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Contents

0

Insights into the Supernova-GRB Connection from Radio Synchrotron

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Relativistic outflows were observed in only a few supernovae, all of them accompanied by Gamma Ray Bursts (GRBs). All other supernovae had Newtonian outflows. This clear demarcation was blurred by discovery of the radio afterglow of SN 2009bb, the first supernova with a relativistic outflow without an observed GRB. We will discuss this, plus exciting new results from observations and modelling of a relativistic shockwave in SN 2012ap. Radio studies are revealing that supernova explosions with energetic relativistic ejecta can be found even without an observed GRB.

1

On Direct Photon Production at RHIC and LHC-energies: A Theoretical Approach

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The Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) recently studied in the laboratories different collisions at extremely high energies and produced a sizable amount of high-precision data. We deal with the direct photon production phenomena in p + p, Au + Au collisions at RHIC energy, √s_NN = 200 GeV and in P b+P b-collisions at LHC energy, √s_NN = 2.76 TeV on the basis of Sequential Chain Model (SCM). Comparisons of the model-based results with the measured data on some observables are generally found to be modestly satisfactory.

2

Effect of flow on the heavy quark damping rate in hot QCD plasma

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We derive an expression for the heavy quark damping rate in hot quark gluon plasma in the presence of flow. All the bath particles in the present case are out of equilibrium due to the existence of nonzero velocity gradient. The magnetic sector exhibits similar infrared divergences even after hard thermal loop corrections as one encounters in the case of nonviscous plasma. We estimate the first order correction in η/s for heavy quark damping rate due to the nonzero viscosity of the QCD plasma.

3

Influence of isospin dependence of radius on fragmentation in heavy ion collisions

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At low temperature and density hadrons are the prevailing degrees of freedom that determine the properties of nuclear matter. However, under extreme conditions of high temperature or of high density (or both) this is expected to change. One of the key quantities for testing the theoretical model of a nucleus is the nuclear radii. The nuclear radii depend primarily on number of nucleons (A) i.e. R0 = r0 A1/3 where r0 = 1.2 fm [1]. However, this formula is not valid for nuclei in which number of protons (Z) and neutrons (N) differ significantly. In order to have the modifications over the liquid drop radii, various parameterizations of radii have been proposed during last 3-4 decades [2]. Various studies exist in the literature that demonstrate the importance of nuclear radii in the reaction dynamics throughout the energy range [3]. Some of the radius parameterizations have different radii for protons and neutrons and thus have explicit isospin dependence in them. The neutron skin thickness (difference between the proton and neutron root mean square radii) is a very sensitive probe to measure the pressure difference that exist between the neutrons and protons. This difference is found to be sensitive to the symmetry energy as well as to the equation of state of isospin asymmetric nuclear matter. This property provide fundamental information about the nuclear structure. Motivated by the above results, we hereby aim to study the role of isospin dependence of radius and its comparison with the liquid drop model in fragmentation. The present study is carried using Isospin dependent Quantum Molecular Dynamics (IQMD) model [4]. Our findings revealed that radius as well as its isospin dependence have a significant role on fragmentation. Lighter systems shows a strong dependence on the isospin dependent radius compared to heavier systems for the same neutron to the proton ratio. Moreover, isospin dependent radius is able to reproduce the experimental findings nicely.

Acknowledgment
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4

Multiple freezeout

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We argue that known systematics of hadron cross sections may cause different particles to freeze out of the fireball produced in heavy-ion collisions at different times. We find that a simple model with two freezeout points is a better description of data than that with a single freezeout, while still remaining predictive. The resulting fits seem to present constraints on the late stage evolution of the fireball, including the tantalizing possibility that the QCD chiral transition influences the yields at sqrt(S)=2700 GeV and the QCD critical point those at sqrt(S)=17.3 GeV.

5

Modification of kick velocity of neutron star due to non-Fermi liquid effects

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In this present work we have incorporated the non-Fermi liquid behavior into the expression of the neutron star kick velocity due to assymetric neutrino emission. We have studied leading order as well as next-to-leading order corrections to the velocity and compared the results with the Fermi liquid case. We have also approximated our results for the case of large magnetic field found in neutron stars.

6

Role of isospin momentum dependent interactions in extreme conditions

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The heavy ion collisions (HIC) between the low and relativistic energies (10MeV/nucleon≤A≤1GeV/nucleon) generates nuclear matter with high density & temperature, i.e. under extreme conditions. The primary motivation is to get the idea about the nuclear equation of state (EOS) and its isospin dependence in HICs. The nuclear stopping is a critical parameter which can provide crucial information regarding the thermalization reached during the HICs, especially at the intermediate energies. During the central HIC process, nuclear stopping governs most of the dissipated energy and constrains the different reaction mechanisms at different incident energies and colliding geometries. It can provide information on the EOS, nucleon-nucleon (N-N) cross section, and the degree of equilibrium reached in HIC [1]. Within the framework of Isospin dependent Quantum Molecular Dynamics (IQMD) model [2] by including the isospin dependence of momentum dependent interaction (iso-MDI) [3], we obtain the information regarding the stopping reached in HICs. The inclusion of term isospin into the momentum dependent interactions, can improve our knowledge of the basic ingredients of the model: namely, the nuclear EOS and, as such, the in-medium properties of the N-N interaction.

