A realist interpretation of QCD

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Abstract

In this paper, we explore the epistemological foundation of quantum chromodynamics. We do so by re-examining the concept of partons, which was introduced by Richard Feynman as a generic term for pointlike constituents of matter. We examine whether or not the concept of a colorless, flavorless and zero-charge parton – onto which we can then load the various properties that are necessary to explain reality – might work. The conclusion is that the parton model may offer sufficient degrees of freedom to model what the quark-gluon model is modelling. In fact, we suggest the idea of quarks and gluons might be a bit like the 19th century *aether* theory: we don't need it. The underlying question is, of course, much more fundamental: do we need quantum field theory?

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A realist interpretation of QCD

Quantum canon dynamics

According to the online Cambridge Dictionary, we may use the term *canon* to refer to a collection of writings or other works that are generally agreed to be good, important, and worth studying. We may also think of it as a list of sacred books. Mainstream quantum-theoretical textbooks combine both meanings. Indeed, I have tried to understand some canonical works dealing with quantum mechanics for many years now. Feynman's *Lectures* (Volume III), basically, and – with much less patience – Aitchison and Hey's *Gauge Theories in Particle Physics*. However, I've come to the conclusion they're canonical nonsense. To be precise: I've come to the conclusion that the idea that forces must be mediated by so-called *virtual* particles is a useless dogma.

19th-century scientists believed there must be some medium for an electromagnetic oscillation to oscillate *in*. That was the *aether* theory. The Michelson-Morley experiment all but demolished it. Modern physicists believe in virtual photons, gluons and W^+, W^- and Z bosons as force carriers. There is no evidence for these whatsoever: the 19th-century *aether* theory currently survives in quantum field theory.

The academics will cry wolf here: the *three-jet* events in electron-positron colliders are supposed to confirm the *reality* of gluons. Likewise, the W and Z bosons were 'discovered' in the proton-antiproton collider at CERN.[1] But where is the wolf? Do these experiments actually *confirm* quarks and gluons exist?

We should, perhaps, first clarify the tricky question: what does it mean when we say this or that particle *exists* if it can only travel as a quasi-free particle at a distance of the order of 10^{-15} *centi*meter. That's *a hundredth* of a femtometer (10^{-15} m). In case you don't know the femto-universe very well[2], you should probably remind yourself of the scattering radius of a proton, which is something tween 0.84 and 0.9 fm. Even when traveling at the speed of light, the equivalent *lifetime* of a particle traveling over a distance of, say, 3 fm is 10^{-23} seconds. That's smaller than anything we can measure. It then decays into other products. That's not a particle: that's a resonance, or an excited state of something.[3] Whatever it is, it is surely *not* something you'd associate with the usual *definition* of a particle.

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[1] The first of these experiments go back to the late 1970s and the early 1980s and are associated with the PETRA accelerator in Hamburg, the Positron-Electron Project (PEP) at the Stanford National Accelerator Laboratory (SLAC), and the Super Proton-Antiproton Synchrotron at CERN. We encourage the reader to *google* and think about these experiments. What do these experiments try to find or measure? And how do they do it?

[2] I will readily admit that I don't, but I will also not hesitate to say that any of the physicists who write about it do. Why? Because you can't 'see' or 'measure' anything with precision in the femto-universe. Hence, your guess about what's going on there – as an amateur physicist – is as good as that of the academic physicist.

[3] A *resonance* in particle physics is effectively defined as a 'particle' whose lifetime is of the order of 10^{-23} seconds. Traveling at the speed of light, these 'particles' can, effectively, only travel about 10^{-15} m (which is about the diameter of a proton), before decaying. Distances of this magnitude cannot be measured in bubble chambers or in whatever other device for detecting subatomic particles, and the lifetime of a resonance is, effectively, analogous to the time an electron stays in an excited state, which is calculated using the Uncertainty Principle: $\Delta E \cdot \Delta T = h \Leftrightarrow \Delta T = \Delta E/h$. See: http://webhome.phy.duke.edu/~kolena/modern/dudley.html.

