

Quantum Monte Carlo simulations of strongly coupled quark-gluon plasma

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In recent years, there has been an increasing interest in dynamics and thermodynamics of non-Abelian plasmas at both very high temperature and density. It is expected that a specific state of matter with unconfined quarks and gluons - the so called quark - gluon plasma (QGP) - can exist. The most fundamental way to compute properties of the strongly interacting matter is provided by the lattice QCD. Interpretation of these very complicated computations requires application of various QCD motivated, albeit schematic, models simulating various aspects of the full theory. Moreover, such models are needed in cases when the lattice QCD fails, e.g. at large baryon chemical potentials and out of equilibrium. A semi-classical approximation, based on a point like quasi-particle picture has been recently introduced in literature. It is expected that it allows to treat soft processes in the QGP which are not accessible by the perturbative means and the main features of non-Abelian plasmas can be understood in simple semi-classical terms without the difficulties inherent to a full quantum field theoretical analysis.

Here we propose stochastic simulation of thermodynamics and kinetic properties for QGP in semi-classical approximation in the wide region of temperature, density and quasi-particles masses. We extend previous classical nonrelativistic simulations based on a color Coulomb interaction to the quantum regime and take into account the relativistic effects as well as Fermi (Bose) statistics of quarks (gluons) and quantum degeneracy self-consistently.

In grand canonical ensemble for finite and zero baryon chemical potential we use the direct quantum path integral Monte Carlo method (PIMC) developed for finite temperature within Feynman formulation of quantum mechanics to do calculations of internal energy, pressure and pair correlation functions. The QGP quasi-particles representing dressed quarks, antiquarks and gluons interact via color quantum Kelbg pseudopotential rigorously derived in for Coulomb particles. This method has been successfully applied to strongly coupled electrodynamic plasmas (EMP) . A strongly correlated behavior of the QGP is expected to show up in long-ranged spatial correlations of quarks and gluons which, in fact, may give rise to liquid-like and, possibly, solid-like structures. This expectation is based on a very similar behavior observed in electrodynamic plasmas.

We have done already the first calculation of the QGP equation of state, spatial and color pair distribution functions, diffusion coefficients and shear viscosity.