Local Transport Analysis
for the Alcator C-Mod Tokamak

by

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Abstract

Two complementary approaches were used to characterize transport on the Alcator C-Mod tokamak. The first was an empirical analysis of the scaling of transport with $\rho^*$, the ion Larmor radius normalized to the plasma size. The second was a comparison of the transport predictions from the IFS-PPPL model of ion temperature gradient (ITG) driven turbulence to observations on C-Mod.

The $\rho^*$ scaling experiments on C-Mod extend the range of plasma parameters over which the dimensionless scaling approach has been tested in both magnetic field (to 8 T) and density (to $n_e = 3.8 \times 10^{20}$/m$^3$). In L-Mode, scaling of the global confinement time $\tau_E$ showed a Bohm-like dependence on $\rho^*$ ($B\tau_E \propto \rho^*^{-2}$) as did the scaling of the local one-fluid effective diffusivity ($\chi_{\text{eff}} \propto \chi_B \rho^*^0$), though mismatched radiated power profiles prevent a definitive statement. H-Mode plasmas showed a gyroBohm scaling both globally ($B\tau_E \propto \rho^*^{-3}$) and locally ($\chi_{\text{eff}} \propto \chi_B \rho^*^1$). Determining the scaling of the individual electron and ion channels was not possible due to the large uncertainty in the electron-ion coupling associated with the high density.

The IFS-PPPL model is a comprehensive first-principles description of ITG turbulence driven transport. Its numeric solution of the linear gyrokinetic equation indicates that the ITG mode is the predominant instability in the plasma core. Nonlinear numerical treatments of the gyrofluid behavior of ITG modes provide parametric models for $\chi_i$ and $\chi_e$ useful for experimental comparison. Transport from the ITG turbulence is described by a marginal stability model; C-Mod plasmas are predicted to be close to the threshold, so they provide a rigorous test bed for the theory.

Comparisons of the model's predictions for $T_i$ and $T_e$ were conducted on C-Mod for both L- and H-Mode plasmas. In L-Mode the $T_i$ predictions were systematically low, with an RMS difference of $\Delta_{\text{RMS}} = 25 - 30\%$ measured over the range ($\frac{3}{4}, \frac{3}{4}$). Predictions of $T_i$ in H-Mode were more accurate, giving an RMS difference of $\Delta_{\text{RMS}} = 5 - 20\%$ over the same range, well within the estimated uncertainty. Predictions of $T_e$ did not show a systematic difference between L- and H-Mode. For some shots the was accurate ($\Delta_{\text{RMS}} < 10\%$) while for others it was very inaccurate ($\Delta_{\text{RMS}} > 50\%$). In all cases, the model predicted marginally stable $T_i$ profiles, with $1.0 \leq \langle L_T,\text{crit}/L_T \rangle \leq 1.2$.

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