§3. Vortex Structure and Heat Transport in Toroidal-ETG Driven Turbulence

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Electron heat transport due to electron temperature gradient(ETG) driven turbulence is considered as one of important issues since electrons are predominantly heated by energetic α-particles in a core region of burning plasmas. In our earlier works, we investigated vortex structures and transport levels in slab ETG turbulence by means of gyrokinetic Vlasov simulations, and found a formation of coherent vortex structures and the associated transport reduction[1].

In the present study, we have extended the above works to toroidal ETG turbulence simulations by means of the 5-dimensional gyrokinetic fluxtube code: GKV[2]. Particularly, dependence of turbulent flows and transport on the magnetic-shear parameter $\hat{s}$ have been explored.

Figures 1(a) and 1(b) show the time evolutions of the heat transport coefficient χ_e and the zonal-flow potential energy normalized by the total potential energy W_{zf}/W_{total} on the various magnetic-shear parameters $\hat{s} = \{+0.4, +0.1, -0.1, -0.2\}$, respectively. From these figures, one can find the significant reduction of the transport level as the magnetic-shear parameter decrease. Correlation between the saturation level of χ_e and W_{zf}/W_{total} is not clearly observed while a slightly smaller saturation level of W_{zf}/W_{total} is found for $\hat{s} = +0.4$ than those for the other values of $\hat{s}$. Also, the normalized energy of the zonal flows in the negative- or the positive-lower shear cases with $\hat{s} = \{+0.1, -0.1, -0.2\}$ grow faster than that in the positive-higher shear case with $\hat{s} = +0.4$. The differences found in the behavior of W_{zf}/W_{total} are associated with the saturation processes and vortex structures of the turbulence.

Figures 2(a) and 2(b) show snapshots of the potential fluctuation at $t = 360$ for $\hat{s} = +0.4$ and $\hat{s} = -0.1$, respectively. In the positive-higher shear case with $\hat{s} = +0.4$[fig. 2(a)], the formation of radially elongated vortices(so called streamers) are clearly observed. The high intensity of the streamers causes the higher transport level shown in fig. 1(a). In contrast, fluctuations with the short wavelength in the radial direction develop in the negative-shear case with $\hat{s} = -0.1$[fig. 2(b)].

Although the ETG-driven zonal flow is weak in comparison with those in the ITG turbulence, it is considered to be still important for the turbulence saturation as well as the transport level. Since the turbulent transport reduction is closely related to the improvement of plasma confinement, and the detail analyses of the simulation results are currently in progress.

1) M. Nakata and T.-H. Watanabe, H. Sugama, and W. Horton, Phys. Plasmas **17**, 042306 (2010)

2) T.-H. Watanabe, and H. Sugama, Nucl. Fusion **46**, 24 (2006)

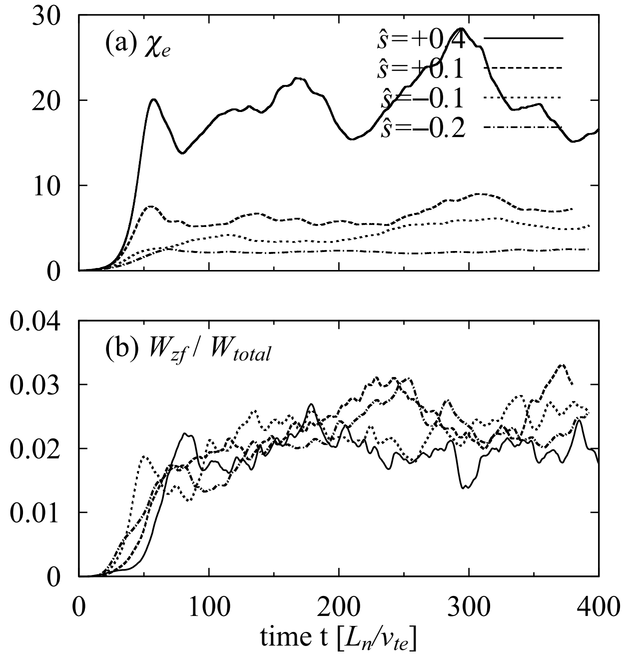

Fig. 1: Time evolution of (a)the transport coefficient χ_e $[\rho_{te}^2 v_{te}/L_n]$ and (b)the zonal-flow potential energy normalized by the total potential energy W_{zf}/W_{total} [-] for the various magnetic-shear parameters $\hat{s} = \{+0.4, +0.1, -0.1, -0.2\}$ obtained by toroidal ETG turbulence simulations.

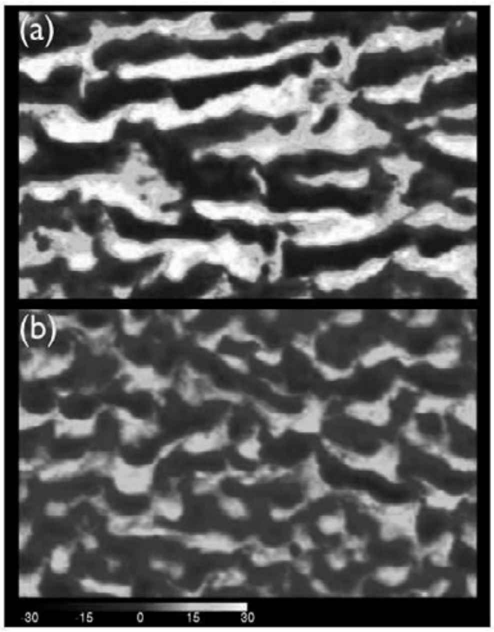

Fig. 2: Contours of the potential fluctuation $\delta\phi$ $[(\rho_{te}/L_n)(T_e/e)]$ for (a)$\hat{s} = +0.4$ and (b)$\hat{s} = -0.1$ at $t = 360$, where each box size is $266\rho_{te} \times 168\rho_{te}$.