Nonlinear Gyrokinetic Theory of Toroidal Angular Momentum Pinch

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The turbulent convective flux of the toroidal angular momentum density is derived using the nonlinear toroidal gyrokinetic equations with proper conservation laws [Hahm, Phys. Fluids, **31**, 2670 (1988)]. We identify a novel pinch mechanism which originates from the symmetry breaking due to the magnetic field curvature. The net parallel momentum transfer from the waves to the ion guiding centers is possible when the fluctuation intensity changes along the magnetic field, resulting in imperfect cancellation of the curvature drift contribution to the parallel acceleration. This mechanism is inherently a toroidal effect, and complements the $k_{||}$ symmetry breaking mechanism due to the mean $\mathbf{E} \times \mathbf{B}$ shear [O. Gurcan *et al.*, submitted to Phys. Plasmas (2007)] which exists in a simpler geometry. In the absence of ion thermal effects, this pinch velocity of the angular momentum density can be also understood as a manifestation of a tendency to homogenize the profile of "magnetically weighted angular momentum density," $nm_iR^2\omega_\phi/B^2$. This part of the pinch flux is mode-independent (whether it's TEM driven or ITG driven), and radially inward for fluctuations peaked at the low-B-field side. Ion thermal effects introduce an additional radial pinch flux from the coupling with the curvature and grad-B drifts. This curvature driven thermal pinch is mode-dependent. Explicit formulas in general toroidal geometry have been derived.

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