Gyrokinetic theory of toroidal Alfvén eigenmode nonlinear saturation via ion Compton scattering

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Shear Alfvén wave instabilities such as toroidal Alfvén eigenmode (TAE) [1] are expected to play important roles in magnetic confinement fusion devices as energetic particles (EPs) contribute significantly to the total power density [2, 3]. TAE can be driven unstable by EPs, and in turn, induce EP transport and degrade overall plasma confinement.

In this work, the TAE frequency cascading via ion Compton scattering and saturation due to enhanced coupling to SAW continuum, originally investigated in Ref. [4] in the long wavelength MHD limit, is extended to the burning plasma relevant short wavelength regime [3]. The equation describing a test TAE nonlinear evolution due to interacting with the bath of background TAEs is derived using gyrokinetic theory, which is then applied to deriving the wave-kinetic equation for the TAE spectrum evolution in the continuum limit. The wave-kinetic equation is solved to obtain the saturation spectrum of TAE, yielding an overall fluctuation level lower than the estimation by drift kinetic theory [4], as a consequence of the enhanced nonlinear couplings in the short wavelength limit [5]. The bulk ion heating rate from nonlinear ion Landau damping is also calculated. Our theory also shows that, for TAE saturation in the parameter range of practical interest, several processes with comparable scattering cross sections can be equally important.

References

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