§14. Gyrokinetic Simulations of Short-wavelength ITG Instability in the Presence of a Static Magnetic Island

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The short-wavelength ion-temperature-gradient (sw-ITG) mode was discovered by Smolyakov *et al.* [1] in shearless slab geometry as a second destabilization of the ITG mode for large poloidal mode numbers. Follow up investigation by Gao *et al.* confirmed that the sw-ITG mode exists in sheared slab geometry [2], as well as in toroidal geometry [3]. They found that the linear growth rate of the sw-ITG mode is comparable to the usual long-wavelength standard ITG (std-ITG) mode. However, the role of such sw-ITG mode on multi-scale interaction is not clarified yet even in linear phase.

In this study, we investigate the effect from the equilibrium magnetic field perturbation arising from a static magnetic island on both std-ITG and sw-ITG instability. Figure 1 shows the growth rates of poloidal modes for $w = 0,6,12,18$, where w is the magnetic island width. For $w > 0$, all modes have an equal growth rates owing to the formation of a global mode. Coupling enables unstable modes to transfer energy to stable modes, where it is then dissipated away through finite Larmor radius effects and/or Landau damping. This is observed as the reduction of the growth rate of the global mode. As a larger island size enhances the coupling between the modes, this stabilization mechanism increases for larger island sizes until a width of $w \sim 15$, as shown in Fig. 2. Such stabilization mechanism is weak compared to that reported by Wang *et al.* [4]. This can be attributed to the appearance of the sw-ITG mode, which reduces the energy dissipation by providing a free-energy source.

For large island widths ($w > 15$), a strong destabilization of the global mode is observed. In order to understand the this destabilization mechanism, we fix the poloidal direction at $y = 0$ and $y = L_y / 2$ for simplicity, which corresponds to the X-point and O-point of the island, respectively. The growth rate's dependence on the island width is shown in Fig. 3. For the X-point equilibrium, the std-ITG mode is slightly destabilized, which agrees well with the general behavior of destabilization for weak magnetic shear and the stabilization for stronger shearing rates. The sw-ITG mode however is very sensitive to the increase in magnetic shear and quickly stabilizes. For the O-point equilibrium, the std-ITG mode is stabilized for small island widths on account of the reduction of local shear, however it is destabilized again for large island widths because of the separation of rational surfaces. As the island width increases and crosses a critical value, the std-ITG mode and also the sw-ITG mode are first destabilized, and then stabilized again, as shown in Fig. 4. However, the critical island width for the sw-ITG mode is smaller than that of the std-ITG. We can understand this underlying mechanism through the response of the ITG eigenmode structures to the island size.

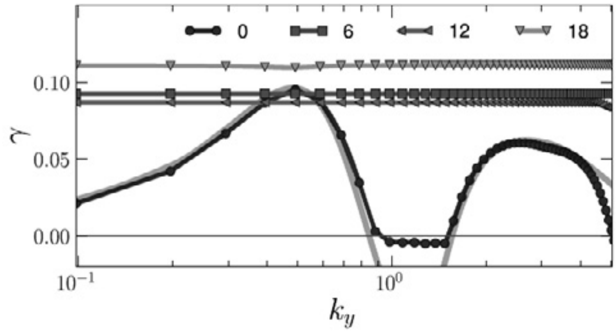

Fig. 1. Growth rates of poloidal modes for $w = 0,6,12,18$.

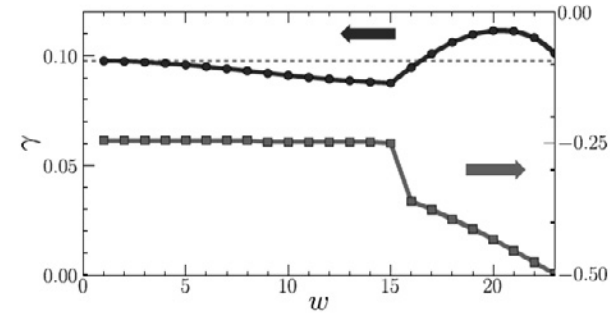

Fig. 2. Growth rate γ and real frequency ω_r of the global mode depending on the magnetic island width w.

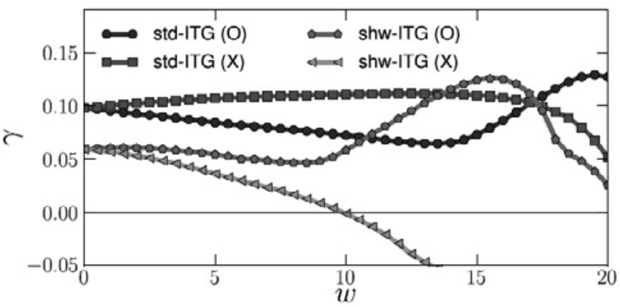

Fig. 3. ITG growth rates at the island's X- and O- point for $k_y = 0.5$ and $k_y = 2.5$ modes versus the island width w.

In summary, we have found that a small magnetic island has a stabilizing effect on the ITG mode, whereas the separation of the rational surfaces caused by the island destabilizes the ITG mode for large islands. In this case, the destabilization of the sw-ITG mode is dominant on account of its smaller radial mode structure, and is therefore more sensitive to rational surface separation compared to the std-ITG mode.

[1] Smolyakov, A., Yagi, M. and Kishimoto, Y. Phys. Rev. Lett. **89** (2002) 125005.
[2] Gao, Z., Sanuki, K., Itoh, K. and Dong, J. Q. Phys. Plasmas **10** (2003) 2831.
[3] Gao, Z., Sanuki, K., Itoh, K. and Dong, J. Q. Phys. Plasmas g, Phys. Plasmas **12** (2005) 022502.
[4] Wang, Z. X., Li, J. Q., Kishimoto, Y. and Dong, J.Q. Phys. Plasmas **16** (2009) 060703.