Regulation of Alfven eigenmodes by microturbulence in fusion plasmas

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Recent theoretical and experimental studies have suggested possible effects of microturbulence on Alfven eigenmode (AE) saturation and energetic particle (EP) transport in the fusion plasmas. Zonal flows can be nonlinearly generated by, and in turn, suppress both the AE and microturbulence. EP Scattering by the microturbulence can affect phase space dynamics in the nonlinear AE-EP interaction. Unstable AE can also be scattered to shorter wavelength damped modes due to modulation by the microturbulence.

In the current work, the cross-scale coupling between AE and microturbulence is studied in state-of-the-art integrated simulations using the global gyrokinetic toroidal code (GTC) with comprehensive physics and kinetic treatment of all particle species. GTC simulations of the DIII-D tokamak experiment find that reversed shear Alfven eigenmodes (RSAE) excited by energetic ions from the neutral beam injection can saturate by self-generated zonal flows. However, the saturated amplitude and EP transport level are an order of magnitude higher than the experimental observations when the background microturbulence is artificially suppressed in the simulations of meso-scale modes only. In contrast, in the simulations coupling micro-meso scales, the saturated RSAE amplitude and EP transport are greatly reduced to the experimental level due to zonal flow shearing and EP scattering by the microturbulence driven by thermal ion temperature gradient (ITG) instabilities. The resulting RSAE mode structure and microturbulence intensity agree very well with experimental measurements using electron cyclotron emission (ECE) and beam emission spectroscopy (BES), as shown in Fig.1.

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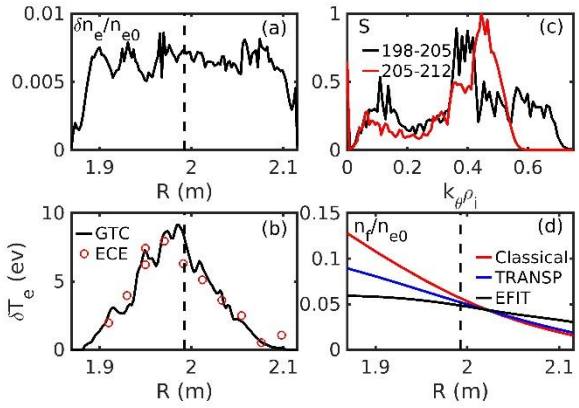

Fig. 1. Comparisons of GTC simulation of coupled RSAE-ITG turbulence with experimental measurement in DIII-D shot # 159243 for radial profiles of perturbed electron temperature δn_e (panel a), perturbed electron density δT_e (panel b), and spectrum of δn_e (panel c) in two radius regions after RSAE saturation (at t=0.24ms). Panel (d) shows radial profiles of beam ion density calculated from classical model, TRANSP, and kinetic EFIT, respectively. Dash line is the q_{min} location.