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Saturation of Shear-flow Turbulence in Magnetized Plasmas[1]

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Shear-flow-instability saturation is examined for turbulent hydrodynamic, gyrokinetic, and MHD systems, showing that critical nonlinear behavior can be modeled and incorporated into improved transport models. It is shown that large-scale, linearly stable (damped) eigenmodes are nonlinearly driven to large amplitude, playing an important role in saturation [Fraser et al. PoP (2017)]. In that situation, accounting for stable modes in Reynolds stress models improves the ability of these models to recover nonlinear parameter scalings.

Unlike previous work on stable modes in gyroradius-scale or quasi-homogeneous systems, this analysis considers stable modes in a macroscopic, fully inhomogeneous instability. These modes are inviscid, with their linear decay corresponding to reversible energy transfer to the base flow, reflected in their significant modifications to the Reynolds stress. Gyrokinetic simulations of a driven, shear-unstable flow show that, for most cases considered, stable and unstable mode amplitudes are nearly equal in the turbulent state [Fraser et al. PoP (2018)]. It is further shown that stable modes are a crucial ingredient in reduced models of Reynolds stress when they are present. These findings are compared to MHD simulations of a shear layer with a flow-aligned magnetic field. There, the role of the magnetic field in determining the amplitudes of stable and unstable modes, and their role in determining the partition of magnetic and kinetic energy at different spatial scales, is of interest. It is observed that as the field is advected by the flow, it triggers secondary instabilities with corresponding stable modes whose energy is predominantly magnetic, and whose inclusion is necessary for reduced models.

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