That's why we cannot directly *see* quarks and gluons. We only see *jets*. As Ali and Kramer put it: "When these colored objects [quarks and gluons] separate to more than of the order of 1 fm, confinement forces become effective which bind the quarks and gluons in hadrons. The hadronization proceeds through the formation of jets."[4] It's those jets that we can see. Not the quarks or the gluons. In short, these experiments only provide *indirect* evidence, and we are justified to wonder whether such indirect evidence is evidence *enough*.

The academics need to answer other questions as well. We should note, for example, that electrons and positrons are supposed to have no internal structure. In fact, because they are leptons, they do surely *not* consist of quarks. Hence, it is about time physicists give us some more *real* explanation for the magic that creates two quarks out of the energy of a colliding electron and its anti-matter counterpart (the positron) – and a gluon ! The sequence of events is supposed to be the following one[5]:

$$\mathrm{e}^- + \mathrm{e}^+ \longrightarrow \gamma \longrightarrow \mathrm{q} + \bar{\mathrm{q}} + \mathrm{g} \longrightarrow 3 \text{ jets}$$

Again, we should emphasize we can only 'see' the jets in those experiments. We cannot directly see the quark, the anti-quark and the gluon that, altogether, should account for the energy of the virtual photon from the collision between an electron and its anti-matter counterpart.

What *decay* products do we get in those jets? What are the hadrons in the hadronic jets? All kinds of stuff. The same magic that produces quarks and gluons, produces more quarks and gluons. If we have energy, we have particles. The various transformations are rather obscure—or magical, we should say. To be fair, we should acknowledge they do obey some intricate but totally *ad hoc* quantum number conservation logic: whenever something is allowed or not allowed to happen, physicists will introduce another quantum number – some *flavor* quantum number like strangeness, topness, or bottomness (aka beauty). Modern physicists resemble the very early chemists in that way.

For example, when the original quark is *heavy* (read: highly energetic) – so when it's a *c* or *b* quark instead of a *u* or *d* quark[6] – we will find heavy mesons in the jet(s), such as D mesons.[7] However, the hadronization process is quite complex – various *fragmentation functions* and *jet algorithms* are

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[4] A. Ali and G. Kramer, *Jets and QCD: A Historical Review of the Discovery of the Quark and Gluon Jets and its Impact on QCD*, October 2011 (https://arxiv.org/pdf/1012.2288.pdf). The 10^{-15} *centi*meter (10^{-17} m) scale that was mentioned was taken from the same article.

[5] Most of the events at electron-positron colliders actually yield two jets only, which are said to emerge from a quark and an anti-quark. No gluon. As for the ratio of two- versus three-jet events, Aitchison and Hey (*Gauge Theories in Particle Physics*, 2012, Volume 2, p. 95) say the energy is shared between *three* jets (as opposed to two jets) in some 10-30% of the cases. In contrast, Ali and Kramer (2011) do mention four-jet events which may emerge from a 'virtual gluon' splitting into two other gluons. If a gluon is a virtual particle, then what is a virtual gluon? Don't worry too much about it: your answer is as good as mine—even if you don't have any, because I don't have one either. We may note that neither Aitchison and Hey, nor Ali and Kramer, mention recent 'discoveries' of tetra- and penta-quark configurations. We must assume they think these 'discoveries' need further confirmation (canonization?).

[6] The energy of *u* and *d* quarks is of the order of a few MeV only, while the energy of *c* and *b* quarks is measured in GeV, so that's about 1,000 higher. The energy of the *s* quark is about 100 MeV, so that's about 40-50 times the energy of the *u* quark. The *t* quark has the same relation to the heavy *b* quark: about 40-50 times heavier.

[7] You might think D mesons should always contain a *d* quark but, no, they are the lightest mesons containing a *c* quark ! High-energy physicists seem to do their utmost to try to confuse us even more !

involved and we will refer you to the excellent concise overview of Ali and Kramer for that.[8] As for now, you should just note that those jets consists of various (unstable) mesons and baryons which take some (more) time to decay into stable products–by which we mean electrons, protons, photons and neutrinos.[9]

It is easy, of course, to criticize the current theoretical framework. The question is: how would an alternative look like? This is what this paper is about. We should be clear from the outset: we do *not* have a full-blown alternative theory. We just want to show how such alternative theory might look like. It should respect some basic principles:

