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Nonlinear excitation of energetic-particle-driven geodesic acoustic mode by Alfvén eigenmode

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Both the Alfvén eigenmode (AE) and the energetic-particle-driven geodesic acoustic mode (EGAM) enhance the energetic particle (EP) transport and thus may degrade the auxiliary heating performance in the fusion device. The coexistence of AE and EGAM may not only lead to a simple summation of the transport effects, but also to a stronger relaxation of the EP distribution function in the nonlinear stage. Recently, EGAM has been nonlinearly excited by AE in the ASDEX-Upgrade (AUG) tokamak[1], and the mode properties are investigated in simulations[2,3]. However, the nonlinear excitation of EGAM has not been demonstrated in detail. In the present work, a hybrid simulation with the MEGA code is performed to investigate the mode properties in both the linear growth phase and the nonlinear saturation phase.

The simulation parameters are selected based on AUG discharge #34924[1]. The nonlinear excitation of EGAM by AE in AUG is successfully reproduced by using the MEGA code, as shown in Fig. 1. The simulated AE frequency is 103.5 kHz and EGAM frequency is 51.5 kHz. During the mode activities, inward EP re-distribution is found. These properties are in good agreement with the AUG experiment. The conclusive evidence for the nonlinear excitation mechanism of EGAM is found by analyzing the contributions of particles with different magnetic moment μ values. In the linear growth phase, AE is excited by satisfying different resonance conditions, and then, AE causes EP re-distribution in the phase space, and this re-distribution destabilizes EGAM in the nonlinear phase, as shown in Fig. 2. The above process is demonstrated in detail for the first time.

References

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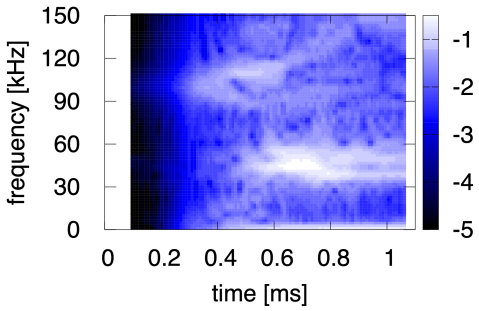

Figure 1. The simulated AE (103.5 kHz) and EGAM (51.5 kHz).

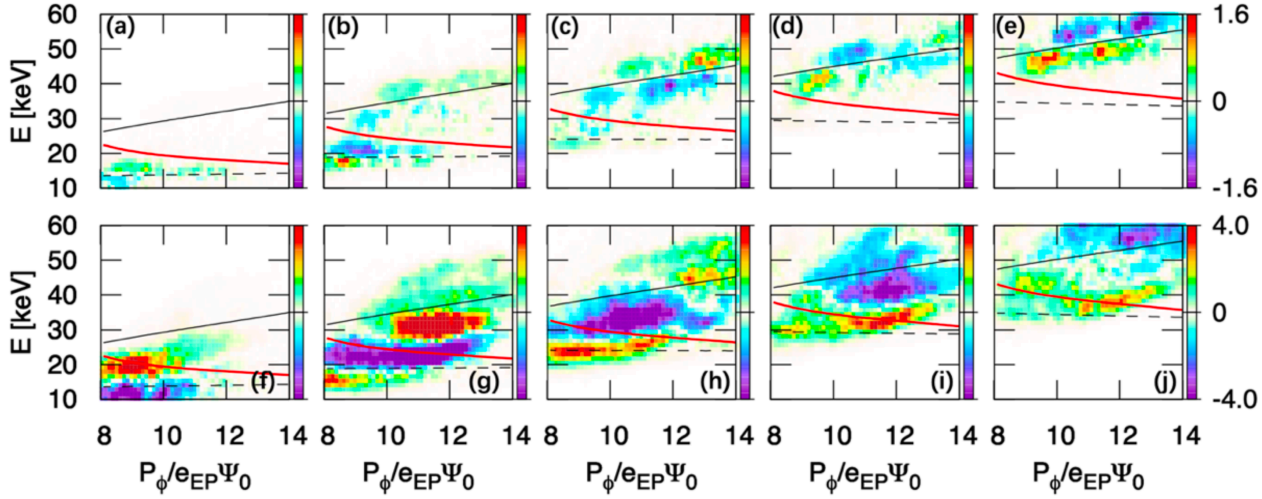

Fig. 2. The δf distribution of EPs in toroidal canonical momentum and energy (P_φ, E) phase space. The top panels are plotted at 0.375 ms when AE is in the linear growth phase, and the bottom panels are plotted at 0.656 ms when EGAM is nonlinearly excited. The μ values of EPs in these 5 columns from left to right are 3 (very low), 6 (low), 9 (medium), 12 (high), and 15 (very high) [arb. unit], respectively. The dashed and solid black curves represent resonance conditions L=0 and 1 for AE, and the red curve represents L=1 for EGAM.