Analysing some important properties of strongly interacting systems

Kinkar Saha[1,2*]
[1] *Department of Physics, Visva Bharati, Santiniketan 731235, INDIA. and*
[2] *Department of Physics, CAPSS, Bose Institute, Kolkata- 700091, INDIA.*

Introduction

Strongly interacting systems in form of hot and dense plasma is predicted to exist in the early stages of the Universe or in the core of Neutron Stars. Various experimental facilities around the World provide us the chance to recreate similar situation and analyze the associated physics. Study of the in-medium properties of such exotic systems and corresponding phase transitions during its evolution is very important from numerous perspectives both theoretically as well as experimentally. This thesis mainly deals with a few important characteristics of strongly interacting systems evaluated under the framework of 2+1-flavor Polyakov−Nambu−Jona-Lasinio (PNJL) model.

Net charge fluctuations

Fluctuations of conserved charges present in a system provide very useful measure regarding the phase transition and associated properties of the system under concern. In case of strongly interacting systems which experince transition from partonic to hadronic phase, the degrees of freedom become different. In connection, *net charge fluctuation* [1], designated by $D - measure$ defined in terms of ratio of leading order charge fluctuation to total charge density serves as a viable signature for the production of Quark-Gluon Plasma (QGP). When extracted from our model framework, D does not exactly show an order parameter like behaviour specially for low baryon charge density. However, D always remains above its temperature and chemical potential dependent free field limit indicating that total charge density is suppressed than the charge fluctuation in this limit. The scenario however changes once high density region is approached. Similar features corroborating with the QCD phase diagram are observed when this is plotted with chemical potential at few characteristic temperatures. D, extracted under experimental conditions at different $\sqrt{s}$ using freeze-out parametrizations reveals interesting facts quantitatively. However, it is to be kept in mind that the freeze-out curve stays below the QCD phase diagram and therefore lies completely within the hadronic sector. Threfore complete match with experimental findings would indicate non-persistence of QGP phase.

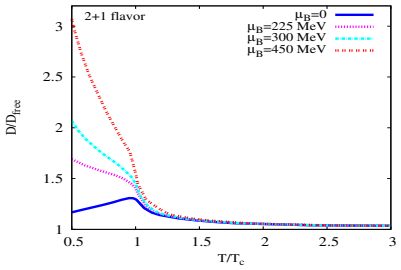

FIG. 1: Variation of D with T/T_c for different values of μ_B around $\mu_Q = 0$

.

Viscous effects

With the advent of Au+Au and Cu+Cu collisions at RHIC, the concept of '$perfect\ fluidity$' eventually went wrong as ideal hydrodynamics even with hadron cascade models could not describe the elliptic flow data adequately. The lack of proper knowledge of initial conditions then grad-

*Electronic address: saha.k.09@gmail.com

ually led to the necessity of incorporation of viscous effects into the analysis. The specific shear viscosity in this context takes up a small value for such strongly interating systems for the temperature domain probed by RHIC or LHC. It is conjectured to have a lowest possible value of $\frac{1}{4\pi}$, popularly known as KSS-bound. In [2], we have computed shear viscous effects using Kubo formalism under the similar framework of PNJL model with upto six-quark type of interactions. Kubo formalism connects the correlations functions of energy momentum tensor to the coefficients of viscosity. The results for vanishing chemical potentials show excellent match with existing findings from meson gas consideration and Lattice-QCD predictions at low and high temperature regimes respectively. The spectral width, Γ has however

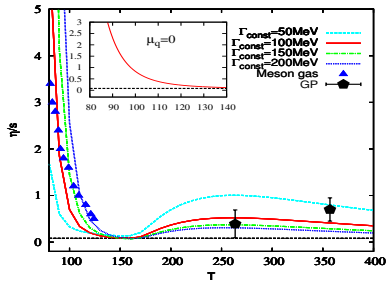

FIG. 2: Variation of $\frac{\eta}{s}$ with temperature for vanishing chemical potentials.

been chosen phenomenologically satisfying the convergence criteria of η. The results in finite chemical potential domain shows interesting facts and provide us with a unique way to draw the associated phase diagram as discussed in [2]. $\frac{\eta}{s}$ at various experimental energies was also evaluated.

On the other hand, bulk viscosity manifests itself by an addition of diagonal term to the stress tensor and signifies the isotropic deviations from equlibrium conditions. It in effect opposes the expansion of a system. In [3], we have taken up two different formalisms, one as the QCD sum rule approach namely the Kubo formalism and the other one as the quasi-particle approach namely the Relaxation Time

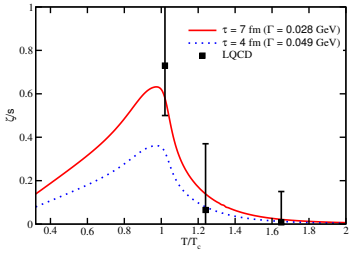

FIG. 3: $\frac{\zeta}{s}$ as a function of temperature at vanishing chemical potential in quasi-particle approache.

Approximation (RTA) method. Our motivation was to draw an equivalence between the two approaches in terms of the set of parameters used based on the quantitative similarities of coefficient of bulk viscosity, ζ extracted using the two mechanisms. ζ shows a peak like nature near the crossover transitions temperature, T_c. Away from T_c however, they show differences occuring mainly because of the folding of conformality breaking terms by the PNJL distribution function in RTA approach, which is however absent in the other method. The specific bulk viscosity $\frac{\zeta}{s}$ matches well with the Lattice findings in high temperature region. The issue however can be resolved by considering different ansatz for the spectral density function. The results in finite chemical potential domain match our expectations and show similarity with the previously extracted phase diagram.

Acknowledgments

KS acknowledges the financial support from CSIR, DST and at present by the SERB-DST Ramanujan Fellowship of Tamal K. Mukherjee under Project no - SB/S2/RJN-29/2013.

References

[1] A. Bhattacharyya, S. Das, S. K. Ghosh, S. Raha, R. Ray, K. Saha, and S. Upadhaya,, arXiv:1212.6010 [hep-ph].

[2] S. K. Ghosh, S. Raha, R. Ray, K. Saha, and S. Upadhaya, Phys. Rev. **D91**, 054005 (2015).

[3] K. Saha, S. Upadhaya, and S. Ghosh, Mod. Phys. Lett. **A 32**, 1750018 (2016).