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EX/P6-13: Nonlinear features of the Alfvénic wave-particle interaction in auxiliary heated HL-2A plasma

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The physics of Alfvénic gap modes and their interaction with energetic particles is of interest in both magnetic fusion and nonlinear physics. Alfvénic gap modes may eject energetic particles from the plasma and impair reactor performance. Alfvénic modes can also provide a paradigm-testing case for nonlinear wave-particle interaction physics. Phenomena related to wave-particle interaction are identified in the tokamak plasma of the HL-2A, where the beta-induced Alfvén acoustic eigen mode (BAAE) are triggered by energetic ions produced by neutral beam heating while Beta-Induced Alfvén Eigenmode (BAE) is driven by fast electrons. The experimental signatures of the nonlinear regime include frequency splitting, chirping and spectral broadening. These phenomena are found to be consistent with a general nonlinear theory of kinetic instabilities near stability threshold developed by Berk.

In this paper, we report the first experimental identification of the strongly nonlinear regime in the interaction of Alfvénic wave on energetic particles in HL-2A. First, a clear splitting was firstly observed for BAAE. Second, pitch-fork splitting is also observed for BAE. At last, an e-BAE can transform into three branches with a feature of broadband rather than discrete in frequency. The nonlinear BERK-Breizman model is used to interpret the phenomena over a wide parameter range. A Vlasov code is used to solve the BERK-Breizman model numerically with the parameters of HL-2A plasma, taking into account a collision term that represents particle annihilation and injection processes, and an external wave damping accounting for background dissipative mechanisms. To compare theory and experiment simulated signal is constructed, using typical HL-2A values to return from normalized time to real time. The phenomena can now be explained in terms of BERK-Breizman theory in the sideband formation, chirping regime or chaotic regime. The experimental data presented here identify for the first time a fast-ion-driven BAAE activity and a fast-electron-driven BAE instability in the nonlinear regime. The observed features agree with predictions of the Berk-Breizman-Pekker model, including rapid, nonperiodic variation in mode amplitudes. Characterizing the non-linear states of the BAAE, BAE yielded information about the fast particle population and the diffusion induced by NBI or ECRH.

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