diffusion time, suggesting that it may be crucial to resolve phase-space turbulence in analytical and numerical studies of transport. These findings are applied to two fundamental paradigms of plasma physics: bump-on-tail instabilities in 1D electronic plasma and current-driven ion-acoustic instabilities electron-ion plasma. Our results expose important limits of routinely-used linear and quasilinear theories.

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