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Energy dynamics in a simulation of LAPD turbulence

BRETT FRIEDMAN, University of California, Los Angeles

It is often assumed that linear instabilities maintain turbulence in plasmas and some fluids, but this is not always the case. It is well known that many fluids display subcritical turbulence at a Reynolds number well below the threashold of linear instability. Certain plasma models such as drift waves in a sheared slab also exhibit subcritical turbulence [1]. In other instances such as drift-ballooning turbulence in tokamak edge plasmas, linear instabilities exist in a system, but they become subdominant to more robust nonlinear mechanisms that sustain a turbulent state [2, 3]. In our simulation of LAPD turbulence, which was previously analyzed in [4], we diagnose the results using an energy dynamics analysis [5]. This allows us to track energy input into turbulent fluctuations and energy dissipation out of them. We also track conservative energy transfer between different energy types (e.g. from potential to kinetic energy) and between different Fourier waves of the system. The result is that a nonlinear instability drives and maintains the turbulence in the steady state saturated phase of the simulation. While a linear restistive drift wave instability resides in the system, the nonlinear drift wave instability dominates when the fluctuation amplitude becomes large enough. The nonlinear instability is identified by its energy growth rate spectrum, which varies significantly from the linear growth rate spectrum. The main differences are the presence of positive growth rates when $k_{||} = 0$ and negative growth rates for nonzero $k_{||}$, which is opposite that of the linear growth rate spectrum.

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