§11. Development of Gyrokinetic Vlasov Code Including Full Geometry of Non-axisymmetric Field

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Geometrical effects of the three-dimensional confinement field play important role in regulating the anomalous transport in helical plasmas as pointed out by experimental and simulation studies [1, 2]. For more understandings about the anomalous transport physics, quantitative comparisons between the experiments and gyrokinetic simulations are required. In our previous simulation studies for microturbulence transport in the helical field, we used the model helical fields including limited number of helical Fourier components with the large aspect ratio approximation to the field geometry, where diagonal metric tensor components are derived from the cylindrical approximation and the Jacobian is assumed to be a constant on the flux surface. Toward the exploration of microturbulence in non-axisymmetric systems, it is a promising path to furnish a well-established gyrokinetic code with detailed geometrical information obtained from three-dimensional equilibrium. Based on this motivation, we developed a new gyrokinetic Vlasov simulation code, GKV-X[3], which includes full geometrical effects of non-axisymmetric field configuration such as the Large Helical Device (LHD). The GKV-X incorporates full geometrical information of the three-dimensional confinement field, e.g. the Jacobian and the metric tensor of the flux surface, as well as all Fourier components obtained from MHD equilibrium code, VMEC[4]. Using the GKV-X code, we investigate the effects of three-dimensional geometry of the LHD plasmas on the ion temperature gradient (ITG) modes, the zonal flow responses, and the geodesic acoustic modes.

In the core plasma region of the standard LHD configuration, we performed the benchmark calculations of the GKV-X against our original gyrokinetic Vlasov code, GKV, which uses the model helical field for the geometry based on the large aspect ratio approximation. From the simulation results of the linear ITG instability, the effects of full geometry and helical ripples on the growth rate, frequency, and mode structure of the ITG instability are clarified in the large poloidal wavenumber region where the finite gyroradius effect is also important, as shown in Fig.1. On the other hand, the collisionless damping of zonal flow potential is found to be less affected in the core plasma region of the LHD, as shown in Fig.2. We consider that this is because the effects are blinded with taking the flux surface average to determine the residual zonal flow potential that loses the poloidal-angle-dependent components associated with the geodesic acoustic mode (GAM) oscillations.

The GKV-X simulation results can be also compared with the experimental observations in the LHD, using the corresponding equilibrium configuration to the experiment through the VMEC code. The GKV-X enables ones to precisely treat the turbulent transport in complicated magnetic configurations, such as the edge region of the helical plasmas.

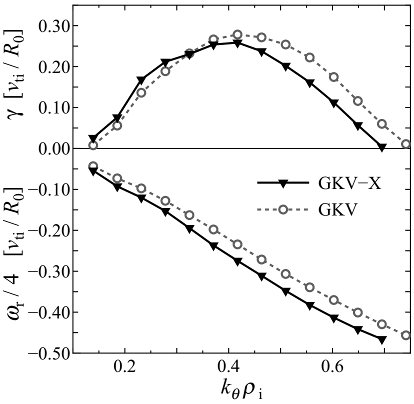

Fig. 1: Growth rates (top) and real frequencies (bottom) of the linear ITG mode, as functions of the normalized poloidal wavenumber, $k_\theta \rho_\mathrm{i}$, for the GKV (dashed lines with circles) and the GKV-X simulation (solid lines with triangles).

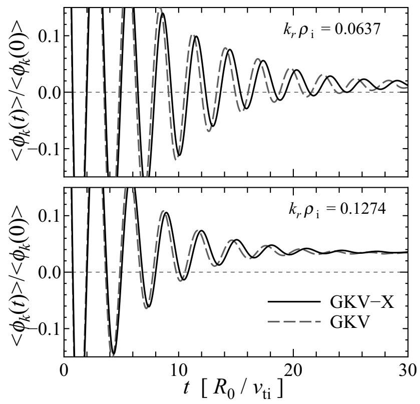

Fig. 2: Linear response of the zonal flow potential to the initial perturbation $\langle \phi_{k_\perp}(t) \rangle / \langle \phi_{k_\perp}(0) \rangle$ for the GKV simulation with model field (dashed curves) and GKV-X simulation with VMEC field configuration (solid curves). Here, the radial wavenumbers are $k_r \rho_\mathrm{i} = 0.0637$ (top) and $k_r \rho_\mathrm{i} = 0.1274$ (bottom) for both codes.

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