Gyrokinetic Studies of Toroidal Momentum Transport

T.S. Hahm[1], P.H. Diamond[2], W.X. Wang[1], O. Gurcan[2], and G. Rewoldt[1]

[1]Plasma Physics Laboratory, Princeton University,
Princeton, New Jersey 08543-0451, U.S.A.
[2]University of California, San Diego,
La Jolla, California 92093, U.S.A.

Toroidal rotation of plasma is beneficial not only for the $\mathbf{E} \times \mathbf{B}$ shear suppression of turbulence, but also for stabilization of resistive wall modes. Since it's not clear whether ITER will have enough wave and NBI power to generate sufficient rotation for these purposes, an enhanced understanding of toroidal momentum transport is required. By constructing a radial flux of toroidal angular momentum from the "energy conserving" nonlinear gyrokinetic equation in toroidal geometry[1], we can readily identify a diffusive flux and a non-diffusive flux. For the diffusive flux from ITG turbulence, it has been shown that $\chi_\phi \sim \chi_i$[2] in rough agreement with observations from NBI-heated TFTR plasmas[3]. We've investigated possible physical mechanisms behind the nondiffusive flux, and found that:
i) Mean $\mathbf{E} \times \mathbf{B}$ shear can induce a net momentum flux by breaking the quasi-translational invariance of the ballooning eigenfunctions. However, our preliminary estimate from the FULL code indicates that the effect is too weak to account for the strong spontaneous rotation observed in experiments including C-Mod[4]. A similar result has been reported based on the gyrofluid simulations by the CEA group[5].
ii) The parallel velocity space nonlinearity can also induce a net momentum flux when a realistic non-adiabatic kinetic electron response is taken into account. This mechanism is currently under investigation using newly developed gyrokinetic simulation capabilities (extensions of GTC) including the mean $\mathbf{E} \times \mathbf{B}$ shear and non-circular cross section[6].

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