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Gyrokinetic Particle Simulation of Fast-Electron Driven Beta-induced Alfven Eigenmodes

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The fast electron driven beta induced Alfven eigenmode (e-BAE) has been routinely observed in HL-2A tokamak. We study e-BAE for the first time using global gyrokinetic GTC simulation, where the fast electrons are described by the drift kinetic model. Frequency chirping is observed in nonlinear simulations in the absence of sources and sinks, which provide a new nonlinear paradigm beyond the standard "bump-on-tail" model. For weakly driven case, nonlinear frequency is observed to be in phase with particle flux, and nonlinear mode structure is almost the same as linear stage. In the strongly driven case, BAAE is also unstable and co-exists with BAE after the BAE saturation. Analysis of nonlinear wave-particle interactions shows that the frequency chirping is induced by the nonlinear evolution of the coherent structures in the fast electron phase space, where the dynamics of the coherent structure is controlled by the formation and destruction of phrase space islands in the canonical variables. Zonal fields are found to affect wave-particle resonance in the nonlinear BAE simulations though shearing effect to the structure of phase space islands. A verification and validation study is carried out for a sequence of fast-electron driven beta-induced Alfven eigenmode (e-BAE) in HL-2A tokamak plasma.

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