DPP08-2008-001589

Abstract for an Invited Paper
for the DPP08 Meeting of
the American Physical Society

Role of Zonal Flows in Trapped Electron Mode Turbulence through Nonlinear Gyrokinetic Particle and Continuum Simulation[1]

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Trapped electron mode (TEM) turbulence exhibits rich zonal flow dynamics, which depends strongly on plasma parameters. The role zonal flows in TEM turbulence is explored through a series of linear and nonlinear gyrokinetic simulations using both PIC (the GEM code) and continuum (the GS2 code) methods. A new nonlinear upshift [1, 2] in the TEM critical density gradient (associated with zonal flow dominated states near threshold) increases strongly with collisionality, for density gradient driven cases. In contrast, zonal flows have little effect on TEM turbulence with strong electron temperature gradients and $T_e = 3T_i$ [3]. This apparent contradiction has been resolved in parameteric studies showing that zonal flows are weaker as the electron temperature gradient and T_e/T_i increase [4]. The parametric variation of zonal flows is consistent with linear stability properties and nonlinear instability theory. A new stability diagram based on 2,000 GS2 simulations clarifies the roles of resonant and non-resonant TEM, "ubiquitous," and electron temperature gradient (ETG) driven modes. Larger electron temperature gradients couple TEM and ETG modes, resulting in short wavelengths $k_\alpha \rho_s > 1$. Accordingly, a sudden onset of nonlinear fine scale structure is seen for $\eta_e \equiv d \ln T_e / d \ln n_e \gtrsim 1$. For short wavelengths, the ions are more adiabatic, the zonal flow potential $\langle \phi \rangle \sim \langle n \rangle / k_r^2 \rho_s^2$ is weaker, and secondary instability growth rates [5] are reduced.

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[1]Supported by U.S. Dept. of Energy Grant DE-FG02-91ER54109 and Coop. Agreement DE-FC02-08ER54966.
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