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# Studying gauge-space geometry via lattice QCD

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Quantum chromodynamics (QCD) is the theory that describes the nuclear strong interaction between quarks, mediated by gauge fields carrying color charge, the gluons. QCD has a very important and unsolved problem, which is finding a mechanism to explain why quarks are never seen alone in nature, but only forming bound states, such as protons and neutrons. This constitutes the color confinement problem, which may be studied in the framework of quantum field theory. It is a hard task because of the non-Abelian character of the theory: the gluons themselves interact with each other and, in the low-energy regime, this forbids us to treat the theory perturbatively, as done in quantum electrodynamics (QED). (1) Consequently, the quantization of non-Abelian gauge fields presents several issues. From the technical point of view, integrating the gauge field over all its possible configurations in the path integral has to be done very carefully, since it involves the inversion of operators in the Yang-Mills' Lagrangian with null eigenvalues, leading to divergences. Using the Faddeev-Popov method, we impose a gauge condition for the gluon field, adding new integration variables in gauge space. The curves that connect physically equivalent fields through gauge transformations in this space are called gauge orbits and, in principle, the resulting formulation solves the divergences by factorization. (2) Ideally, the gauge-fixing method just described causes a gauge orbit to intersect the region specified by the gauge condition only once. But this is not guaranteed for a general Yang-Mills theory, and hence there are still ambiguities coming from equivalent configurations in gauge space, called Gribov copies. For a gauge transformation, the existence of Gribov copies is directly related to the fact that there are non-trivial eigenstates of the Faddeev-Popov operator with null eigenvalues. Among the proposed confinement scenarios, the one due to Gribov and Zwanziger associates color confinement to infrared properties of propagators of (gauge-fixed) fields around null eigenvalues of the Faddeev-Popov operator in gauge space. (3) Our main objective is to explore and test the Gribov-Zwanziger confinement scenario, comparing analytical predictions with numerical results from lattice QCD. In particular, we investigate how the static quark-antiquark potential relates to the gauge-fixing procedure.

**Palavras-chave:** Color confinement; Lattice Gauge theories; Gribov-Zwanziger scenario.

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