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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 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 much higher than experimental levels at nonlinear saturation, but quickly diminish to very low levels after the saturation when background microturbulence is artificially suppressed. In contrast, in simulations coupling micro-meso scales, the RSAE amplitude and EP transport decrease drastically at the saturation but increases to the experimental levels after the saturation due to regulation by thermal ion temperature gradient (ITG) microturbulence. In the quasi-steady state ITG-RSAE turbulence, the resulting RSAE amplitude agrees very well with experimental measurements using electron cyclotron emission (ECE), and the microturbulence density fluctuation amplitude of 0.5-0.8% has the right order of the integrated low-k density fluctuation amplitude of 0.3-0.4% from beam emission spectroscopy (BES) measurement.

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