Abstract

This thesis examines the quark-gluon plasma (QGP) through non-perturbative effective theories and kinetic theory approaches, focusing on transport properties, heavy quark dynamics, and collective behavior relevant to RHIC and LHC experiments. Using the effective matrix model of QCD, the first part evaluates shear and bulk viscosities of a pure glue plasma, revealing a minimum in η/s near the deconfinement temperature and a pronounced peak in ζ/s. These feature capture near-critical dynamics that lie beyond the reach of perturbation treatments. The second part applies the Gribov-Zwanziger formalism to heavy quarkonium physics. The modified gluon propagator leads to a stronger screening, reducing quarkonium stability. This framework is further used to study collisional energy loss of fast partons, where the infrared dynamics amplify the parton energy loss. The final component analyzes the heavy quark potential in an anisotropic and collisional QGP. Incorporating a Bhatnagar-Gross-Krook collision kernel shows that collisions significantly enhance the imaginary part of the potential, increasing quarkonium decay widths, however the real potential is hardly affected by collision. Together, these studies link the non-perturbative structure of QCD with experimentally measurable signatures in heavy-ion collisions.