Nonlinear gyrokinetic investigation of energetic-particle-driven geodesic acoustic modes

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Geodesic acoustic modes (GAM) are axisymmetric perturbations of the radial electric field, oscillating in tokamaks with the characteristic acoustic frequency [1]. Their importance is linked to the nonlinear interaction with turbulence, present in tokamak plasmas due to temperature and density gradients. GAMs can also interact with fast ions in tokamaks, taking the name of energetic-particles (EP) driven GAMs (EGAM) [2]. Understanding the nonlinear dynamics of EGAMs is crucial for predicting their relevance in present tokamaks and future reactors.

The nonlinear dynamics of EGAMs is investigated here by means of numerical simulations with the global gyrokinetic particle-in-cell code ORB5 [3,4]. A bump-on-tail distribution function for the energetic particles is considered. Axisymmetric modes only are investigated. In previous works, ORB5 has been successfully verified and benchmarked for the linear dynamics of EGAMs [5,6]. In this work, we extend the previous linear investigation to the nonlinear saturation phase. The nonlinear modification of the frequency and mode structure is described. A special effort is dedicated to understanding the saturation mechanisms. In particular, when wave-particle nonlinearity only is considered, a quadratic scaling of the saturated electric field on the linear growth rate is found, defining a saturation due to wave-particle trapping. Differences with wave-wave nonlinearity (i.e. EGAM self-coupling) are discussed. Comparisons and benchmarks with analytical theory [7] and with other gyrokinetic codes are also shown.

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