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[**x**] Theory [~] Experiment

Some Linear Properties of Zonal Flows,* F.L. Hinton, R.E. Waltz, and J. Candy, *General Atomics* – We previously showed that zonal flows, driven nonlinearly by ITG turbulence in tokamaks, are not damped by linear collisionless processes,[1] and are weakly damped by ion-ion collisions. We have now included the effects of diamagnetic flows, electron-ion collisions, finite beta, and toroidal rotation shear, in the small $k_r\rho_i$ limit. Diamagnetic flows couple the m=0 and ± 1 potentials, but the polarization is only slightly modified. Electron-ion collisions come into the electron response to the m=$\pm$1 potentials and could potentially cause growth or damping of the zonal flows, but we find that they have no effect. Finite beta couples the scalar and vector potentials, but leads to only a small modification of the polarization, for low beta. Toroidal rotation and rotation shear also give small corrections to the polarization. These effects do not lead to linear damping or growth. They do not give the polarization any frequency dependence; considered as normal modes, the zonal flows have zero frequency and do not propagate. The extension of these results to $k_r\rho_i \sim 1$ will be given, and illustrative results from the GYRO code will be presented.

[1] M.N. Rosenbluth and F.L.Hinton, Phys. Rev. Lett. **80**, 724 (1998).

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