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Electric and Hall Conductivity of Quark Gluon Plasma Using Running Coupling

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Abstract—*In this work we have studied the effect of running coupling constant on Electrical and Hall conductivity. We have Plotted the variation of Electrical and Hall conductivity with running coupling, it is found that on increasing running coupling the conductivity decreases. These transport properties of quark gluon plasma is calculated using the KUBO FORMULA, this formulation is also used to calculate the shear and bulk viscosity of quark gluon plasma.*

Keywords: *Quark Gluon Plasma, Electric Conductivity, Hall Conductivity, Shear Viscosity, Bulk Viscosity.*

1. INTRODUCTION

The quark gluon plasma (QGP) has been predicted by quantum chromodynamics by theoretical calculations, experimentally produced at RHIC and LHC by heavy ion collisions at high temperature. Many research groups has calculated electric and hall conductivity but they do not take into account strong magnetic fields[1-5]. In this work we have taken into account the influence of magnetic field on electrical and hall conductivity. We attempt to compute the relaxation time. Kinetic theory predicts that the relaxation time $\tau_{rel} = \frac{6\eta}{sT}$, the range of shear viscosity to entropy density of QGP is between $1/4\pi$ and $5/\pi$].Electric conductivity in the absence of magnetic field is given by $\sigma_0 = ne^2\tau_{rel}/3T$ [1-2].

The degree of influence of magnetic field on electric conductivity is dependent of cyclotron frequency $\omega_c = eB/\varepsilon$ of particles with low energy (i.e low temperature) are larger than those with higher energy, the effect of magnetic field on their electric conductivity is significant.

Kubo Formula for conductivity of Quark Gluon Plasma(QGP):

The electric and hall conductivity can be calculated using Kubo formula, it is also widely employed to calculate shear viscosity and bulk viscosity[6-8].Using the linear response approximation Kubo [9] has shown that conductivity tensor is related to a two-current correlation function. If we take the volume of the system unity, the conductivity tensor $\sigma_{\mu\nu}$ is given by $\sigma_{\mu\nu} = \int_0^\beta dt \int_0^\beta < J_\nu(-i\hbar\lambda) J_\mu(t) d\lambda >$ $= \int_0^\infty \phi_{\mu\nu}(t)dt$

Where $\phi_{\mu\nu}(t)$ is the current response function and J_μ is the electric current.

Therefore for the classical gas, the electric and hall conductivity is given by the following expressions:

$$\sigma^{el} = \sum_i \frac{n_i e_i^2 \tau_{rel}}{m_i} \frac{1}{1 + (\omega_c \tau_{rel})^2}$$

$$\sigma^{H} = \sum_i \frac{n_i e_i^2 \tau_{rel}}{m_i} \frac{\omega_c \tau_{rel}}{1 + (\omega_c \tau_{rel})^2}$$

and for relativistic gas,

$$\sigma^{el} = \sum_i \frac{n_i e_i^2 \tau_{rel}}{3T} \frac{1}{1 + (\omega_c \tau_{rel})^2}$$

$$\sigma^{H} = \sum_i \frac{n_i e_i^2 \tau_{rel}}{3T} \frac{\omega_c \tau_{rel}}{1 + (\omega_c \tau_{rel})^2}$$

Where i=q,$\bar{q}$.The cyclotron frequency $\omega_c = \frac{eB}{m}$ for the non relativistic case and $\omega_c = \frac{eB}{\varepsilon}$ case, respectively. The relaxation time is given by the following expressions:

$$\tau_{rel} = \frac{3}{2\sum_i < n_i V_{rel} \sigma_{tot}^{ij} >}$$

Where $i = q, \bar{q}, g$ and $j = q, \bar{q}$.n_i is the particle density and for massless particles v_{rel}=1 holds.

The bulk and shear viscosity are given by the following relations:
$\zeta = \frac{1}{\alpha_s^2 \log(1/\alpha_s^2)}$ and $\eta = \frac{bT^3}{\alpha_s^2 \log(c/\alpha_s)}$

Where,

$$\alpha = \frac{12\pi}{(11N - 2N_f)\ln(M^2/\lambda^2)}$$

Here,

$$N_f(M) = \frac{1}{\ln(M^2/\lambda^2)} \sum_f \frac{M^2 + m_f^2(M)}{\lambda^2 + m_f^2(M)}$$

