Dirac-mode expansion for quark-number holonomy in lattice QCD

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Abstract

We consider the Dirac-mode expansion for quark number holonomy in both large and small quark mass regimes on the lattice. Quark number holonomy is a topological order parameter for the deconfinement transition. Dirac-mode is strongly related to chiral symmetry breaking. We derive the analytical Dirac-mode representation of the quark number holonomy and our results indicate that the low-lying Dirac modes are irrelevant for the quark-confinement.

Motivation

Quark number holonomy

- Quark number holonomy $\Psi(T)$ is defined as a integral of the dimensionless quark number $n_q$ on a loop for the direction of the dimensionless imaginary chemical potential $\theta$.

Quark confinement at imaginary chemical potential

- The RW periodicity has deep relations with the free-energy degeneracy.

Dirac mode expansion

- Low-lying Dirac eigenmodes: the important modes for chiral symmetry breaking

Large quark mass

- We expand the quark number density by $1/M$.

Small quark mass

- We consider the IR-cutoff dependence of quark number density $n_q(\theta = \pi/3)$.

Summary

- The absolute value and sign of the quark number density is drastically changed by removal of the low-lying Dirac eigenmodes.

Reference

1. In the large-quark mass regime, we analytically found that the quark number density shows the same behavior as the Polyakov loop, an usual order parameter for the confinement-deconfinement transition.
2. In the small-quark mass regime, we numerically found that the quark number holonomy, the topological order parameter for the deconfinement transition, is insensitive to the low-lying Dirac eigenmodes.
3. Our results suggest that low-lying Dirac modes do not play important roles in deconfinement transition as the topological phase transition defined by the quark number holonomy.