MF-I2

Nonlinear processes and saturated spectrum of Alfvén eigenmodes in tokamak plasmas

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Shear Alfvén waves (SAW), manifested as various kinds of Alfvén eigenmodes (AEs) in toroidally confined plasmas, are expected to play important roles in future tokamaks such as ITER [1]. SAWs could be excited by energetic particles (EPs) via resonant wave-particle interactions; and, in turn, induce EP transport and degrade overall plasma confinement. Nonlinear processes due to SAW and their resonant interactions with EPs also have broader implications for space plasmas and nonlinear dynamics [1].

In this work, we take toroidal AE (TAE) [2] as an example, and illustrate various nonlinear processes and the resultant saturated spectrum, by which the level of transport can then be determined. Employing the nonlinear gyrokinetic framework, the theory of nonlinear interplay of TAE, zonal structures (ZS) and spectral transfer via cascading is presented. Specifically, the theory includes 1) excitation of low frequency ZS (LFZS) by TAE [3] and, 2) nonlinear scattering of TAE by ion quasi-mode to stable TAE spectrum [4]. We found that, due to the typically radially localized TAE mode structures, the associated nonlinear processes also exhibit both the well-known and often studied meso-scale structures as well as fine-scale radial structures; resulting in qualitative and quantitative modifications in the nonlinear processes of AEs [5]. Further theoretical considerations and practical implications of these findings will also be discussed.

References

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