§10. Coherent Vortex Structures in Slab Electron Temperature Gradient Driven Turbulence

Nakata, M. (GUAS), Watanabe, T.-H., Sugama, H.

Electron temperature gradient (ETG) driven turbulence is considered as one of the possible candidates causing the anomalous electron heat transport in a core region of magnetically confined plasmas.

In the present study, we have investigated the relation between vortex structures and transport levels in the slab ETG turbulence by means of gyrokinetic Vlasov simulation with high phase-space resolution. Figure 1 shows the time evolution of heat transport coefficient χ_e and two snapshots of potential contour at $t=1250$ and at $t=3000$. From these figures, one can find transition of vortex structure from a turbulent state with a high transport level to a coherent state with a low transport level. Spectral anlyses clarify that the transport reduction in the coherent state is related to decrease of the phase difference between the potential and temperature fluctuations.

In order to analyze the coherent vortex structure more in detail, a fluid equation has been derived from the zeroth-order velocity moment of the gyrokinetic equation with neglecting the parallel advection term $ik_{\|}v_{\|}\delta f_{\boldsymbol{k}}$ such that,

$$\frac{\partial}{\partial t}\left\{1-(1+\tau)\nabla_{\perp}^{2}\right\}\delta\psi-\frac{\partial}{\partial y}\left(1+\frac{\eta_{e}}{2}\nabla_{\perp}^{2}\right)\delta\psi - \left[\delta\psi,\ (1+\tau)\nabla_{\perp}^{2}\delta\psi\right]=0\,, \quad (1)$$

where, $\delta\psi$ denotes gyro-averaged potential fluctuation and $\tau = T_i/T_e$ and $\eta_e = L_n/L_T$. The square brackets denote the Poisson brackets $[A,B] = (\partial_x A)(\partial_y B) - (\partial_x B)(\partial_y A)$. Formally, this equation is similar to Hasegawa-Mima equation [1]. Since the coherent vortex structure sustained for a long time slowly propagates in the ion diamagnetic direction, it is described by a traveling wave solution of Eq. (1). Then, the traveling wave solution should satisfy the following condition,

$$\left[\nabla_{\perp}^{2}\delta\psi-\left(\frac{1+u}{1+\tau}\right)x\ ,\ \delta\psi-\left\{u-\frac{\eta_{e}}{2(1+\tau)}\right\}x\right]=0\,, \quad (2)$$

where $\delta\psi = \delta\psi(x, y-ut)$ with the traveling velocity u. This condition means that there should be a functional relation between $S_1 \equiv \nabla_{\perp}^{2}\delta\psi - x(1+u)/(1+\tau)$ and $S_2 \equiv \delta\psi - x\{u-\eta_e/(2(1+\tau))\}$. Relations of S_1 and S_2 obtained from the simulation data are plotted in Fig. 2. One finds a nonlinear functional relation between S_1 and S_2 in the coherent state, while it is not clearly identified in the turbulent state. Thus, it is concluded that the coherent vortex structure related to the transport reduction is approximated by the traveling wave solution of Eq. (1).

Since the formation of the coherent vortex and the resultant transport reduction is related to the improvement of plasma confinement, extensions of the present work to the toroidal configuration are currently in progress.

1) A. Hasegawa and K. Mima, Phys. Fluids **21**, 87 (1978)

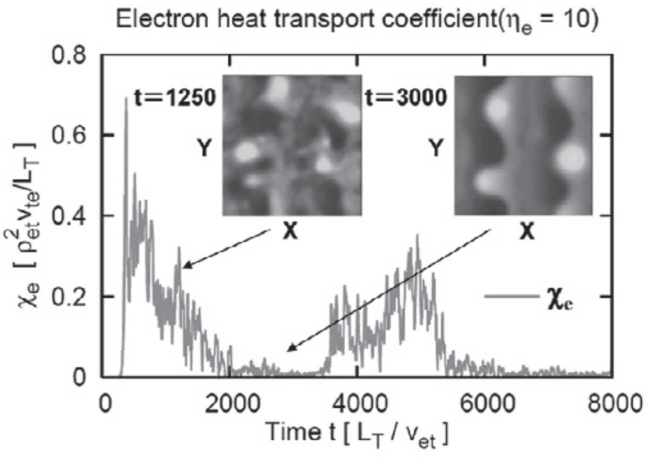

Fig. 1: Time evolution of the transport coefficient χ_e $[\rho_{et}^2 v_{te}/L_T]$ obtaied by the gyrokinetic Vlasov simulation of the slab ETG turbulence. Contours of electrostatic potential fluctuations $(L_T/\rho_{st})(e\delta\phi/T_s)$ in the turbulent state ($t=1250$) and the coherent state ($t=3000$) are also shown here.

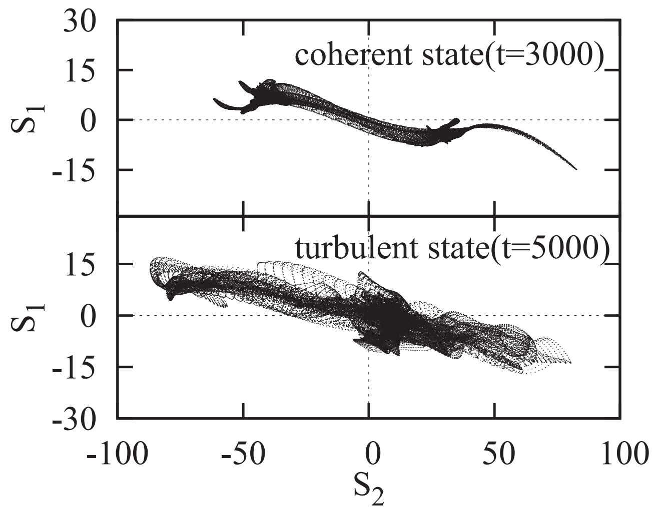

Fig. 2: Lissajous plots of S_1 and S_2 for the coherent (upper) and the turbulent states (lower). A nonlinear functional relation between S_1 and S_2 is found in the upper.