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Self-Collision Driving Ion Flux and Radial Electric Field

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In the presence of steep density gradients, self-collisions may drive a considerable ion flux. On the other hand, electron transport is much less affected by this finite orbit effect. This leads to imbalance in particle transport. A radial electric field then develops to maintain ambipolar neoclassical transport. To understand the basic features of this problem, the ion drift kinetic equation with time derivative retained is solved, assuming poloidal Larmor radius $\rho_{i\theta}$ to be small compared with density gradient length L_n, but keeping high order corrections. Self-collision driven ion flux of 4th order in $\rho_{i\theta} / L_n$ is calculated. An equation which governs the time evolution of the radial electric field is derived from Ampère's law, giving rise to variation in the time scale $\tau_{ii}(\rho_{i\theta} / L_n)^2$, where τ_{ii} is ion collision time. On the other hand, density change is negligible because it happens in a much longer time scale. An equilibrium state with zero ion flux is established when the potential ϕ satisfies $e\phi(r) / T_i = -\ln n_i(r) / n_i(a)$. This represents a neoclassical transport barrier in the form of potential well in the region of large density gradient. A low noise δf code, incorporating the self-consistent evolution of background and radial electric field, is under development to simulate this transport barrier in toroidal plasma with steep gradients. The study provides new insight into the physics of radial electric field and plasma confinement.

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