The interaction of neoclassical and turbulent transport in toroidal systems

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We study the interaction of neoclassical and turbulent transport in tokamaks and stellarators. The theory of neoclassical transport in these devices is well developed, and a large amount of work has also been done on turbulent transport, mainly in tokamaks or simpler systems. We consider how the transport changes when one superposes on the background fields producing the neoclassical transport a spectrum of (possibly time-dependent) electrostic modes ϕ_k representing turbulence. A simple guess, commonly assumed, is that the effects are approximately additive, with total diffusion coefficient $D = D_0^{nc} + D^{an}$ being the sum of neoclassical and anomalous contributions, *e.g.*, with D^{an} having a linear dependence $D^{an} \simeq D_1|\phi|$ characteristic of strong turbulence, or a quadratic dependence $D^{an} \simeq D_2|\phi^2|$ characteristic of weak turbulence, quasilinear theory, and some ripple transport regimes, increasing with larger ϕ. Instead, one might expect the turbulence to enhance the total effective collisionality $\nu_{ef} = \nu_0 + \nu_{an}$ over the purely collisional rate ν_0, shortening the decorrelation time. For axisymmetric systems, such an effect would again increase D over D_0^{nc}. However, stellarators and rippled tokamaks have collisionality regimes where $D \sim 1/\nu$, so for these, an enhanced ν_{ef} would *decrease* D, of possible significance for finding an optimal stellarator design or operating point. Using a guiding-center code as our primary tool for exploration, we investigate under what circumstances these two intuitions, and others, prove valid.