The present results will shed light on the conditions which prevail during the formation of hot and dense nuclear matter. Nuclear stopping has been investigated in central collisions at intermediate energies for a large variety of symmetric systems. Our findings show that the stopping power has the tendency to provide information regarding the properties of the nuclear matter at extreme conditions.

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7

Gluon Radiation off Heavy Flavour Jets

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Gluon emission spectrum off heavy flavour (HF) jet is suppressed in the forward direction due to the well-known 'Dead Cone Effect'. We endeavour to explore the effect of non-eikonality (bent path of HF) on the gluon emission spectrum of heavy quark and show that when the heavy quarks are allowed to bend, additional gluons turn up along the direction of propagation of HF. Hence this study, on one hand, helps remove the prevalent eikonal approximation in jet-quenching models and on the other hand revisits the notion of dead-cone within the non-eikonal regime.

8

QCD back-scattering photons in relativistic heavy ion collisions

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We have investigated the correlations of photons produced by back scattering of fast partons in quark gluon plasma with their away-side jets. Back-scattering photons or the jet-conversion photons was first proposed as a unique source of photons in PRL 90,132301(2003). Attempts to identify this source in experiment through inclusive direct photon spectra or direct photon v_2 at intermediate pT at RHIC have been inconclusive so far. We have shown that there is a possibility to separate back-scattering photons from other photon sources using trigger jets. We have calculated the back-scattering photon spectra in coincidence with trigger jet at the RHIC and LHC energy and shown the distinct behaviour of nuclear modification of photon production around the trigger jet E_T window.

Summary:

A new method has been proposed to separate the back-scattering photons from the inclusive direct photon spectrum obtained in heavy ion collisions at the RHIC and LHC energies.

9

Relativistic third-order viscous hydrodynamics from kinetic theory

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We present the derivation of a novel third-order hydrodynamic evolution equation for shear stress tensor from kinetic theory. Boltzmann equation with relaxation time approximation for the collision term is solved iteratively using Chapman-Enskog like expansion to obtain the non-equilibrium phase-space distribution function. Subsequently, the evolution equation for shear stress tensor is derived from its kinetic definition up-to third-order in gradients. We quantify the significance of the new derivation within one-dimensional scaling expansion and demonstrate that the results obtained using third-order viscous equations derived here provides a very good approximation to the exact solution of Boltzmann equation in relaxation time approximation. We also show that the time evolution of pressure anisotropy obtained using our equations is in better agreement with transport results when compared with an existing third-order calculation based on the second-law of thermodynamics.

Summary:

We have derived a novel third-order evolution equation for the shear stress tensor from kinetic theory within relaxation time approximation. Instead of Grad's 14-moment approximation, iterative solution of Boltzmann equation has been used for the non-equilibrium distribution function and the evolution equation for shear tensor is derived directly from its definition. Within one-dimensional scaling expansion, we have demonstrated that the third-order hydrodynamics derived here provides a very good approximation to the exact solution of Boltzmann equation in relaxation time approximation. Our results also show a better agreement with the parton cascade BAMPS for the P_L/P_T evolution compared to those obtained from entropy derivation.

10

Medium effects on the transport coefficients of a pion gas

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The shear and bulk viscosities, as well as the thermal conductivity of a pion gas at finite temperature are obtained by solving the relativistic transport equation in the Chapman-Enskog approximation. The in-medium effects are introduced in the $\pi\pi$ cross section through one-loop self-energies of the exchanged ρ and σ mesons. The effect of early chemical freeze-out in heavy ion collisions is implemented through a temperature-dependent pion chemical potential. These shows a noticeable effect in the temperature dependence of the viscosities and thermal conductivity.

Summary:

The interaction cross-section for $\pi\pi$ scattering gets modified in the presence of a hot and dense medium, which in turn affects the temperature dependence of transport coefficients significantly. This realistic modifications are needed to be taken care of, since they could affect the quantitative estimates of signals of heavy ion collisions,such as the p_T spectra and elliptic flow of hadrons.

11

Maximum mass and radial modes of hybrid star in presence of strong magnetic field

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Compact stars such as neutron stars (NS) can have either hadronic or exotic states like strange quark or color superconducting matter. Stars also can have a quark core surrounded by hadronic matter, known as hybrid stars (HS). The HS is likely to have a mixed phase in between the hadron and quark phase. Observational results suggest huge surface magnetic field in certain neutron stars. Therefore,we study here the effect of strong magnetic field on the eigenfrequencies of radial pulsations of neutron star .The equations of state (EOS) used to estimate such eigenfrequencies have been derived by taking proper care of the hadron-quark phase transition. The hadronic matter EOS is described basing on RMF theory and we include the effect of strong magnetic fields leading to Landau quantization of the charged particles. For the quark phase we use the simple MIT bag model, assuming the density dependent bag pressure and magnetic field. The magnetic field strength increases going from the surface to the center of the star. We construct the intermediate mixed phase using Glendenning conjecture. We find the maximum mass for a hybrid star and in the presentation we will show the periods of oscillations of hybrid stars.

