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TH/P6-14: Subcritical Growth of Coherent Phase-space Structures

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Coherent phase-space structures are an important feature of plasma turbulence. They can drive nonlinear instabilities, intermittency in drift-wave turbulence, and cause transport that departs from quasilinear predictions. Our theoretical and numerical efforts are directed toward a comprehensive understanding of turbulence, not merely as an ensemble of waves, but as a mixture of coupled waves and localized structures. This work focuses on phase-space structure dynamics and reports significant progress in this direction. We start with the Berk-Breizman model, a tractable paradigm for wave-particles interactions, in the presence of extrinsic dissipation. Despite its apparent simplicity, this model exhibits a wealth of complex nonlinear behavior, relevant to Alfvén wave experiments, the travelling wave tube quasilinear experiment with a lossy helix, or nonlinear wave-particle interaction effects on zonal flows. In this work, we present a new theory which describes the growth of coherent structures called as holes and clumps, which can in turn drive the wave by direct momentum exchange due to the dissipation. This mechanism explains the existence of nonlinear instabilities in both barely unstable and linearly stable (subcritical) regimes. In addition, theory predicts a criterion for nonlinear instability, which sets a minimum size of the seed structure. Simple expressions of the hole/clump growth rate and the initial perturbation threshold are in quantitative agreement with numerical simulations. The nonlinear instability in the barely unstable regime, which is predicted by our theory, is observed for the first time in simulation. Extending the model to multiple resonances, our simulations show that coalescing holes survive much longer than the classical quasilinear diffusion time and dominate the nonlinear evolution.

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