§12. Ion Temperature Gradient Modes in Helical Systems

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The ion temperature gradient (ITG) modes are drift-wave-like instabilities and have been studied as a candidate to explain the anomalous transport in high temperature plasmas. For toroidal systems, the properties of ITG modes are significantly affected by the magnetic field geometry through the ∇B- and curvature-drift motion of particles. For helical systems, the magnetic field strength is approximately given by

$$B/B_0 = 1 - \epsilon_t \cos\theta - \epsilon_h \cos(L\theta - M\zeta), \qquad (1)$$

where θ and ζ represent poloidal and toroidal angle, respectively, and $\epsilon_t = r/R$ represents toroidicity with minor radii r and major radii R and $\epsilon_h \propto (r/R)^L$ represents helical ripple with poloidal and toroidal polarity numbers L and M:for LHD $(L, M) = (2, 10)$ and for CHS $(L, M) = (2, 8)$.

In this work, we investigate the linear stability of electrostatic ITG modes. In the presence of the electrostatic perturbation ϕ, the Boltzmann distribution of electrons is assumed, and the gyrokinetic equation of ions is used to describe the ion dynamics. The dispersion relation is determined by the charge-neutrality condition for charge density perturbations.

We consider a large aspect-ratio and low β system with magnetic field geometry (1) and use the ballooning representation to solve the parallel structure of ϕ and to obtain the dispersion relation, numerically. The perpendicular structure is represented by the wavenumber vector $\boldsymbol{k}_\perp = k_\alpha(\nabla\alpha + \theta_k \nabla q)$ where q is the safety factor, $\alpha = \zeta - q\theta$ is the label for magnetic field line, and $k_\alpha = -n$ represents the toroidal mode number, which is related to the poloidal wavenumber as $k_\theta = nq/r$. We assume that $\theta_k = 0$ and $\alpha = 0$. The charge-neutrality condition(or the dispersion relation), is represented as an integral equation of the form

$$\left(1 + \frac{T_e}{T_i}\right)\phi(\theta) = \int_{-\infty}^{+\infty} \frac{d\theta'}{\sqrt{2\pi}} K(\theta, \theta')\phi(\theta'), \qquad (2)$$

where T_e and T_i are temperatures of electrons and ions, respectively, and θ is treated as a parallel coordinate variable. The integral kernel K depends on parameters such as $\eta_i = [d(\ln T_i)/dr]/[d(\ln n_i)/dr]$, $\epsilon_n = [d(\ln n_i)/dr]^{-1}/R_0$, $\tau_e = T_e/T_i$, and $\hat{s} = (r/q)(dq/dr)$. The boundary conditions $\phi(\theta \to \pm\infty) = 0$ are used. The complex-valued eigenfrequencies and eigenfunctions of the ITG mode for the helical systems are obtained by numerically solving Eq.(2). Since, here, we are concerned with the effects of the helical ripple, we neglect the toroidal ripple by putting $\epsilon_t = 0$ (straight helical system) for simplicity. Typical parameters used here are $q = 2$, $k_\theta \rho_{Ti} = 0.75$, $T_i/T_e = 1$, $L_n/R_0 = 0.2$, $L_n \epsilon_h / r = 0.2$, and $\hat{s} = -1$ (negative shear).

Figure 1 shows the normalized real frequency ω_r/ω_{*e} and growth rate ω_i/ω_{*e} of the ITG mode as a function of M for various η_i's in the case of $L = 2$, where $\omega_{*e}(> 0)$ is electron diamagnetic drift frequency. Other parameters used here are the same as mentioned above. The real frequencies obtained here are all negative, which corresponds to the ion diamagnetic rotation. The growth rate decreases with increasing M.

Corresponding to the cases for various M's in Fig. 1, the profiles of the eigenfunction ϕ and the helical drift frequency $\omega_D = \boldsymbol{k}_\perp \cdot \boldsymbol{v}_\perp \propto \cos[(L - Mq)\theta] + \hat{s}\theta \sin[(L - Mq)\theta]$ in the covering space (θ-space) are plotted in Fig. 2. The regions where the helical drift frequency is positive (negative) corresponds to bad (good) curvature. As M increases, the connection length between the good and bad curvature regions becomes shorter. Then eigenfunction ϕ becomes more rippled in the covering space and has a larger amplitude in the good curvature region, which is related to the reduction of the growth rate for larger M.

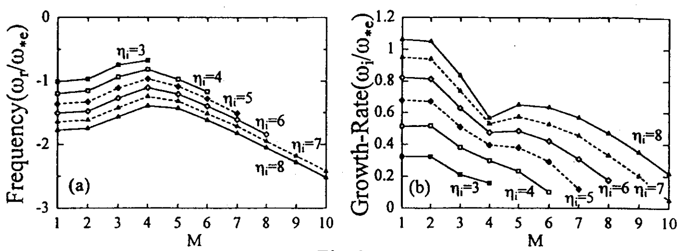

Fig.1

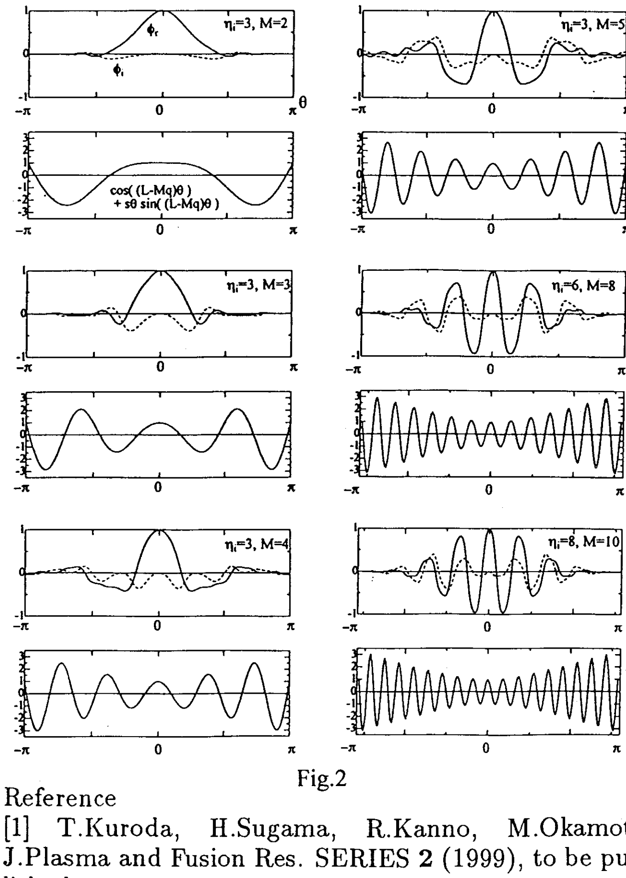

Fig.2

Reference

[1] T.Kuroda, H.Sugama, R.Kanno, M.Okamoto, J.Plasma and Fusion Res. SERIES **2** (1999), to be published.