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Turbulent transport of heat/particle in high ion temperature discharge in Large Helical Device

LHD高イオン温度放電における乱流熱・粒子輸送

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Turbulent transport in a high ion temperature discharge of Large Helical Device (LHD) is investigated by means of electromagnetic gyrokinetic simulations. It is found that the plasma is unstable against the ion temperature gradient (ITG) instability at a local region where the minor radius is 0.65. The effect of kinetic electrons makes the growth rate of the ITG mode twice larger than that obtained by the adiabatic electron calculation. The ion heat transport coefficient is about 1.5 times an evaluated value from the experimental data. The electron heat transport coefficient and particle flux for a discharge of LHD are firstly reported in this work. The electron heat transport coefficient is about 1.5 times the experimental observed value and the particle flux is negative.

1. Introduction

The Large Helical Device (LHD) is a heliotron system which confines a plasma by magnetic field produced in a set of external coils[1]. Turbulent transport in LHD experiment has not been explored by gyrokinetic simulations with kinetic electrons and finite beta, while the anomalous transport in a low beta regime where the interplay between ion temperature gradient (ITG) turbulence and zonal flows has been investigated by means of electrostatic gyrokinetic simulations with adiabatic electrons[2,3]. In this work, the electromagnetic δf gyrokinetic equations for ions and electrons are solved with the gyrokinetic Poisson equation for the electrostatic potential and the Ampere's equation for the parallel component of the vector potential by using the GKV+ code[4,5,6].

2. Linear growth rate of micro-instability

Micro-instabilities in a high ion-temperature discharge 88343 of LHD with Ti(ρ=0.65)= Te(ρ=0.65)=2.2 keV, β(ρ=0.65)=0.3% is investigated in this section. Figure 1 shows that the ITG mode is unstable for the experimental value of beta. When the beta is increased with keeping the magnetic configuration and density and temperature profiles, the growth rate of ITG mode is suppressed by magnetic field line bending effects, while the KBM is destabilized at high beta. The beta of 88343 at ρ=0.65 is so small (β=0.3%) that the effect of magnetic perturbation on the instability is negligible. It is noted that the most unstable KBM has a finite radial wavenumber as plotted by the red open circles. Figure 2 shows the growth rate as a function of the wavenumber in the field line label direction ky. The ITG mode in the high ion temperature discharge 88343 has a peak of the growth rate at ky ρ_{Ti} = 0.4.

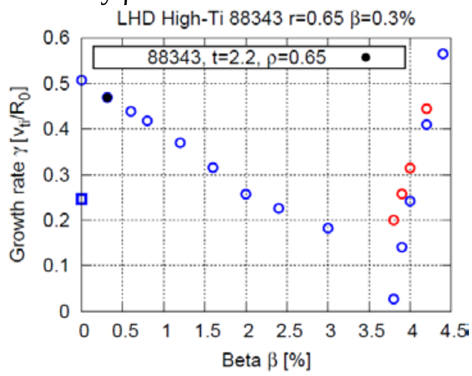

Fig.1. Growth rate as a function of β for the LHD shot numbers 88343 (high-Ti discharge, local β=0.3%, banana regime). The black point shows that the ITG mode is unstable for the experimental value of beta. The blue open circles show that the ITG mode is suppressed by increasing β with the same magnetic configuration and profiles, and also show that the KBM is destabilized at high beta. The blue open square denotes the growth rate for the adiabatic electron calculation. The red open circles show the growth rate of instabilities with finite ballooning angles.

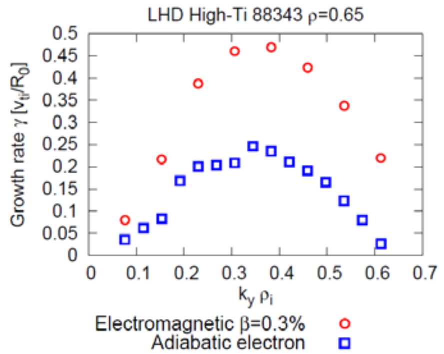

Fig.2. Growth rate of the ITG mode as a function of poloidal wavenumber ky for LHD 88343.

3. Turbulent transport

Figure 3 shows the ion heat transport coefficients obtained by an electromagnetic simulation, an adiabatic electron simulation, experimental observation, and anomalous part of the experimental observation. The ion heat transport coefficient is saturated after t=35 and is about 1.5 times the experimentally observed anomalous transport, which is obtained by subtracting the neoclassical part from the observed value. Figure 4 shows the electron heat transport coefficient obtained by the electromagnetic simulation and experimental observation. The heat transport coefficient is about 1.5 times the experimentally observed value in the statistical steady state. The particle flux is negative which implies the particles are transported toward the magnetic axis by the ITG turbulence. The density gradient at ρ=0.65 is slightly negative, so that the particle transport coefficient has positive sign.

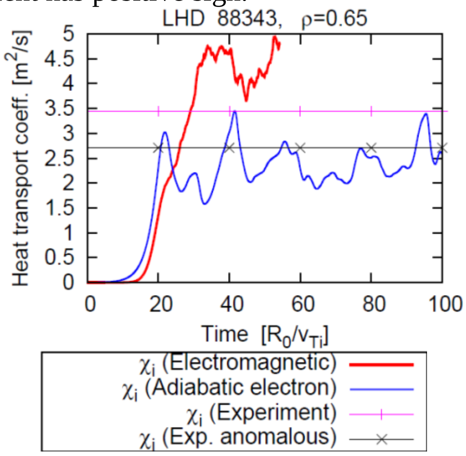

Fig.3. Ion heat transport coefficient.

4. Summary

Turbulent transport in a high-ion-temperature LHD plasma is studied by means of electromagnetic gyrokinetic simulations. The linear growth rate of the ITG mode is two times larger than that obtained by the adiabatic electron calculation, while the turbulent ion heat transport is about 1.5 times that obtained by the adiabatic electron calculation. The experimental observation of ion heat transport coefficient is close to the value obtained by the adiabatic electron calculation. The turbulent electron heat transport coefficient is about 1.5 times the experimental observation. The turbulent particle flux is negative, and this would be compared with an experimental value in our next work.

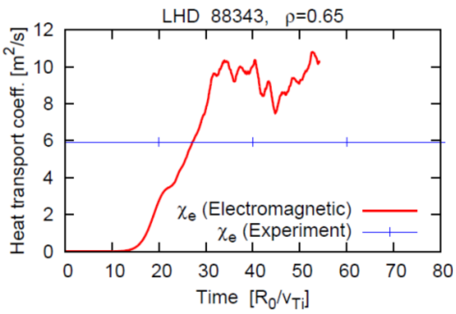

Fig.4. Electron heat transport coefficient.

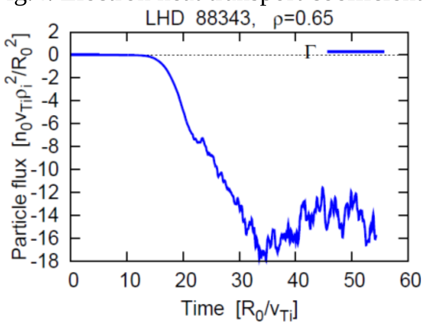

Fig.5. Particle flux.

Acknowledgments

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