12

Three loop HTLpt thermodynamics at finite temperature and baryonic chemical potential

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We calculate thermodynamic potential at finite temperature and finite baryon chemical potential of a system of quarks and gluons using three-loop hard-thermal-loop perturbation theory. This is the highest order accessible by finite temperature perturbation theory applied to a non-Abelian gauge theory before the high-temperature infrared catastrophe. We compare the resulting pressure and diagonal quark number susceptibilities with available lattice data. We find reasonable agreement between our analytic results and lattice data at both zero and finite chemical potential. We further calculate other thermodynamical quantities like trace anomaly, speed of sound etc. both at zero as well as finite chemical potential and we get good agreement with lattice data.

13

Cooling of neutron star including magnetic interaction

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In the core of the neutron star the density may go up to 5 ~ 6 times the normal nuclear matter density, where the matter is not expected to be in the hadronic phase, rather it is more appropriate to describe the core as degenerate quark matter. In this regime, the constituents like quarks are moving with a velocity close to the velocity of light, where the magnetic interaction can no longer be neglected. In fact, the transverse interactions, due to its infrared sensitivity, may become more important than its longitudinal counterpart in this kinematic regime. This characteristic behavior having non-trivial origin in the analytical structure of the Fermion self-energy close to the Fermi surface. The introduction of magnetic interaction changes some of the characteristic behavior of dense plasma which enters in thermodynamic response functions, show departure from normal Fermi liquid case. We investigate and see the effect of such non-Fermi liquid corrections in quantities like specific heat (Cv), neutrino emissivity (ε) and neutrino mean free path. Equipped with these results, we have studied the cooling behavior of neutron star with dense quark core.

14

On realizability of relativistic acoustic geometry under a generalized perturbation scheme for matter flow onto a Schwarzschild black hole.

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It is a general practice in the community to study the stationary solution for matter flow on an astrophysical Schwarzschild black hole since at the close proximity of the event horizon, in-falling matter encounters extreme conditions due to the strong curvature of the space time and hence a full space time dependent dynamics of such matter at extreme state is not possible to examine within the analytical framework. The main issue, however, in this approach is, whether the stationary solutions of the aforementioned physical configuration are stable. We introduce a novel stability analysis scheme within the framework of Einstein's theory of gravity which can address the aforementioned issue. Using our linear perturbation analysis scheme, we study the stability properties of the curved acoustic manifold embedded within the background fluid configuration and investigate the influence of the introduction of the higher order perturbation in destabilizing the associated relativistic acoustic geometry.

16

Contribution of π-η mixing to the difference between nn and pp scattering lengths

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We revisit the problem of charge symmetry violation (CSV) in nucleon-nucleon interactions due to π-η mixing driven by the neutron-proton mass difference. We construct the CSV potential and estimate the contribution to the difference between nn and pp scattering lengths.

17

A Novel Mechanism for J/ψ Disintegration in Relativistic Heavy Ion Collisions

Authors: Abhishek Atreya[1]; Ajit Mohan Srivastava[1]; Partha Bagchi[1]

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In this paper we discuss the possibility of J/ψ disintegration due the $Z(3)$ domain walls that are expected to form in QGP medium. These domain walls give rise to localised color electric field which disintegrates J/ψ, on interaction, by changing the color composition and simultaneously exciting it to higher states of $c\bar{c}$ system. For $E = 3.2\ GeV$ (or higher) we find that about 90% of J/ψ interacting with the domain wall make the transition.

18

Some Features of Levy Stability Related to Intermittency in 32S-Emulsion Collisions at 200A GeV/c

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An attempt is made to study the behaviour of higher order and second order scaled factorial moments of relativistic shower particles produced in 32S-emulsion collisions at 200A GeV/c in η- phase space for different Ns –intervals. It has been observed that the two ratios of higher order and second order anomalous fractal dimensions (dq/d2) expressed in terms of the Levy stable law gives an evidence of self- similar cascade mechanism responsible for multiparticle production. The experimental results give an agreement for the requirement of the Levy stable region (0 ≤ μ ≤ 2). Finally, it can be concluded that the value of universal scaling exponent (υ) gives no clear evidence for the existence of second order phase transition.

19

Analytical approach for the approximate solution of the gluon distribution function with respect to the GLR-MQ evolution equation at small-x

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In this paper we show that the singularity behavior of gluon distribution function at small-x can be controlled by the nonlinear corrections to the gluon distribution function with respect to GLR-MQ equations. For the gluon distribution the nonlinear effects are found to play an increasingly important role at x≤ 〖10〗ˆ(-3) and Qˆ2≤20 GeVˆ2, but rapidly vanish at higher values of x and Qˆ2. We compare our results with H1 and ZEUS data and with the global QCD fits viz. MSTW2008, CT10. Our results show that nonlinear gluon distribution function increases as x decreases which also corresponds with perturbative quantum chromodynamics (QCD) fit at small-x, but this behavior is tamed with respect to nonlinear terms at GLR-MQ equation.

