Synoptic Overview on Quantum Chromo Dynamics its Applications

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Commentary

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ABOUT THE STUDY

In theoretical physics, Quantum Chromo Dynamics (QCD) is the theory of the strong interaction between quarks mediated by gluons. Quarks are fundamental particles that make up composite hadrons such as the proton, neutron and pion. QCD is a type of quantum field theory called a non-abelian gauge theory, with symmetry group SU. The QCD analogue of electric charge is a property called colour. Gluons are the force carriers of the theory, just as photons are for the electromagnetic force in quantum electrodynamics. The theory is an important part of the Standard Model of particle physics. A large body of experimental evidence for QCD has been gathered over the years.

The Yang-Mills theories of gauge interactions

Gauge bosons: A bosonic (having the integer value of the spin) fields (particles) that mediate/transfer interactions.

Source matter: The matter fields that generate and react to the mediating fields.

The concept of gauge symmetries plays the fundamental role in YM theories. The idea is to start with a physical model that has certain global symmetry (here "global" meaning using the same transformation parameters at every point if space-time), and try to see if that physical model can be generalized to support the same symmetry applied with different values at different points in the space-time. Such procedure brings into the model the additional fields (gauge fields) which look as the generalization of the Maxwell's electromagnetic fields. One nontrivial element of this generalization is that if the gauge symmetry is non-Abelian. The gauge field acquire the self-interaction terms, i.e. the corresponding gauge bosons can generate more of the similar bosons (which does not happen for photons corresponding to the Abelian group U (1).

The other modern uses of the Yang-Mills models

1. The Maxwell's theory of electromagnetic interaction, which is the gauge theory based on the one-parameter U (1) group of symmetries. The source matter here is any charged matter (e.g. electrons), and the gauge matter is the photon.
2. The "Standard Model" of electro-weak interaction, which provides currently accurate description of both electromagnetic interaction and of the weak nuclear interaction (causing the CP parity violation and nuclear fission). The source matters here are leptons and quarks with their electromagnetic charges and the weak charges. The gauge matter here is the collection of four bosonic intermediaries: massless photon, and three heavy wikons (one electricaly neutral Z^0, and two charged W^+, W^-).
3. The Einstein's General Relativity and its many generalizations are really the double-stacked gauge theory based on the localized group of Poincare symmetries, 4-dimensional translations R^4 and the 4-dimensional "rotations" SO (1,3). The source matter here is any matter that has energy (even the massless matter, too). In the most basic model (the original Einstein's General Relativity) the role of the gauge matter is played by the gravitational field whose quantum is massless graviton with spin=2. One additional quirk here is that, since even gravitons have energy, they act as a source of the additional gravitational field, which is mathematically expressed in the very non-linear nature of the Einstein's equations. In more complex variants of the model (Einstein-Cartan theories, etc) the spin of the all matter is also playing a role of the source of interaction, and there may be extra mediating bosons (in addition to gravitons).