Gyrokinetic Simulations of Trapped Electron Mode Turbulence in Alcator C-Mod Internal Particle Transport Barriers

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Mechanisms for internal transport barrier formation and control in Alcator C-Mod are elucidated via nonlinear gyrokinetic simulations of trapped electron mode (TEM) turbulence[1] using the GS2 code.[2] Internal particle transport barriers form in Alcator C-Mod experiments with off-axis RF heating applied near the half-radius, following the transition to EDA H-Mode.[3] During ITB formation, the density profile peaks, keeping the temperature profile unchanged. The density peaking and concomitant impurity accumulation are controlled by injecting low levels of on-axis RF power.[4] We show this is consistent with the temperature dependence arising from gyoBohm scaling of the turbulent transport, with collisionality playing a second order, but additive role.

The critical density gradient for onset of TEM turbulent transport is nonlinearly up-shifted, as shown in Fig. 1. This new nonlinear upshift is analagous to the Dimits shift of the critical ion temperature gradient for toroidal ion temperature gradient driven turbulence,[5] associated with zonal flow generation. The turbulent particle diffusivity from GS2 gyrokinetic simulations matches the particle diffusivity from transport analysis, within experimental error bars, after accounting for the Ware pinch. Further, the TEM turbulent particle flux and the Ware pinch are in balance in the ITB. The simulated one-fluid thermal diffusivity matches the TRANSP experimental value. With no core particle source and high-resolution density diagnostics, the C-Mod experiments provide a nearly ideal test bed for particle transport studies. The electron continuity equation simply expresses the balance between the neoclassical (Ware) and turbulent fluxes, $\partial n_e/\partial t + \nabla\cdot(n_e V_{\mathrm{Ware}} - D_{\mathrm{eff}}\nabla n_e) = 0$, where $\Gamma_{\mathrm{Ware}} = n_e V_{\mathrm{Ware}}$ is the Ware flux.

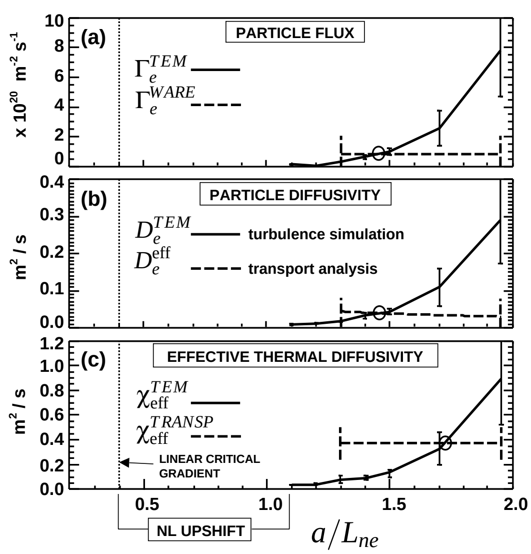

Figure 1: In the ITB at $\rho = 0.4$, 1.20 sec. (a) Simulated particle flux balances Ware pinch within error bars (representing uncertainty in the Z_{eff} gradient) (b) Simulated turbulent diffusivity matches transport analysis within error bars. (c) Simulated effective one-fluid thermal diffusivity matches TRANSP. Nonlinear critical density gradient is upshifted relative to linear threshold.[1]

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