§10. Impact of Hydrogen Isotope Ion Mass on Microinstabilities in Helical Plasmas

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Understanding transport processes of particle, momentum, and energy in magnetically confined plasmas is a central issue in fusion plasma research. In general, turbulent transport level is larger than the neoclassical (or collisional) one in the core region. The gyrokinetic model is a powerful tool for both analytic and numerical studies of core turbulent transport. Especially, since the burning plasmas in ITER and DEMO reactors are composed of mixture of hydrogen isotopes such as the deuterium(D) and tritium(T), its impacts on the microinstabilities, turbulent transport, and zonal flows should be clarified for achieving better energy and particle confinements.

In this study, electrostatic microinstabilities in helical plasmas with LHD configurations are investigated by using the gyrokinetic Vlasov simulation code GKV with hydrogen isotope species and real-mass kinetic electrons[1,2]. Comprehensive scans for the equilibrium parameters clarify the physical properties of ion-temperature-gradient modes (ITG) and trapped-electron modes (TEM), including the magnetic-configuration dependence such as the standard and inward-shifted plasma configurations[3,4].

Figures 1(a) and 1(b) show comparisons of the ITG and TEM growth rates in the hydrogen(H) plasma with standard magnetic configuration and the inward-shifted case, respectively, where the ion-temperature-gradient (R_{ax}/L_{Ti}) dependence of the growth rate(γ) is plotted. One finds transition of the dominant linear instability from ITG to TEM, depending on the ion-temperature gradient. Note that the TEM growth rate in the inward-shifted case is larger than that in the standard one. Also, distinct differences in the density gradient dependence in the ITG and TEM cases have been identified, i.e., TEM can be stabilized in the hollow density profile whereas ITG modes remain unstable.

The impacts of hydrogen isotope species on the ITG and TEM instabilities are examined. Figure 2 shows the collisionality dependence of the normalized linear growth rate $\gamma R_{ax}/v_{ts}$, where v_{ts} is the ion thermal speed for s=H, D, and T. It is found that the significant isotope dependence appears as reduction in the TEM growth rate, while the ITG case indicates a gyro-Bohm like ion-mass dependence, where the mixing-length diffusivity yields $\gamma/k^2 \propto m_i^{1/2}$. The strong isotope effect in the TEM stems from the ion-mass dependence of the ratio of the electron-ion collision frequency to the ion transit frequency, which is essential for the stabilization of the collisionless TEM. Also, the collisionality scan reveals that the TEM stabilization by the isotope ion mass becomes more significant in relatively higher collisionality regimes. The TEM- and ITG-driven turbulence and zonal flows in helical plasmas with isotope species will be investigated by means of nonlinear gyrokinetic simulations in the future works.

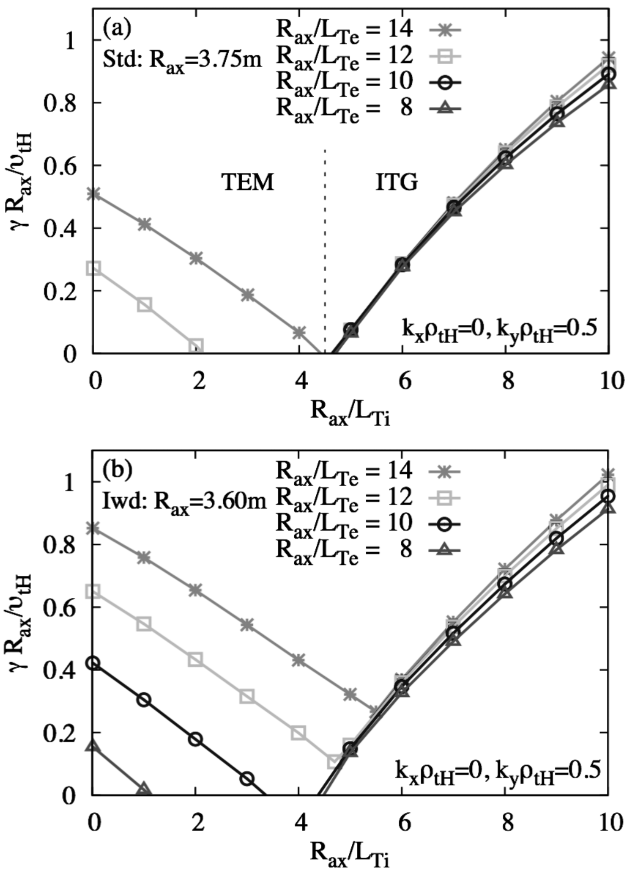

Fig. 1: Comparison of ITG and TEM growth rates in the hydrogen(s=H) helical plasma between (a)the standard and (b)inward-shifted magnetic configurations, where R_{ax}/L_n =2, T_e/T_i =2, and $\nu^* \simeq$ 0.04 are fixed.

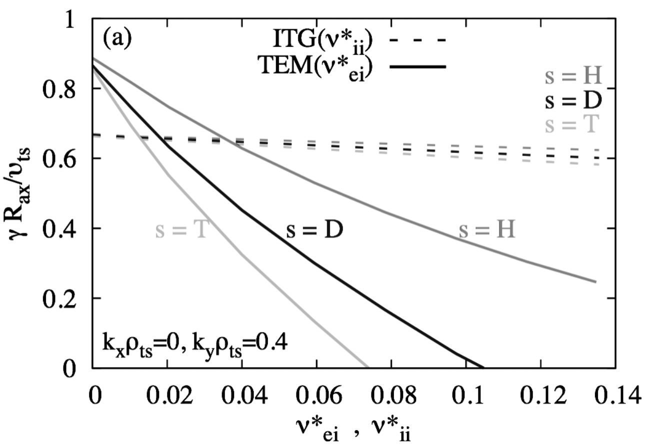

Fig. 2: Collisionality dependence of the normalized ITG(dashed) and TEM(solid) growth rates at $k_x\rho_{tH}$=0 and $k_y\rho_{tH}$=0.5.

1) Watanabe, T. –H. et al.: Nucl. Fusion **46** (2006) 24.
2) Nakata, M. et al.: Comput. Phys. Comm., **197** (2015) 61
3) Nakata, M. et al.: Plasma Phys. Control. Fusion **58** (2015), in press.
4) Nakata, M. et al.: 20th international Stellarator-Heliotron workshop (2015).