- Pointlike particles are not necessarily dimensionless: if something carries charge, it may have some (tiny) physical dimension.
- Properties such as spin should be explained in terms of some internal structure. Hence, even leptons – which do not consist of quarks in the Standard Model – must have some internal structure. That is why we believe the *Zitterbewegung* model of an electron (a term coined by Schrödinger), Wheeler's idea of 'mass without mass' and the associated interpretation of Einstein's mass-energy equivalence relation makes sense.[10]
- A particle is something with properties and it's the properties that *define* the particle—not partially but *completely*. It's like John Locke's question in regard to the idea of an apple. We think of an apple having some shape, some flavor and some color. We also think of an apple as some fruit grown by a tree. Can we imagine an apple without all those *properties*? Are the properties all of the *object*, or do objects have some other *essence* beyond the properties we can *measure*? We think there is no essence: the idea of a particle is to be explained by its properties—not partially but *completely*.
- We shouldn't be multiplying the number of categories: a particle that constantly changes its charge (quarks are supposed to change color all of the time) doesn't make much sense from an philosophical-epistemological point of view.

Let us explore these things.

Color and flavor theory

Quark theory suggests the strong charge comes in three colors. We might also have referred to these colors as flavors but that term has been reserved for something else already – different *types* of quarks: *up*, *down*, *strange*, *charm*, *beauty* (or *bottom*) and *top* – so we can't use that for the strong charge: do *not* confuse colors with flavors in the QCD kitchen ! 😉

The point is: the strong charge is *not* binary. In other words, it is *not* like the electric charge: plus or minus one unit. We think of protons and neutrons as RGB color white: equal amounts of red, green and blue. If you're into programming, it's hex code #FFFFFF or decimal code rgb(255,255,255). The colors are

[8] Reference above.

[9] The reader of this paper will, of course, not hesitate to write me in case I would have forgotten any other *stable* particle. The *graviton* (or Higgs particle?) perhaps?

[10] See: Jean Louis Van Belle, *The electron as a harmonic electromagnetic oscillator*, 31 May 2019 (http://vixra.org/abs/1905.0521)

pure: we can only have white: rgb(255,250,250) makes for snow. That color is *off*. Only a little bit, but it's off. I mean: *not* possible. Forget about it.

According to quark theory, you can also make pure white by mixing color and anti-color: green and anti-green also makes white, and so does red and anti-red, and blue and anti-blue. So you might think we have five varieties of particles: (1) red/blue/green, (2) anti-red/anti-blue/anti-green, (3) green/anti-green, (4) blue/anti-blue, and (5) red/anti-red. But six varieties is a bit too much, perhaps. Let's think.

We have protons and neutrons: they combine red, blue and green. We also have their anti-matter counterparts: anti-protons and anti-neutrons consist of anti-red, anti-blue and anti-green. Then we have mesons. Mesons have a color and an anti-color. Pions are examples of mesons. We'll say more about them later. For the time being, we should think of two types of matter only:

1. Baryons (e.g. protons and neutrons): they consist of three colors (or three anti-colors).
2. Mesons (e.g. pions): they consist of a color and an anti-color.

What's *matter*? Good question. We do *not* think of photons as matter: they are the particles of light, but they're not material. We think of them as an electromagnetic oscillation traveling through space.[11] What about electrons? Electrons don't partake in the strong force – so they don't carry any color charge – but they are, obviously, matter too. Leptons, in general, are. So we think of matter – or the elementary *constituents* of matter – as carrying electric charge.

Let us think about the use of the *anti*-prefix in this context: it should make you think of anti-*matter*. Anti-matter is just plain matter with an opposite *electric* charge. Hence, anti-red, anti-blue and anti-green may just refer to red, blue and green 'things' with the opposite *electric* charge. There is no such thing as an opposite *strong* charge. If you want to think of opposites, you should, perhaps, think of blue *and* green as the opposite*s* (plural!) of red. Likewise, you can think of blue and red as the opposites of green. Hence, we may wonder if the concept of an *anti*-color is actually necessary.

