Low-q resonances, transport barriers, and secondary electrostatic convective cells

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Recent experimental observations have illuminated key characteristics of internal transport barrier (ITB) formation near low-q resonant surfaces in off-axis minimum-q (OAMq) discharges. These observations[1] indicate a local flattening of the mean temperature profile in the vicinity of a low-q surface in the absence of observable magnetic field perturbations. This necessitates a description of ITB formation which accounts for strong transport in the immediate vicinity of the low-q surface, as well as the formation of an ITB nearby the surface, without perturbing the magnetic field topology. Here, we present a kinetic theory of a low-m electrostatic convective cell driven by modulational instability of the background drift wave turbulence in the context of ITB formation near low-q resonances. Unlike pure $m = n = 0$ zonal flows, convective cells are capable of intense mixing near low-q resonant surfaces, thus relaxing mean profiles near the $\mathbf{k} \cdot \mathbf{B} = 0$ resonance, while simultaneously inducing steepening in the adjacent regions. Field line bending coupled with collisional viscosity are found to strongly damp the intensity of the vortical flows except in the case of weak magnetic shear. In that case however, the saturated intensity of the vortical flow asymptotes to a value similar to that found in previous studies of the drift wave-zonal flow system, thus explaining why the occurrence of these cells is limited to plasmas with weak or reversed shear. This suggests that, in addition to zonal flows, low-m convective cells can play a strong role in the regulation of turbulent transport near low-q resonances for OAMq discharges. The excitation threshold for the convective cell, as well as the scaling for the width of the cell, are derived. Using a simplified version of our model, the scaling of the critical power for ITB transition with magnetic shear and collisional flow damping have been determined.

[1] M. E. Austin, *et al.*, Phys. Plasmas 13, 082502 (2006)