§11. Gyrokinetic Analysis of Turbulent Particle and Heat Transport in Helical Plasmas

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Gyrokinetic simulation of turbulence in torus plasmas is an important task for predicting the performance of fusion reactors and a great challenge in computational science due to multiple spatio-temporal scales related to electromagnetic ion and electron dynamics [1]. The simulation becomes further challenging in non-axisymmetric plasmas because of complex three-dimensional magnetic structures. In order to capture the three-dimensional magnetic structure, a large number of grid-points along the magnetic field line is needed, and thus the gyrokinetic simulations of helical plasmas require much more computational resources than those of tokamak plasmas. In this work the K- supercomputer, which is the largest supercomputer in our country, is used to carry out gyrokinetic simulations.

Turbulent transport in a high-ion-temperature (high-Ti) discharge of the Large Helical Devices (LHD) was investigated by means of gyrokinetic simulations with the adiabatic electron model [2] and with the full kinetic electron model [3]. It is demonstrated that the temperature gradient length reproducing the heat flux observed in the experiment is predicted within 20% error to the experimentally observed value, and turbulent particle flux has a pinch effect [3].

Some issues are still unresolved in the previous gyrokinetic analysis with the adiabatic electron model. One is that the experimentally observed finite turbulent transport at a low temperature phase (t=1.8s) [4] is not reproduced by the simulation because the ion temperature gradient (ITG) mode is stable or weak.

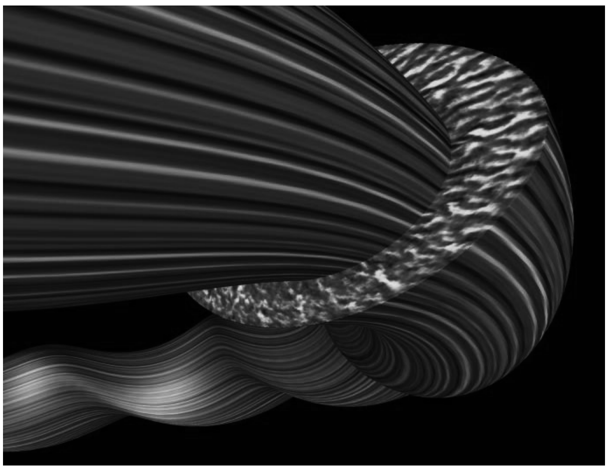

Fig. 1 Turbulence in the helical plasma.

In this work, it is shown that the kinetic electron effects enhance the growth rate of the ITG mode and lead to a finite turbulent transport even in the low temperature phase (t=1.8s) of the LHD discharge (the shot number 88343). Figure 1 shows the fluctuation of the ITG turbulence in the LHD plasma. Figure 2 shows the linear growth rates of instabilities in a low-Ti phase (t=1.8s, Ti0=1.7keV) and in a high-Ti phase (t=2.2s, Ti0=3.9keV) in the LHD discharge (the shot number 88343). It is found that the ITG modes with the full kinetic electron model are more unstable than those with the adiabatic electron model. Thus, the energy fluxes from the kinetic electron model in the low-Ti phase (t=1.8s, Ti=1.7keV) are finite at rho=0.68 and are in good agreement with the experimental observation (Fig. 3). In addition, the transition of the energy flux from the low-Ti phase to the high-Ti phase (t=2.2s, Ti=3.9keV) in the experiment is reproduced as shown in Fig. 3.

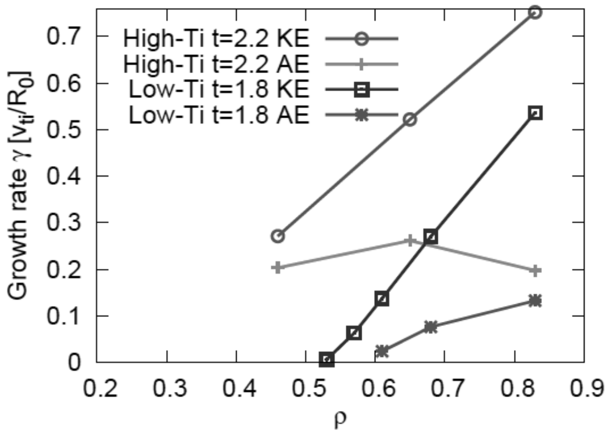

Fig. 2 Linear growth rate as a function of the minor radius.

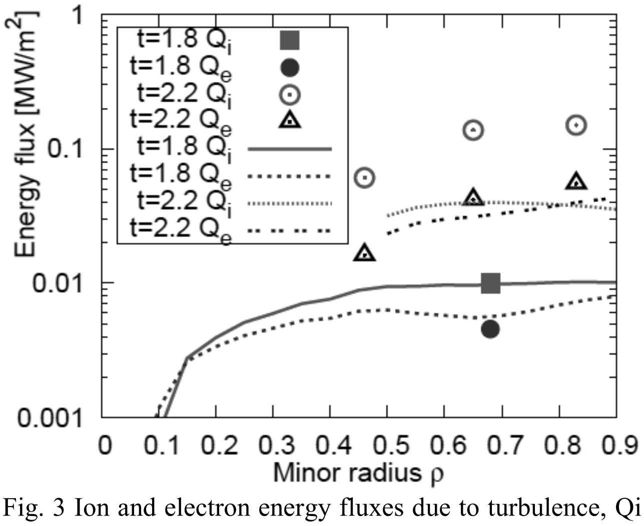

Fig. 3 Ion and electron energy fluxes due to turbulence, Qi and Qe. Symbols are from the simulations, and curves are from the experiments.

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2) M. Nunami, et.al., Phys. Plasmas **19**, 042504 (2012)
3) A. Ishizawa, et.al., Nuclear Fusion **55**, 043024 (2015)
4) K. Tanaka, et.al., Plasma Fusion Res. **5**, S2053 (2010)