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First Implementation of Gyrokinetic Exact Linearized Landau Collision Operator and Comparison with Models[1]

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The gyrokinetic exact Landau operator has now been formulated in conservative and symmetric Landau form[2] and implemented for the first time in a gyrokinetic code (GENE). The new exact operator makes it possible to assess the accuracy of widely used model collision operators for the first time. The gyrokinetic Landau form, though equivalent to the Rosenbluth form[3], explicitly preserves the symmetry between test- and field-particle terms. This symmetry underlies the conservation laws and the H-theorem, and enables finite-volume or spectral methods to preserve the conservation, independent of resolution. The present implementation utilizes the same finite-volume method recently employed to discretize the Sugama collision model in GENE[4], allowing direct comparison between the two operators. Neoclassical tests confirm that the Sugama model overestimates ion heat fluxes by about 20-25% relative to the exact operator. The exact operator has now been used in nonlinear gyrokinetic simulations of density-gradient-driven trapped electron mode (TEM) turbulence with finite Larmor radius (FLR) collisional corrections. Results are (1) the Sugama model operator underestimates TEM growth rates by about 10%; (2) the exact operator and the Sugama model produce similar particle and heat fluxes near the nonlinear threshold; and (3) the Sugama model yields accurate zonal flow and GAM damping rates. The finite-volume scheme, though conservative, requires high velocity resolution for convergence. Future work will improve the performance by using spectral methods and implicit time stepping.

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