IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Volume 6, PP 48-51

Concise View At The Super-Dense Plasma State

Abhilasha Saini[1], Dr. Sudhir Bhardwaj[2], Dr.O.S.Lamba[3] , Dr.P.N.Nemade[4]

[1]*(Department of Applied Sciences, Assistant Professor, Atharva College of Engg.Mumbai, Research Scholar, Suresh Gyan Vihar University, Jaipur, India)*
[2]*(Department of Physics ,Assistant Professor, Govt. College of Engineering & Technology, Bikaner, India)*
[3]*(Department of Electronics &Communication Engg. Professor, Suresh Gyan Vihar University, Jaipur, India)*
[4]*(Department of Applied Sciences, Professor,Atharva College of Engg.Mumbai*

Abstract: *The vital intent of the physics behind the relativistic bulky-ion encounters is to unlock the inherent attributes of the completely novel phase of vigorously interacting nuclear stuff, commonly denominated as the quark-gluon plasma [1]. For the purpose of attaining this goal, one entails the authentic signals for the creation of such a phase or stage. This probe attempts to detain indispensable proposals also the ongoing stature of the abstract studies made for the most encouraging quark-gluon plasma indicators. These propounded quark-gluon plasma signatures can be studied in conformity with the physical traits of super-dense hadronic stuff to which they are sentient of. Here a perfunctory review of the contemporary depiction of the dynamical and constructional features of QGP phase, its erection and evolution is proffered. This certainly assists one for better assimilation about the very novel quark gluon state.*

Keywords: *Bulky ion collision , Quark-Gluon Plasma ,Hadronic stuff.*

I. Introduction

The investigations going on at Brookhaven also at CERN are delivering captivating affirmation of existence of snug and torrid plasma state during encounter of bulky ions in the ultra-relativistic energy environment, which is permeated through energy densities surplus to the value of 1 GeV/fm^3 [2]. The probing of rapidity dispensations of particle multiplicities and transverse energy also the diminution of charmonium yield, favors the occupancy of dense particle cloud approaching ahead with rapidity matching to the charmed quark duo and interact with it, culminated the above mentioned fact. This dense hadronic stage may contemplate as locally quasi-thermal phase, also the studies based on postulates signalizes toward the brisk approach to the local thermalization of nuclear stuff in encounter of bulky ions at relativistic energies by shooting the colliding energy up. Reckoning the thermalization time substructure on perturbative quantum chromo dynamics, on the parton model [3-5]also the contemporary non-perturbative review of lattice gauge theory [6] supply values lower to 0.5 fm/c for the magnitude of energy of bombardment (more than 100 GeV of individual nucleon in the CM framework). The equation of state of snug and super-dense hadronic stuff is a hitch also an elemental concern of QCD. Theory recommends the sensibility to support an elucidation of vigorously interacting nuclear stuff existing for energy densities higher to 1 GeV/fm^3 on a depiction unfolding with non-interacting hadrons. Moreover it seems to be more relevant to commence from the elemental fragments of hadrons, called quarks and gluons, as interactions of quarks and gluons get feebler at short extents. This perspective has been professed well by many physicists during the days prior to the QCD approach.

It is intricate due to the verity that the quantum chromo-dynamics super dense phase of plasma perpetuates crucially non-perturbative facets even for the elevated density conditions, since the collective modes (plasmons) are to be extant also the shielding of static colour-magnetic forces of extensive range in perturbation theory is missing. Yet the characteristics of hot plasma may be grouped in accordance to the orders of the coupling constant g of QCD($not\ \alpha_s = {g^2}/{4\pi}$), $g \ll 1$does not clench even at the maximal tenable energy magnitudes (g ≈ 0.5 at the Planck scale).

II. Composition Of The Super Dense Quark Gluon State

Basically the equation of state conjecture of the QGP phase from abstraction point of view is very straight forward, as it is precisely rooted on the rudimentary QCD Lagrangian

$$\mathcal{L}_{QCD} = \frac{1}{4}\sum_a F^a_{\mu\nu} F^{a\mu\nu} + \sum_{f=1}^{N_f} \bar{\psi}\left(i\gamma^\mu \partial_\mu - g\gamma^\mu A^a_\mu \frac{\lambda^a}{2} - m_f\right)\psi.$$

(1)

In the above expression the notation f signifies the variegated quark flavors u, d, s, c, etc, also the potency of non-linear agglutinate domain is specified as

