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A new approach to stochastic relativistic fluid dynamics from information flow

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The study of thermal fluctuations in relativistic hydrodynamics is essential for understanding physics near the expected critical endpoint in the QCD phase diagram. Furthermore, the incorporation of stochastic fluctuations may be important for the modeling of hydrodynamics in small systems such as proton-proton and proton-nucleus collisions. We present a new general formalism for introducing thermal fluctuations in relativistic hydrodynamics which incorporates the recent developments on the causality and stability of relativistic hydrodynamic theories. Our approach is based on the recently introduced information current [1], which measures the net amount of information carried by perturbations around equilibrium in a relativistic many-body system. The resulting noise correlators are guaranteed to be observer-independent for thermodynamically stable models, which differs from previous approaches employed in the literature. We obtain a Martin-Siggia-Rose [2] action principle within our formalism and compare it to previous proposals for hydrodynamic effective actions. Finally, we present a few applications, which include the Israel-Stewart theory in a general hydrodynamic frame [3]. We find the adoption of a general hydrodynamic frame introduces new independent structures to the two-point function of the energy-momentum tensor which are not present in previous calculations done in the Landau or Eckart hydrodynamic frames.

[1] L. Gavassino, M. Antonelli, and B. Haskell, "Thermodynamic stability implies causality,"Physical Review Letters 128 (2022)

[2] P. C. Martin, E. D. Siggia, and H. A. Rose, "Statistical Dynamics of Classical Systems,"Phys. Rev. A 8, 423–437 (1973).

[3] Jorge Noronha, Michal Spalí nski, and Enrico Speranza, "Transient relativistic fluid dynamics in a general hydrodynamic frame,"Physical Review Letters 128 (2022)

Category

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