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Nonlinear Interaction of Drift Wave Turbulence with Zonal Flows

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The nonlinear interaction, of generic drift wave turbulence with zonal flows (nonlinearly driven poloidal flows) is considered in cylindrical geometry. A gyrokinetic description is used, which contains kinetic effects which are essential in toroidal geometry. We have previously shown (Rosenbluth and Hinton, Phys. Rev. Lett. 1998) that poloidal flows driven by drift wave turbulence are linearly damped only by collisions. Here, the nonlinear damping due to mode coupling is calculated. A reduced set of equations containing only the potentials is first derived. In the electrostatic approximation, electrons don't respond to the zonal flow potentials, although they are assumed to respond adiabatically to the drift wave potentials. For small ion gyroradius, the drift wave–zonal flow scattering is dominated by the ExB nonlinearity due to the nonadiabatic response of electrons to the zonal flow potentials. The Kadomtsev weak coupling theory is used in the resonance approximation to obtain equations for the drift wave and zonal flow intensities. Since the nonlinear coupling conserves energy, a steady state requires a balance between linear growth of drift wave energy and collisional damping of zonal flow energy. It is reasonable to expect that the zonal flow intensities are proportional to an average linear drift wave growth rate, and the drift wave intensities are proportional to an average collisional damping rate. For small collision frequency, the zonal flow potentials should be much larger than the drift wave potentials. Assuming this and using the dominant mode coupling terms, a zonal flow damping rate is derived which is the sum of terms linear and quadratic in the intensities. For small zonal flow intensities (near linear marginality), nonlinear instability must be balanced by collisional damping. For larger zonal flow intensities (well above linear marginality), the quadratic damping rate allows a steady state balance without collisions.

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