§9. Short Wavelength ITG Modes with Toroidal and Trapped Particle Effects

Yamagishi, O., Watanabe, T.-H., Nakajima, N., Nakamura, Y. (Kyoto Univ.), Sugama, H.

The ion temperature gradient (ITG) mode is one of the drift instabilities and it is regarded as a candidate to cause the anomalous transport. It is well known that the ion FLR effects can stabilize the linear ITG modes when wavelength of the modes becomes short. Thus it is conventional to investigate the ITG at $k_\theta \rho_{thi} <\sim 1$. However, recently the ITG modes have been found at relatively short wavelength region, $k_\theta \rho_{thi} > 1$[1,2]. In these papers, the ITG modes were treated with some assumptions; the adiabatic electrons are assumed, and the trapped particles dynamics and the toroidal effects are neglected. Here we include these effects formally based on Ref.[3]. The basic parameters used are cyclone base: s=0.78, α=0(zero β thus electrostatic limit), m_i/m_e=3670, T_e/T_i=1, q=1.4, ε_t=r/R_0=0.18, and the ballooning angle θ_k=0. The remaining parameters $k_\theta \rho_{thi}$, and two of (R_0/L_n, R_0/L_T, $\eta=L_n/L_T$) are changed in the following. Here L_n=-n/(dn/dr) and L_T=-T/(dT/dr) are scale length of n and T respectively.

In Fig.1, the ITG frequencies are shown as a function of $k_\theta \rho_{thi}$, which are normalized as $\omega/(v_{thi}/qR_0)=\omega/[\omega_{*e} \times (L_n/qR_0) / k_\theta \rho_{thi}]$ to eliminate the parameter dependence relevant to X-axis in the diamagnetic frequency. Here η=5 is fixed and some R_0/L_n values are taken into account. In the R_0/L_n=2 case, the modes are stabilized at about $k_\theta \rho_{thi}$=1, while in the higher R_0/L_n cases the modes remain unstable at higher $k_\theta \rho_{thi}$. A case of R_0/L_n=10 with adiabatic electrons is also shown by squares, and it can be confirmed that the non-adiabatic electrons are not necessary for the short wavelength ITG. In the case of R_0/L_n=4 or 10, there is a local minimum of growth rates at near $k_\theta \rho_{thi}\sim 1$, as in Ref.[1,2]. The eigenfunctions for $k_\theta \rho_{thi}$=0.6, 1.0, and 2.0 are shown in Fig.2 for R_0/L_n=10. It can be seen that the modes with $k_\theta \rho_{thi}$=2.0 is more broad, that is $k_{//} \sim \partial / \partial \theta$ is more small. This is not the case for usual ITG as can be seen from the cases of $k_\theta \rho_{thi}$=0.6 and 1.0, and thus the local minimum of the real frequencies also exits through the $k_{//}v_{//}$ resonance in Fig.1.

We next show frequencies of short wavelength ITG as a function of R_0/L_T in Fig.3, where $k_\theta \rho_{thi}$=1.6 is assumed and the value of R_0/L_n=2 and 10 are taken into account. There is a cut-off of instabilities at slightly above $R_0/L_T\sim 10$ for R_0/L_n=2. The case of R_0/L_n=2 is unstable although that value is stable in Fig.1. Thus the high R_0/L_n value itself may not be necessary for instabilities but the high R_0/L_T is necessary. At the marginal stability, the value of η is 6 for R_0/L_n=2 while $\eta <\sim 1$ for R_0/L_n=10. Thus η itself seems also not to be essential.

We can find the similar tendency of short wavelength ITG modes to that reported in Ref.[1,2]. Thus the short wavelength ITG modes are essentially slab-like (parallel resonance is dominated), and the non-adiabatic electrons (including trapped electrons) are incidental. The value of $R_0/L_T\sim 10$ gives an estimate of normalized temperature gradient as $|dT/d\rho|/T\sim 10(a/R_0)$. This value is high but seems to be sustained in the transport barrier or plasma edge region. In these cases, there is a possibility that the ITG modes with short wavelength may limit the temperature gradient.

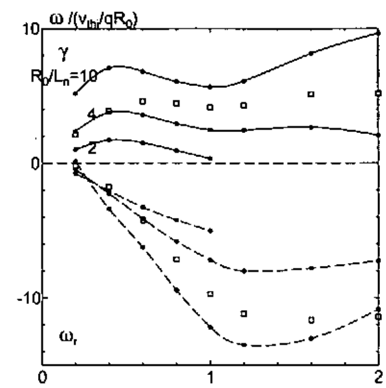

Fig. 1. Frequencies of ITG as a function of $k_\theta \rho_{thi}$ for R_0/L_n=2,4, and 10.

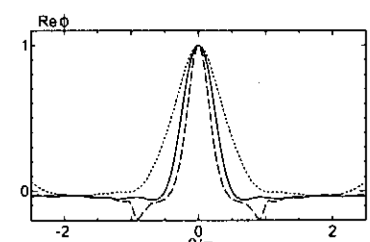

Fig. 2. Eigenfunctions at $k_\theta \rho_{thi}$=0.6 (solid), 1.0 (dashed) and 2.0 (dotted) for R_0/L_n=10.

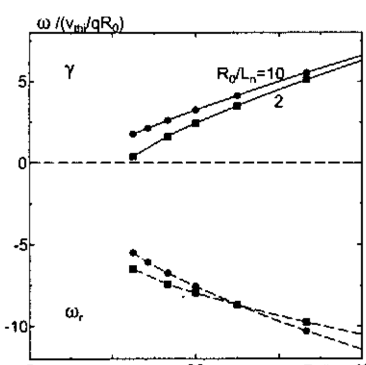

Fig. 3. ITG frequencies with $k_\theta \rho_{thi}$=1.6 as a function of R_0/L_T, for R_0/L_n=2(squares) and 10(circles).

Reference

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