Self-organised momentum transport in the tokamak core

B.F.McMillan
CFSA, Physics Department, University of Warwick, UK

The spontaneous rotation of the tokamak core in the absence of core momentum sources, as seen injection in various experiments, presents a challenge to the simple picture of the tokamak as an essentially diffusive system. Maintaining momentum gradients in this situation requires off-diagonal transport to drive momentum fluxes and balance momentum profile relaxation.

It can be shown via symmetry arguments that in the large-system limit, up-down symmetric tokamaks without large-scale flows are expected to possess zero momentum flux in the ensemble average sense. Various studies have therefore focussed on finite system size-related fluxes, rotation driven momentum fluxes, and up-down asymmetry effects.

A neglected possibility which we have explored recently is that spontaneous symmetry breaking can take place: we have previously shown that tight aspect-ratio systems are able to generate strong momentum gradients from initially small flow states without any external symmetry breaking.

The most direct way to determine how these effects interact with each other and whether they give rise to realistic profiles of toroidal rotation is to directly simulate the full tokamak core.

We present simulations of moderate-sized tokamaks with varying aspect ratio, on the momentum transport timescale, allowing the rotation levels to come to steady state. The simulation code used, ORB5, has recently been extended to handle strong flows. We demonstrate using these simulations that this code is able to consistently evolve global profiles in response to turbulent momentum fluxes.

We show that finite-system size effects are able to drive substantial rotation gradients in these moderate-sized tokamaks, which act as a stabilising mechanism in addition to neoclassical poloidal flows. The tight aspect ratio cases also show strong rotation gradients, but this is shown to be a separate effect due to spontanteous symmetry breaking; simulations at smaller $\rho*$ are performed and maintain similar flow gradients with near-zero momentum flux.