The Effects of Shaping on Zonal Flows, and of Noise on PIC ETG Simulations*

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The effects of flux surface shape on turbulence in tokamak plasmas with kinetic electrons have been studied using the nonlinear GS2 gyrokinetic code (E.A. Belli, Princeton Ph.D. Dissertation, 2006). In particular, we find that the Dimits nonlinear shift (the shift in the effective critical temperature gradient) increases as the plasma elongation increases (at fixed q). This can be understood as due to an enhancement of the Rosenbluth-Hinton component of zonal flows as elongation increases, due to a reduction in the neoclassical polarization shielding. This is illustrated by a simple particle orbit picture of neoclassical polarization shielding (the banana widths are reduced as elongation is increased, since the plasma current and poloidal flux increase with elongation at fixed q), and by studying how the amplitude of the residual Rosenbluth-Hinton flow depends on flux surface shape.

In order to understand the differences between particle-in-cell and continuum gyrokinetic simulations of Electron Temperature Gradient (ETG) turbulence, we have investigated the role of discrete particle noise. A detailed theory of the spectrum of noise fluctuations in a gyrokinetic particle simulation has been developed. As demonstrated in (W.M. Nevins, et al., Phys. Plasmas 12, 122305 (2005)), this theory, with no free parameters, agrees very well both with the spectrum and the transport observed at late times in gyrokinetic particle simulations when noise dominates. The theory is based on Krommes' calculation of the gyrokinetic noise spectrum (J.A. Krommes, Phys. Fluids B5, 1066 (1993)), extended to include the effects of numerical filtering, finite-size particles, and a resonance-broadening type of renormalization of the dielectric shielding and of the test particle trajectories. The noise builds up in time in present δf algorithms and eventually becomes large enough in typical particle simulations to suppress ETG turbulence, thus explaining why they give lower transport levels at late times than observed in continuum simulations.

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