3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Nonlinear Dynamics of Toroidal Alfvén Eigenmodes in HL-2A NBI Plasmas

W. Chen[1], L. M. Yu[1], P. W. Shi[1], Y. M. Hou[1], Z. Y. Qiu[2], X. T. Ding[1] and HL-2A team
[1] Southwestern Institute of Physics, P.O. Box 432 Chengdu 610041, China
[2] Institute for Fusion Theory and Simulation, ZJU, Hangzhou 310027, China
e-mail:chenw@swip.ac.cn

The nonlinear dynamics of shear Alfvénic wave fluctuations have become a major concern in magnetically confined fusion, since they can be driven unstable by energetic particles (EPs). There are two routes for the Alfvénic fluctuation nonlinear dynamic evolution, with one corresponding to wave-particle phase space nonlinear dynamics dominated by resonant particles, while the other, dubbed as nonlinear wave-wave interactions, describing nonlinear spectrum evolution due to the nonlinear couplings among modes. The former route can be described by the bump-on-tail paradigm or fishbone paradigm. The latter route may take place via Compton scattering of the bulk ions and MHD nonlinearities effects as well as zonal structure generation. Those theoretical predictions had been shown to be relevant in realistic fusion plasmas. On experiments, many nonlinear dynamics phenomena of shear Alfvénic wave fluctuations occur and are identified in laboratory and space plasmas.

In this talk, the nonlinear dynamics of Toroidal Alfvén Eigenmodes (TAEs), including nonlinear wave-particle and wave-wave interactions, have been observed in the HL-2A NBI plasmas. Frequency chirping properties of TAEs have been analyzed with a method based on the so-called Berk–Breizman (BB) model, which predicts that the interaction between wave, energetic ions and collision effects may exhibit steady-state, periodic, chaotic and explosive regimes. Nonlinear wave-particle interaction behavior with observed chirping structures belongs to the chaotic regime. Those four typical unstable regimes are reproduced by a simulation code with two collision models: pure diffusion and pure Krook operator. Further, it is found that there are strong nonlinear mode couplings between TAEs with n=3 and low frequency MHD mode (kink or fishbone) with n=1. The pitch-fork phenomena of TAEs can grow explosively and become an explosive instability. The explosive events have two kind fine structures, i.e., multi-modes and pitch-fork. The two kind structures can coexist, but the strong nonlinear mode coupling induces that the pitch-fork weakens or vanishes and the modes blow-up in finite-time, and this indicates that the nonlinear mode coupling may redistribute energetic-ions, destroy hole-clump pairs in the phase-space, and induce three-wave mixing nonlinearly.