20

Accretion dynamics in SdS space

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Active galactic nuclei (AGN), as the unifying scheme to explain various exotic objects like Seyfert galaxies, Quasars, Blazars etc, remain one of the centre of attraction in Astrophysics community for more than couple of decades. Generally a centrally located accreting supermassive (solar mass) black hole is thought to be playing the role of the gravitational powerhouse of gigantic scale in AGN. The accretion process for such a black hole has been studied and is being studied using general relativistic as well as post Newtonian scheme for various possible flow geometries with different equation of states of the accreted matter. For the sake of simplicity, hydro-dynamical inviscid flow

models are generally adopted to get an analytical estimate for those accretion process. At the same time, instead of rigorous general relativistic scheme, in post-Newtonian approach a suitably modified potential in Newtonian framework is chosen to approximate the motion of the matter within a region not too close to the event horizon. In our work, accretion process over a region far beyond the dimension of a single galaxy by a much more massive object (solar mass, a cluster of galaxies or a possible super-giant black hole) has been studied where the large scale feature of the space-time structure of the Universe may be relevant. In the non-rotating limit of the accreting black-hole with accelerated expansion of the Universe, Schwarzschild-de Sitter (SdS) space is chosen to be a suitable one. For a Schwarzschild space the most popular post-Newtonian prescription is Paczynski-Wiita potential. Pseudo-Newtonian potential describing the gravitational field of static and spherically symmetric black holes in the universe with a repulsive cosmological constant, i.e. for SdS space, has been recently introduced by Stuchlik and Kovar. Using this potential, here we have studied the phase topology of the flow and also formation of stationary shocks for transonic flows both in adiabatic and isothermal limits in accretion discs. In AGN, the existence of stationary shock is believed to be a plausible explanation of the extremely hot annular region there. In our study, in adiabatic (and in isothermal) cases, a significant region of parameter space spanned by specific angular momentum-specific enegy (specific angular momentum-flow temperature) allow shock formation and those regions shift in comparison with the same for Schwarzschild case due to the effect of cosmological constant in SdS space.

Summary:

The hydrodynamic accretion flow in SdS space has been studied in post-Newtonian approach for different disc models. The transonic flow characteristics and the shock characteristics are found to be appreciably dependent on the accretor mass and the value of the cosmological constant.

21

Development of Secular Instability in Different Disc Models of Black Hole Accretion

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Analytical treatment of black hole accretion generally presumes the stability of the stationary situation. Various authors in past decade actually demonstrated the validity of such an assumption at least for inviscid hydrodynamic flow. Though inviscid condition is an reasonable approximation for low angular momentum advection dominated flow in the case of certain AGN, consideration of a weak viscosity, may show more accurate results. But recently, some of the authors demonstrated that an introduction of slightest amount of viscosity in quasi-viscous form makes a stationary accretion disc (in vertical equilibrium model) unstable. We made the same sort of analysis in other disc models for quasi-viscous models under post-Newtonian scheme. We introduced perturbation on the stationary flow solution both in standing wave and travelling wave form and studied their time evolution to observe whether they grow with time. Our analysis shows that same sort of secular instability exists in other disc models too. We tried to estimate the time scale of the growth of the initial perturbation and length scale where it predominates. We further argued that with sufficiently low value of viscosity in the realistic Astrophysical perspective the instability does not effectively jeopardize the stationary condition.

Summary:

Quasi-viscous accretion flow in different disc geometries has been studied. Using pseudo-potential formalism, it is found that there exists a secular instability of the stationary flow solution for a weak viscosity however small. The effective length and time scale for real Astrophysical situation has been estimated.

22

Upsilon Production in Pb-Pb and p-Pb Collisions at Forward Rapidity with ALICE at the LHC

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The ALICE apparatus at the LHC was designed and built to perform dedicated studies of the Quark-Gluon Plasma (QGP), a strongly interacting phase of QCD matter, expected to be created in heavy-ion collisions, where quarks and gluons are deconfined. In such collisions heavy flavours are produced at the very early stage of the interaction by the initial hard scattering processes and hence can be used to characterize the hot and dense medium. In particular the sequential suppression of quarkonia (charmonia and bottomonia) was proposed as a thermometer of the deconfined medium. The inclusive $\Upsilon(1S)$ production has been measured down to zero transverse momentum in its dimuon decay channel at forward rapidity $(2.5 < y_{\rm lab} < 4.0)$ using the Muon Spectrometer. Here results on the $\Upsilon(1S)$ nuclear modification factor $(R_{\rm AA})$ in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV will be discussed and compared to the measurement at mid-rapidity by the CMS Collaboration and to theoretical predictions. Also recent results on $R_{\rm pPb}$ and forward-to-backward yield ratio $(R_{\rm FB})$ in p-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV will be discussed.

