Kinetic and fluid simulations on steady and quasisteady states of slab ion temperature gradient driven turbulence

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Anomalous transport caused by plasma turbulence has long been a central subject in research on the magnetic confinement fusion. Ion temperature gradient (ITG) driven turbulence is considered to be responsible for the anomalous ion heat transport in a core of magnetically confined plasmas. Kinetic and fluid simulation studies on the ITG turbulence transport have been actively done in the last decade. Our concern here is to examine the following two fundamental conjectures of the kinetic plasma turbulence by means of Eulerian (Vlasov) simulations of the velocity distribution function f ; first, in the case with constant drive of instability, existence of a quasisteady state is necessary for collisionless turbulence to sustain the steady transport, where high-order moments of f continue to grow while keeping low-order ones constant as well as the transport flux. Second, in the case with finite collisionality, a real steady state of turbulence should be realized by a statistically steady distribution function, where, in the low-collisionality limit, the transport coefficient approaches the value of the collisionless one. Our simulations [1,2] have confirmed the both properties for the ITG driven turbulence in a two-dimensional slab geometry with uniform magnetic field. Throughout the kinetic simulations, importance of the phase mixing process has been recognized in considering the steady transport as well as dynamic behaviors of the distribution function in the phase space.

Collisionless fluid simulations of the steady turbulence transport are based on the above conjecture on existence of the quasisteady state. Thus, the kinetic simulation results provide a useful reference for checking whether a closure relation assumed in the collisionless fluid model could be valid in the quasisteady state of turbulence. We have also made a detailed comparison between kinetic and fluid simulations, where the Hammett-Perkins (H-P) [3] and the nondissipative (NCM) [4] closure models are benchmarked [5]. In the saturated turbulent state, the ion heat flux obtained from the H-P model is significantly larger than that given by the NCM, where the latter is closer to the kinetic result.

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