Gyrokinetic prediction of momentum transport in spherical tokamaks

W. Guttenfelder[1], S.M. Kaye[1], Y. Ren[1], W. Solomon[1], R.E. Bell[1], J. Candy[2], S.P. Gerhardt[1], B.P. LeBlanc[1], H. Yuh[3]
(email: wgutten@pppl.gov)

[1] Princeton Plasma Physics Laboratory, Princeton NJ 08543
[2] General Atomics, San Diego, CA 92186
[3] Nova Photonics Inc., Princeton, NJ 08540

Understanding the mechanisms that determine the tokamak rotation profile, important for macroscopic stability and confinement, will help develop predictions for future devices such as ITER or a Fusion Nuclear Science Facility (FNSF). Previous perturbative H-mode experiments in NSTX demonstrated the existence of an inward momentum pinch, with pinch numbers RV_φ/χ_φ=(-1)-(-7) and Prandtl numbers $Pr=\chi_\varphi/\chi_i$=0.3-0.6. Local, linear gyrokinetic simulations run for these H-modes find the microtearing (MT) mode as the dominant instability. While MT is not expected to contribute to momentum transport, there is also evidence of unstable kinetic ballooning modes (KBM) at lower $k_\theta\rho_s$. The predicted quasilinear KBM Prandtl numbers (Pr~0.3-0.6) are similar to experimental values, but would be smaller if neoclassical transport was included ($\chi_{tot}\approx\chi_{i,nc}>\chi_{i,turb}$ from TRANSP analysis). Furthermore, the predicted Coriolis pinch number is small and directed outward ($RV_\varphi/\chi_\varphi\geq0$), in contradiction to the measurements, and is relatively insensitive to variations in normalized temperature or density gradients, beta or collisionality. Similar predictions have been done for an NSTX L-mode plasma. Because of much lower beta, ITG/TEM modes are unstable. However, the pinch remains relatively weak, RV_φ/χ_φ~(-1)-(-2), compared to the H-mode observations, and is also relatively insensitive to parameter variations. Nonlinear simulations have been run for the low beta L-mode case to investigate nonlinear and E×B shearing effects on the momentum transport. When ignoring the parallel velocity gradient in the gyrokinetic equation ($u'\sim dv_\parallel/dr\rightarrow0$, i.e. purely perpendicular E×B flow), a strong inward directed momentum flux is predicted, suggesting it could significantly modify the quasilinear results and interpretation presented above. However, if one assumes the flow is purely toroidal (parallel and perpendicular E×B flows are locked together, a good assumption in the NSTX core), the momentum flux increases (outward) up to the experimental value of γ_E. Repeating the toroidal shear scan including the finite toroidal flow reduces the transport, consistent with the quasilinear prediction of a weak inward pinch (RV_φ/χ_φ=-1). As quasi-linear, nonlinear, and finite E×B shear effects appear unlikely to explain the strong observed momentum pinch, global simulations are being run to investigate the effect of profile shear at finite ρ_*. This work is supported by US DOE contract DE-AC02-09CH11466.