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Isotope effects on micro-instabilities in tokamak plasmas with impurities

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The isotope effect has been observed in many different devices with a degree of confinement improvement in energy, particle, and momentum depending on plasma regimes, which may be beneficial to stabilize micro-instabilities [1, 2]. The turbulence processes driven by micro-instabilities that govern anomalous transport in tokamak plasmas occur on multiple temporal and spatial scales. At the scale of ion gyro-radius, the trapped electron mode (TEM) and ion temperature gradient (ITG) mode are two of the most plausible contributors to turbulent transport, which may couple into one hybrid mode or coexist simultaneously in certain parameter regimes [3, 4].

A gyrokinetic integral eigenvalue equation is applied to investigate mode coupling in tokamak hydrogen, deuterium, and tritium plasmas with impurities [5]. Systematic analyses of impurity effects on the mode characteristics has been performed such as density gradient $L_{ez} = L_{ne}/L_{nz}$, charge concentration f_z, and charge number Z of impurity ions. It is found in this work that the impurity ions with inwardly peaked density profile have strong stabilizing effects on modes. As shown in Figure 1, the (η_i, Z) planes are divided into three regions, i.e. the TEM, ITG mode, and stable regions, meaning that the strength of coupling is weakened by the decrease of driving source η_e, so that the TEM and ITG mode dominate in different regions. The blank area indicates that neither the TEM nor ITG mode can be excited in such parameter regimes, which is the so-called stable region. Besides, the TEM (ITG mode) region is narrowed (widened) towards the low η_i regime by the impurity ions playing a stabilizing (destabilizing) role.

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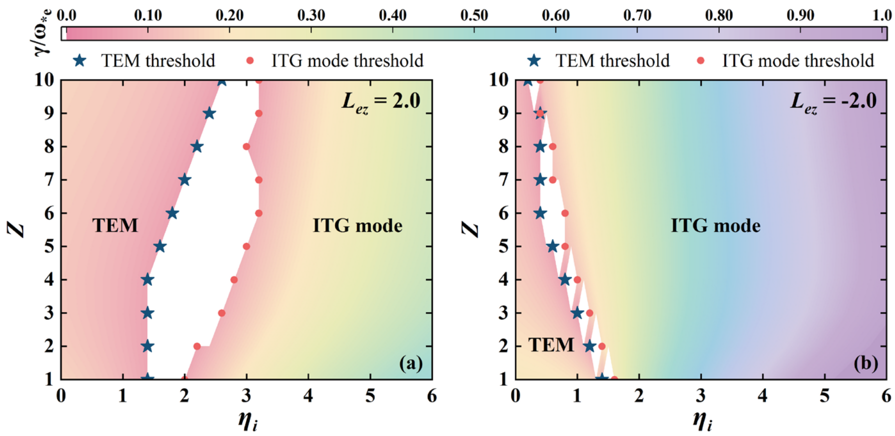

FIG.1 Contour plots of TEM and ITG mode growth rates