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Transport-driven toroidal rotation in the tokamak edge[1]

T. STOLTZFUS-DUECK, IPP Garching

The edge of H-mode tokamak plasmas without external momentum input almost always rotates toroidally in the co-current direction, which has prompted a theoretical search for non-diffusive momentum transport mechanisms. In contrast to these efforts, the present work treats a model drift-kinetic ion equation for the pedestal and SOL containing only parallel free streaming, magnetic drifts, and spatially inhomogeneous but purely diffusive transport. The solution demonstrates that passing-ion orbits and spatially inhomogeneous diffusion interact to cause a variation of the orbit-averaged diffusivities that depends on the sign of $v_\parallel$, typically resulting in preferential transport of counter-current ions. If the plasma at the boundary with the core is allowed to rotate toroidally to annihilate toroidal momentum transport, the resulting pedestal-top rotation reaches experimentally relevant values and exhibits several features in qualitative agreement with experiment. It is almost always in the co-current direction, with a rate that is proportional to $T_i|_{\mathrm{ped-top}}/B_{\mathrm{pol}}L_{Te}$ for small $q\rho_i/L_{Te}$, thus inversely proportional to I_p in accord with Rice scaling. It is independent of the toroidal velocity and its radial gradient, representing a residual stress. The $T_i|_{\mathrm{ped-top}}/B_{\mathrm{pol}}L_{Te}$ scaling implies co-current spin-up at the transition to H-mode, as T_i increases and the gradient of T_e steepens. Untested predictions of the model include a sensitivity of the rotation to the major-radial position of the X-point, with a more inboard X-point leading to stronger co-current rotation. Beyond intrinsic rotation predictions, comparison of heat and momentum transport reveals that neutral beam injection must be significantly unbalanced in the counter-current direction to cause zero toroidal rotation at the pedestal top.

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