Detail Analysis of Quantum Chromodynamics and Properties

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Commentary

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ABOUT THE STUDY

Quantum Chromodynamics (QCD) is the theory of the strong interaction between quarks mediated by gluons in theoretical physics. Quarks are fundamental particles that contribute to the formation of composite hadrons such as the proton, neutron, and pion. QCD is a non-abelian gauge theory with the symmetry group SU in quantum field theory. The colour property is the QCD analogue of electric charge. Gluons are the theory's force carriers, much like photons are for the electromagnetic force in quantum electrodynamics. The theory is an important component of particle physics' Standard Model. Over the years, a large body of experimental evidence for QCD has been accumulated.

QCD has three distinct properties

- Color restriction is the force between two color charges remains constant as they are separated, the energy grows until a quark-antiquark pair spontaneously forms, transforming the initial hadron into a pair of hadrons rather than isolating a color charge. Color confinement is well established from lattice QCD calculations and decades of experiments, despite being analytically unproven.
- Asymptotic freedom is characterized by a steady decrease in the strength of interactions between quarks and gluons as the energy scale of those interactions increases (and the corresponding length scale decreases). David Gross and Frank Wilczek discovered QCD's asymptotic freedom in 1973, and David Politzer independently discovered it the following year. All three received the Nobel Prize in Physics in 2004 for their contributions to this field.

- Chiral symmetry breaking is the spontaneous symmetry breaking of an important global symmetry of quarks, described below and resulting in masses for hadrons far above the masses of the quarks and extremely light pseudo scalar mesons. Yoichiro Nambu received the Nobel Prize in Physics in 2008.

The force between quarks is known as the color force, and it is responsible for the nuclear force.

Because the theory of electric charge is called "electrodynamics," the theory of color charge is called chromodynamics. Every particle physics field theory is based on natural symmetries whose existence is deduced from observations. These could be

- Local symmetries or symmetries that operate independently at each point in space-time. Each such symmetry serves as the foundation for a gauge theory and necessitates the introduction of its own gauge bosons.
- Global symmetries, which are symmetries whose operations must be applied to all points in space-time at the same time.

QCD is a non-abelian gauge theory (or Yang-Mills theory) of the SU (3) gauge group obtained by defining a local symmetry with the color charge.

Because the strong interaction does not distinguish between different flavors of quarks, QCD has approximate flavor symmetry, which is broken by the quark masses.

There are other global symmetries whose definitions require the concept of chirality, or the distinction between left and right-handedness. If a particle's spin has a positive projection on its direction of motion, it is said to be right-handed; otherwise, it is left-handed.

1. Chiral symmetries involve these two types of particles undergoing independent transformations.
2. Vector symmetries (also known as diagonal symmetries) imply that the same transformation is applied to both chiralities.
3. Axial symmetries occur when one transformation is applied to left-handed particles and the inverse transformation is applied to right-handed particles.