§10. Vortex Structure and Turbulent Transport in Gyrokinetic Simulation of Slab Electron Temperature Gradient Turbulence

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The electron temperature gradient (ETG) turbulence is considered as one of the possible candidates causing the anomalous electron heat transport in a core region of magnetic fusion plasmas [1]. Although the ETG mode with the adiabatic ion response is isomorphic to the ion temperature gradient (ITG) mode, the nonlinear evolution of the ETG instability is totally different from the ITG turbulence that is largely affected by the self-generated zonal flows, and is actively studied in recent years [2, 3].

In the present study we have carried out gyrokinetic Vlasov simulations of the ETG turbulence in a two-dimensional slab geometry with high velocity space resolution by utilizing the Plasma Simulator at NIFS. We have found spontaneous transition of the ETG turbulence accompanied with significant reduction of the electron heat flux as shown in Fig. 1. In the early nonlinear phase of the ETG turbulence simulation ($t < 200\ L_n/\ v_{te}$), potential fluctuations observed in a wide wave number range cause a high-level heat transport. Then, we see the transition from high to low transport levels, where the turbulent heat flux is decreased about an order of magnitude. As the zonal flows are generated by strong turbulent vortices, a coherent potential structure with large amplitude is formed. Figure 2 shows contours of the electrostatic potential in high and low transport levels. The transition of the potential structure and the transport level was not observed in the simulation results of the slab ITG turbulence [4]. Fine scale structures of the temperature fluctuations are also found in the present ETG simulations, which reflect generation of fine scale fluctuations of the distribution function in the phase space.

For a certain parameter range near the marginal stability of the ETG mode, we have also found a regular flow pattern with ranging vortices in the nonlinear saturation phase of the instability, where the turbulent transport is strongly suppressed. The more detailed investigation will reveal the transition process of the transport level and the vortex structures.

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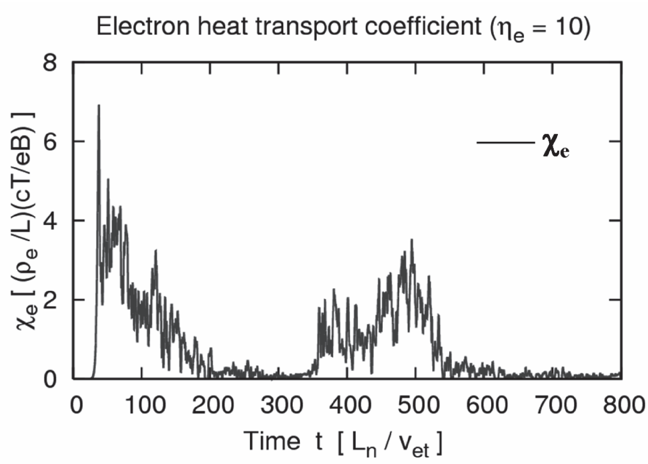

Fig. 1: Time evolution of the electron heat transport coefficient χ_e in the slab ETG turbulence obtained by the gyrokinetic Vlasov simulation. Transport coefficient normalized by Gyro-Bohm unit is defined by $Q\ /\eta_e$, where Q represents the heat flux caused by the $\mathbf{E}\times\mathbf{B}$ convection and η_e stands for the temperature gradient parameter.

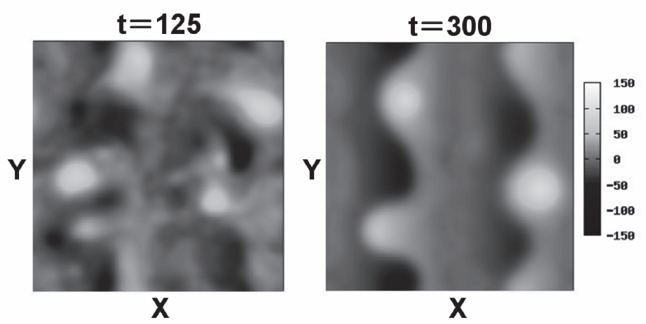

Fig. 2: Contours of the normalized electrostatic potential $e\phi L_n/T_e\rho_e$ in the slab ETG turbulence. The left contour shows the turbulent vortex state in the high transport, and the right one corresponds to the coherent vortex state with strong zonal flow in the low transport.

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