7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Cross-scale interactions between trapped electron mode and electron-temperature-gradient-driven turbulence

Shinya Maeyama[1], Tomo-Hiko Watanabe[1], Shaokang Xu[2], Motoki Nakata[3]
[1] Department of Physics, Nagoya University, [2] Southwestern Institute of Physics, [3] National Institute for Fusion Science
e-mail (speaker): smaeyama@p.phys.nagoya-u.ac.jp

Plasma turbulence and micro-instabilities are characterized by small spatial scales, on the order of the electron or ion gyro-radii. Recent studies of cross-scale interactions between electron and ion-scale turbulence make significant progress. The importance of cross-scale interactions or electron-scale effects was reported from experiments in Alcator C-Mod [1], DIII-D[2], JET, ASDEX-Upgrade, and TCV [3].

In this study, we report on the results of numerical simulations by using the gyrokinetic Vlasov simulation code GKV [4] on the supercomputer Fugaku. This is progress from our latest publication [5], which carried out multi-scale turbulence simulations of high electron temperature plasma including trapped electron modes (TEM) and electron-temperature-gradient (ETG) modes.

First, the impact of cross-scale interactions on particle transport has been investigated. Fig. 1a plots the comparison of deuterium particle fluxes in multi-scale, ion-scale, and electron-scale simulations. Multi-scale and electron-scale simulations agree well at Te/Ti < 2 where the dominant instability is ETG modes. On the other hand, Multi-scale and ion-scale simulations agree well at Te/Ti=4 where TEMs dominate. Significant cross-scale interactions were observed at Te/Ti=3, where TEM turbulence is suppressed in the presence of ETG turbulence. At the same time, the perturbed gyrokinetic simulation rigorously satisfies the ambipolar diffusion condition, $1 = \sum_s Z_s \Gamma_s/\Gamma_e$, where Z_s is the charge number and Γ_s is the particle flux of the species s. Since the present simulation contains electrons, fuel deuterium and tritium ions, and helium ash, we have examined the detailed breakdown of the ambipolar diffusion condition in Fig 2b. By comparing the breakdowns with those of electron-scale or ion-scale simulations, we found that the main impact of cross-scale interaction was the modification of turbulent amplitude, but not the change of the breakdown of each species.

Second, we have also carried out multi-scale TEM/ETG simulations with employing JT-60U experimental equilibrium profile. We observed the suppression of TEM turbulence by ETG turbulence, as well as our previous works in analytic magnetic geometry [5,6]. This suggests that the stabilization of TEM by ETG can play a role in the evaluation of experimental transport levels.

References

[1] HOWARD, N.T., HOLLAND, C., WHITE, A.E., et al., Nucl. Fusion 56 (2016) 014004.
[2] HOWARD, N.T., HOLLAND, C., RHODES, T.L., et al., Nucl. Fusion 61 (2021) 106002.
[3] MARIANI, A., BONANOMI, N., MANTICA, P., et al., Nucl. Fusion 61 (2021) 116071.
[4] WATANABE, T.-H., SUGAMA, H, Nucl. Fusion 46 (2006) 24-32.
[5] MAEYAMA, S., WATANABE, T.-H., NAKATA, M., et al., Nat. Commun. 13 (2022) 3166.
[6] WATANABE, T.-H., MAEYAMA, S., NAKATA, M., Nucl. Fusion 63 (2023) 054001.
[7] NAKATA, M., HONDA, M., YOSHIDA, M., et al., Nucl. Fusion 56 (2016) 086010.

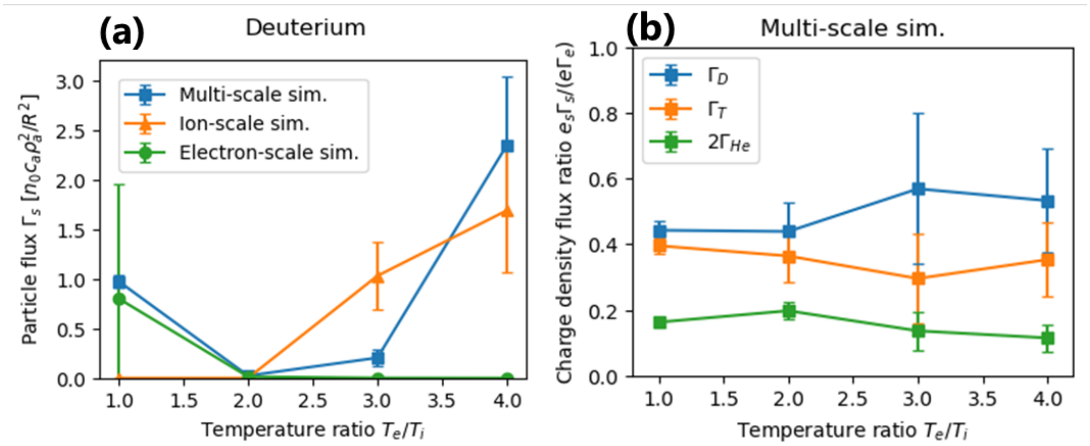

Figure 1. (a) Comparison of deuterium particle fluxes in multi-scale, ion-scale, and electron-scale simulations as functions of electron-to-ion temperature ratio. (b) Breakdown of ambipolar diffusion condition $1 = \sum_{s=D,T,He} Z_s\Gamma_s/\Gamma_e$ in multi-scale turbulence simulations.