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Characteristics of global micro-instabilities in L-mode states consistent with JT-60U reversed magnetic shear plasmas

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The formation of internal transport barrier (ITB) is a key to achieving high performance fusion plasmas in magnetically confined devices, such as tokamak. In JT-60U experiments in reversed magnetic shear (RS) configuration using neutral beam (NB) injection, a heating power threshold is found to exist for triggering ITBs, under which plasmas show L-mode characteristics with strong profile stiffness [1, 2]. To study such ITB formation, we first need to understand the characteristic of L-mode plasma in such RS configurations, especially the free energy source that drives linear instability. In this work, by using the 5D global gyro-kinetic code GKNET [3, 4], we investigated the linear instabilities in JT-60U L-mode RS plasmas. Here, we found two different branches of drift modes excited in different radial locations, which regulate nonlinear dynamics causing profile stiffness.

The obtained linear dispersion relations, i.e. (a) real frequency, (b) growth rate, and (c) mode radial location, with respect to the toroidal mode number n, are shown in Fig.1. In Fig.1 (c), corresponding $k_\theta \rho_i$ values are shown to study the mode characteristics. Here, two different branches which are excited in different radial locations, i.e., one is inside region with higher safety factor q values, the other is outside minimum q (q_{min}) region, are found to appear. Between the inside and outside branch, there exists a “gap”. The modes in the two branches all rotate in the ion diamagnetic direction ($\omega < 0$). It is also found that the inside branch approximately follows the line satisfying $k_\theta \rho_i = 0.2 \sim 1.0$, while the outside branches weakly depend of $k_\theta \rho_i$ indicating that they are non-resonant infernal type modes. Note that the inside mode with lower toroidal mode number $n = 2$ with $k_\theta \rho_i = 0.4$ exhibits the maximum growth rate, which decreases with n by shifting slowly outside with increasing real frequency in the ion direction.

Fig. 2 shows corresponding mode structures to $n = 2$ and $n = 30$ mode in Fig. 1, which are the most unstable mode for the inside branch and outside branch, respectively. It is found that $n = 2$ mode owes a large poloidal mode number due to the high q value, and $n = 30$ mode is highly localized at q_{min} region.

In addition, we study the mode characteristics by changing the temperature and density profiles independently to identify the mode characteristics. To be specific, the inside branches are considered to the pressure driven modes, which are excited by both ion and density gradient, while the outside branches are the ion temperature gradient driven infernal type modes, which show a weak dependence with respect to the density gradient. The special characters of the modes are strongly related to the q profile, especially the q_{min} location. Further study is carried out to investigate the two branches nonlinear evolution and turbulence transport.

References

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Figures

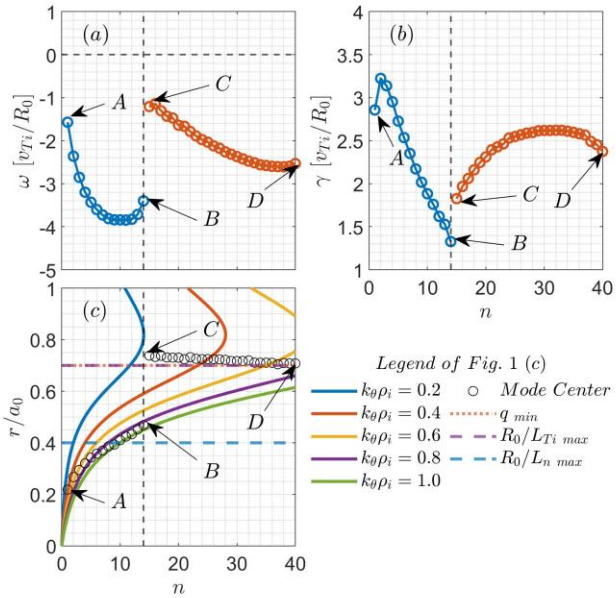

Fig. 1. (a), (b) The relation between real frequency ω, growth rate γ to the toroidal mode number n; (c) The center location r of each toroidal mode.

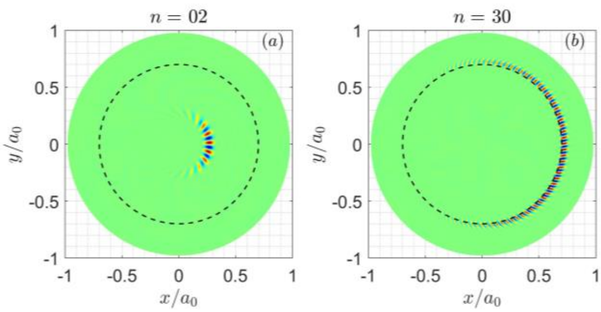

Fig. 2. (a), (b) The $n = 2, 30$ mode structures in poloidal cross section, where the black dashed circle represents q_{min} location.