Abelian dominance without gauge fixing in SU(2) gluodynamics

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Abelian mechanism of non-Abelian color confinement is observed in a gauge-independent way by high precision lattice Monte Carlo simulations in gluodynamics. An Abelian gauge field is extracted with no gauge-fixing. A static quark-antiquark potential derived from Abelian Polyakov loop correlators gives us the same string tension as the non-Abelian one. The Hodge decomposition of the Abelian Polyakov loop correlator to the regular photon and the singular monopole parts also reveals that only the monopole part is responsible for the string tension. Gauge independence of Abelian and monopole dominance strongly supports that the mechanism of non-Abelian color confinement is due to the Abelian dual Meissner effect [1][2].

Our simulation is performed on the $24^3 \times 4$ lattice at the coupling constant $\beta = 2.5$, where the lattice spacing is $a(\beta) = .191(8)$ [fm]. Since the expectation values of the Poliyakov loop correlation functions of Abelian, monopoles and photon are still very small with no gauge-fixing, we adopt a new noise reduction method. For a thermalized vacuum ensemble, we produce many gauge copies applying random gauge transformations, compute the operator for each copy, and take the average of all copies. Note that as long as a gauge-invariant operator is evaluated, such copies are identical, but they are not if a gauge-variant operator is evaluated. Practically, we prepare 1000 gauge copies for each configuration. We also apply one-step hypercubic blocking (HYP) to the temporal links for further noise reduction. We obtain very good signals for the Abelian, the monopole and the photon contributions to the static potential as shown in Fig. 1. We try to fit the potential in Fig. 1 to the function $V_{\rm fit} = c/R + \sigma R + \mu$ and extract the string tension and the Coulombic coefficient of each potential as summarized in Table 1. Abelian dominance is seen beautifully in this case. Moreover, we can see monopole dominance, namely, only the monopole part of the Polyakov loop correlator is responsible for the string tension. The photon part leads to no linear potential.

The numerical simulations of this work are done using SX5 at RCNP of Osaka University.

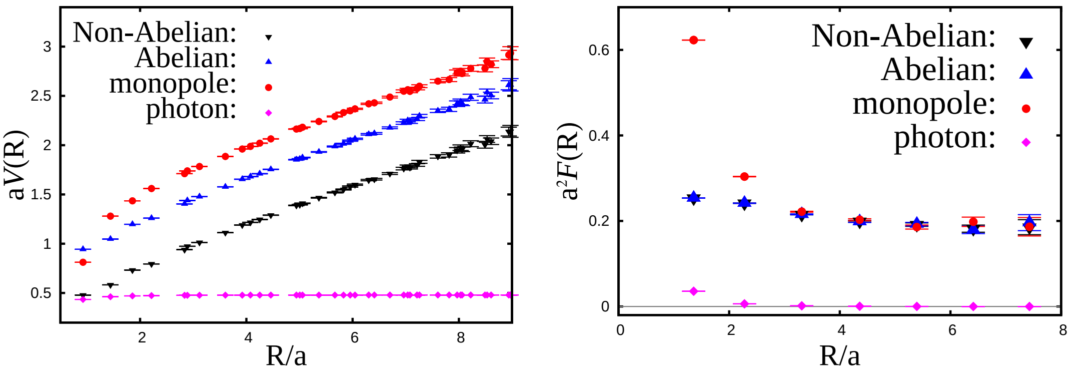

Figure 1: The Abelian, monopole and photon parts of the static potential (left) and the force (right) in comparison with the non-Abelian potential and the force, respectively.

	σa^2	c	μa	FR(R/a)	χ^2/N_{df}
Non-Abelian	0.181(8)	0.25(15)	0.54(7)	3.92 - 8.50	1.00
Abelian	0.183(8)	0.20(15)	0.98(7)	3.92 - 8.23	1.00
Monopole	0.183(6)	0.25(11)	1.31(5)	3.92 - 6.71	0.98
Photon	-0.0002(1)	0.010(1)	0.48(1)	4.94 - 9.44	1.02

Table 1: The string tension σ obtained by the best fit. FR means the fitting range before tree-level improvement. $\chi^2/N_{\rm df}$ is usual reduced chi-square. The errors are estimated by the jackknife method.

References

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