Study of Magnetic Field in Early Universe Expansion of Quark Gluon Plasma

Y. Kumar[1],* R. Rani[1], T. bhalla[2], P. Jain[3], P. Bangotra[4], V. Kumar[5], M. P. Gupta[6], and R. Rai[6]
[1]*Department of Physics, Hansraj College, University of Delhi, Delhi, India*
[2]*Department of Physics and Astrophysics, University of Delhi, Delhi, India*
[3]*Department of Physics, Sri Aurobindo College, University of Delhi, Malviya Nagar, New Delhi-110017, India*
[4]*Department of Physics, Netaji Subhas University of Technology, Dwarka, Delhi, India*
[5]*Department of Physics, University of Lucknow, Lucknow-226007, U.P., India and*
[6]*Department of Physics, SRCASW, University of Delhi, Delhi, India*

Introduction

The equation of state (EoS) of quark gluon plasma (QGP) are rich sources of information in the study of quark-gluon plasma (QGP). Consequently, they have gained prominence among other QGP signatures [1, 2].

In the context of nucleus-nucleus collisions at RHIC and LHC, it is postulated that a colossal and intense magnetic field is generated [3, 4], exerting a significant influence on the properties of QGP. It is also believed that a huge magnetic field exists in the core of neutron star, strange quark matter, etc. This magnetic field, generated in heavy-ion collisions at RHIC and LHC, is oriented perpendicular to the collision plane. Its strength is estimated to be approximately 10^19 Gauss at RHIC and around 10^20 Gauss at LHC [5]. We have used a simple quasi-particle model [6] in which we consider a thermal dependent quark mass incorporporating the magnetic field.

In order to calculate the time evolution of thermodynamic paramter such as energy density ϵ, we tried to solve the time evolution equation, i.e. $\frac{d\epsilon}{dt}$ with the help of Friedmann equation [7] in the finite value of magnetic field created at RHIC and LHC. It is really interesting to see the effects of magnetic field on equation of state (EOS) of QGP in the early universe. Experiments at RHIC and LHC have not currently obtained an exact measure of this magnetic field. However, ongoing efforts persist in unraveling the intricacies of this complex system.

*Electronic address: yogesh.du81@gmail.com

Model Description

The quasi-particle model used widely in this sector where the effect of temperature on the quark mass have been discussed in the absence of magentic field. Uisng thermal quark mass, we consider the effect of a magnetic fields. We use thermal value of quark mass [8]:

$$m_q^2(T) = \gamma_q(g^2(p))T^2 \tag{1}$$

The free energy of quarks and gluon can be determine using Ref. [8, 9]:

$$F_j = \mp T g_j \int \rho_j(p) \ln(1 \pm e^{-\sqrt{[(m_q)^2+p^2+eB]}/T}) dp \tag{2}$$

All factors are explained in Ref. [8, 9]. We also have the interface free energy term used in Ref. [8, 9]:

$$F_{int} = \frac{1}{4}\gamma r^2 T^3 \tag{3}$$

Here r is taken as radius of QGP bubble.

$$\gamma = (\sqrt{2})\sqrt{\frac{1}{\gamma_g^2} + \frac{1}{\gamma_q^2}} \tag{4}$$

The total pressure is used as the sum of the individual pressure terms contributed by the total free energy term. It is defined as [10]:

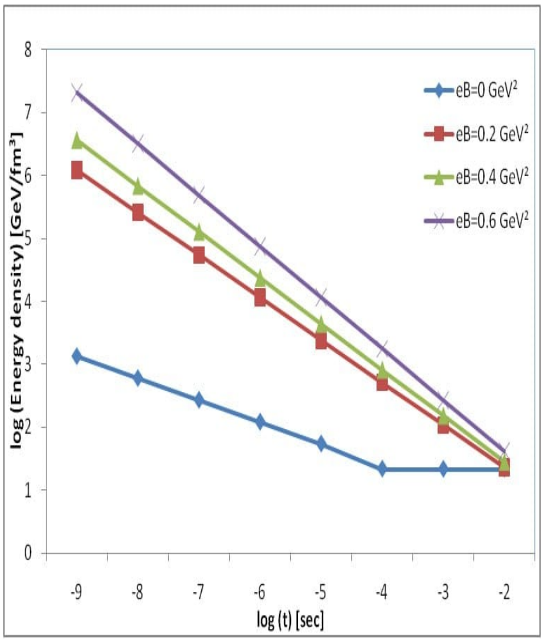

FIG. 1: Plot of energy density evolution in the presence of magnetic field.

$$P = -(\frac{dF_j}{dV}) \quad (5)$$

We further determine the energy density time evolution equation usning Friedmann equations as [11]:

$$\frac{d\epsilon}{dt} = -\sqrt{\frac{8\pi G}{3}}(3\sqrt{\varepsilon}(\varepsilon + P)) \quad (6)$$

Finally we compute the energy density with respect to time and explore the properties of early universe of QGP in the presence of magnetic field.

Results and Conclusion

Since a signigificant magnetic field produce at RHIC, LHC and star formation, we solved for the expressions of $\epsilon(t)$ in the presence of magnetic field and tried to analyze the QGP evolution in the early universe. The study is well motivated authors Sanches et al. [11] and Kumar [12] who studied the EoS of QGP in the early universe. The plot shows the energy density evolution with time where we observe that as we increase the value of magnetic field, energy density also increase up to 10^{-2} and afterwards it meets at one point. Also Energy density spectra decreases very rapidly for all values of magnetic field with respect to time and meets at one junction. The current analyses may be useful to look deep inside the QGP and provide some new insights at some finite values of magnetic field.

The more analyses is required to explain its property in the presence of magnetic field. Therefore, it's important to study the evolution of our universe at finite magnetic field. The future work may confirm these predictions clearly based on the fundamental probing techniques at RHIC and LHC. We should also acknowledge the relevance of these research work within the realm of astrophysics and other field of high energy physics. A deeper comprehension of QGP with magnetic field and its evolution can shed light on the initial conditions of the universe and explains the origin of our universe where intense and strong magnetic field exists.

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