Contribution ID: **455** Type: **Parallel Talk**

A resummed method of moments for the relativistic hydrodynamic expansion

Wednesday, 16 May 2018 10:20 (20 minutes)

A modern approach to obtaining the equations of motion of dissipative relativistic hydrodynamics relies on various approximations of the relativistic Boltzmann equation. There is a mounting evidence that the standard Chapman-Enskog expansion of the Boltzmann equation has a vanishing radius of convergence. The method of moments, on the other hand, is free from such problems. The equations thus obtained can be systematically improved, and their convergence properties checked. However, if one introduces mean-field interactions, for example in the form of a medium-dependent mass or an external gauge field interacting with the plasma, this systematic expansion breaks down: Successive moments are found to couple not only to energy moments of higher, but also of lower order,which diverge in the ultra-relativistic (massless) limit, orrequire unrealistic machine precision. This problem is even worse if one starts with the Wigner quasi-probability distribution, in order to generalize the results of the expansion. In the absence of the on-shell condition, all of the moments are ill defined, with the notable exception of the conserved currents (the stress-energy tensor).
We solve the issue using resummed moments which consist of a sum of all the moments of the same tensorial rank, but different energy weights. The resulting equations are always well defined. The evolution of the hydrodynamics moments (four-velocity, energy density, pressure, pressure corrections etc.) is exactly the same as the one provided by the traditional method of moments, if such an expansion is well defined. We tested numerically the convergence properties of the resummed expansion for some known solutions of the microscopic theory, and we checked that the convergence remains intact in the simplest case in which the traditional expansion breaks down. Namely the Boltzmann-Vlasov equation for charged mass-less particles coupled to the Maxwell equations in a (0+1)-dimensional expansion.

Content type

Theory

Collaboration

Centralised submission by Collaboration

Presenter name already specified

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Session Classification: New theoretical developments

Track Classification: New theoretical developments