Electrons as gluons?

Jean Louis Van Belle, 20 August 2019

Synopsis

This paper offers some alternatives to the standard quark-gluon theory of nucleons and the nucleus. We readily admit these ideas are probably more fun than serious. However, we do invite the reader to think through it for himself, and we kindly request him to point out more inconsistencies – on top of the ones we identified ourselves – so as to further stimulate the ongoing quest for a realist model of nucleons.

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Thinking about gluons

According to common wisdom, we need to introduce a new charge – and, therefore, a new *force* – to explain why protons will stick together. But we have neutrons too, right? Can't they serve as *glue*? Do we need the idea of *gluons*? It is true that all nuclei with two or more protons also have one or more. The most obvious example is helium. About 99.999866 per cent of helium on this planet consists of two protons and two neutrons: we write this isotope as ^{4}He. The only other stable isotope is ^{3}He, which consists of two protons and one neutron. This is what Wikipedia writes about the neutron: "Within the nucleus, protons and neutrons are bound together through the nuclear force. *Neutrons are required for the stability of nuclei*, with the exception of the single-proton hydrogen atom."[1] So, yes, neutrons may, perhaps, serve as gluons.

Let us examine its role as glue: what *is* it? We will probably not be able to answer that question but we can think about it, at least. Let's start by thinking about the difference between a neutron and a proton. One key difference is the following: protons are stable, but neutrons are not. *What?* Yes. Neutrons are only stable inside of a nucleus: free neutrons *decay*. Their mean lifetime is almost 15 minutes – so that's almost *eternity* in atomic physics – but still: we may want to think of free neutrons as *transient* oscillations – just like all of the other so-called particles in the *particle zoo*.[2]

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

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

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.[3] 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 *nickel-and-dime*, so to speak.[4]

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[1] https://en.wikipedia.org/wiki/Neutron.

[2] The Particle Data Group (http://pdg.lbl.gov) dutifully provides the most up-to-date listings. We say they are *so-called* particles because they are all unstable. We like to associate the term 'particle' with a permanent fixture.

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

[4] When you talk money, you need big and small denominations: banknotes versus coins. However, the role of coins could be played by photons too. Gamma-ray photons – produced by radioactive decay – have energies in the MeV order of magnitude, so they should be able to play the role of whatever change we need in an energy equation, right? Yes. You're right. So there must be more to it. We see neutrinos whenever there is radioactive decay. Hence, we should probably associate them with that, but how exactly is a bit of a mystery. Note that the decay equation conserves linear, angular (spin) momentum and (electric) charge. What about the color charge? We're not worried about the color charge here. Should we be worried? I don't think so, but if you'd be worried, note that this rather

Is this *decay* reversible? It is: a proton can *capture* an electron to, somehow, *become* a neutron. It usually happens with proton-rich nuclei absorbing an inner atomic electron, usually from the K or L electron shell, which is why the process is referred to as K- or L-electron capture:

$$\mathrm{p}^{+} + \mathrm{e}^{-} \rightarrow \mathrm{n}^{0} + \nu_{\mathrm{e}}^{0}$$

Once again, we have a neutrino providing the *nickel-and-dime* to ensure energy conservation. It is written as the anti-particle of the neutrino in the neutron decay equation. The obvious question is: neutrinos and anti-neutrinos are neutral, so what's the difference? The specialists in the matter say they have no idea and that a neutrino and an anti-neutrino may well be one and the same thing.[5] If that's the case, then we might as well write ν_e for both. However, we'll stick to convention for the time being.

Nucleons cannot be ions

How should we think about this *exchange* of an electron between a proton and a neutron? Perhaps we should think of the proton as some kind of *atomic system* itself: a positive *ion* to which we may add an electron so as to get a neutron. However, that can't work: if we think of the proton as an ion and we add an electron to it, then we get the hydrogen atom. The hydrogen atom is much larger than a neutron: the Bohr radius of a hydrogen atom is about 0.53 *pico*meter (1 pm = 1×10^{-12} m). In contrast, the radius of a neutron is of the order of 0.8 *femto*meter (1 fm = 1×10^{-15} m), so that's about 660 times smaller.

