Gyrokinetic simulation of energetic particle turbulence and transport

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In a burning plasma such as ITER, the shear Alfven wave (SAW) instability excited by fusion products (energetic α-particle) can be dangerous to energetic particle confinement. The SAW instability, e.g., toroidal Alfven eigenmode (TAE) and energetic particle mode (EPM), has thresholds that are imposed by damping from both thermal ions and trapped electrons. In particular, there is significant damping via local/global resonant mode conversion due to kinetic effects of thermal ions to kinetic Alfven waves with radial wavelengths comparable to the thermal ion gyroradius ρ_i (*micro* scale) and finite parallel electric field. Effects of collective SAW instabilities on the energetic particle confinement depend ultimately on the self-consistent nonlinear evolution of the SAW turbulence, which depends critically on the complex nonlinear phase space dynamics of energetic particles as well as on the complex nonlinear mode-mode couplings among the multiple SAW modes that are expected in ITER-scale plasmas. Both nonlinear effects, in turn, depend sensitively on the global features of wave-particle resonances and mode structures. More challenging still are the physics of couplings between energetic particle-induced SAW turbulence and microscopic drift-Alfven wave turbulence driven by thermal particles.

The fully self-consistent simulation of energetic particle turbulence and transport must therefore incorporate three new physics elements: kinetic effects of thermal particles, nonlinear interactions of a large number of *meso*-scale SAW modes, and cross-scale couplings of *meso-micro* turbulence. The large dynamical ranges of spatial-temporal processes further require global simulation codes that are efficient in utilizing massively parallel computers at the petascale level and beyond. Therefore, the studies of energetic particle physics in ITER burning plasmas call for a paradigm shift to the gyrokinetic turbulence approach. In this talk, the rationale and the progress of the gyrokinetic simulation of energetic particle turbulence and transport will be summarized.

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