ABSTRACT

The realisation that the non-abelian gauge theory of the quark-gluon interaction weakening at short distances or asymptotic freedom suggests the existence of deconfined quarks and gluons at sufficiently high temperatures and/or densities. This results in the formation of a new state commonly termed Quark-Gluon-Plasma–(QGP), characterised by the presence of free colour charge. The experimental confirmation of QGP occurred in 2005 during Au+Au collisions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL).

The existence of the QGP a few microseconds after the Big Bang marks its physical importance in exploring this matter in highly controlled experimental setups. Previous findings of QGP suggest it to be a highly interacting fluid with extremely low shear viscosity to entropy density ratio thereby making it the most perfect fluid ever created. Further investigation of the QGP, its transport coefficients and thermodynamics and its evolution through various phases needed proper modelling. Fortunately, the time evolution of the QGP can be described by the laws of relativistic fluid dynamics, commonly termed relativistic Hydrodynamics.

QCD thermodynamics are well-established in the high-temperature regime through resummed perturbation theory and lattice calculations. However, transport properties remain elusive, particularly near the critical temperature. Coefficients such as shear (η) and bulk (ζ) viscosities have been calculated in the high-temperature regime using perturbation theory but results from lattice calculations in the phenomenologically relevant temperature regime are inconclusive due to large uncertainties. The non-perturbative regime of QCD on the other hand is strongly coupled due to long-range correlations that result in confinement of colour degrees of freedom. The Gribov-Zwanziger prescription offers an efficient approach to treating the infrared regime of QCD by improving the infrared dynamics of the Yang-Mills theory by treating the redundant gauge degrees of freedom which remain after Faddeev-Popov quantization, leading to an infrared-improved dispersion relation for gluons and introducing a new energy scale, the Gribov parameter γ_G, which can be fixed by, solving the gap equation or utilizing the lattice QCD equation of state.

Using the Gribov-Zwanziger (GZ) approach, we have studied several transport coeffi-

cients, which are discussed in this thesis. We have also matched our obtained results with the available lattice finding of the same and have observed some promising results in the temperature domain ($1 \leq T/T_c \leq 3$), in particular.

Using the GZ prescription, the momentum diffusion coefficient (κ) and the spatial diffusion coefficient (D_s) for quenched QCD have been explored, and quark effects have been incorporated in the perturbative limit. The final result has been compared with the lattice findings, along with leading order (LO) and next-to-leading order (NLO) perturbative findings. We observe a great improvement in comparison to the LO findings.

In the next study, we explore the transport properties of the QGP, focusing on bulk viscosity ζ and shear viscosity η at zero chemical potential. To describe the QGP, we use a quasiparticle model for quarks combined with the GZ approach for gluons, which captures the non-perturbative behaviour of the system. The Gribov parameter (γ_G) and the gluon dynamical mass (m_g) are determined by solving the one-loop gap equation in the $\overline{\text{MS}}$ renormalization scheme and consequently making use of lattice QCD (lQCD) data for the equation of state (EoS) of gluonic matter. The interaction between quarks and gluons is reflected in the quark quasi-mass (m_q), which we calculate using lattice data from (2+1)-flavour QCD. Our main goal is to study how these quasiparticle quarks affect the transport properties of the QGP. A systematic reduction in the scaled transport coefficients is observed as the temperature increases within the range $1 \leq T/T_c \leq 3.5$.

Additionally, the electrical conductivity (σ) is another transport coefficient. The non-zero value of the electrical conductivity signifies the linear response of the medium to the external electrical field, thereby generating the electrical charge current. We also have explored the quark flavour dependence of the electrical conductivity scaled with the medium temperature (T) and compared it with the available lattice data of the same, for each quark flavour. For this, we have considered the quasi masses of the quarks flavours running coupling as a free parameter fixed by utilising the lattice data of entropy density for (2+1) QCD.