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Nonlinear excitation of energetic-particle-driven geodesic acoustic mode by ions drift waves

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Geodesic acoustic mode (GAM) is a unique electrostatic fluctuation phenomenon in toroidal plasmas with toroidally symmetric and poloidally near symmetric structure.[1,2] In tokamak plasmas, GAM was widely observed and proved to have an important effect on the plasma turbulence modulation. As a stable oscillation mode, the phase velocity of GAM is on the order of ions thermal velocity. However, energetic particles (EPs) can interact with GAM and produce unstable GAM branches, which is called energetic-particle-driven GAM (EGAM). EGAM was first predicted analytically by Fu in 2008.[3]

In addition to the EPs excitation method, GAMs can be induced through nonlinear ways. The theoretical investigation indicated that large-scale electromagnetic mode can be triggered by small-scale electrostatic drift waves. Under the framework of the four-wave drift wave-zonal flow modulation interaction model, equations for the nonlinear interaction between drift wave and zonal flow were developed by Zonca et al.[4] Besides, we investigated the nonlinear excitation of GAM by ions drift waves in anisotropic toroidally rotating tokamak plasmas through fluid model two years ago.[5]

Then based on our previous work, we focus on the combined effects of ions drift waves and EPs on the excitation of GAM with anisotropy and toroidal rotation in tokamak plasmas in the present work. Through the MHD and gyro-kinetic equations, we derive the dispersion conditions of EGAMs, in which the nonlinear effects arouse the instability of the inherent stable high frequency branch and contribute to the growth/damping rates of the low frequency branches. It is found that in the presence of nonlinear effects, each EGAM branch is separated into two modes with different growth rates and frequency shifts. Since the frequency shifts are ignorable compared to the EGAM real frequency, we only focused on the imaginary part of the frequency by assuming the split modes with the same real frequency. For the inherent stable high frequency branch, the nonlinear characteristic of the growth rate is shown in Fig. 1.

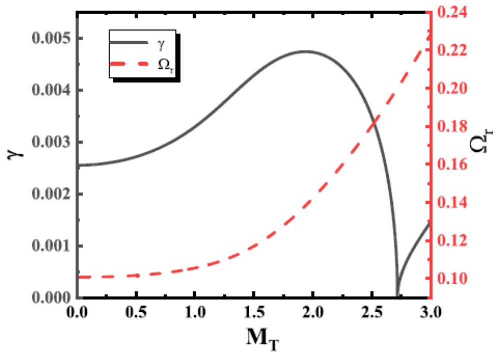

Figure 1. The dependence of the growth rate γ and real frequency Ω_r of the high frequency EGAM branch on the Mach number M_T, in a typical tokamak with q = 4.

Unlike the effect of EPs, the nonlinear driving does not always improve the growth rate in all conditions. Considering the resonance condition of efficiently excited GAM by nonlinearity, the frequency of GAM and the poloidal wave number of the pump drift wave jointly affect the nonlinear effects. The collective effects of EPs and pump wave cause the growth rate as illustrated in Fig.2. The changes of EPs parameters influence on the frequency of EGAM, which makes the same nonlinear driving produce different effects.

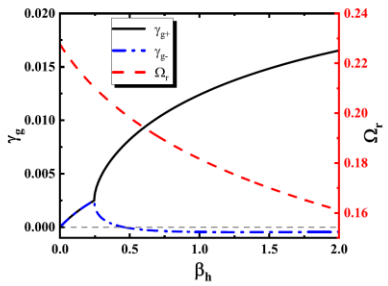

Figure 2. The dependence of the growth rate the beta of EPs.

References
[1] N. Winsor, Phys. Fluids 11, 2448 (1968).
[2] P. H. Diamond, S.-I. Itoh, K. Itoh, and T. S. Hahm, Plasma Phys. Controlled Fusion 47, R35 (2005).
[3] G. Y. Fu, Phys. Rev. Lett. 101, 185002 (2008).
[4] F. Zonca and L. Chen, Europhys. Lett. 83, 35001 (2008).
[5] H. Huang, H. Ren, Z. Ming, and D. Zhang, Phys. Plasmas 29, 032503(2022).