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Nonlinear dynamics of frequency chirping energetic particle driven modes in fusion plasmas

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As emphasized in [1] and references therein, the energetic particle (EP) contribution is non-perturbative for instabilities relevant for EP transport. In addition, field geometry and plasma nonuniformity are crucial, and the self-adjustable mode structures play important roles during the mode evolution. A hybrid gyrokinetic-MHD code is used to study all above issues by performing self-consistent simulations. Nonlinear dynamics, particularly the frequency chirping behaviors, are the focus of the current work. The Hamiltonian mapping method [2] is used to analyze the phase space structures in the nonlinear stage. It will be shown that resonance structure analysis will help predicting frequency chirping behaviors. It is shown that frequency chirping is in general a non-adiabatic procedure. The nonlinear time scale is comparable with wave-particle trapping time. Detailed and comprehensive analysis of particle dynamics will be shown.

References

[1] L. Chen and F. Zonca, Physics of Alfvén waves and energetic particles in burning plasmas, Reviews and Modern Physics 88, 015008-p1-p72, (2016).

[2] S. Briguglio, X. Wang, F. Zonca, G. Vlad, G. Fogaccia, C. Di Troia and V. Fusco, Analysis of the nonlinear behavior of shear-Alfvén modes in Tokamaks based on Hamiltonian mapping techniques, Physics of Plasmas 21, 112301, (2014)

[3] X. Wang, S. Briguglio, Ph. Lauber, V. Fusco and F. Zonca, Structure of wave-particle resonances and Alfvén mode saturation, Physics of Plasmas 23, 012514 (2016)

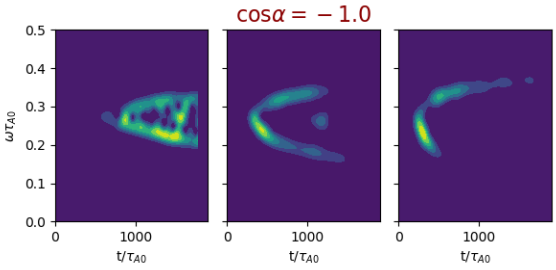

Figure1. (a)

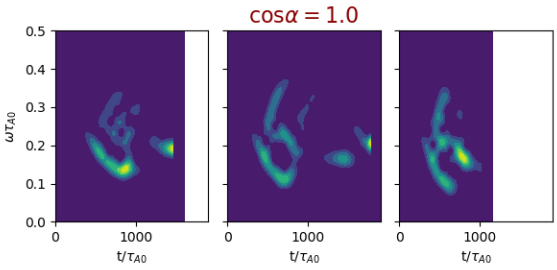

Figure1. (b)

Figure1: (a) are examples of EPM chirping by using anisotropic slowing down EP distribution for deeply counter-passing particles with pitch angel cosα=-1. (b) are examples for deeply co-passing particles with pitch angel cosα=1. From left to right, the density of EP increases.

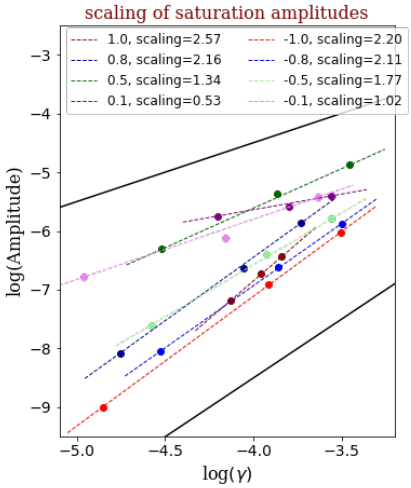

Figure2: mode saturation scaling vs. mode linear growth rates for different pitch angle cases. The saturation mechanism for fixed frequency modes have been studied in [3].