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On subcritical excitations of plasma turbulence

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Message of this presentation:

This talk discusses issues of subcritical excitation of turbulence in plasmas. It first revisits the studies in fluid dynamics, in which the condition for the onset of turbulence has long been investigated: One might recognize an analogy in the study of the turbulence and structure formation in plasmas. Here we explain possible routes of subcritical excitations of turbulence. How the mechanisms of subcritical excitation appear in multi-scale turbulence is noted. Then applications of this way of thinking to the problems of turbulent transport and abrupt events are discussed.

In studies of **neutral fluids**, research on the subcritical excitation of fluctuations has been one of the central issues. The linear stability of inhomogeneous flow has widely been investigated, and important instability mechanisms have been discovered. However, linear stability theories are far from sufficient in understanding excitation of turbulence. A famous example is the Qouette flow between the two parallel plates. Although this flow is linearly stable for any Reynolds number, Re, [1], it becomes turbulent when the Reynolds number exceeds the critical value, $Re_c \sim 320$ [2]. In the study of excitation mechanism of turbulence in fluids, it is now standard to focus on the 'structure' (which is driven by flow via nonlinear interactions) in transferring the energy from the inhomogeneous mean flow into the fluctuations [3]. Thus, one needs to study in detail the mechanism of subcritical excitation in turbulence fluids.

In magnetically-confined plasmas, it is also the case. It is true that the linearly unstable modes explain some features of fluctuations and turbulent transport [4]. However, there are outstanding issues that cannot be explained in the framework of 'linear, local and deterministic' view of plasma turbulence [5]. In order to extend the framework, possibilities of nonlinear excitation mechanisms, which lead subcritical excitation of fluctuations, have been pointed out (e.g., [6, 7]).

On the generation mechanisms of meso-scale and nonlinearly-excited structures (e.g., zonal flow, etc.), a through survey is found in [8]. Their nonlinear mechanisms have been confirmed in experiments and are known to have essential influence on the excitation and saturation of turbulence [9]. The nonlinear destabilization mechanisms have also been confirmed in experiments for global mode (e.g., tearing mode [10]) and for meso-scale mode (GAMs [11]). A recent experiment has shown that a hyper-fine-scale turbulence is strongly excited in the parameter regime, where the ETG mode is predicted linearly-stable [12]. This implies that a subcritical excitation mechanism works in such a turbulence.

The phase-space structure has been known to induce nonlinear instability for drift wave fluctuations [13]. Taking the nonlinear destabilization effect of the phase-space structure, subcritical excitation of drift wave fluctuation is studied in [14]. It is shown that the fluctuations are self-sustained even in the regime of linear stability. The critical condition for the self-sustained turbulence is discussed. Near the boundary condition of linear instability, the fluctuation level is far from the quasi-linear estimate. Dependence of fluctuation level on plasma parameters (such as the hydrogen mass) is also discussed. Possible role of transition in turbulence was pointed out in triggering some type of ELMs [15].

These analyses pave the path to establish the 'nonlinear, nonlocal and probabilistic' view of plasma turbulence.

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