Color Glass Condensate and Glasma

Raktim Abir*
Department of Physics, Aligarh Muslim University, Aligarh - 202002, India.

In this talk we will review the Color Glass Condensate, an effective field theory of QCD at small-x and the physics of gluon saturation. This is essential to describe the gluon content of a saturated hadron or nucleus in high energy. Emphasis would be on its application to high energy heavy ion collisions. In particular we will discuss the Glasma phase, that precedes the formation of an equilibrated quark-gluon plasma in the heavy-ion collisions. We end this review by citing some recent theoretical developments.

1. Parton dynamics at small-x

A typical scattering event in any high energy collider experiment usually involves rapidly growing cascade of gluons. This is partly because high energy (and/or) high virtuality emitted gluons themselves emit further gluons. At high enough energy this cascade of gluons may occupy all the available final state phase space to such an extent that fusion of multiple gluons to single gluon begin to start. This could eventually develop a thermodynamical detailed balance with the multiple gluons produced from single gluon which leads to the origin of gluon saturation with a characteristic momentum scale Q_s. This is a dynamically generated and energy dependent scale below which stochastic (almost) independent multiple scattering approximations are no longer valid and highly correlated non-linear gluon interactions dominates the phase space. This gluon recombination also restores unitarity of the scattering S-matrix which will otherwise violated by an exponential growth of gluon multiplicity. Consequently this saturation of gluons also avoids possible violation of Froissart bound for the total scattering cross section through the power law growth of the Balistky-Fadin-Kuraev-Lipatov (BFKL) solution which encode energy evolution of the cross-section away from the non-linear region. Unitary corrections to the BFKL equation in the Regge kinematics were first studied by Balitsky within a Wilson line formalism and soon after by Kovchegov in the Mullers color dipole approach. The Balistky hierarchic chain formed by the Wilson line operators reduced to the closed form equation derived by Kovchegov in the large N_c limit. Integral kernel in the Balitsky-Kovchegov (BK) equation for both linear and non linear terms are identical and has a simple interpretation of splitting of one parent color dipole into two daughter dipoles - the Mueller dipole model. A lot of progress have been made since then in various aspects including solving the equation both analytically and numerically and extending the equation beyond its leading order accuracy. In this talk we will present our resent analytical results for the solution of Balitsky-Kovchegov (BK) equation [1].

2. Color Glass Condensate (CGC)

High energy scattering in QCD can be most conveniently addressed using the color dipole degrees of freedom by Mueller. In the study of high energy scattering of a projectile parton and a target nucleus the small-x evolution can be introduced either in the wave function of the projectile (the parton) or in the wave function of the target (the nucleus). The Balitsky-Kovchegov (BK) evolution equation / Balitsky hierarchy accomplishes the first while the other equivalent approach is realised by Jalilian-Marian - Iancu - McLerran - Weigert - Leonidov - Kovner (JIMWLK) evolution equation. In this context when estimating color averaged expectation value of certain operator one generally is in need of an appropriate weight function for the color field. In the Color Glass Condensate (CGC)

*Electronic address: raktim.ph@amu.ac.in

effective theory the spatial distribution of the color sources that produce classical color field inside the large targetnucleus is taken to be Gaussian. The JIMWLK formalism generalizes this Gaussian weight of classical gluon field to a rapidity-dependant weight functional $\mathcal{W}_Y$ which no longer remains Gaussian as it evolve across the energy or rapidity. Unlike McLerran - Venugopalan (MV) model where the weight function is Gaussian always, here the weight function has to be determined from the JIMWLK equation itself for evaluation at certain rapidity Y. All physical measurable quantities are expressed as gauge invariant operators build with the color field and corresponding expectation values are obtained after averaging over the stochastic color field [1–4].

In this talk we will review the Color Glass Condensate effective theory and the physics of gluon saturation at small-x. We also present some recent works from our group in the broad area of small-x and CGC.

References

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