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Long range Alfvenic frequency chirping in tokamaks

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Unstable Alfvén eigenmodes (AEs) can lead to frequency chirping events and enhanced particle transport in magnetic fusion devices. Refs. [1, 2] explain the frequency sweeping events in terms of evolution of coherent structures (holes and clumps), in the energetic particles (EPs) phase-space using a perturbative method. This method implies small deviations of frequency from the initial eigenfrequency of the linear mode, as the spatial structure of the mode is fixed. A nonperturbative adiabatic model was then developed in Ref. [3] to study the long range frequency chirping [4, 5] of a plasma wave whose spatial structure is notably affected by EPs. The model was subsequently extended to describe the effects of EPs collisions [6, 7] and equilibrium drift orbits [8].

In the present work, we use a Lagrangian formalism and finite element method to study the hard nonlinear frequency sweeping of a Global Alfvén eigenmode (GAE). We focus on the evolution of the radial structure of the eigenfunction. The eigenfunction is represented by a single poloidal and toroidal mode number. Toroidal effects are retained on EPs dynamics in a high aspect ratio tokamak limit. The evolution of the frequency is tracked using the balance between the energy extracted from the EPs distribution function and the energy deposited into the bulk plasma. For later evolution, we have found a region where the frequency chirps even faster than the square root dependency in time. Due to MHD properties of this mode, the impact of frequency change on the radial profile is more significant at the earlier stages of chirping.

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