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Gyrokinetic Turbulence Driven Toroidal Momentum Transport and Comparison to Experimental Observations[1]

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Global gyrokinetic simulations using the GTS code [1] have found that a large inward flux of toroidal momentum is driven robustly in the post saturation phase of ion temperature gradient (ITG) turbulence. As a consequence, core plasma rotation spins up resulting in $\Delta u_{\|}$ a few percent of v_{th} in the case with no momentum source at the edge. The underlying physics for the inward flux is identified to be the generation of residual stress due to the $k_{\|}$ symmetry breaking [2] induced by self-generated zonal flow shear which is quasi-stationary in global simulations. The elatively low level momentum flux in the long- time steady state appears to be approximately diffusive, with effective χ_ϕ/χ_i on the order of unity, in broad agreement with experimental observations and theory predictions for ITG turbulence [3]. Neoclassical simulations using the GTC- NEO code [4] also show that the ion temperature gradient can drive a significant inward nondiffusive momentum flux. However, the overall neoclassical contribution to the momentum transport is negligibly small compared to experimental levels for NSTX and DIII-D plasmas. It is also found that finite residual turbulence can survive strong mean ExB shear flow induced damping. This residual turbulence in the presence of strong $\mathbf{E}\times\mathbf{B}$ shear may drive an insignificant ion heat flux reasonably close to the neoclassical value, and a finite momentum flux significantly higher than the neoclassical level. Moreover, the equilibrium $\mathbf{E}\times\mathbf{B}$ flow shear is found to reduce the turbulence driven transport for energy more efficiently than for momentum. These findings may offer an explanation for rather peculiar observations of near neoclassical ion heat and anomalous momentum transport in experiments, which has been often observed in various machines, but with little theoretical understanding. [1] W.X. Wang et al., Phys. Plasmas 14, 072306 (2007). [2] O.D. Gurcan et al., Phys. Plasmas 14, 042306 (2007). [3] N. Mattor and P.H. Diamond, Phys. Fluids 31, 1180 (1988). [4] W.X. Wang et al., Phys. Plasmas 13, 082501 (2006). In collaboration with: T.S. Hahm, S. Ethier, S.M. Kaye, W.W. Lee, G. Rewoldt, W.M. Tang (PPPL), P.H. Diamond (UCSD), M. Adams (Columbia U.).

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