Let us try to do without. Instead of a quark-gluon model, we'll try to develop a *parton* model. The term parton was coined by Richard Feynman and it, therefore, has a rather specific historic meaning. We will just borrow his term here to refer to some pointlike *constituent* of matter. Note that pointlike does *not* necessarily it has no dimension whatsoever. On the contrary, we think the assumption it occupies some (very tiny) space is essential. Think of our explanation of the anomalous magnetic moment here![12]

So let us start building our parton model. We can do it by combining electric and color charges. We get the following combinations:

charge and color	red	green	blue
+2/3	+2/3	**+2/3**	**+2/3**
−1/3	−1/3	**−1/3**	**−1/3**
−2/3	−2/3	**−2/3**	**−2/3**
+1/3	+1/3	**+1/3**	**+1/3**

[11] See: Jean Louis Van Belle, *A Classical Quantum Theory of Light*, 13 June 2019 (http://vixra.org/abs/1906.0200).
[12] See: Jean Louis Van Belle, *The Anomalous Magnetic Moment: Classical Calculations*, 11 June 2019 (http://vixra.org/abs/1906.0007).

So we have 12 partons. That looks like a lot. Quark theory has only two. For its first generation, that is. We'll say more about the second and third generation later. Indeed, Gell-Mann – the inventor of quark theory – apparently thought *something* should carry the *electric* charge, and he defined the *up* and *down* quark. I prefer the *u* and *d* abbreviation because up and down makes you think of spin, and the name of these quarks has nothing to do with that: they're both spin-½ particles and the spin of both the *u* and the *d* quark can be up or down.

Let us think about why these quarks are different from our partons. The up and down quark do not carry the color charge. To be precise, they actually do but they are thought of swapping colors all of the time. That's a bit weird but it is what it is. You might think the quark model is more economical because we avoid having to define six particles (and their anti-particles, of course). Two quarks (and two anti-quarks) is better, isn't it?

I am not so sure because we have nine different gluons:

gluons	red		green		blue	
anti-red	**red**	**anti-red**	**green**	**anti-red**	**blue**	**anti-red**
anti-green	**red**	**anti-green**	**green**	**anti-green**	**blue**	**anti-green**
anti-blue	**red**	**anti-blue**	**green**	**anti-blue**	**blue**	**anti-blue**

Hence, what I will refer to as the *quark-gluon* model doesn't come with any simplification:

1. The quark-gluon model gives us two quarks, two anti-quarks and nine gluons, so that adds up to 13 different objects.
2. If we just combine the possible electric charges (±2/3 and ±1/3) and the possible color charges (red, green and blue), we only have 12 objects. I'll refer to this as the parton model.

Note that our parton model has no need for anti-colors: the anti refers to the opposite *electric* charge, so we capture that in the possible electric charges, of which we have four. Also note that, when you read up on quark theory, physicists will tell you there are only eight *independent* color-anticolor combinations, so instead of 13 objects, we'd also have 12.

Twelve or thirteen. It doesn't matter all that much. I find the quark-gluon model weird. Something inside of me tells me physicists prefer the quark-gluon model because it allows them to think of stuff using their *pet* theory: quantum field theory. If you read anything of what I wrote on QED and QCD so far, you will understand that I am very hesitant to think in terms of elementary particles exchanging *virtual* particles as part of their interactions. I don't see why we need the concept in QED, and so I need to be convinced of why we would need it in QCD.

You'll say: the *up* and *down* quarks have a different (bare) mass, so that's probably the reason why we need these two quarks. I'd say: if we have different charges (+2/3 and −1/3 are both red but they are not the same) then we may think of some 'mass without mass' theory – some kind of *Zitterbewegung* idea for the nucleus – that *gives* us this mass difference.

I am *not* saying this is going to be easy. I am just saying that, in my search for a *realist* interpretation of quantum mechanics, I am *imagining* it can be done, *somehow*. We don't need the concept of quarks for that.

Accounting for variety with quantum numbers

We have a lot of quantum numbers in QCD. The ones we know: spin and electric charge, for example. But also quite a few that sound weird. The flavor quantum numbers: isospin (I_3), charm (C), strangeness (S, not to be confused with spin), topness (T), and bottomness (B'). The accent (′) in the symbol for the bottomness (B') is to distinguish it from yet another quantum number: the baryon number B. The baryon number is 1/3 for all quarks. It's just something physicists have thrown into the chemistry equations of QCD so as to be able to make sense of them.

