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Effect of q-profile structure on intrinsic torque reversals[1]

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Intrinsic toroidal rotation plays an important role in mitigating macroinstability and regulating turbulent transport in ITER, where neutral beams are not sufficient to provide the requisite torque. Recent experiments on C-Mod with LHCD observed rotation reversal related to a change in the q profile [1]. In this work, we focus on understanding the physics of intrinsic rotation reversals in LHCD plasmas, using nonlinear, global gyro-kinetic simulations [2] and analysis of mode structure and spectrum symmetry breaking [3]. The sensitive dependence of turbulent residual stress on magnetic shear is identified and characterized. The basic residual stress is non-vanishing when the k-parallel spectrum symmetry is broken, e.g., by E x B shear induced radial shift, non-uniformity in turbulence intensity, etc. [3]. It is found that at low magnetic shear, the poloidal harmonics can shift strongly in the radial direction, as a feature of non-local effects, due to radial propagation and amplitude variation of the mode. This new symmetry breaking mechanism leads to a change in the sign of spectrum averaged parallel wave vector and thus the direction of intrinsic torque. Theoretical study [4] shows that the competition between magnetic drift and ion kinetic effects determines the non-local effects and the structure of the asymmetry. Specifically, it is found that the direction of the intrinsic torque changes from counter- to co-current in the core, when magnetic shear decreases through a critical value. A critical shear $\hat{s}_R = 0.2 \sim 0.5$ for reversal of CTEM-induced intrinsic torque found by simulation is consistent with that from the LHCD C-Mod reversal experiments. In addition, simulations indicate $\hat{s}_R = 1 \sim 2$ for the reversal of ITG-induced torque, a prediction which can be tested by experiments.

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[2] Wang W.X. et al 2006 Phys. Plasmas 13, 092505
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[4] Lu, Z.X. et al. 2012 Phys. Plasmas 19, 042104

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