Multi-scale turbulence simulation in magnetic fusion plasma

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ABSTRACT

Magnetic fusion plasma is generally subject to various kinds of instabilities at differing spatio-temporal scales due to varied magnetic configurations and plasma profiles. As the progress in the study of plasma theory/experiment and the rapid development of the supercomputer system and the parallel computation technology, large-scale simulations on the physics of multi-scale turbulence in magnetic fusion plasmas have been greatly promoted recently. In this talk, we will present a strategic simulation plan on this important issue based on gyrokinetic theory and gyrofluid model, which aims at understanding the complex multi-scale turbulence dynamics and relevant transport properties in future burning plasmas such as the ITER.

We perform gyrofluid simulation of mixed-scale resistive MHD and ion temperature gradient (ITG) driven turbulence in slab geometry as a trial to understand the turbulent transport produced by the cross-scale turbulence. In fact, this is a common and typical example of the multi-scale problems in tokamak plasmas. Two main findings are achieved: (1) A magnetic island seesaw accompanying with an oscillatory zonal flow is created in the multi-scale fluctuation. It is identified to result from the perturbed electromagnetic torque due to the micro-turbulence. (2) A new short wavelength ITG instability is induced by MHD magnetic island as a consequence of the breakdown of the ideal MHD equilibrium, which is a corollary of the frozen-in magnetic field law. Such mechanisms offer new insights in understanding complex nonlinear interaction among multiple scale fluctuations in plasmas and fluids.

We have developed a new gyrokinetic full-*f* Vlasov code based on the conservative form of the Interpolated Differential Operator (IDO-CF) scheme aiming to simulate the long time dynamics of multi-scale plasma turbulence in burning plasmas. This scheme conserves exactly the total mass. The spatial discretization is derived by not only point values but also cell-integrated values so that the high-*k* components are captured with less phase error. This property is beneficial to the multi-scale simulation with wide spectrum in time and space. The numerical accuracy and parallelization efficiency of the code will be discussed. Some preliminary multi-scale simulations in magnetic fusion plasmas will be addressed.