Enhanced Neoclassical Polarization, Zonal Flow Suppresion and Elevated Turbulence in Tokamaks

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Abstract

Simulations[1] of ion temperature gradient (ITG) turbulence in tokamaks show a strong saturating effect from zonal flows driven by the turbulence. The effectiveness of this saturation mechanism has been attributed to the linearly undamped nature of the zonal flows as first discussed by Rosenbluth and Hinton [2] in the collisionless regime. Although much of the attention has focused on the zonal flows, it is actually the neoclassical polarization that determines the effectiveness of the zonal flow shearing in saturating the turbulence. The smaller the polarization the larger will be the zonal flow response which leads to the relatively small saturated turbulence levels observed in simulations. Several neoclassical polarization regimes are present depending on collisionality. The low frequency, collisional, limit, is well known and is larger than the Rosenbluth, Hinton result by a factor of order, $\varepsilon^{-3/2}$. This limit of the zonal flow response is not present in any of the simulations, and looms as a concern. The zonal flow spectra observed peak at zero frequency where this collisional limit is clearly the correct polarization, not the Rosenbluth-Hinton value that is being achieved in the codes. It is not a simple matter to include collisions accurately enough to capture this effect, but the implications for turbulence simulations are serious. Underprediction of the neoclassical polarization will lead to underprediction of the turbulence level. We have also argued elsewhere (Sherwood Fusion Theory Meeting, 2003), that even at lower collisionality, the Rosenbluth-Hinton result is too small. This paper compares the various theories and makes suggestions for the simulation codes to help resolve what is an important question for tokamak turbulence.

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