I am not joking: QCD equations are like chemistry. Instead of keeping track of atoms (or ions) and electric charges, you keep track of quarks, spin and charges. But do we need quarks? Do we need gluons? Can't we just keep track of spin and (electric) charge? And energy, of course!

I think that should work for all *stable* configurations—for all *real* particles, that is. Here we need to be precise in our language. In our introduction, we questioned the *reality* of a particle that exists for 10^{-23} seconds only—we preferred to refer to it as a resonance or some *excited* state of some more fundamental reality instead. So how *real* is a particle that exists only for like 26 nanoseconds only? Is that a stable configuration? It obviously is *not* stable—but it's obviously something else than a resonance: the order of magnitude of their lifetime differs by a factor that is equal to 10^{15}. Let me write that out: 1,000,000,000,000,000. That's a huge number. In case you wonder, this number – 26×10^{-9} seconds – is the mean lifetime of a (charged) pion.

Let's call pions and other short-but-fairly-long-lived-particles-as-compared-to-resonances *transients*. They are transient because they do die out. In contrast, I'll define a *real* particle as a permanent fixture: it doesn't decay. In contrast, transients die out. That's where the concept of a mean lifetime comes in. For a resonance, we can't even talk about a *mean* lifetime—because its lifetime is shorter than anything we can measure so any talk of some *mean* value is completely *mean*-ingless. 😉

What about free neutrons? They have a mean lifetime of about 881.5 ± 1.5 seconds, so that's about 14 minutes and 41.5 seconds (the concept of the half-life of this process (611 ± 1 s) is somewhat different but the order of magnitude is the same). Are they stable? No. They are *quite* (or *very*) stable as compared to transients, but all is relative. They decay. Protons don't. As far as we know, at least: we haven't *observed* proton decay, so we must assume protons are as stable as electrons: protons and electrons don't decay. Why not? We cannot really answer that question but – practically speaking – you may want to remind yourself that we wouldn't exist if they'd be decaying.

Of course, that answer won't satisfy you because it's a typical answer using the *anthropic principle*.[13]

Why are neutrons stable in a nucleus but not in free space? We think it's the Planck-Einstein relation: two protons, two neutrons and two electrons – a helium atom, in other words – are stable because all of the angular momenta in the *oscillation* add up to (some multiple of) Planck's (reduced) quantum of action. The angular momentum of a neutron in free space does not, so it has to fall apart in a (stable)

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[13] For some reason, few people like the anthropic principle (https://en.wikipedia.org/wiki/Anthropic_principle). For me, it has got nothing to do with *human chauvinism*: the anthropic principle is identical to imaging what universes might be *possible*.

proton and a (stable) electron – and then a neutrino which carries the remainder of the energy. Let's jot it down:

$$n^0 \rightarrow p^+ + e^- + \bar{\nu}_e^0$$

Let's think about energy first. The neutron's energy is about 939,565,420 eV. The proton energy is about 938,272,088 eV. The difference is 1,293,332 eV. That's almost 1.3 MeV.[14] The electron energy gives us close to 0.511 MeV of that difference – so that's only 40% – but its *kinetic* energy can make up for a lot of the remainder! We then have the neutrino to provide the change—the Euro *cents*, so to speak.

Let's say something about neutrinos here. They are neutral, so what's an *anti*-neutrino? Well… The specialists in the matter say they have no idea and that a neutrino and an anti-neutrino might well be one and the same thing.[15] Hence, we might as well write ν_e. No mystery there—not for me, at least. Or not here and not right now, I should say—because neutrinos are a bit mysterious. Did you know there is a neutrino theory of light?

You may like to think of them as change. Indeed, when you talk money, you need big and small denominations—banknotes and coins. However, that role can be played by photons. Gamma-ray photons – produced by radioactive decay – can have energies with a MeV order of magnitude. So they will do when one needs change or coins. So there's more to it: you see neutrinos whenever there is radioactive decay. Hence, we should associate them with the weak force but *how exactly* is a bit of a mystery. Let's get back to spin and charge. The equation above conserves angular momentum (spin) and electric charge. We're not worried about the color here. Should we be worried? I don't think so: the proton consists of three colors too, so we're fine.

We could look at an equation that looks like the reverse of the equation above – electron capture by a proton – but we will let you do that as an exercise. Let's have a look at pions—just to check if we need that color business there.

