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Kinetic Neoclassical Transport in the H-mode Pedestal[1]

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This paper presents the first quantitative comparison between the multi-species transport rates in H-mode pedestals on DIII-D and NSTX and the kinetic neoclassical transport calculated using XGC0, a full-f particle-in-cell drift-kinetic solver with self-consistent neutral recycling and sheath potentials. The best quantitative agreement between the simulation and measurement of the pedestal density, temperature and flow profiles during the ELM-free period following the L-H transition is achieved when assuming ion transport is reduced to the kinetic neoclassical level within the steep-gradient region while additional turbulent transport ($D \sim 0.5\,\mathrm{m}^2/\mathrm{s}$) exists in regions of low $E_r \times B$ shear such as the pedestal top and in the scrape-off layer (SOL). The non-Maxwellian ion distributions from kinetic effects lead to a co-I_p intrinsic torque that matches the measurements in the pedestal on DIII-D. The kinetic neoclassical mean $E_r \times B$ shear is strongly dependent on the plasma boundary shape, and the predicted dependence of L-H transition conditions versus X-point radius is consistent with experiments on NSTX. In QH-modes on DIII-D, T_i is larger than in the early ELM-free H-modes, and the drift-kinetic effects that are absent in fluid models become more pronounced. The ion distributions are calculated to be non-Maxwellian through the entire pedestal, driving T_i anisotropy, poloidal asymmetries and intrinsic flows. For example, $T_i^{\perp} > T_i^{||}$ in the pedestal, consistent with the orthogonal measurements of T_i^{C6+}. Also, the observation that $T_i^{C6+} \geq T_{i,ped}$ in the far-SOL is reproduced in the simulations and attributed to long-lived collisionless ion orbits at low SOL densities. These studies indicate that kinetic neoclassical transport will play an important role in the L-H transition, H-mode transport and interpretation of measurements in the high-T_i pedestals expected in ITER.

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