Paleoclassical Model For Electron Temperature Pedestal*

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At the recent IAEA Chengdu meeting, the paleoclassical model [1] of radial electron heat transport was compared favorably [2] with mostly ohmic-level experimental results from a number of toroidal plasma experiments. Anomalous transport induced by drift-wave-type microturbulence usually scales with the gyroBohm diffusivity $D^{\rm gB} \equiv (\varrho_S/\bar{a})(T_e/eB) \propto T_e^{3/2}/\bar{a}B^2$; it becomes small in the edge when T_e is low and $\mathbf{E}\times\mathbf{B}$ flow shear is large. In contrast, for the recently hypothesized paleoclassical transport model [1] the electron heat diffusivity $\chi_e^{\rm pc} \propto \bar{a}^{1/2}T_e^{-3/2}$ increases as the electron temperature decreases toward the plasma edge and divertor separatrix. Thus, we can anticipate [2,3] that for $T_e \lesssim T_e^{\rm crit} \simeq B({\rm T})^{2/3}\bar{a}({\rm m})^{1/2}$ keV ($\sim$ 1–1.6 keV in present plasmas, but $\sim$ 3.5–5 keV in ITER) paleoclassical radial electron heat transport could be dominant. In particular, it could be dominant in the pedestal of H-mode plasmas.

A model has been developed [3] for the edge electron temperature profile $T_e(\rho)$ in H-mode, diverted tokamak plasmas based on the paleoclassical model for the radial electron heat transport. Moving inward from the separatrix, T_e profile predictions are: first an increasing T_e gradient with $\eta_e \equiv d\ln T_e/d\ln n_e \simeq 2$, a maximum $|\boldsymbol{\nabla} T_e|$ where q drops to $\lesssim 5$, then a decreasing $|\boldsymbol{\nabla} T_e|$, and finally a pedestal electron pressure determined by balancing collisional paleoclassical transport against gyro-Bohm-scaled anomalous electron heat transport: $\beta_e^{\rm ped} \equiv n_e^{\rm ped}T_e^{\rm ped}/(B^2/2\mu_0) \simeq (0.032/f_\# A_i^{1/2})(\bar{a}/\bar{R}q)(\eta_\parallel^{\rm nc}/\eta_0) \propto (\bar{a}/\bar{R}q_{95})$, in which $f_\# \sim 1$ is a gyroBohm multiplier for T_e transport. These model predictions compare favorably [3] with experimental data from DIII-D. In addition, the paleoclassical radial electron heat diffusivity $\chi_e^{\rm pc}$ compares well [3,4] with the transport analysis χ_e, which both scale roughly as $T_e^{-3/2}$ near the separatrix. Also, the ASTRA code [5] has been used to perform a predictive transport analysis of the edge T_e profile; it shows that $\chi_e^{\rm pc}$ dominates for $\rho \gtrsim$ 0.85–0.9 and is needed to obtain the neutral or slightly positive curvature of the T_e profile (i.e., $d^2T_e/d\rho^2 \geq 0$) near the separatrix.

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