A reduced drift magnetic island theory of neoclassical tearing modes for low collisionality tokamak plasmas

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Successful operation of next generation fusion devices, such as ITER, directly depends on understanding the physics of the NTM onset and its control techniques. This, in turn, requires a more quantitative theory of the NTM threshold physics.

In our new theoretical approach, we solve the drift kinetic equation for both the ion and the electron plasma components, employing an expansion in the small ratio of island width w to tokamak minor radius to obtain orbit-averaged equations. From these we derive the streamlines, S, along which the distribution function is constant, if collisions are neglected. This S function describes drift islands of the same geometry as the real magnetic islands but shifted radially by a value comparable to the poloidal Larmor radius ρ_ϑ in the absence of the electrostatic potential. The radial shift of the islands is in opposite directions for the two streams $V_\| > 0$ and $V_\| < 0$. Adding a low level of collisions provides the S dependence of the distribution function, showing it is flattened inside the S islands (not the magnetic islands, Fig. 1) due to a competition between the ion parallel flow and plasma drifts. Hence, the density and temperature profile flattening becomes incomplete for magnetic islands comparable to the ion banana orbit width, reducing the bootstrap current drive and hence suppressing the drive for NTMs with widths $w \sim \rho_\vartheta$. These results provide a new understanding of how finite ion orbit width effects influence the NTM threshold.

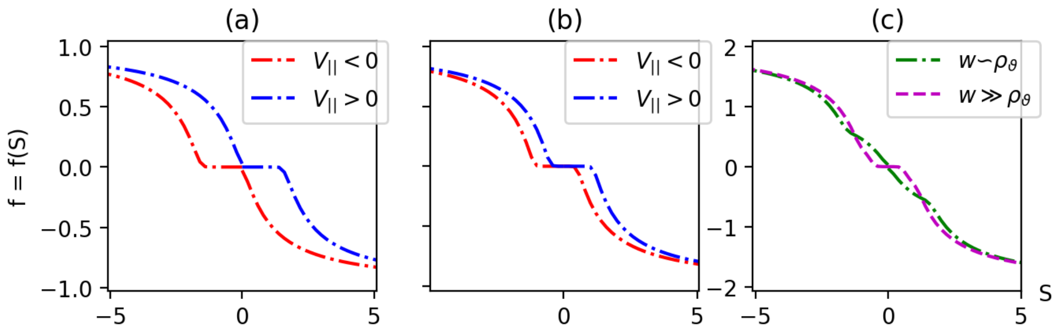

Fig. 1. The distribution function flattening across the O-points of the $S = constant$ drift islands (the magnetic island is centred at $S = 0$): (a) $w \sim \rho_\vartheta$ and (b) $w \gg \rho_\vartheta$ for the two streams $V_\| > 0$ and $V_\| < 0$. (c) The sum over the two streams, representative of density, showing almost complete flattening across the magnetic island at $S = 0$ for $w \gg \rho_\vartheta$, but a substantial gradient for $w \sim \rho_\vartheta$.