Lattice study of the gluon and ghost propagators in Coulomb gauge QCD

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To understand the mechanism of color confinement is a challenging issue in particle and nuclear physics. Color confinement has two complementary aspects: (i) there is a long-range interaction which confines color charges, and (ii) the gluons which mediate the confining interaction are absent from the spectrum of physical states. It is difficult to incorporate these two features of confinement phenomenon into the infrared (IR) behavior of the gluon propagator in the covariant gauge since the former aspect requires the gluon propagator to have a strong IR singularity while the latter is accounted for by the vanishing gluon dressing function at zero momentum. By contrast, the Coulomb gauge allows the coexistence of the complementary aspects of confinement: (i) the instantaneous interaction is responsible for the confining force, and (ii) the transverse would-be physical gluon propagator is suppressed in the IR region.

Both the instantaneous interaction and the transverse gluon propagator are related to the Faddeev-Popov (F-P) ghost degree of freedom. The time-time component of the gluon propagator can be decomposed into the instantaneous part and the retarded part,

$$D_{44}(x-y) = V_c(\vec{x}-\vec{y})\delta(x_4-y_4) + P(x-y), \tag{1}$$

where V_c is called the instantaneous color-Coulomb potential and is given by

$$V_c(\vec{x}-\vec{y})\delta^{ab} = \left\langle \int d^3z (M^{-1}[A])^{ac}_{\vec{x},\vec{z}}(-\nabla^2_{\vec{z}})(M^{-1}[A])^{cb}_{\vec{z},\vec{y}} \right\rangle. \tag{2}$$

The color-Coulomb instantaneous interaction is mediated by time-like gluons. Since the color-Coulomb potential contains the ghost Greens function M^{-1} twice, it becomes a long-range confining potential if the ghost propagator diverges stronger than the free propagator in the IR limit. Furthermore, the analysis of the ghost Dyson-Schwinger equation has revealed that if the ghost dressing function diverges in the IR limit the transverse gluon propagator vanishes in the IR limit, which indicates the confinement of gluons [1]. Therefore, the F-P ghosts play a central role in the confinement mechanism in the Coulomb gauge.

We have calculated the ghost propagator and the equal-time transverse gluon propagator in the Coulomb gauge using quenched SU(3) lattice gauge simulations [2]. Our numerical simulation shows that the ghost dressing function diverges in the infrared limit, which leads to the confining feature of the color-Coulomb instantaneous interaction. We also found that the equal-time transverse gluon propagator shows a IR suppression. Our result implies that, in the Coulomb gauge, the confining force between color charges is provided by the instantaneous interaction which is mediated by the time-like gluons, and the spatial gluons are confined.

Our simulations were performed on SX-8(NEC) vector-parallel computer at the RCNP of Osaka University.

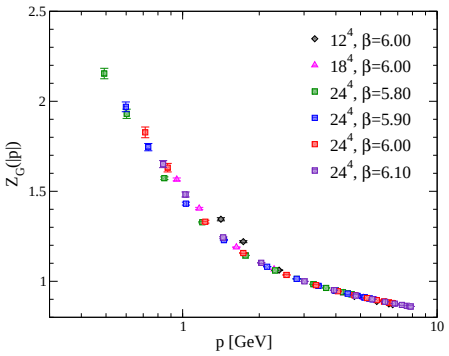

Figure 1: The ghost dressing function

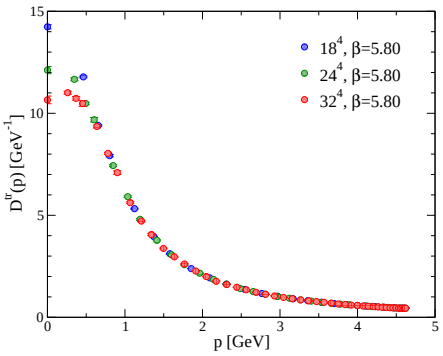

Figure 2: The transverse gluon propagator

References

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[2] Y. Nakagawa, A. Nakamura, T. Saito and H. Toki, PoS **LAT2007** (2007) 319.