§8. Gyrokinetic-Vlasov Simulations of the ITG Turbulent Transport in Helical Systems

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In order to clarify physical mechanisms of the anomalous transport found in magnetically-confined fusion plasmas, gyrokinetic simulations of the toroidal plasma turbulence have been developed so far. It is noteworthy that the conventional fluid approximation can not be valid for the high-temperature plasma in fusion devices with low collision frequencies where the mean-free-paths of particles are much longer than the device size. This remarkable property of the fusion plasma demands numerical approaches which can resolve dynamic behaviors of distribution functions in the multi-dimensional phase-space. Then, we have developed the gyrokinetic-Vlasov simulation code[1)] (GKV code) which can deal with the nonlinear gyrokinetic equation of a perturbed distribution function in toroidal geometries. The original GKV code implemented on the Earth Simulator with high performance of vector and parallel operations is further extended so that effects of helical-ripple-trapped particles are taken into account. Accuracy of the code is thoroughly benchmarked for the collisionless damping of zonal flows in helical systems[2)]. Then, it has been applied to the ion temperature gradient (ITG) turbulence and zonal flows in helical systems with L=2 and M=10 like the Large Helical Device (LHD), where L and M denote the poloidal and toroidal periodicities of the main helical magnetic field.

By using 192 computational nodes of the Earth Simulator, first, we carried out the GKV simulation of the ITG turbulent transport in helical systems with a single-helicity component[3)]. The peak performance of the computation speed exceeds 5 T flops. It is clearly observed that the zonal flow generated by the ITG turbulence leads to reduction of the ion heat transport in the nonlinear saturation phase of the ITG instability. Accuracy of the present simulation is verified by the entropy balance calculation.

The GKV simulations of the ITG turbulence for the standard and inward-shifted model configurations of the LHD are also carried out by introducing the multi-helicity components of the confinement field. A snapshot of the simulation result is shown in Fig.1, where the innermost toroidal magnetic flux surface in the flux-tube simulation region is shown by color contours according to levels of potential fluctuations in the ITG turbulence. The nonlinear GKV simulations show that the ion heat transport in the inward shifted model, which has the larger linear growth rates of the ITG instability, is observed in a level comparable to the standard case[4)]. This is attributed to the stronger zonal flows generated in the inward-shifted model configuration.

References
1) T.-H. Watanabe and H. Sugama: Nuclear Fusion 46 (2006) 24.
2) H. Sugama and T.-H. Watanabe: Phys. Plasmas 13 (2006) 012501.
3) T.-H. Watanabe, H. Sugama, and S. Ferrando i Margalet: Proceedings of Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, Varenna, 2006 edited by J. W. Connor, et al. (American Institute of Physics, Melville, New York, 2006) p.264.
4) T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet: "Gyrokinetic Simulation of Zonal Flows and Ion Temperature Gradient Turbulence in Helical Systems" submitted to Nuclear Fusion, May 2007.

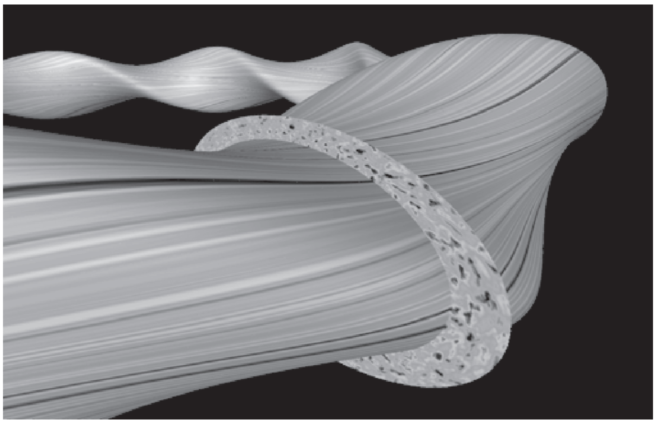

Fig.1: Results of gyrokinetic-Vlasov simulations of the ion temperature gradient turbulence in a helical system with L=2 and M=10 like the LHD (where L and M denote the poloidal and toroidal periodicities of the main helical magnetic field). Colors represent electrostatic potential perturbations in the ITG turbulence.

* This work is carried out using Earth Simulator under the support by JAMSTEC.