Pions can have positive, negative or no charge: we have π^+, π^- and π^0 particles, or *resonances*, we should say—because they decay so fast. Pions are often thought of as the carrier particles of the strong force – the stuff that Yukawa wanted to predict – but, as mentioned before, I think QCD still has to make the case for the need of a carrier particle. Let us just look at them as resonances: some temporary arrangement that quickly decays into something more stable.

The π^+ and π^- particles have a slightly higher energy than the π^0 particle but, more importantly, their mean lifetime is much more measurable: it's about 26×10^{-9} seconds. In contrast, the mean lifetime of the π^0 particle is measured as something like 84×10^{-18} seconds. The difference between nanoseconds (10^{-9} seconds) and attoseconds (10^{-18} seconds) is 10 to the power 9, so that's a *billion*. The disintegration process is also *very* different:

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[14] CODATA data gives a standard error in the measurements that is equal to 0.46 eV. Hence, the measurements are pretty precise.

[15] See the various articles on neutrinos on Fermi National Accelerator Laboratory (FNAL), such as, for example, this one: https://neutrinos.fnal.gov/mysteries/majorana-or-dirac/. The common explanation is that neutrinos and anti-neutrinos have opposite spin but that's nonsensical: we can very well imagine one and the same particle with two spin numbers.

1. The π^+ and π^- resonances decay into a *muon* (positive or negative) and a *muon neutrino*.
2. The π^0 resonance just leaves two photons.[16]

Muons are unstable as well, but their mean lifetime is measured in *micro*-seconds (10^{-6} seconds). Guess what? They decay into an electron or a positron (depending on their charge) and neutrinos. Let's write it down:

$$\pi^+ \to \mu^+ + \nu_\mu \to e^+ + \nu_e + \nu_\mu$$

Just change the signs for the π^- decay.[17] What about the energy equation? The energy of charged pions is about 139.57 MeV. That's a sizable chunk of money—at the nuclear level, that is. To put that number into perspective: it's about 15% of the energy of the proton. Hence, if it *would be* some kind of 'exchange particle', then it's pretty heavy. We'll come back to why we are so skeptic as to its actual role—I mean the *italics* in the preceding sentence. The (rest) energy of a muon is about 105.66 MeV but, just like with neutron decay, we must assume kinetic energy explains most of the missing energy in this story.

As for the next step – a step *down* from the muon to the electron (or positron, in this case) – we get another *muon* neutrino. What's the difference between an *electron* neutrino (ν_e) and a *muon* neutrino (ν_μ)? One is heavier than the other. That's all. What's *heavier*? More energy. That's all. But that's a lot—obviously!

That's the interesting thing with these flavors or generations of particles. The next flavor – or next generation – comes with higher energy, but shorter lifetime. In that regard, we should remind ourselves that theorists and experimentalists also think *tau*-leptons are, *somehow*, quite real—even if their mean lifetime is only about 29×10^{-12} s. *Pico*-seconds.

You might think there is some easy relation between decay times and energies but that's not the case. The table below lists energy and mean lifetime for electrons, muons, pions and tau particles. In the third and fourth column, we multiply both and then express it in terms of Planck's quantum of action.

	energy (eV)	lifetime (s)	E·t (eV·s)	E·t/h
Electron (e)	5.11E+05	∞	∞	∞
Muon (μ)	1.06E+08	2.20E-06	2.32E+02	5.61E+16
Pion (π)	1.40E+08	2.60E-08	3.63E+00	8.77E+14
Tau (τ)	1.78E+09	2.90E-13	5.15E-04	1.25E+11

It shows that the pion and the muon have comparable energies – the order of magnitude is the same – but their lifetimes are quite different, although 2.2 microseconds and 26 nanoseconds differ by a factor that's not too large: to be precise, they differ by a factor that's equal to 84.5. In contrast, the energy of the tau particle is about 16.8 times that of a muon, but its lifetime is about 7.5 *million* times shorter.

[16] We will quality this statement in a minute.

[17] The second step in the decay makes abstraction of the muon neutrino that was produced in the first step of the decay process.

