Dual QCD Dynamics and Phase Structure of QCD

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Introduction

In view of the vital role of low energy non-perturbative sector of QCD in deciding the hadron dynamics and the potential importance of the topological structure of the non-Abelian gauge theories for exploring their inherent dual properties useful in understanding the non-perturbative dynamics, the present work deals with the study of some typical non-perturbative features of QCD in its dual version, explores the mechanism of color confinement, quark-hadron phase transition, associated critical parameters using flux-tube formulation, QGP formation alongwith analysis of the phase structure of QCD at high temperatures/densities and a dual magnetohydrodynamic description to study the dual magnetized plasma near QCD phase transition temperature in the context of dual QCD formulation.

Dual QCD Dynamics and Color Flux-Tube Structure in QCD

In order to explore the large scale structure and the non-trivial dynamics of QCD, a dual version of color gauge theory based on fibre bundle formulation, has been developed [1]-[3] by taking into account the magnetic symmetry as an additional isometry and the dynamical structure of the resulting gauge independent dual QCD formulation, its color flux tube dynamics and characterization of QCD vaccum at different hadronic scales with the characteristic behavior of associated flux tube structure have been investigated. Starting with the mathematical foundations of the dual QCD in principal fibre bundle form, the magnetic symmetry has been indroduced and shown to restrict the dynamical degrees of freedom by projecting out its Abelian part that determines the second homotopy which identifies the topological object as colored monopole in QCD. The dual dynamics between color isocharges (quarks) and topological charges (monopoles) has been shown to lead to a magnetically condensed state for QCD vacuum as a result of the dynamical breaking of magnetic symmetry. The field equations associated with the dual QCD Lagrangian and their asymptotic solution, has been shown to lead a precise flux tube structure to the QCD vacuum which has been analysed for the flux tube energy, characteristic mass scales and characterization of QCD vacuum in view of the running nature of strong coupling constant. A multi-flux tube representation of dual QCD vacuum has been shown to emerge in the physically realizable near-infrared region of QCD that characterizes their characteristic interacting behavior in its both type-I and II category.

Flux-Tube and Confined Fields in Dual QCD and QCD Phase Transition

Further, the study of the multi-flux tube structure of dual QCD vacuum has been analysed by deducting the critical parameters of confinement-deconfinement phase transition and analysing the color electric field for a multi-flux tube system in the full infrared sector of QCD [1]-[2]. The total energy of the color flux tube at different length scales, has been examined by taking it as a periodic system on a S^2-sphere which has been shown to lead to the strong confinement forces in QCD vacuum at large hadronic scales. Evaluation of the ratio of the factors associated with the small and large distances is shown to, lead to characterize the quark-hadron phase transition boundary and has been used to evaluate the associated phase transition parameters of critical radius and the critical color flux tube density which have been computed numerically also in the whole infrared sector of QCD. The energy profiles have also been presented and used to evaluate the critical parameters. The profiles of color electric field using flux quatization and energy balance conditions have been investigated in terms of 2d- and 3d- representation in full infrared sector of QCD that has been shown to lead to the color electric flux homogeneity with the possibility of

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QGP formation in near infrared region of QCD and its localization of color electric field. In low energy regime in the viscinity of the optimal coupling phase, the QCD vacuum has been shown to acquire its multi-flux tube structure where the the flux-tube interaction for their annihilation occurs because of their sufficiently high critical density for phase transition. Two possible QGP formation scenario as a result of flux tube annihilation and unification have also been discussed for pure gauge case as well as in the full QCD case.

Thermal Dynamics and Phase Structure of QCD

In view of the need of the analysis of QCD vacuum under extreme conditions, the behaviour of the QCD vacuum at finite temperature and finite bariochemical potential have been analysed for exploring its phase structure. Using the path integral formalism an high temperature expansion technique, the effective potential as a thermodynamic potential at finite temperature has been investigated and used to evaluate the thermalized version of monopole condensate and glueball masses which on their graphical representation exhibit a large reduction in their values at high temperature domain [2]. The analytical expression of QCD phase transition temperature has also been deduced and has been shown to be in a close agreement with the graphical presentation of thermalized glueball masses and monopole condensate.The thermal evolution of color electric field has also been presented with 2d and 3d- graphics for optimal and intermediate couplings and has been shown to lead the reduction in its amplitude with temperature which as a result demonstrate the weakening of confining forces during its thermal evolution and a smooth transition of hadronic system via a intermediory QGP phase to the deconfined phase. The consequences of field profiles in near T_c regime and subsequent plasma oscillations have also been discussed for the stability of color flux-tubes and their interaction by defining the thermal version of critical parameters. The thermodynamical description of the dual QCD vacuum has also been extended to the bag model description of hadrons and analysed for the QGP phase of hadronic matter. Using the grand canonical ensemble formulation, the equation of state has been constructed that has been shown to lead to critical parameters and critical point in the phase diagram for a QGP phase transition. For quark matter at finite baryon densities, profiles of various important parameters have shown to indicate a second order phase transition possibly reconciling into a rapid crossover

Dual Magnetohydrodynamics and Flux Tube Dynamics in QCD

In view of the need of the understanding of dynamics and stability of microscopic color flux-tubes at finite temperature near QCD transition region, the dual discription of magnetohydrodynamics is presented for defining the time evolution of color flux-tubes, life time at different hadronic scales in dual magnetized phase of QGP and its implications has been discussed. The dual diffusion equation with finite conductivity has been solved to determine the time-dependent color flux-tube radius. Further, by defining the total collision rate in dual magnetized phase of QCD, the associated conductivity has been solved for full infrared sector near QCD phase transition. Using the energy per unit length diffused durng the magnetic phase, the life time of color flux-tubes has been calculated at different hadronic length scales in full infrared sector. In view of the recent RHIC experiments, the production of ridge correlation has also been discussed. Further, in view of the very small life time of color flux-tubes observed with DMHD treatment in the dual magnetized phase of QGP, the limitations of semi classical description of DMHD has been shown to lead to open a new window to use the full quantum treatment for real physical description of QGP in the magnetized phase of QCD.

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