2. RESULTS AND DISCUSSION

In the present work, we have investigated the effect of magnetic field on the conductivity of QGP using Kubo formula. It is found that the presence of magnetic field leads to decrease of electrical conductivity is more significant, the hall conductivity decreases on increasing running coupling. The Physics behind the bulk viscosity is fascinating, due to the compression or rarefaction there occurs conformal symmetry breaking. Bulk viscosity depends on the size of the conformal symmetry violation, to find the departure of QCD Plasma from the equilibrium we must have to incorporate forward scattering corrections, collinear splitting processes and compton processes. By combing all this physics together we finds leading-log order bulk viscosity $\zeta \backsim \alpha_s^2 T^3/\log(1/\alpha_s)$. For shear viscosity the scalar field theory provides a successful toy model. In this work we have plotted variation of shear viscosity with running coupling and we see on increasing running coupling shear viscosity (η/T^3) decreases for $N_f = 0,1,2$ flavours and plotted bulk viscosity $\zeta\alpha^2 T/m_0^4$ with running coupling which also decreases on increasing temperature.

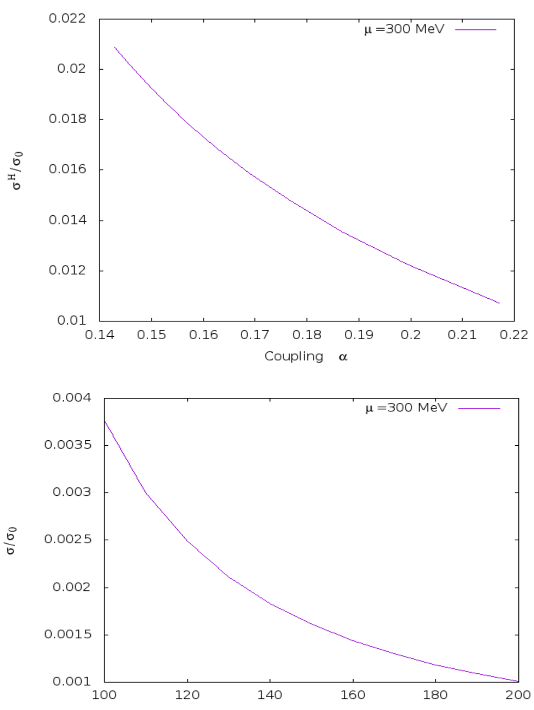

Fig. 1: Variation of Hall conductivity with running coupling, Electric Conductivity with temperature.

Therefore the variation of the transport coefficients with running coupling and temperature are given above. Transport phenomena in QGP has very interesting physics.

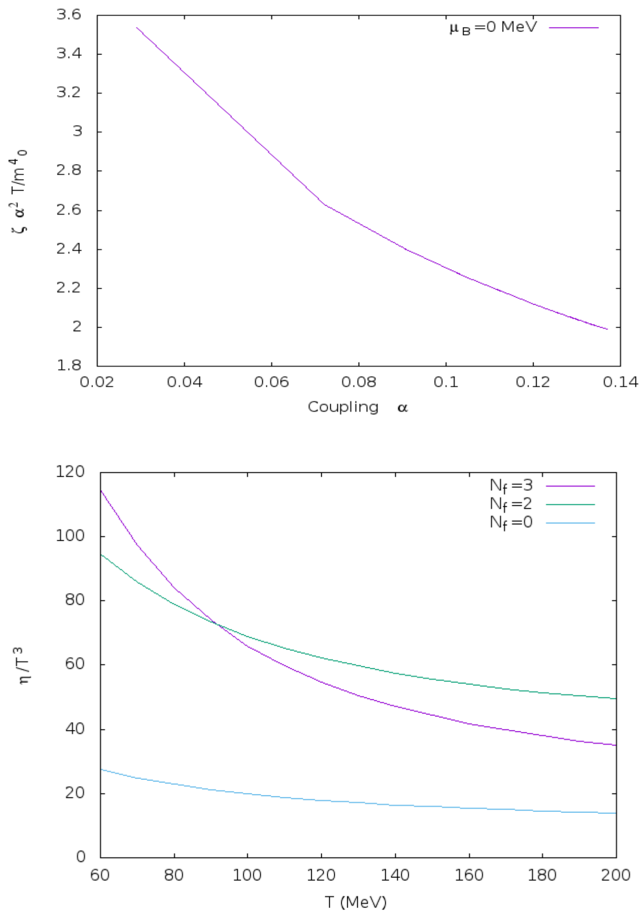

Fig. 2: Variation of Bulk Viscosity with running coupling, Shear Viscosity with temperature.

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