In short, that won't work: we shouldn't think of nucleons as ions. However, now that we're here, let us look at some numbers. While a neutron is much *smaller* than a hydrogen atom, its energy (and, therefore, its mass) is significantly higher: the energy difference between a hydrogen atom and a neutron is about 0.78 MeV. That's about 1.5 times the energy of an electron. The table below shows these interesting numbers.

Table 1: Energies of protons, neutrons electrons and hydrogen

free proton	938,272,088 eV
free electron	510,999 eV
free proton + free electron	938,783,087 eV
hydrogen atom (bound state)	938,783,073 eV
difference (ionization or Rydberg energy)	13.6 eV
free neutron	939,565,420 eV
difference between neutron and atom	782,347 eV
difference between neutron and proton	1,293,332 eV

Let us think about sizes once more. If we try the mass of a proton (or a neutron—almost the same) in the formula for the Compton radius, we get this:

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simple decay equation does respect color conservation – regardless of your definition of what quarks or gluons might actually *be*.

[5] 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. However, that doesn't make them two different particles.

$$a_{\mathrm{p}} = \frac{\hbar}{\mathrm{m_p} \cdot c} = \frac{\hbar}{\mathrm{E_p}/c} = \frac{(6.582 \times 10^{-16}\ \mathrm{eV} \cdot s) \cdot (3 \times 10^{8}\ m/s)}{938 \times 10^{6}\ \mathrm{eV}} \approx 0.21 \times 10^{-15}\ \mathrm{m}$$

That's about 1/4 of the actual radius as measured in scattering experiments. We have a good rationale for calculating the Compton radius of a proton (or a neutron). It is based on the *Zitterbewegung* model for elementary particles: a pointlike charge whizzing around at the speed of light. For the electron, the charge is electric. For the proton or the neutron, we think of some *strong* charge and we, therefore, get a very different energy and, hence, a very different Compton radius.[6] However, a factor of 1/4 is encouraging but not good enough. If anything, it may indicate that a good model of a proton (and a neutron) should, besides some strong force, also incorporate the classical electric charge. It is difficult to think about this, because we think the pointlike electric charge has a radius itself: the *Thomson* or *classical* electron radius, which is equal to:

$$r_{\mathrm{e}} = \frac{\mathrm{e}^2}{\mathrm{m}c^2} = \alpha \cdot r_{\mathrm{C}} = \alpha \frac{\hbar}{\mathrm{m}c} \approx 2.818 \ldots \times 10^{-15}\ \mathrm{m}$$

This is about 3.5 times *larger* than the proton or neutron radius. It is even larger than the measured radius of the deuteron nucleus, which consists of a proton and a neutron bound together. That radius is about 2.1 fm. As mentioned above, this 'back-of-the-envelope' calculation of a Compton radius is encouraging, but a good model for a proton (and for a neutron) will need to explain these 1/4 or 3.5 factors.

Electrons as nuclear glue?

Let us think some more about energies. The nucleus of deuterium – the hydrogen isotope with a proton *and* a neutron – is referred to as deuteron. The energy equivalent of the (rest) mass of a deuteron nucleus (one proton and one neutron) is equal to about 1.878 MeV. If we add the energies of a neutron and a proton, then we get an energy that is about 2.2 MeV *less*. We may think of this energy as the binding energy explaining the stability of the nucleus.

Table 2: Energies of deuteron and constituent parts

Deuteron	1,875,612,942 eV
neutron + proton	1,877,837,508 eV
difference (deuteron binding energy)	2,224,566 eV
2 protons + 1 electron	1,877,055,175 eV
Difference	1,442,233 eV

The table above also shows something else: if we would break up the deuteron nucleus into a proton and a neutron, the neutron would decay into a proton and an electron. Hence, we would end up with two protons and one electron (we neglect the energy of the neutrino because it is, effectively, negligible). If we add the energy of two protons and one electron, we also get a number that is *higher* than the energy of the deuteron: the difference is about 1.44 MeV, so that's almost three times the

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[6] See: Jean Louis Van Belle, *Who Needs Yukawa's Wave Equation?*, 24 June 2019 (http://vixra.org/abs/1906.0384).

