iFP: An Optimal, Fully Implicit, Adaptive, Equilibrium Preserving and Fully Conservative Vlasov-Fokker-Planck Code for Spherical ICF Simulations

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ABSTRACT

Contrary to rad-hydro predictions, the National Ignition Facility has not achieved ignition. Recent experimental evidence suggests that plasma kinetic effects may play an important role during Inertial Confinement Fusion (ICF) capsules' implosion. Consequently, kinetic models and simulations may be needed to understand better experimental results and design ICF targets. We present a new, optimal, fully implicit, and fully conservative 1D2V Vlasov-Fokker-Planck (VFP) code, iFP [1,2,3,4,5], which simulates ICF implosions kinetically. Such simulations are difficult because of the disparate time and length scales involved. The challenge in obtaining a credible solution is complicated further by the need to enforce discrete conservation properties and the Maxwellian equilibrium for the collision operator.

iFP employs a multi-grid preconditioned Anderson acceleration as a solver [1,6] in order to step over stiff collision time-scales while ensuring exact conservation (mass, momentum, and energy). Conservation is ensured by solving a set of discrete nonlinear constraints, which are derived from the continuum symmetries present in the VFP equations [2,3]. We optimize mesh resolution requirements by 1) adapting the velocity-space mesh based on the species' local thermal-velocity [4], 2) treating the cross-species collisions exhibiting disparate thermal velocities by a coarse-graining strategy [4], 3) ensuring an analytical equilibrium in the limit of $\Delta t \nu_{col} \rightarrow \infty$ using a new equilibrium preserving discretization scheme [5] for our multiple grid approach, and 4) tracking capsule implosions with a moving mesh in physical space. We demonstrate the efficiency and accuracy properties of the approach with challenging ICF capsule simulations in spherical geometry.

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