23

Thermodynamics of non-ideal quark gluon plasma using Mayer's cluster expansion method

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This work investigates the applicability of using the Mayer's cluster expansion method to derive the equation of state (EoS) of the quark gluon plasma. The possibility of the existence of quarkonium system after deconfinement at higher temperature than the critical temperature T >Tc is investigated. The EoS has been studied by using cornell potential with the effect of the screening term. It is compared with the theoretical and lattice results and has been done for different number of flavors, nf = 0, 2, 3. The EoS has been studied by calculating second and third cluster integrals using Mathematica program.

Summary:

The main advantage of above mentioned method is that we can apply the classical particle picture to the quarks and investigate phase transitions in a QGP. The initial non-ideal gas (the plasma) has been phase transformed to an ideal gas of droplets (two and three particle droplets), where the latter can be considered as a fluid in the sense of gas dynamic theory. This is the mechanism we applied here. The equation of state found here shows the occurrence of heavy quarkonium at Tc = 150 − 200M eV.

24

Deconfined Quark matter EoS using Quasiparticle model with out reformulation of Statistical mechanics.

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The equation of sate for quark matter is important for quark star research, but very difficult to obtain one such from the first principle calculation of QCD. Therefore a common approach is to use phenomenological models to obtain the equation of state. Here we study the statistical mechanics and thermodynamics of quark matter at zero temperature and finite chemical potential using a thermodynamically consistent frame work of the quasiparticle model for QGP without the need of any reformulation of statistical mechanics or the thermodynamic consistency relation by following the standard statistical mechanics. The quarks are considered as quasiparticles which acquire an effective mass generated by the interaction with the other quarks of the dense system. This leads to a thermodynamic selfconsistent description of quark matter as an ideal Fermi gas of quasiparticles.

Summary:

Studied the statistical mechanics and thermodynamics of quark matter
at zero temperature and finite density using quasiparticle model.
The obtained equation of state is used to study mass-radius relation of
quarkstar.

25

Beam Energy dependence of Kshort & lambda production in STAR: A model study

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We report Kshort & lambda production from 7.7GeV to 39GeV center of mass energy in Au+Au collision using AMPT model. Invariant mass of these two particles was reconstructed using like-sign method. Their transverse momentum spectra, and elliptic flow were measured using 100k events.

26

Modified surface tension of a QGP-droplet under one loop correction in Peshier potential

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Under one loop correction in Peshier potential surface tension of a Quark Gluon Plasma (QGP)droplet has been recomputed. The correction implies the decrease in the stable size of a QGP droplet. The value of surface tension is also getting matched with the current lattice result.

27

Baryon Anti-Baryon Segregation in the Early Universe due to Spontanoues CP Violation from QCD Z(3) Domains

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We investigate the possibility of segregation of baryons and anti-baryons in the quark-gluon plasma phase of the early universe due to spontaneous CP violation in scattering of quarks and anti-quarks from moving Z(3) domain walls. CP violation here is spontaneous in nature and arises from the nontrivial profile of the background gauge field (A0) between different Z(3) vacua. We calculate the spatial variation of A0 across the Z(3) interface from the profile of the Polyakov loop (L(x)) for the Z(3) interface and determine the reflection of quarks and anti-quarks using the Dirac equation. Our results show that the reflection coefficients of quarks and anti-quarks can differ by a large amount. We discuss the implications of this CP violation in context of early universe and study the possibility of segregating quarks and anti-quarks from collapsing large Z(3) walls (which can arise in the context of certain low energy scale inflationary models).

28

Dependence of acoustic surface gravity on geometric configuration of matter for axisymmetric background flow in Schwarzschild metric

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In black hole evaporation process, the mass of the hole anti-correlates with the Hawking temperature enabling us to infer that the smaller mass holes will have higher surface gravity. For analogue Hawking effects, however, the acoustic surface gravity is determined by the local value of the dynamical velocity of the stationary background fluid flow and the speed of propagation of the characteristic perturbation embedded in the background fluid, as well as their space derivatives evaluated along the direction normal to the acoustic horizon, respectively. The mass of the analogue system - whether classical or quantum - does not directly contribute to extremise the value of the associated acoustic surface gravity. For general relativistic axisymmetric background fluid flow in the Schwarzschild metric, we show that the initial boundary conditions describing such axisymmetrically accreting matter flow influence the maximization scheme of the acoustic surface gravity as well as the corresponding characteristic temperature. Aforementioned background flow onto astrophysical black hole can assume three distinct geometric configurations. Identical set of initial boundary conditions can lead to entirely different phase space behaviour of the stationary flow solutions, as well as the salient features of the associated relativistic acoustic geometry. It is thus important to investigate how the acoustic surface gravity for the aforementioned classical analogue system gets influenced by the geometric configuration of the stationary axisymmetric matter flow described by various astrophysically relevant thermodynamic equations of state. Our work is useful to study the effect of gravity on the non-conventional classical features in Hawking like effect in a dispersive medium as is expected to be observed in the limit of a strong dispersion relation.

