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Confinement of Quarks

In the SM of particle physics, quarks are assumed to be spin½ particles. All other elementary fermions of the SM, i.e. leptons, ***must*** be elementary spin½ particles, just like the often observed relatively stable hadrons, like the uncharged neutron and +electron-charged proton of the first (lightest) particles-family. Where it should be noted that the hadrons are build from 3 quarks each (proton uud and neutron udd).

Why must all possible stable fermions possess spin, i.e. intrinsic angular momentum, equal to ½ℏ? This is most easily answered while proofing David Hilbert's 6[th] problem. This answer is given at http://quantumuniverse.eu at the link:

Is it possible to derive all axioms of physics from a mathematical analysis!?!

A mathematical representation of any allowed spin s ∈ {½, 1, 1½, 2} is a representation with an integer n(s) = 2s + 1 amount of degrees of freedom. Solving David Hilbert's 6[th] problem requires writing down all possible space-time-like symmetries possible in the searched for ónly possible mathematical space. As explained in the solution of Hilbert's 6[th] problem the only possible space to describe always massive fermions is 4D-space-time-like!

This results in all possible continuous space-time-like transformations given by a 16 dimensional 4x4 matrix, which should be a tensor to comply to the CAP:

$$\mathbf{T} = \mathbf{A} + \mathbf{S} \tag{1}$$

The anti-symmetrical transformation-tensor **A** has just 6 degrees of freedom. These degrees of freedom can also be given with the following spin-representation:

$$\mathbf{A} \equiv \text{spin1 x spin½} \tag{2}$$

The spin1 representation represents the EM-field (photon) and the spin½ charges as its sources.
Likewise, the 10 degrees of freedom of the symmetrical transformation tensor **S** can mathematically also be represented by the following spin-representation:

$$\mathbf{S} \equiv \text{spin2 x spin½} \tag{3}$$

The spin2 representation just represents the spin2 gravitational-field (graviton) and the spin½ sources are just the (relatively) stable spin½ masses.

Here it should be noted that in fact the EM-field isn't specified completely without application of a gauge-symmetry. Non-relativistic the Coulomb-gauge is used and SR the Lorentz-gauge is used. The maximum allowed gauge-symmetry in the only possible mathematical-space to describe our reality, i.e. 4D-space-time, is:

$$U(1) \times SU(2) \times SU(3) \tag{4}$$

The U(1) x SU(2) gauge-symmetry describes the massless photon and the massive weak-nuclear forces, the charged $W^{\pm}$ and neutral Z gauge-bosons, in which the neutral photon and the Z-boson appear mixed by the so-called Weinberg-angle.

The last possible gauge-theory in the 4D-space-time-like analysis is the most difficult one:

The SU(3)-gauge symmetry describes all possible quarks and all their possible interactions. In SU(3) S stands for Special, i.e. the determinant of the transformation matrix det(SU(3)) = +1, the U for Unitary and the index three for the fact that any transformation-tensor is a 3 x 3 tensor.

In the SM of particle physics all (assumed spin½) quarks possess an additional property called color-charge. This property follows completely from the SU(3)-gauge-symmetry. The name color comes from the mathematical fact that SU(3) has 3 linearly independent so-called quark-color (**RGB**) solutions.

The property spin of all the quarks is a result of compliance with the CAP. The fact that quarks cannot be observed on their own, implies that the spin isn't spin½, but must be the only other allowed half-integer spin s_{quark} = 1½. And the always used "iso-spin½" should be omitted as an invalid property of quarks.

In this way confinement of quarks is a logical result of re-writing the SM in compliance with the CAP, i.e. include ***always demanded*** curvature of 4D-space-time in the mathematical description of physics.

As a direct consequence of CAP, gluons can't be elementary particles, but have to be compound particles build from an even amount (mostly 2) of quarks. The combinations of 2 quarks must be such that the gluon carries color-charge to participate in the strong interaction in addition to mediating it. I.e. gluons exchange color of quarks inside an uncolored hadron.

This is also why gluons aren't massless, but always possess rest-mass due to the non-zero masses of the constituent quarks. Please remember that only the spin1 photon and the spin2 graviton are massless and as a result of that always move with the maximum allowed speed in any relativistic description!

At the website of Edward Witten he gives his view on quark confinement at the following link:

Black Holes and Quark Confinement

In this PDF he doesn't seem to have a clue why quarks are never observed as elementary particles, that is, without interactions with other quarks. The main reason for this problem is the assumption that quarks are spin½ particles with additional so-called iso-spin (also ½) instead of using the correct derived fact that quarks are elementary spin1½ fermions and as a result of that fact cannot exist on their own as stable elementary particles.

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