$F^a_{\mu\upsilon} = \partial_\mu A^a_\upsilon - \partial_\upsilon A^a_\mu + g f_{abc} A^b_\mu A^c_\upsilon.$
(2)
As per the speculation of QCD there is a feeble interaction amidst the quark-quark for small separations (or high momenta Q^2), since the single-loop sequence for the gluon propagator supplies an ongoing coupling constant
$g^2(Q^2) = \frac{16\pi^2}{\left(11-\frac{2}{3}N_f\right)ln(Q^2/\Lambda^2)} \xrightarrow{Q^2\to\infty} 0$
(3)
Here N_f indicates the agile quark flavours count. Also the scale parameter of quantum chromo-dynamics Λ is ascertained fairly [2] to posses the magnitude Λ = 200 MeV. Adopting the supposition of adequately smaller interactions among quark and gluons for elevated energy values, one can easily utilize the thermal perturbation approach to gauge the energy density E, the pressure P of plasma phase for the temperature T and quark chemical potentialμ_f. If the quark masses are overlooked for the case of first-order perturbation theory, one can write the expression of the equation of state as
$\varepsilon = \left(1-\frac{15}{4\pi}\alpha_s\right)\frac{8\pi^2}{15}T^4 + N_f\left(1-\frac{50}{21\pi}\alpha_s\right)\frac{7\pi^2}{10}T^4 + \sum_f\left(1-\frac{2}{\pi}\alpha_s\right)\frac{3}{\pi^2}\mu_f^2\left(\pi^2T^2+\frac{1}{2}\mu_f^2\right) + B$
(4)
In the above equation the notation B represents the variation of the energy density estimates from the perturbative and the non-perturbative approach of QCD vacuum (named as the bag constant), The pressure is given by $P = \frac{1}{3}(\varepsilon - 4B)$; the entropy density is $s = \left(\frac{\partial T}{\partial P}\right)_\mu$. More precisely one perceives that the expression given in (4) should obligatory represents the equation of state for a gas containing mass-less particles with some rectifications because of the QCD trail peculiarity and perturbative interactions. These are inevitably negative, truncating the energy density value for a certain thermal condition by around a factor two when α_s = 0.5. This perturbative super-dense phase turns unsteady when the thermal condition drops lower to $T_c \approx 0.8B^{1/4} \approx 170MeV$(for $\mu = 0$), considering the standard values of the bag constant.

For better and authentic speculations regarding the transformation of phase, the most utilized technique available is achieving the culminations by numeric simulations of the quantum chromo-dynamics expression of state performed on a restricted disjunct volume in space-time, ordinarily alluded to as lattice gauge theory. In the perspective mentioned [7], one roughly enumerates for the partition function for a disjunct variant of the QCD Lagrangian (1) through implementation of Monte Carlo modus operandi. At the theoretical and conceptual level, this mode delineates the plasma state also the hadronic phase explicitly, yet realistically, the exactness substantially for low-lying thermal conditions is restrained by finite-size efficacies moreover due to supplemental technological issues. In such a thermal condition the numeric conclusions are rather very genuine, means, for the abstract gluon theory lacking the dynamical quarks, the estimations suggest an abrupt bounce in the energy density value for a destined temperature magnitude whereas the pressure advances more moderately. As the dynamical quarks count is taken into account, the depiction gets ambiguous due to two causes. First one is because of the enumerations implicated the fermion fields on the lattice are very long-winded and time taking, this tends to the low authenticity and less statistical significance of the numerical outcomes. Furthermore, the quark confinement explanation gets misty due to the existence of light quarks, as the colour flux tube amidst bulky quarks duo can rend by built up of a light-quark couple $Q\bar{Q} \to (Q\bar{q})(q\bar{Q})$. Like the extremely excited states in charmonium would rend into a D-mesons duo. Therefore in enumerations $q\bar{Q}$ potential is not advanced with inter-space linearly but functionally concealed.

A novel parameter is in existence there for mass-less dynamical quarks i.e. the quark-antiquark condensate in the vacuum$\langle 0|\bar{q}q|0\rangle$. For a value supposed to be other than zero, the chiral symmetry is wrecked impulsively which can be explained in the given manner: The scalar density of quarks possess the chiral perishing $\bar{q}q = \overline{q_L}q_R + \overline{q_R}q_L$, thus the quarks with chirality of oppugning kind is restrained by the split vacuum state. Hence for example if a sinistral quark can annihilate on a sinistral anti-quark inside the vacuum condensate, extricating its dextral associate. This mechanism is discerned as the modification of chirality of the independent quark that imparts precisely the effect similar to a non-dispersing quark mass. Nevertheless, in actual situation the light quarks u,d own the non-zero masses also their chirality is not at all absolutely sustained, yet to the case where the quark condensate disappears.