(rest) mass of the electron. Physicists think this explains the stability of the neutron *inside* of the nucleus but the *exact* logic here is somewhat unclear.[7]

But let us get back to what we were doing, and that is to think of an alternative model for the nucleus – a theory that is *not* expressed in terms of quarks exchanging gluons.[8] What if we would think of protons and neutrons – as a whole – continually exchanging electrons? We'd be assuming that, inside a nucleus, these two reactions are happening all of the time:

$$\mathrm{p^+ + e^- \rightarrow n^0 + \nu_e^0}$$

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

Now *that* would give a meaning to the anti-particle of a neutrino: we don't see any neutrinos coming out of a nucleus because they annihilate each other. Is this a sensible theory?

Maybe. Maybe not. Perhaps we should explain why we don't like the idea of gluons. It's Occam, really: we think the idea of (virtual) messenger particles (bosons) carrying energy, momentum and charge back and forth is like 19th century aether theories: we don't need them. Our dislike for this theory was triggered when we realized photons – the supposed messenger particles for the electromagnetic force – do *not* carry charge. They carry electromagnetic *energy*, but they don't carry any electric charge.

Of course, we are well aware that quark-gluon theory also serves other purposes: besides the idea of a color charge, the theory also incorporates the idea of *flavors*. However, the concept of these flavors can be traced back to Gell-Mann's attempts to explain why certain decay processes are possible, and others aren't. Gell-Mann, Pais and others effectively invented various strange new conservations laws, and these informed their quark-gluon model. We think one should keep explanations of different things (a theory for a stable nucleus as opposed to a theory of decay reactions) separate: we feel quark-gluon theory tries to explain everything and, therefore, ends up explaining very little.

You may think our 'electron glue' theory does the same: instead of gluons, we now have electrons carrying charge, right? Yes, but that's what electrons do: they carry electric charge. We think an 'electron glue' theory might simplify things. Protons would not repel each other because they're constantly being attracted by some intermediate electron, so we wouldn't need the concept of a strong force to explain why protons stick together.

Of course, the idea of electrons inside of the nucleus would also have to offer some kind of explanation for the magnetic moment of a nucleus. Let us have a look at that.

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[7] See, for example: http://hyperphysics.phy-astr.gsu.edu/hbase/Particles/deuteron.html.

[8] We think the idea of (virtual) messenger particles (bosons) carry energy, momentum and charge back and forth is like the 19th century aether theory: it is unnecessary. Note that photons – the supposed messenger particles for the electromagnetic force – do *not* carry charge. They carry electromagnetic *energy*, but they don't carry any electric charge. We should also note that we are, of course, well aware that quark-gluon theory also incorporates the idea of *flavors* (besides color). However, these flavors can be traced back to Gell-Mann's attempts to explain why certain decay processes are possible, and others aren't. Gell-Mann, Pais and others effectively various strange new conservations laws, and this informed his quark-gluon model. We think one should keep explanations of different things (a theory for a stable nucleus as opposed to a theory of decay reactions) separate.

Nuclear electric currents

If – in analogy with the electron model – we would (also) have some electric current inside of the nucleus – think of the electron going back and forth – then we should be able to calculate that current. Note that we limit ourselves here to some very rough analysis of the *electric* current only. Why? Because we don't have much of an idea about what a strong current would represent. A circular electric current creates a magnetic moment. We got the right value for an electron[9]:

$$\mu_e = \mathrm{I} \cdot \pi a^2 = \mathrm{q_e} \cdot f \cdot \pi a^2 = \mathrm{I} \cdot \pi a^2 = \mathrm{q_e}\frac{\mathrm{m_e} c^2}{h} \cdot \pi a^2 = \mathrm{q_e} c \frac{\pi a^2}{2\pi a} = \frac{\mathrm{q_e} c}{2}\frac{\hbar}{\mathrm{m_e} c} = \frac{\mathrm{q_e}}{2\mathrm{m_e}}\hbar$$

