Physics of Intrinsic Rotation

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We discuss the theory of the turbulent transport of toroidal momentum, with special emphasis on the implications of recent theoretical developments for the understanding of intrinsic rotation. In particular, we show that:

i.) The particle pinch produces a convective inflow of momentum.

ii.) Most generally, the radial flux of parallel flow (i.e. the $\langle \tilde{v}_r \tilde{v}_\parallel \rangle$ Reynolds stress) can be written as

$$\langle \tilde{v}_r \tilde{v}_\parallel \rangle = S(r) + V(r)\langle v_\parallel \rangle - \chi_\phi \frac{\partial \langle v_\parallel \rangle}{\partial r}.$$

Explicit expressions for $S(r)$, $V(r)$ and $\chi_\phi(r)$ are obtained.

iii.) $S(r)$, which is, in essence, a ∇p-driven momentum flux, can, along with the edge boundary conditions on $\langle v_\parallel(r) \rangle$, produce interesting levels of intrinsic rotation, especially in H-mode plasmas (where the edge ∇p steepens). For 'no-slip' boundary conditions, $\langle v_\parallel \rangle / v_{Thi} \sim 2$ for a typical case. Moreover $\langle v_\parallel \rangle / v_{Thi}$ scales with the product $(\nabla p/p)(\nabla n/n)$ evaluated for edge values.

iv.) The stationary flow profile is set by the balance of $S(r)$ and the diffusive flux, proportional to χ_ϕ. $S(r)$ thus defines the levels of off-set rotation predicted for balanced torques.

v.) The momentum for the intrinsic rotation originates from wave momentum. The latter is rendered unambiguous by the presence of mean electric field shear, which breaks $k_\parallel \to -k_\parallel$ symmetry.

vi.) An additional inward pinch of $\langle v_\parallel \rangle$ arises from toridal effects, and the homogenization of $n v_\parallel / B^3$. We discuss the relation of this mechanism to TEP-type models.

Throughout, we discuss the theoretical developments in the context of experimental results on intrinsic rotation.