Gyrokinetic simulation on turbulence spreading dynamics in a magnetic shearless plasma

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Turbulence spreading is a common nonlinear phenomenon in plasmas. It is one of important issues toward quantitatively predicting transport in burning plasmas, e.g. the ITER. Updated interest in such dynamics is probably ascribed to its correlation with the transport scaling of the machine size. It may also contribute to the transport nonlocality observed in experiments. On the other hand, fully understanding the role of the zonal flow(ZF) in turbulent transport is one of the challenging problems in plasma theory and simulation. In this work, the turbulence spreading is investigated based on a full-*f* gyrokinetic global simulation with a focus on its correlation with both the *linear mode structure* and the *ZF dynamics*. To elucidate the former dependence, simulation is performed in a magnetic shearless plasma considering the similarity of global structures between toroidal ITG and shearless slab ITG modes, in which the global mode envelops are determined by the pressure profile. Furthermore, the ZF effect is analyzed by comparing the averaged spreading distance δx in both ITG and ETG turbulence as well as the ITG without ZFs. Here $\delta x^2 = \int_{x_b}^{\infty} (x - x_b)^2 \langle \phi^2 \rangle dx \Big/ \int_{x_b}^{\infty} \langle \phi^2 \rangle dx$ with stability boundary x_b.

In present gyrokinetic model, a shearless slab with normalized equilibrium magnetic field $\vec{B} = (0, \theta, 1)$ is employed, which may correspond to tokamak plasma with a flat q profile. Here the constant factor θ is the ratio of poloidal and toroidal magnetic field components. On the other hand, electrostatic ITG turbulence and its isomorphic contourpart ETG mode are considered on an equal footing except for different normalization since the ZF is strong in ITG turbulence but relatively weak in the ETG turbulence. Two main results have been achieved. First, the turbulence spreading is subject to the radial width of the local ITG eigen mode rather that the global mode. The former one increases with decreasing the factor θ whilst the latter one is mainly determined by pressure profile. As a result, δx increases as decreasing θ for given pressure profile as plotted in Fig.1, showing that linear feature of eigen mode impact on the turbulence spreading. Second, while the ZF is enhanced in ITG turbulence for small θ, it can reduce the turbulence spreading effectively, as shown in Fig.2. The coherent ZF structure may play a role of potential barrier to limit the radial propogation.

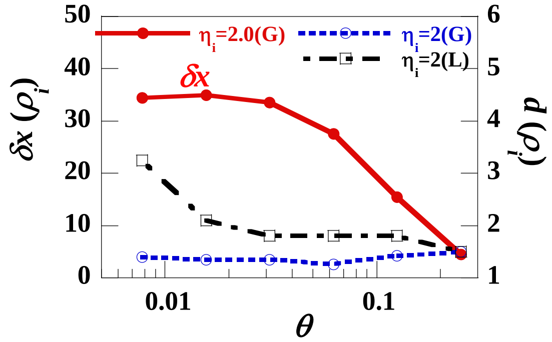

Fig.1 Dependence of turbulence spreading on the mode width of linear local (L) and global (G) eigen mode width *d*.

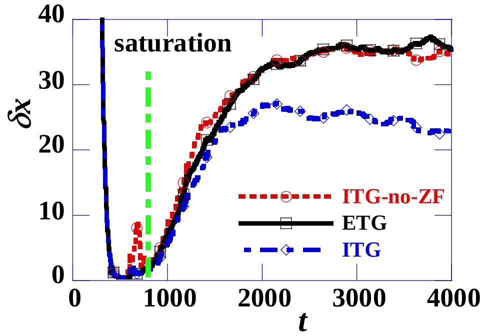

Fig.2 Dependence of turbulence spreading on the zonal flow level in ITG (strong ZF), ETG (weak ZF) and ITG turbulence without ZF.