For the purpose of understanding one can therefore, observe for the instant alterations in the spacing for which the colour forces get concealed, else in quark condensate. If these are erratic, we handle with a transformation of phase or state, apart from this with perhaps a expeditious, yet steady modification in the structure of interior as it happens. This is well observed during the electromagnetic plasma conversion of an atomic gas. In fact the reorganization of phase transformation's character is convoluted due to the finite-size effects. The same consequences are observed in many published numeric data.

Screening of large-range colour forces:

The energy density of gluons is endowed to be IR region divergent in the succeeding order of the coupling constant. The concrete cause of the observed IR divergence is the evolution of effective mass due to gluon-quark degrees of freedom, which governs to conceal the large range colour-electric forces. Mechanically to get the concealing mass, a limitless string of single-loop lodgings in the gluon propagator is appended, and summation can be performed logically and supply an endowment to the gluon energy *of* order $\alpha_s^{3/2}$ having preferably a sizable value of coefficient [8]. One acquires a supplementary acuity into the attributes of the interplaying quark-gluon super-dense phase by contemplating the gluon propagator$D_{\mu\upsilon}(k)$. As per the gauge invariance, $k^\mu D_{\mu\upsilon}(k)$=0, also its is fragmented into the its longitudinal and transverse segments, and these are scalar concomitants of the inconstant $\omega = k^0$ and $k = |k|$. They can be communicated in a most expedient manner

$$D_L(\omega, k) = \frac{1}{\varepsilon_L(\omega,k)k^2}$$

(5)

$$D_T(\omega, k) = \frac{1}{\varepsilon_T(\omega,k)\omega^2 - k^2}$$

(6)

Here the colour-dielectric inconstant are expressed as[9]:

$$\varepsilon_L(\omega, k) = 1 + \frac{g^2T^2}{k^2}\left[1 - \frac{\omega}{2k} ln\left(\frac{\omega+k}{\omega-k}\right)\right]$$

(7)

$$\varepsilon_T(\omega, k) = 1 - \frac{g^2T^2}{2\omega^2}\left[1 - \left(1 - \frac{k^2}{\omega^2}\right)\frac{\omega}{2k} ln\left(\frac{\omega+k}{\omega-k}\right)\right].$$

(8)

The above mentioned equations implicate that steady longitudinal colour arenas are concealed

$$D_L(0, k) = \frac{1}{\varepsilon_L(0,k)k^2} = \frac{1}{k^2+g^2T^2}.$$

(9)

The Debye length evidently is expressed by $\lambda_D = (gT)^{-1}$. On the contrary the expressions (5) to (8) manifest that steady transverse (magnetic) colour arenas endure unshielded at this extent of guesstimate [10].

The steady magnetic shielding length is of eminent order in the coupling constant; it is been well exhibited through the lattice gauge calculations [11] also by methodical reviews[12] that $\lambda_M^{-1} = Cg^2T$ with C≈0.31 for SU(3) gauge supposition.

In the case of a given determinate frequency ω the in-medium propagators (5), (6) hold poles commensurate to proliferating collaborative modus operandi of the glue arena. The dispersion interconnection for the longitudinal practice:

$$\varepsilon_L(\omega, k) = 0$$

(10)

This is specified as plasmons and doesn't have any complementary part to the exterior of the medium. The cognate correlation for the transverse approach:

$$\varepsilon_T(\omega, k) = k^2/\omega^2$$

(11)

This delineates the medium's efficacy on the unbound and self directing gluons. Also the comportment of the two practices is exceptionally alike. For the condition$k \to 0$, an effectual Plasmon mass is supplied by the two modes.

$$\omega_L, \omega_T \xrightarrow{k\to 0} m_g^* = \frac{1}{\sqrt{3}gT}$$

(12)

Yet for the case of substantial mometa magnitudes (k→ ∞), we perceive

$$\omega_L(k) \to k \qquad \omega_T(k) \to \sqrt{k^2 + \frac{1}{2}g^2T^2}$$

(13)

For the purpose of creating plasma ambiences reasonably feasible in nuclear impacts (T≈300MeV, $\alpha_s \approx 0.3$) the efficacious value of mass of gluon m_g^*possesses the order of the temperature itself. On the basis of this fact one can establish the concept, that the perception of nearly self-ruling quarks and gluons during the inflated-temperature context of quantum chromo-dynamics is entirely faraway from the actual veracity.

