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Nonlinear Interactions of Low Frequency Alfven Eigenmodes

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In this paper, we report gyrokinetic simulations of nonlinear interactions between beta-induced Alfven eigenmode (BAE) and beta-induced Alfven-acoustic eigenmode (BAAE), low frequency modes that have strong interactions with both thermal and energetic particles. When the ion temperature is comparable to the electron temperature, the unstable BAAE can be excited by realistic energetic particle density gradient, even though the damping rate of the BAAE (in the absence of energetic particles) is comparable to the real frequency. This is due to a smooth and broad radial mode structure of the unstable BAAE as compared to a singular mode structure of the damped BAAE. In the simulations with reversed magnetic shear, BAAE frequency sweeping is observed and poloidal mode structure has a triangle shape with a poloidal direction similar to that observed in tokamak experiments. By scanning the device size while keeping all other plasma parameters unchanged, we find that the BAAE dominates in the larger machine size (similar to ITER). For the smaller machine size, the dominant mode is BAE. At some machine size (similar to DIII-D tokamak), the BAE and BAAE can have the same growth rates, an interesting regime where BAE and BAAE can co-exist and interact nonlinearly as demonstrated in the following nonlinear simulation.

The nonlinear simulation of the machine size where BAE and BAAE have the same growth rate has been carried out. Zonal fields are not included in this simulation. In the linear regime, BAAE and BAE co-exist and have similar amplitudes. The mode structure is the superposition of BAE and BAAE. The BAE saturates first, followed by the saturation of the BAAE, which becomes dominant. The amplitudes of BAE and BAAE decrease significantly after saturation and various nonlinear modes including a very low frequency, a beat wave frequency, and its conjugate are successively excited. The BAE can later become dominant. In this long time simulation, the amplitudes of all these modes oscillate with certain phase shift, indicating energy exchanges between these linear and nonlinear modes. Furthermore, we have also performed nonlinear simulation with zonal fields included. Simulation results show that zonal flows reduce the saturation amplitudes of BAE, BAAE, and nonlinear modes.

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