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Effects of equilibrium radial electric field on ion temperature gradient instability in the scrape-off layer of a field-reversed configuration

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Existing studies have shown in experiments and simulations, that both electron and ion scale drift-waves can be unstable in the scrape-off layer (SOL) of a field-reversed configuration (FRC).[1,2] The extensive study on drift-wave suppression due to E×B shear flow in tokamaks motivates us to investigate the similar suppression effect of microturbulence in FRC SOL by sheared equilibrium flows. Although a high β (ratio of kinetic pressure to magnetic pressure) value near the FRC core is expected, a typical β in the SOL could be around 0.05 in our simulation. Therefore, a gyrokinetic particle code, GTC-X, can be used for simulations with a single toroidal mode, n=20, to understand the radial equilibrium electric field effects on ion temperature gradient (ITG) instability in SOL.[3,4]

Linear simulations with adiabatic electrons find that the E×B flow shear reduces the growth rate and causes a radial tilting of the mode structure on the toroidal plane. Based on a slab model dispersion relation, the radial shear of the total local mode frequency is found to be important for the growth rate suppression. The maximal growth rate occurs when the radial shear of the Doppler-shifted local mode frequency is zero. Similar results are also reported in previous tokamak studies.[5,6]

Nonlinear simulations find that the E×B flow shear significantly decreases ITG saturation amplitude and ion heat transport in the SOL by reducing both turbulence intensity and eddy size. The turbulence intensity is determined by fluid eddy rotation, which is the dominant saturation mechanism for the SOL ITG instability with a single toroidal mode number. The growth rate is very similar to the inverse of the eddy turnover time. On the other hand, the effective decorrelation time responsible for the ion heat transport is closer to the parallel wave-particle decorrelation time. Before completing the whole circulation around the eddy, the particles already decorrelate from the wave due to parallel streaming in the SOL. A random walk model, using the guiding center radial excursion as the characteristic length scale and the eddy turnover time as the characteristic time scale, fits very well to the scaling of ion heat conductivity with the E×B flow shear.

References

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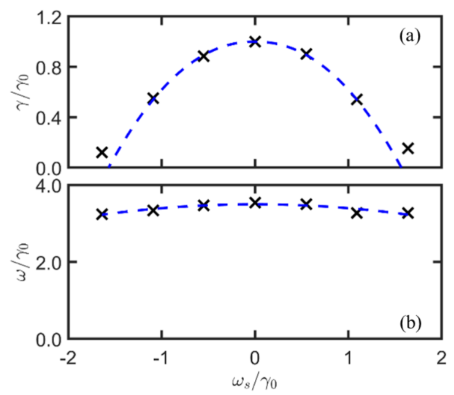

Figure 1. Dependence of SOL ITG growth rate γ (panel a) and real frequency ω (panel b) on shearing rate ω_s from GTC-X simulations. Dashed lines are fitting curves based on simulation data points ("x")

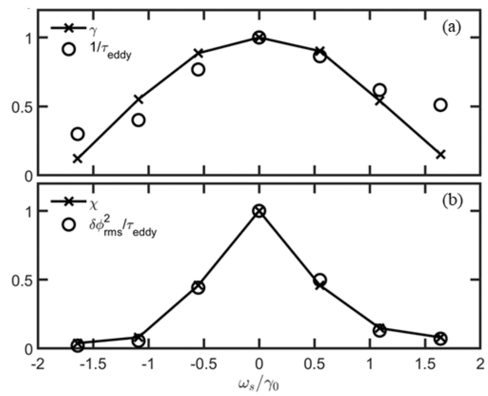

Figure 2. Dependence on the shearing rate for (panel a) linear growth rate γ and inverse of eddy turnover time τ_{eddy}, and (panel b) the measured heat conductivity χ, and $\delta\phi_{rms}^2/\tau_{eddy}$ at the nonlinear saturation. All quantities are normalized by their values for the case of $\omega_s = 0$.