29

Exploring the QCD critical region in the QCD-like two flavor models

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We have calculated the phase diagram for exploring the critical behavior around the critical end-point (CEP) and located the chiral limit existence of the tri-critical point (TCP) in the μ and T plane of the Polyakov loop extended Quark Meson Model (PQM) and the pure Quark Meson (QM) model which become effective Quantum-chromodynamics (QCD) like models due to the augmentation of the effective potential by the renormalized fermionic vacuum one loop fluctuation. These models yield the second order transition at $\mu = 0$ on the temperature axis after incorporating the fermionic vacuum correction. The proximity of the TCP to the QCD critical end-point (CEP) has been quantified in the phase diagram. We have plotted the contours of appropriately normalized constant quark number susceptibility and scalar susceptibility around the CEP in different model scenarios. In order to investigate the qualitative as well as quantitative effect of the fermionic vacuum term and the Polyakov loop potential, on the critical behavior around CEP, we have compared the shape of these contours as obtained in different model calculations. Further, we have computed and compared the critical exponents resulting from the divergence of quark number susceptibility at the CEP in different model scenarios. The possible influence of the TCP on the critical behavior around CEP, has also been discussed. Finally, we plotted the temperature variation of the σ and π meson masses at $\mu = 0$, $\mu = \mu_{CEP}$ and $\mu > \mu_{CEP}$ in different model scenarios and compared the emerging mass degeneration trend in the σ and π meson mass variations as the chiral symmetry gets restored at higher temperatures.

30

Imaginary part of the medium modified heavy quark potential

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NOTE: The full version of this abstract contains equations that have been omitted.

The aim of the experiments at the Relativistic Heavy Ion Collider (RHIC) and in the Large Hadron Collider (LHC) is to perform ultra-relativistic heavy-ion collisions to produce and study the properties of Quark gluon plasma. The main probes considered so far are the jet quenching, the real or virtual photon spectra, the pT distribution of secondary hadrons, quarkonia etc. Heavy quarkonium systems have turned out to provide extremely useful probes for the deconfined matter because the force between a heavy quark and its anti-quark, is weakened due to the presence of light quarks and gluons and leads to the dissociation of quarkonium bound states [1]. Based on potential models there were early predictions that J/ψ production would be suppressed in heavy ion collisions. Among the recent theoretical developments in the quarkonium studies, the first-principle calculations of imaginary contributions to the heavy quark potential due to gluonic Landau damping [2], the additional contribution due to singlet to octet transitions etc. [3] are well known. The imaginary part of the potential are generically related to the quarkonium decay processes in the plasma whose consequences on spectral functions [4], thermal widths [2] etc. have recently been studied. As the anisotropic distribution is a more realistic description of the parton system generated in heavy-ion collisions, it is worthwhile to consider the properties of quarkonia such as the binding energy, decay width and hence the dissociation in such a system. So far we have studied the real part of the potential [5] in the presence of small momentum anisotropy by considering both perturbative as well as the non-perturbative part of the vacuum potential. The imaginary part was calculated earlier by considering only the short-distance part of the vacuum potential, assuming the long-distance part vanishes beyond Tc . But the non-perturbative effect such as the string tension is found to survive till very higher temperatures [6], so we retain the effect of long-distance part in deriving the imaginary

part, contrary to others calculation [7] for short distance part. In our work we use the real-time formalism [7] to determine the imaginary part of the potential in the anisotropic medium. Imaginary part can be calculated by using the symmetric propagator. So we first obtain the gluon self-energy by using the phase-space distribution in anisotropic medium and hence the resummed propagator to calculate the imaginary part of the potential. Medium-modification at finite temperature can be obtained by correcting both the short- and long-distance part of the potential (T=0) with a dielectric function encoding the effect of deconfinement [8]. Imaginary part of the heavy quark potential is found to be perturbation to the vacuum potential and thus provides an estimate for the decay width for a particular resonance state. The effects of anisotropy on the imaginary part of the potential and its effects on the quarkonium dissociation is being investigated further in our work.

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31

Rapidity dependence of the produced particles at FAIR energies

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The variation of width of the rapidity distribution on beam rapidity and the rapidity distribution of strangeness enhancement factor have been studied for a number of mesons and baryons with UrQMD-3.3p1 generated events at various FAIR energies. The results on the width of the rapidity distribution on beam rapidity, thus obtained with our UrQMD generated events, have been compared with the existing experimental data (E877, E891, E896, NA49). For both experimental and UrQMD data, the width of the rapidity distribution is found to bear a power law with beam rapidity for all the studied hadrons. Such power law behavior follows a mass ordering separately for mesons and baryons which is observed to be violated at Λ baryon if the studied hadrons are taken together. From the study of variation of strangeness enhancement factor E_S with rapidity, two distinct patterns could be seen for the studied mesons and baryons.

32

Nuclear suppression of muons at forward rapidity at relativistic heavy ion collisions

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Heavy quarks produced in the initial stage of heavy ion collisions would traverse the quark gluon plasma, colliding with quarks and gluons and radiating gluons. In the process of collision with the quarks and gluons and also by radiation of gluons they lose energy. After their production, they may get fragmented into heavy mesons by picking up light quarks/antiquarks and in turn may decay through leptonic channels. These leptons would carry information of the initial stage of heavy ion collisions and also the evolution of the plasma. In this work, we have made a detailed study for the nuclear modification factor of production of leptons from the initial fusion of partons in a nuclear collision at RHIC and LHC energies. The pT distribution of heavy quarks produced from the initial fusion of partons in nucleus-nucleus collisions at RHIC and LHC energies is obtained by FONLL program. We consider both the radiative and collision energy loss along with longitudinal expansion of the plasma for the prediction of nuclear modification factor. Peterson fragmentation function is used for fragmentation of heavy quarks into D-mesons. We compare our result of muon RAA for Pb+Pb collisions at 2.76 ATeV with the ALICE data. Our prediction is found to agree well with the experimental data.

