Ion temperature gradient turbulence simulations and plasma flux surface shape

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Abstract. A generalization of the circular $\hat{s}$-α local magnetohydrodynamic (MHD) equilibrium model to finite aspect ratio (A), elongation (κ), and triangularity (δ) has been added to a gyrokinetic stability code and our gyrofluid nonlinear ballooning mode code for ion temperature gradient (ITG) turbulence. This allows systematic studies of stability and transport for shaped flux surfaces with the same minor midplane radius label (r), plasma gradients, q, $\hat{s}$ and α while varying A, κ, and δ. It is shown that the (linear, nonlinear, and sheared) E×B terms in the equation of motion are unchanged from a circle at radius r with an effective field $B_{\mathrm{unit}} = B_0 \rho d\rho / r dr$ where $\chi = B_0 \rho^2/2$ is the toroidal flux, r is the flux surface label, and B_0 is the magnetic axis field. This leads to a "natural gyroBohm diffusivity" χ^{natural} which at moderate q = 2–3 is weakly dependent on shape (κ) at fixed B_{unit}. Since $B_{\mathrm{unit}}/B_0 \propto \kappa$ and $\left\langle |\nabla r|^2 \right\rangle \approx (1+\kappa^2)/(2\kappa^2)$, the label independent $\chi^{\mathrm{ITER}} = \chi_{\mathrm{natural}}/\langle|\nabla r|^2\rangle$ at fixed B_0 scales as $2/(1+\kappa^2)$ with much weaker scaling at high-q and stronger at low-q where increased κ is stabilizing. The generalized critical E×B shear rate to be compared to the maximum linear growth rate is a flux surface quantity $(r/q)\, d/dr\, (cq/rB_{\mathrm{unit}} d\phi_0/dr) = (r/q)\, d\, (E_{x0}/B_p R)/dr$.

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