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Stochastic relativistic advection-diffusion equation and viscous hydrodynamics in density frame

We study an approach to simulating the stochastic relativistic advection-diffusion equation based on the Metropolis algorithm. We show that the dissipative dynamics of the boosted fluctuating fluid can be simulated by making random transfers of charge between fluid cells, interspersed with ideal hydrodynamic time steps. The random charge transfers are accepted or rejected in a Metropolis step using the entropy as a statistical weight. This procedure reproduces the expected strains of dissipative relativistic hydrodynamics in a specific (and non-covariant) hydrodynamic frame known as the density frame. Numerical results, both with and without noise, are presented and compared to relativistic kinetics and analytical expectations. An all order resummation of the density frame gradient expansion reproduces the covariant dynamics in a specific model. In contrast to all other numerical approaches to relativistic dissipative fluids, the dissipative fluid formalism presented here is strictly first order in gradients and has no non-hydrodynamic modes. The physical naturalness and simplicity of the Metropolis algorithm, together with its convergence properties, make it a promising tool for simulating stochastic relativistic fluids in heavy ion collisions and for critical phenomena in the relativistic domain. In addition, we compare our full density frame viscous hydrodynamics with BDNK and MIS, and found very good agreement in small shear viscosity regime and better in large viscosity regime.

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