Nonlinear Frequency Chirping of β-induced Alfvén Eigenmode

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Abstract.

The β-induced Alfvén eigenmode (BAE) observed in tokamak experiments can be destabilized by energetic particles and has strong interaction with both thermal ions and energetic particles. In this work, BAE is studied using global gyrokinetic toroidal code GTC. Linear simulations[1] show that nonperturbative contributions by energetic particles and kinetic effects of thermal ions modify BAE mode structure and reduce the frequency relative to the MHD theory. Both passing and trapped energetic particles contribute to BAE excitation through transit and bounce-precessional resonance, respectively. Nonlinear simulations show that the unstable BAE saturates due to nonlinear wave-particle interaction with both thermal and energetic particles. The saturated amplitude exhibits a coherent oscillation with an asymmetric growing and damping phase (Fig. 1a). Wavelet analysis shows that the mode frequency has a strong chirping (Fig. 1b) associated with the oscillation of the mode amplitude. Analysis of nonlinear wave-particle interaction shows that the frequency chirping is induced by the nonlinear evolution of coherent structures in the energetic particle phase space of toroidal angle and precessional frequency (Fig. 1c). Controlled simulations further find that thermal particle nonlinearity plays a key role in controlling the saturation amplitude. Simulations with wave-particle and wave-wave nonlinearity treated will also be reported. This Work is in collaboration with GTC team and supported by DOE SciDAC GSEP Center.

[1] H. S. Zhang et al, *Phys. Plasmas* **17**, 112505 (2010).

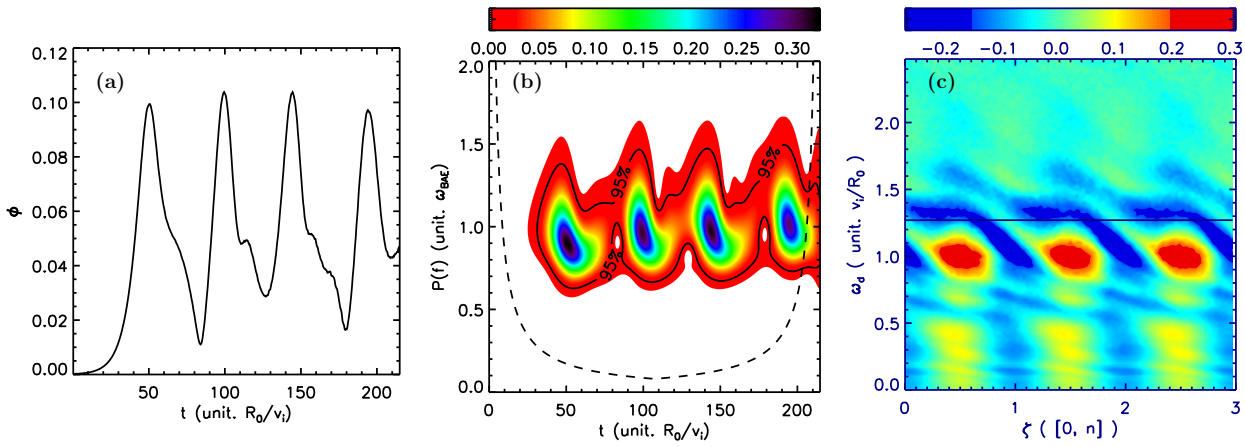

Fig. 1: Nonlinear gyrokinetic simulation of BAE. (a): Time evolution of the BAE amplitude; (b): Wavelet analysis showing frequency chirping; (c): Perturbed distribution function showing wave-particle coherent phase-space structures at $t = 71R_0/v_i$(toroidal precession frequency vs. toroidal angle).