Extension of GAM theory to Helical Systems

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Abstract

GAM oscillations, whose existence have been reported first as early as in 1986, is now gathering attention. Electrostatic fluctuations are divided into those in high and low frequency ranges. Drift waves belong to the former and the GAM oscillations belongs to the latter with other residual zonal flows. The interaction of the fluctuations in these two frequency ranges is broadly accepted as key mechanisms to determine the turbulence and governs the transports. The existence of Zonal flows including GAM have been recently evidenced in tokamak experiments in DIII-D and JIPP-TII U by using developed fine diagnostics BES and HIBP, respectively. Similar oscillations were found also in a helical device CHS by use of a dual HIBP. The most significantly, these papers indicate that the associated flows have rather narrow radial structure with the shearing rates attaining the decorrelation times. The present paper addresses a problem, if a GAM oscillation can be found in theory as it is extended to cover helical systems, which so far has been applied to tokamaks. By using drift kinetic equations for three-dimensional equilibriums, a generalized dispersion relation is obtained including Landau damping. It is found that the GAM frequency in a helical system is typically higher than that of tokamaks. An analytic form of the damping rate of GAM is obtained by solving the dispersion relation perturbatively. It is found that the damping is stronger in helical systems than in tokamaks due to the shorter connection length associated with the larger toroidal mode number. The connection length, however, becomes exceptionally large in the radial domain satisfying m-nq=0 and suggests presence of a singular layer of weaker damping. For instance, (m,n)=(2,6) for CHS giving the helical pitch of the device and the singularity occurs just a little out side the last closed flux surface.
The same formula is applied to tokamaks of noncircular cross-section regarding it as a class of multi-helicity problem. The obtained formula suggests an additive in the oscillation frequency proportional to the degree of ellipticity and singularity. It also suggests an enhancement of the damping rate due to the presence of the harmonics with their shorter connection length. Common through all the cases, it is shown that the damping rate is small for large values of Te/Ti and it is the case for JIPP T-IIU and CHS. Comparison of the experimental transport coefficients with the damping rate of the GAM in their radial structure and dependence on Te/Ti will give some clues to an assessment of the role of GAM in regulating turbulences via associated shearing rate.