If we believe the energy of a particle reflects some kind of elementary cycle, then the eternal lifetime of the electron ensures we can associate it with an infinite amount of physical action. In contrast, because of its very short lifetime, a tau particle can*not* pack a lot of physical action—expressed in eV·s or as a multiple of Planck's quantum of action. We referred to these unstable particles as *resonances*, but *transient* particles is probably a more appropriate term: they're just like an oscillation that dies out.

Three-body problems, oscillators and symmetries

The ternary structure of the strong force is a bit daunting. We know we don't have an analytical solution for the three-body problem, so how can we hope to make sense of the strong force?

We should make two remarks here. First, there is a very special case of the three-body problem that is referred to as the *elastic* 3-body problem. I'll refer you to an animated *gif*-file – it's one of those animations that is worth a zillion words[18] – that shows starting conditions for the gravitational 3-body problem usually result in chaos. In contrast, there is no such problem (no chaos) for an elastic three-body problem. So we may want to think along those lines.

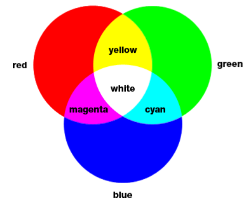
We noted above that it looks like there is no *conceptual* difference between thinking of a red, blue or green quark and its anti-quark (an anti-red, anti-blue or anti-green quark with opposite *electric* charge) or – a bit simpler – to think of some *parton* with three possible colors and four possible charges. We prefer the parton approach. Why? What's in a name? We just think the concept of some parton that comes in 12 possible varieties (three colors and four charges) separates stuff better.

So now we want to make particles of partons. We need to introduce some rules, of course. One of them is that the charges have to add up to the elementary charge (+1 or –1) or – for neutral particles – have to equal zero. That's where the *anti*-color in the quark-gluon model comes in, but we don't want to think in terms of anti-colors. The electric charge rule will do. What about our white-color rule? We can drop that for the time being. If we allow red to combine with itself and with blue and green, we get a matrix. To be precise, the strong force may be different for red and red, red and green, and red and blue, so we can put some coefficients in.

	red	**green**	**blue**
red	$S_{red-red}$	$S_{red-green} = S_{green-red}$	$S_{red-blue} = S_{blue-red}$
green	$S_{green-red} = S_{red-green}$	$S_{green-green}$	$S_{green-blue} = S_{blue-green}$
blue	$S_{blue-red} = S_{red-blue}$	$S_{blue-green} = S_{green-blue}$	$S_{blue-blue}$

We have nine coefficients but only six of them will be independent. This is actually where the color mixing picture comes to mind: red and blue makes purple (or, to be precise, magenta), red and green makes yellow, and green and blue makes blue-green (which is also referred to as cyan). So we have three primary colors and three mixed colors.

[18] See: https://commons.wikimedia.org/wiki/File:3bodyproblem.gif#/media/File:3bodyproblem.gif



If you know anything about QCD, the matrix may make you think of the Cabibbo–Kobayashi–Maskawa matrix, but it's got nothing to do with it: that matrix gives you the probability (or amplitude) for the *flavor* (u, d, c, s, t, b) to change into another. As for now, we don't think we need quark *flavors* to explain transient particles. We have enough degrees of freedom here.

We should probably remind ourselves of the properties of a symmetric matrix here: An n-by-n symmetric matrix will have n eigenvalues, and we can then find a set of n eigenvectors – one for each eigenvalue – that are mutually orthogonal. The matrix here is a 3-by-3 matrix: something inside of me tells me this should explain the three *generations* of matter in the Standard Model.

The electric charge rule – the electric charge has to add up to +1, 0 or −1 – should then explain the rest. The concepts of quarks, gluons or flavors sounds a bit like the *aether* theory. The philosophical concept of a colorless, flavorless and zero-charge parton – onto which we can then load the various properties we need to explain reality – may work just as well.

What about Yukawa's $e^{-r/a}$ factor in the force and/or potential function? We can add it. In fact, the easiest functional form for the six color coefficients would be one with an $e^{-r/a}$ factor in which the *range* parameter a depends on the color charges.

Let us examine whether we have enough degrees of freedom in this model.

Accounting for variety by combining charges

Our partons come in 12 varieties but they will only make a meson together if the total charge adds up to 0 or ±1. That works in half of the cases, so that's eight of sixteen possibilities. Of course, we can't distinguish the A and B combination from the B and A combination, so we only have four possibilities, as shown below.