33

Gluon Bremsstrahlung Off Charm Quark & Charm Quark Equilibrium Distribution Function

Author: Surasree Mazumder[1]

[1] *Variable Energy Cyclotron Centre*

The effect of soft gluon bremsstrahlung off the charm quark on different transport coefficients like drag, transverse and longitudinal diffusion of charm has been observed while it is propagating inside Quark Gluon Plasma. The elastic collision of charm with the medium particles and the gluon radiation are seen to contribute in comparable magnitudes while evaluating of the transport coefficients. However, it is noticed that the ultimate shape of the charm quark distribution function after it has come to equilibrium remains more or less unaffected by the radiation of charm. We also observe that the shear viscosity to entropy ratio of the quark gluon plasma (QGP) is closer to the experimentally extracted value when the gluon radiation by the charm quark is included.

34

FAIRy tale of charmonium

Author: Purnendu Chakraborty[1]

[1] *Variable Energy Cyclotron Center*

We calculate the spectral function and bound state properties of charmonium states in a hot and dense plasma using phenomenological potential models augmented by inputs from perturbative QCD. The temperature and density region that we focus on will be relevant for future heavy ion collision experiments at FAIR.

35

Exploring nuclear matter at neutron star core densities

Author: Peter Senger[1]

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Substantial experimental and theoretical efforts worldwide are devoted to explore the phase diagram of strongly interacting matter. At top RHIC and LHC energies, the QCD phase diagram is studied at very high temperatures and very low net-baryon densities. These conditions presumably existed in the early universe about a microsecond after the big bang. For larger net-baryon densities and lower temperatures, it is expected that the QCD phase diagram exhibits a rich structure such as a critical point, a first order phase transition between hadronic and partonic matter, or new phases

like quarkyonic matter. The experimental discovery of these prominent landmarks of the QCD phase diagram would be a major breakthrough in our understanding of the properties of nuclear matter. The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt. The goal of the CBM research program is to explore the QCD phase diagram in the region of high baryon densities using high-energy nucleus-nucleus collisions. This includes the study of the equation-of-state of nuclear matter at neutron star core densities, and the search for the deconfinement and chiral phase transitions. The CBM detector is designed to measure rare diagnostic probes such as multi-strange hyperons, charmed particles and vector mesons decaying into lepton pairs with unprecedented precision and statistics. Most of these particles will be studied for the first time in the FAIR energy range. In order to achieve the required precision, the measurements will be performed at very high reaction rates of 1 to 10MHz. This requires very fast and radiation hard detectors, and a novel data read-out and analysis concept based on free streaming front-end electronics and a high-performance computing cluster for online event selection. The layout, the physics performance, and the status of the proposed CBM experimental facility will be discussed.

36

Equation of State in Dense Matter and Neutron Star

Author: Tetsuo Hatsuda[1]

[1] *RIKEN, Japan*

We discuss the equation of state of dense matter from the point of view of the hadron-quark crossover. Its implication to the recently found massive neutron stars is also discussed.

37

UA(1) breaking effects and eta'at finite temperature

Author: Su Houng Lee[1]

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We first discuss about the how chiral symmetry and UA(1) breaking effects are related and reflected in correlator. Then, using these relations and the the Witten Veneziano formula at finite temperature, we discuss the eta'properties at finite temperature.

38

Heavy Quarks in the Quark-Gluon Plasma: Boltzmann vs Langevin dynamics

Author: Vincenzo Greco[1]

[1] *University of Catania*

The propagation of heavy flavour through the quark gluon plasma has been treated commonly within the framework of Langevin dynamics, i.e. assuming the heavy flavour momentum transfer is much smaller than the light one. On the other hand a similar suppression factor, R_AA, has been observed experimentally for light and heavy flavor. We present a thorough study of the thermalization dynamics and of the approximations involved by Langevin equation by mean of a direct comparison with the full collisional integral within the framework of Boltzmann transport equation. The nuclear suppression factor, R_{AA} and the elliptic flow v_2^{HF} of the charm and bottom quarks have been evaluated at RHIC and LHC energies within both the Langevin and Boltzmann approach. We have compared the results obtained in both approaches which can differ substantially leading to quite different values extracted for the the heavy quark diffusion coefficient.

39

De-confinement and the clustering of color sources

Author: Brijesh Srivastava[1]

[1] *Purdue University*

Possible phase transition of strongly interacting matter from hadron toa quark-gluon plasma state have in the past received considerable interest. It has been suggested that this problem might be treated by percolation theory. The clustering of color sources with percolation (CSPM) is used to determine the equation of state (EOS) and the transport coefficient of the Quark-Gluon Plasma (QGP) produced in central A-A collisions at RHIC and LHC energies.