Depiction of upshots of mentioned corollaries:
(i) Over the super-dense plasma condition, the potential amidst static colour charge duo, like two bulky quarks, is concealed. From the result of estimating the Fourier transformation of the expression (9) provides the potential term as

$$V_{Q\bar{Q}}(r) \approx \frac{1}{r} e^{-r/\lambda_D}$$
(14)

having the screening distance $\lambda_D \approx 0.4\, fm$ for the thermal condition T$\approx 250\, MeV$. The fact behind the concealment of extended ranged colour forces in the snug dense phase is, definitely the process of de-confinement of quark.
(ii) The colour screening or concealing mechanism for sizable extents restores the majority of IR divergences in smattering exercises amidst quarks and gluons. A self-compatible contrivance carrying out this technique mechanism is been contrived by Braaten and Pisarski [13]. The methodology implies the re-addition of gluon kinks incorporating gluons having the momenta of the order of gT and found to obey gauge invariance by considering the vertex rectifications.
(iii) The determinate effectual mass of gluon mass m_g^* heads to the subduing of large-wavelength gluon vogues accompanied $k < gT$ within the plasma phase. Consequently, the pressure is turned down. Thus one has dual methodologies which are accountable for $P < \frac{1}{3}\varepsilon$: the effectual mass of gluon m_g^* also the non-dissipating vacuum energy B.

III. Summary

From the conceptual deliberation presented here we expect the diminution of long-wavelength vogues within the dense plasma state occurs to be somewhat competently entrenched. This depiction justifies that their count is straightforwardly repressed collaborative mass of the coloured plasmons. On the contrary the strong depletion of the lower momentum vogues within plasma phase because of the bunching into colour-singlet quasi-particles (leftovers of hadronic phase for temperature overT_c) is been surmised. Emphatically, gauge enumerations on lattice supply the affirmation of persistence of colour-singlet clutches at high thermal conditions regardless of colour screening. Various indicators are anticipated to be much sensitized to the microscopic formation of the super-dense plasma at low momentum spectra, like the creation of multi-strange baryons or may be the lepton couples of lower-mass values. The more appropriate cognizance of plasma's long-range compositions and elucidation of the suitable lattice-QCD outcomes is thus of cardinal paramount importance.

References

[1] For an introduction to lhis field. *see* e.g., MiIller B 1985 *The Physics nf the Quark-Glunn Plnsma (Lecture* McLenan L 1986 *Rev. Mod. Phy. 58* 1021; 1991 *Quark-Glunn Plasma* ed R C Hwa (Singapore: World scientific)
[2] Stachel J and Young G R 1992 *Ann. Ret,. Nucl Pan. Sci. 42* 537
[3] Shuryak E 1992 *Phys. Rev. Lett. 68 3270*
[4] Geiger K 1992 *Phys, Re*.* D 46 4965,4986; *Phys. Rep*
[5] Bid T S, van Doom *E,* Miiller B, *Thoma* M H and *X N* Wang I993 *Phys. Rev.* C 48 1275
[6] Bir6 T *S.* Gong C, Muller B and Trayanov A 1994 *Int J. Mod. Phys. C 5* 113.
[7] Creutz M 1983 *Quarks,* Gluons *and Lattices* (Cambridge: Cambridge University Press)
[8] Kapusta J I 1979 Nucl. *Phys.* B 148 461 Toimela T 1983 *Z. Phys.* C 17 365
[9] Silin V P 1960 *Sov. Phys.-JETP* 11 1136 Klimov V V 1982 Sov. *Phys.-JEW 55* 199 Weldon H A 1982 *Phys. Rev.* D *26* 1394
[10] Baym G and Chin *S* A 1976 Nucl. *Phys.* A 262 527
[11] Billoire A, Lazarides G and Shali Q 1981 *Phys. Len.* 1038 450 DeGrand T A and Toussaint D 1982 *Phys.* Rev. D *25* 526 Lazarides G and Sarantakos *S* 1985 *Phys. Rev.* D 31 389
[12] Bir6 T S and Miller B 1993 Nucl, *Phys.* A 561 477
[13] Pisarski *R* D 1989 *Phys, Rev.* Lett. *63* I129 Braaten E and Pisarski R D 1990 *Phys.* Rev. D 42 2156