The effect of safety factor and magnetic shear on turbulent transport in nonlinear gyrokinetic simulations

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Abstract

We report on over 100 nonlinear simulations used to systematically study the effects of safety factor q and magnetic shear $\hat{s}$ on turbulent energy and particle transport due to ion temperature gradient (ITG) modes and trapped electron modes (TEM) for several reference cases using the GYRO gyrokinetic code. Nearly all the simulations are in the collisionless limit. Our motivation is to create a database for benchmarking and testing of turbulent transport models. In simulations varying q, we find the ion and electron energy transport scale approximately linearly with q for $1 \leq q \leq 4$. This result is valid for cases where the spectrum is dominated by either TEM or ITG modes. The particle transport also follows a linear q dependence if the diffusivity D is positive (outward). If a particle pinch is predicted, however, then D is found to be insensitive to q. In kinetic electron simulations varying the magnetic shear $\hat{s}$, we find that the particle transport can exhibit a null flow at a particular value of $\hat{s}$. In the vicinity of the null flow point, the transport spectrum shows that some modes drive an inward flow while others drive an outward flow. For negative magnetic shear, the magnetohydrodynamic (MHD) α parameter is shown to be stabilizing for both the energy and particle transport but can be destabilizing for large positive shear. Compared to the ITG dominated case, the TEM cases show the same linear q dependence, but a weaker $\hat{s}$ dependence is exhibited for positive magnetic shear values when TEM modes dominate the spectrum. In general, the q, $\hat{s}$, and α dependence of the transport including kinetic electrons is consistent with ITG adiabatic electron simulation results.

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