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Characteristics of global dispersion modeled for JT-60U strongly reversed magnetic shear plasmas exhibiting L-mode with strong profile constraints

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In magnetically confined plasmas, such as tokamaks, turbulence and associated transport arising from various unstable free energy sources are the primary factor regulating the confinement of particle and energy and then the origin of the L-modes, leading to global profile constraints referred to as profile consistency. Such L-mode characteristics have been widely studied in conventional magnetic field configuration that the safety factor q monotonically increase in the radial direction. To achieve higher performance plasmas, such L-mode characteristics have to be broken. For this purpose, the control of the equilibrium magnetic field, especially, the q profile, are found to be the key for triggering internal transport barriers (ITBs). Recently, Kin et al. analyzed L-mode characteristics for strongly RS plasmas observed in JT-60U in the sub-critical regime for the neutral beam injection (NBI) power, i.e. $P_{in} < P_c$, above which ITBs are formed [1]. However, even in such plasmas, the plasma shows the strong profile constraints, indicating that the L-mode characteristics weakly depends on the magnetic structures, though the instability free energy source sensitively depends on them.

Here, we revisit the properties of instability free energy source for plasmas with strongly reversed q profiles, highlighting the variety of mode structures based on the simulations using the global gyro-kinetic code (GKNET) [2,3]. A notable feature is the separate nature of the established profiles for ion and electron temperature, and that for the density. That is, temperatures, T_i and T_e, which show similar profiles with $T_i > T_e$, are both located in the outer region around the q_{min} surface at $r/a_0 \sim 0.7$, whereas n_e is located in the inner region of $r/a_0 \sim 0.4$. From the series of simulation study based on the above motivation, we found qualitatively different two branches are identified, one is ballooning type resonant modes with lower-n (toroidal mode number) values lied in the inner negative magnetic shear region ($\hat{s} < 0$) exhibiting highly localized structure in the poloidal direction, the other is non-resonant modes with higher-n values lied in the outer region, which are all localized and coupled via the toroidal effect around the q_{min} surface exhibiting found that the former is density driven trapped electron modes (TEMs) while the latter is η_i-mode and/or ITG modes. Interestingly, each branch is found to exhibit poloidally extended structure as shown in Fig.1. We nearly the same values for the growth rates in the inner and outer regions, which is consistent to the discussion of *marginal stability* in a global system. Namely, the established profile will be such that the deviation from the critical/marginal parameter of the instability free energy sources is at approximately the same level throughout the system, which is expected to maintain a nearly same turbulence level and then the transport in the entire system. This is considered to be a global version of such marginal stability.

We also perform the nonlinear simulation in Fig.2 which show the evolution of ion heat flux Q_i. Two modes excited inner and outer branches differently evolve exhibiting spatial spreading. The spreading speed of two branches are different, namely $v_{in} \sim 4v_d$ and $v_{out} \sim v_d$, where v_d represents the ion diamagnetic drift velocity. Both inner and outer flux show an avalanche structure, and the cross point shows a kind of intermittent bursting phenomenon. Such a global turbulence is considered to be the origin of profile constraints.

References

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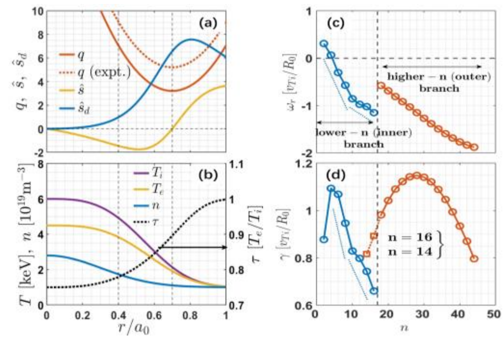

Figure 1 The equilibrium JT-60U-like profiles (a), (b), and the dispersion relation (c), (d).

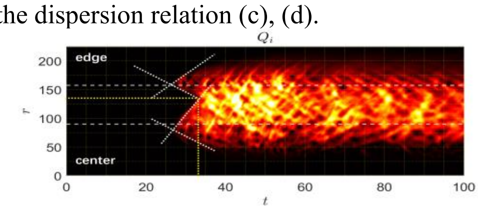

Figure 2 The time evolution of ion heat flux Q_i at different radial directions.