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Damping of Poloidal Flow Driven by Turbulence in Tokamaks

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Plasma turbulence generates, through mode coupling and finite gyroradius and banana width effects, fluctuating radial currents which have an axisymmetric component. The sheared poloidal flows driven by these currents are important in saturating the modes responsible for transport. We have considered an important aspect of this problem, the kinetic linear plasma response to such currents, treating them as a known source. The driven flows are not damped by collisionless processes, such as transit time damping, although they are attenuated by plasma polarization. When the source currents are assumed to be random and statistically stationary, the mean square E×B flow is found to increase linearly with time, for times longer than a few ion transit times. By solving the gyrokinetic equation and quasineutrality as an initial value problem, the flow is found to asymptote to a nonzero value. This was confirmed by gyrokinetic simulation, while gyrofluid models incorrectly predict a total collisionless decay of the flow because present gyrofluid closures have no trapped ion bounce averaging. We have proposed [1] that this gyrofluid over-damping may lead to overestimation of turbulent diffusion by gyrofluid codes.

When ion-ion collisions are included in the solution of the drift kinetic equation, the poloidal flow is found to decay to zero, although not exponentially in time. In particular, the decay is faster than exponential for short times, because collisions have an effect first in a boundary layer, while it is slower than exponential for long times because it is dominated by more energetic ions with small collision rates. The decay time, defined by an integral over the time history of the flow, is found to be $\tau_{\mathrm{d}} = 1.5\,\tau_{\mathrm{ii}}\,\varepsilon$, where τ_{ii} is the bulk ion-ion collision time, and ε is the inverse aspect ratio. Plasma polarization plays an important role in the dynamics. To second order in the ion banana width, the E×B flow is again found to asymptote to a non-zero value at large times, determined by the plasma polarization, which is modified by collisions.

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[1] M.N. Rosenbluth and F.L. Hinton, to be published in Phys. Rev. Lett.

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