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Massive gluodynamics: unlocking the infrared regime of QCD using perturbative techniques

At the turn of the century, the availability of larger and more powerful supercomputers made it possible to push the lattice QCD calculations down into the deep infrared, where ordinary perturbation theory fails due to the presence of a Landau pole in its running coupling constant. There it was discovered that, instead of growing to infinity as would be typical of a massless field, the gluon propagator saturates to a finite value in the limit of vanishing momentum –an indication that the gluons develop an infrared dynamical mass due to the interactions. Despite being an established result, the fact that the gluons behave as massive degrees of freedom at low energies has somewhat eluded widespread recognition by the scientific community.
The aim of this contribution is to give an overview of the issue of dynamical mass generation in the gluon sector of QCD and to discuss some of the analytical methods that have been developed to describe it, with emphasis on two perturbative techniques termed the screened massive expansion and the dynamical model. We will show that these non-standard reformulations of ordinary perturbation theory are capable both of accounting for a non-vanishing gluon mass and of providing an accurate picture of the infrared dynamics of QCD –as revealed by the lattice calculations –already at one loop. Instead of developing a Landau pole, the running coupling constant computed by using these techniques remains finite and moderately small across all energy scales, thus ensuring that perturbation theory remains self-consistent down to arbitrarily small energies. A candidate mechanism for dynamical mass generation will be identified in the effect brought by a dimension-2 gauge-invariant gluon condensate on the vacuum structure of QCD, whose value can be computed from first principles and is directly proportional to the gluon mass squared.

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