A and B	-0.67	-0.33	0.33	0.67
-0.67	-1.33	-1.00	-0.33	0.00
-0.33	-1.00	-0.67	0.00	0.33
0.33	-0.33	0.00	0.67	1.00
0.67	0.00	0.33	1.00	1.33

Both particles can come in one of three colors, so we have 3×4 = 12 possible combinations. You may think that is *not* enough to explain the huge variety in mesons: the Particle Data Group[19] lists about 200 of them. Yes. *Two hundred*. Maybe there are more. QCD has enough weird quantum numbers (not only the electric and color charge but also isospin, flavor and other numbers (e.g. the baryon number). It just

[19] The Particle Data Group keeps track of what is found. The latest list of mesons can be found on this link: http://pdg.lbl.gov/2019/tables/rpp2019-sum-mesons.pdf.

shows that QCD is just an *ad hoc* theory: physicists invented a lot of numbers and then found the particles they wanted to find.

I am being too harsh here, but there is a grain of truth in it: quantum numbers such as *strangeness*, *charm*, *beauty* (or *bottomness*) don't give any *real* explanation. You'll say: yes – but you somehow need to explain the variety, so how do you do that?

In any *realist* interpretation of QCD, a charge will be associated with spin and orbital angular momentum. As we've argued in our classical explanation of the anomalous magnetic moment of an electron, these two may also be coupled *classically* – which is why we think the anomalous magnetic moment is not anomalous at all.[20] Hence, the four possible electric charges ($\pm$1/3 and $\pm$2/3) may have their spin up or down, so that multiplies the 12 varieties of our parton by 2. But, you are right, 24 combinations is not enough. We need other *variables*. Are there are any other candidates than *strangeness*, *charm* or *beauty*? Yes. Some kind of classical coupling between the spin and the orbital angular momentum multiplies the possibilities once more. If we assume – rather conservatively – that the orbital angular momentum may also take two values only, then we can multiply the possibilities by four (two spin-only numbers combined with two orbital angular quantum numbers).

But that's electric charge only. If we believe the color charge is something real – and I mean: more *real* than the hypothetical quarks or gluons that carry it – then we may imagine something similar to the electric current and the magnetic moment: we can imagine a *color* current, and a *color* moment. I must be joking, right? I am not. *Strange*, *charm* and *beauty* sound like characters out of a story for kids, so I think color current and color moment may be more rational and, therefore, more scientific. This color moment may be binary, ternary or *n*-nary (and, yes, I invented a new word here) and – importantly – it will be binary, ternary or *n*-nary for *each color*. And we may also distinguish between a spin-only and an angular color moment, so even if it's binary (like the *up* or *down* of the magnetic moment of an electron), then we can multiply the possibilities by nine (three spin-only numbers combined with six orbital color momentum numbers).

Twelve times four times nine makes 432. That's variety enough, I guess. 😉

What about baryons? We can follow the same reasoning: we have 12 varieties of partons that can combine. Of course, we should avoid double- or, in this case, triple-counting, so we have $12^3/3 = 576$ possibilities. We don't even need to think of color spin and color moments: that's plenty to cover the current list of baryons or baryonic resonances.

[20] See the reference above.

Conclusions

Maxwell said the following about the aether theory:

> "Aethers were invented for the planets to swim in, to constitute electric atmospheres and magnetic effluvia, to convey sensations from one part of our bodies to another, and so on, until all space had been filled three or four times over with aethers... The only aether which has survived is that which was invented by Huygens to explain the propagation of light."[21]

We may say the same thing about virtual particles or bosons: it is a magical concept which explains absolutely nothing. The concept of a colorless, flavorless and zero-charge parton, which was introduced by Richard Feynman as a generic term for pointlike constituents of matter, and which we can then associate with various properties, is much more appealing.

We think such parton model comes with sufficient degrees of freedom to model what the quark-gluon model is modelling. In short, the idea of quarks and gluons might be a bit like the 19th century *aether* theory: we don't need it.

The next question is, of course, much more fundamental: do we need quantum field theory?

Jean Louis Van Belle, 16 July 2019

[21] Various sources say Maxwell wrote this in the *Encyclopedia Britannica* in 1878, but I have not been able to verify that.