Mass gap and quark confinement due to a novel vacuum condensate in Yang-Mills Theory

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We argue that a novel vacuum condensate of mass dimension 2 in Yang-Mills theory can be an origin of mass gap and quark confinement. It is defined as the vacuum expectation value of the composite operator which is both BRST and anti-BRST invariant in the most general manifestly Lorentz covariant formulation of Yang-Mills theory. The physical picture is based on Bose-Einstein condensation of gluon pairs (and ghost pairs simultaneously) mediated by the attractive force due to gluon self-interactions.
This scenario is supported by the following facts.
(1) The renormalization group flow in the parameter space of the theory (gauge coupling constant, gauge fixing parameters) shows the existence of fixed subspaces with different internal symmetries for the gauge fixing part, e.g. Osp(4/2).
(2) The proposed composite operator of mass dimension 2 is multiplicatively renormalizable.
(3) Its renormalized version is also invariant under the renormalized BRST and anti-BRST transformation.
(4) The operator product expansion of the gluon and ghost propagators leads to the non-zero Wilson coefficient corresponding to the vacuum condensate of mass dimension 2, which implies the existence of the effective mass of gluon (and ghost).

(5) The existence of the vacuum condensate enables us to derive the string representation of the Wilson loop by way of the equivalent effective antisymmetric tensor gauge theory, which implies the area law of the Wilson loop.
(6) By applying the duality transformation to the antisymmetric tensor theory, it is possible to derive the dual Ginzburg-Landau theory describing the dual superconductor without breaking global color symmetry. These are confirmed by making use of the exact renormalization group. The relationship with Slavnov-Taylor identities and Schwinger-Dyson equation is also discussed.

Finally, (7) when taken into account quarks, the generation of gluon mass implies dynamical generation of quark mass, due to Slavnov-Taylor identities and Schwinger-Dyson equation. Therefore, quark confinement due to gluon pair condensation leads to the chiral symmetry breaking due to chiral condensation in QCD.

References

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