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Gyrokinetic Analysis and Simulations of Pedestals

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Major progress has been made in understanding the pedestal transport in several areas. 1) For the first time, the instabilities that dominate energy transport in present experimental pedestals are determined, using identifying ratios of the transport they produce in different channels - their "transport fingerprint". These are derived from the drift kinetic equation for pedestal parameters, and corroborated by gyrokinetic simulations using GENE[1]. For the typical case where the electron density sources are relatively small compared to the energy sources, MHD-like modes (such as KBM) cannot dominate pedestal energy transport. The analysis is applied to experimental observations from multiple devices, and also, in detail to two DIII-D pedestals, considering transport in multiple channels, measured fluctuations and pedestal equilibrium reconstructions. Microtearing modes (MTM) and Electron Temperature Gradient (ETG) modes dominate energy transport, rather than KBM. Multiple disparate experimental observations can be explained and unified using this analysis, including, surprisingly, density transport from applied Resonant Magnetic Perturbations (RMP). 2) Gyrokinetic simulations of velocity shear suppression of ITG for pedestal equilibria, using GENE[1], find excellent agreement, in detail, with the decorrelation theory of Zhang and Mahajan[2]. This physics-based theory can thus be exploited to estimate/predict turbulent transport in new regimes. In a controlled ρ^* scan (velocity shear ~ ρ^*), the suppressed heat flux from ITG modes scales much more poorly than gyro-Bohm, so that it may become relatively large at the low ρ^* of burning plasmas, unlike present experiments. 3) Hence, a detailed examination of the properties of ITG/TEM modes in pedestals and ITBs with high β_{pol} has been undertaken. Unlike core modes, pedestal electrostatic modes are slab-like: destabilization results from parallel resonances, not curvature. Consequently, the density gradients are stabilizing in pedestals, and so is high β_{pol}, impurities and impurity gradients. Routes to optimize confinement in fusion relevant tokamaks, for both for inductive and steady state operations, are discussed.

[1]Jenko F., Dorland W., Kotschenreuther M., et. al., Phys. Plasmas 7 (2000) 1904
[2]Y. Z. Zhang and S. M. Mahajan, Physics of Fluids B, 5, (1993) 2000

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