Global gyrokinetic simulation of linear micro-scale instability in HL-2A tokamak plasmas with anisotropic temperature

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1. Introduction

Internal Transport Barrier (ITB), which acts as the shielding layer of particle and heat transport by suppressing turbulence, is a key issue to achieve high-performance magnetically confined fusion plasmas. In recent HL-2A experiments [1], an ion-ITB is found to be formed just after the onset of co-NBI in the almost flat q-profile region but collapsed after ECRH. Ion-temperature gradient (ITG) mode and trapped electron modes (TEM) are considered to be related to these transitions, while the detailed mechanism has not been studied yet. In order to understand which mode is responsible for the onset and collapse of the ion-ITB, we perform a series of linear global gyro-kinetic simulations by utilizing the electrostatic δf version of GKNET [2]. For understanding the effect of ECRH and NBI, we also study the impact of anisotropic electron/ion temperature on micro-scale instability by changing $\Lambda_s = T_{s\perp}/T_{s\parallel}$ [3].

2. Linear analyses of micro-instabilities referring to HL-2A plasma

In this study, referring to HL-2A plasma, we set up three sets of density and ion/electron temperature gradient ([A] $R/L_{T_i} = 15.5$, $R/L_{T_e} = 4.0$, $R/L_n = 2.1$, [B] $R/L_{T_i} = 4.0$, $R/L_{T_e} = 15.5$, $R/L_n = 2.1$, [C] $R/L_{T_i} = R/L_{T_e} = 4.0$, $R/L_n = 7.4$). Figure 1 shows (a) real frequency and (b) linear growth rate as a function of $k_\theta \rho_i$ case [A], [B] and [C]. We can see the characteristics of the standard ITG mode in case [A] that the real frequency is negative and the linear growth rate has a local maximum at $k\theta\rho i{\sim}0.5$. In case [B], the standard TEM appears and the corresponding growth rate is shifted to the high-$k_\theta \rho_i$ region. In case [C], the real frequency is lower compared with those of ITG/TEM and changes the sign from electron diamagnetic direction to that of ion continuously as the poloidal wavenumber increases. Through the parameter scans we found that such a low frequency mode become dominant when the density gradient is enough steep, namely, $\eta_i{\sim}\eta_e{\sim}1$. Comparing the corresponding electrostatic potential structure with that of ITG mode and TEM, we found that the tilting angle from the mid-plane is nearly zero, showing nearly up down symmetry on the poloidal cross section as seen in Fig.1 (c1)-(c3).

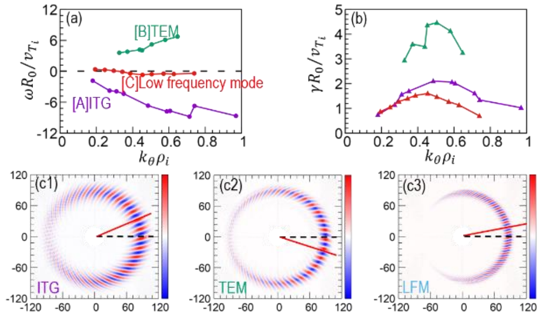

Fig. 1 (a) Real frequency and (b) linear growth rate as a function of the poloidal wavenumber $k_\theta \rho_i$ for case ITG, TEM and low frequency mode. The corresponding electrostatic potential structures are shown in (c1) - (c3).

Sensitivity scans on anisotropic temperature, namely, $\Lambda_s = T_{s\perp}/T_{s\parallel}$, are shown in Fig. 2. The ITG mode is almost independent on $T_{e\perp}$ (a1) but weakened when $T_{i\perp}$ become large (a2). While TEM is enhanced by increase of $T_{e\perp}$ significantly (b1), showing a strong sensitivity, but independent on $T_{i\perp}$ (b2). The low frequency mode is found to have an interesting feature that it is enhanced by $T_{e\perp}$ similar to TEM, meanwhile, suppressed by $T_{i\perp}$ like ITG mode.

The simulation indicates that this low frequency instability appears before and during the ECRH phase in HL-2A experiment. Moreover, the response to anisotropic temperature proves it could be enhanced by ECRH. Thus, this low frequency mode is possible candidate to explain the collapse of ITB in HL-2A experiment.

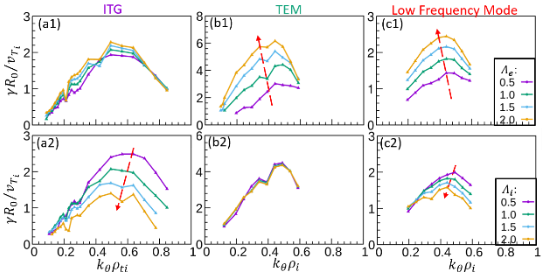

Fig. 2 linear growth rate spectrum of ITG mode (a), TEM (b) and low frequency mode (c) when Λ_s is changede from 0.5 to 20 respectively.

References

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