Entropy-based accelerated Monte Carlo methods for Coulomb collisions

Lee Ricketson (UCLA)

Co-authors and their institutions: Mark Rosin (UCLA), Russel Caflisch (UCLA), Andris Dimits (LLNL), Bruce Cohen (LLNL)

Abstract: We present a computational method for the simulation of Coulomb collisions in plasmas that significantly improves upon our earlier hybrid method, which combines a Monte Carlo particle scheme and a fluid dynamic solver in a single uniform method across phase space. The hybrid method represents the velocity distribution function f(v) as the sum of a Maxwellian M(v) and a collection of discrete particles g(v). M evolves in space and time through fluid equations, and g through a Monte Carlo particle in cell (PIC) method. Interactions between M and g are mediated by mean fields and simulated collisions. Computational resources are reallocated by (de-)thermalization processes that move particles from g to M and vice versa. We present a new algorithm for performing these (de-)thermalizations that is more accurate and rigorously justifiable than previous efforts. This new algorithm assigns a passive scalar to each simulated particle that approximates a ``relative entropy.'' Particles are thermalized (dethermalized) when this quantity is sufficiently small (large). We present results from numerical simulations of two test problems - a two temperature Maxwellian and a bump-on-tail distribution, finding a computational savings between a factor of 5 and 20 over PIC.

Relevant references: L.F. Ricketson, M.S. Rosin, R.E. Caflisch, A.M. Dimits, An entropy based thermalization scheme for hybrid simulations of Coulomb collisions, arXiv:1301.5678; submitted to Journal of Computational Physics