40

Describing extreme matter using perturbative QCD - A status report

Author: Mike Strickland[1]

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Shortly after the emergence of RHIC data on heavy ion collisions, there was a backlash against the application of perturbative QCD to heavy ion collisions. This was based on the purported inability of pQCD to properly account for the QCD equation of state, the short thermalization time of the QGP, the smallness of the shear viscosity to entropy density ratio, and the quenching of high energy jets. In the interim some of these issues have been resolved by more detailed consideration of the pQCD processes at play or have been revealed to be "straw men". In this talk I will review the status of pQCD applications to heavy ion collisions and discuss what issues have been resolved (or partially resolved) and what open issues remain. Finally, I will speculate about how the remaining open issues might be resolved in the future.

41

What have we learned from angular correlation studies in p–Pb collisions?

Author: Panos Christakoglou[1]

[1] *NIKHEF, Netherlands*

Angular correlations have been used extensively in heavy–ion collisions to probe the transport properties of the system. Similar studies in p–Pb collisions have recently revealed intriguing features, surprisingly similar to the heavy-ion results. In this talk, I will review the latest results from the analysis of the p–Pb run of 2013 on charged and identified particle correlations obtained with the ALICE detector at the LHC, and I will discuss their implications.

42

Overview of quarkonia measurements in pPb and PbPb collisions with

Author: Prashant Shukla[1]

[1] *BARC, Mumbai*

In this talk results from CMS measurements of quarkonia in pPb and PbPb collisions will be presented. CMS has excellent muon detection capabilities which has resulted in a wealth of results on quarkonia (both charmonia as well as bottomonia) measured in dimuon channel. The good mass resolution in dimuon channels allows precise measurement of all three Upsilon states and their relative yields in pp, pPb as well as PbPb systems which have ability to quantify the properties of strongly interacting matter. In the charmonia sector, measurements of relative yields of J/psi, psi(2S) are equally useful. In addition excellent vertex capability of CMS enables measurement of B mesons via its decay to J/psi which are useful tool to verify energy loss mechanisms of heavy quarks in medium. A detailed overview of all these measurements will be given. How the absolute and relative yields of different charmonia and bottomonia states are modified in heavy ion collisions will be discussed. The results will be compared with other experiments at RHIC and LHC and with theory wherever available.

43

Exploring the Phase Diagram of QCD Matter with the RHIC Beam Energy Scan

Author: Daniel Cebra[1]

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Collisions between relativistic heavy-ions (gold or lead) are energetic enough to vaporize the participating neutrons and protons creating an equilibrated plasma of quarks and gluons. This plasma is thought to be similar to the state of the universe about one microsecond after the big bang. The existence of this deconfined partonic phase has been well established an the top energies available at the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC). However, this plasma is a new and complicated phase of matter; the nature of the force between objects operating under the color force is quite different from those interacting through the electromagnetic force, which has driven our understanding of what it means to be 'matter' or to be a 'phase of matter'. Although we have made progress in understanding the nature of hot dense nuclear matter, there are still important open questions about how the matter undergoes the transition between a quark-gluon plasma and a hot hadronic gas. If the plasma has an equal mix of quarks and anti-quarks, lattice QCD calculations now tell us that there will be a crossover transition. However, in heavy-ion collisions, we create systems with an excess of quarks, and under these circumstances we expect a first order phase transition, the termination will be a critical point. In 2010 and 2011, RHIC performed a scan of several beam energies in order to map the QCD matter phase diagram. This talk will report on the conclusions drawn from that program and outline what remains to be done.

44

Perturbative QCD at nonzero temperature and density : Recent developments

Author: Purnendu Chakraborty[1]

[1] *VECC, Kolkata*

Perturbative QCD at nonzero temperature and density : Recent developments.

45

Hadrons and multi-hadrons from lattice QCD

Author: Nilmani Mathur[1]

[1] *TIFR, Mumbai*

Lattice QCD is a first principle non-perturbative method to study the theory of strong interaction with controlled systematic. Using lattice QCD energy spectra of many hadronic states can be obtained precisely. Moreover prediction from lattice QCD can led to experimental discovery of many other hadronic and multi-hadronic states. Recent results on hadron and multi-hadrons from lattice QCD will be presented.

46

The equation of state at finite chemical potential.

Author: Sourendu Gupta[1]

[1] *TIFR, Mumbai*

I will show results on the equation of state and preliminary studies of the critical exponents in QCD at finite chemical potential.

47

The Multiple Facets of Correlation Functions.

Author: Claude Pruneau[1]

[1] *Wayne State University*

I will review studies of fluctuations and correlations carried out over the last 20 years and hopefully provide some insights for new measurements.

48

Matter at Extreme Conditions : From RHIC to LHC

49

Heavy Ion Collisions : Experimental Overview

50

Long Range Correlations

51

Exploring the Phase Diagram of QCD Matter with the RHIC Beam Energy Scan

52

Theory - Summary

53

Experiment - Summary