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LHDにおける高イオン温度および高電子温度同位体プラズマの乱流輸送シミュレーション

Gyrokinetic turbulence simulations of high-Ti and high-Te isotope plasmas in LHD

仲田資季、永岡賢一、田中謙治、高橋裕己、沼波政倫 et al.
Motoki Nakata, Kenichi Nagaoka, Kenji Tanaka, Hiromi Takahashi, Masanori Nunami et al.

自然科学研究機構 核融合科学研究所
National Institute for Fusion Science

Impacts of the hydrogen isotope ion mass on the energy confinement, which are observed in earlier tokamak and helical plasma experiments, have been a long-standing issue in plasma and fusion research, despite its broad interests and importance. One of the scientific goals in new deuterium plasma experiments in Large Helical Device (LHD) is to explore such "*isotope effects*" on transport and confinement.

In this study, we present a recent progress in gyrokinetic turbulence simulation studies and the related experimental analyses in LHD. Gyrokinetic Vlasov simulations of trapped-electron-mode (TEM) and ion-temperature-gradient (ITG) driven turbulence in LHD plasmas with hydrogen isotope ions and real-mass kinetic electrons are carried out. It has been clarified that combined effects of the collisional TEM stabilization by the isotope ions and the associated increase of the steady zonal flows at the near-marginal linear stability lead to the transport reduction [1, 2], which is distinct from the ion mass dependence in the conventional gyro-Bohm scaling. On the other hand, the gyro-Bohm like dependence is found for the ITG case without the effect of poloidal rotations by equilibrium radial electric fields.

Linear and nonlinear GKV simulations are carried out for high-Ti isotope plasmas in LHD[3]. The experimental data indicate that the thermal diffusivity is reduced in the deuterium-dominated plasmas, where the deviation from the gyro-Bohm scaling in the overall tendency are identified. Linear calculations identify that the growth rates of the ITG instabilities in the deuterium plasmas are reduced due to the change in the profile gradients and/or the isotope ion mass, and the radial dependence of the mixing-length diffusivity is qualitatively consistent with the experimental tendency.

Nonlinear turbulence simulations reproduced qualitative behavior in transport reduction for the deuterium case, where the reduction rate in the turbulent heat diffusivity is similar to the experimental value(Fig. 1). We also observe the zonal-flow enhancement in the deuterium plasma.

Also, by using PCI and HIBP/CXS measurements in LHD and GKV calculations, TEM-like fluctuations propagating to the electron diamagnetic direction have been identified in high-Te deuterium and hydrogen plasmas with ECRH.

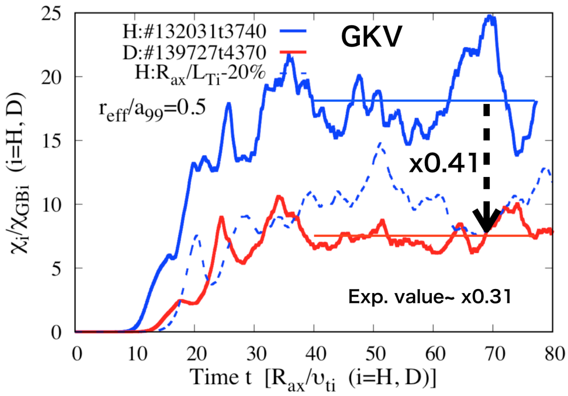

Fig. 1 Nnonlinear GKV simulations for LHD high-Ti isotope plasmas.

[1] M. Nakata, M. Nunami *et al.*, Physical Review Letters **118,** 165002 (2017)
[2] M. Nakata, M. Nunami *et al.*, Plasma Physics and Controlled Fusion **58,** 074008 (2016)
[3] M. Nakata, K. Nagaoka *et al.*, Plasma Physics and Controlled Fusion **61,** 014016 (2019)