The $\mathrm{q_e}\hbar/2\mathrm{m_e}$ ratio is referred to as the Bohr magneton, which is denoted a μ_B. There is a similar unit which is referred to as the nuclear magneton (μ_N) but we don't need that right now. The magnetic moment of deuteron – the nucleus of deuterium – has been measured as being equal to about 0.00047 times μ_e. That's tiny, right?[10] Does that make any sense? Perhaps it does. Perhaps it doesn't. We should note that we have a much larger current loop for the electron: its Compton radius is 386 fm (10^{-15} m). In contrast, the effective scattering radius of deuteron is of the order of 2 fm, so that's almost 200 times smaller. However, a smaller loop is not necessarily a smaller current: if we think of the electron as a pointlike charge whizzing around at the speed of light – which is what we do in our *Zitterbewegung* model of an electron – then the current is actually going to be huge, because the frequency of the oscillation is going to be huge.

Now that we're here, we should think about the magnetic moment of the proton and the neutron. Let's do the proton first. In terms of the Bohr magneton, the magnetic moment of a proton is about 0.0015 times that of the (spin-only) electron. Again, much smaller, and the ratio resembles the ratio between the radii. At this point, we should introduce the *nuclear* magneton. The calculation is similar in terms of structure but we use the proton mass instead of the electron[11]:

$$\mu = \mathrm{I} \cdot \pi a^2 = \mathrm{q_e} \cdot f \cdot \pi a^2 = \mathrm{I} \cdot \pi a^2 = \mathrm{q_e}\frac{\mathrm{m_p} c^2}{h} \cdot \pi a^2 = \mathrm{q_e} c \frac{\pi a_\mathrm{p}^2}{2\pi a_\mathrm{p}} = \frac{\mathrm{q_e} c}{2}\frac{\hbar}{\mathrm{m_p} c} = \frac{\mathrm{q_e}}{2\mathrm{m_p}}\hbar = \mu_\mathrm{N}$$

So that's a *theoretical* value for the proton magnetic moment. Unsurprisingly, the actually *measured* value is quite different, and the difference is much larger than Schwinger's $\alpha/2\pi$ fraction. To be precise, $\mu_p \approx 2.8 \cdot \mu_N$, so the *measured* value of the proton's magnetic moment is almost three times that of its theoretical value. It should be no surprise to us – because we use a radius that's 1/4 of what might be the actual radius of the loop. In fact, the measured value of the proton's magnetic moment suggests the *actual* radius of the loop should be 2.8 times the theoretical Compton radius:

$$\frac{\mathrm{q_e} c}{2} a_\mathrm{p} = 2.8\frac{\mathrm{q_e}}{2\mathrm{m_p}}\hbar \Leftrightarrow a_\mathrm{p} = 2.8\frac{\hbar}{\mathrm{m_p} c}$$

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[9] See: Jean Louis Van Belle, *The Electron as a Harmonic Electromagnetic Oscillator*, 31 May 2019 (http://vixra.org/abs/1905.0521).

[10] The CODATA value is $4.669754570(12)\times10^{-4}$ μ_B.

[11] Note that the electron and proton charge have the same magnitude but opposite sign. However, to not confuse the reader, we used $\mathrm{q_e}$ in both formulas. However, the reader should remind him- or herself that the signs are, effectively, opposite.

Having noted the discrepancy, we think these results are actually rather encouraging: they give us the feeling we should probably continue to try to describe the proton in terms of some *realist* interpretation of quantum mechanics. Some kind of hybrid model – something that mixes the classical electric charge with some strong charge. This model may or may not involve the idea of partons, but we don't see any need for quarks and gluons at this point in time.[12]

At this point, we need to say something about one of the most remarkable phenomena in high-energy physics: the phenomenon of matter-antimatter pair production.

Matter-antimatter pair production

A good model of what a proton and a neutron actually *are*, will definitely need to explain why electron-positron pair production only happens when the photon is fired into a nucleus. Dirac was fascinated by it, as evidenced by his preface to the 4th and last edition of his seminal '*Principles of Quantum Mechanics*', in which he recognized the significance of matter-antimatter pair creation:

> "In present-day high-energy physics, the creation and annihilation of charged particles is a frequent occurrence. A quantum electrodynamics which demands conservation of the number of charged particles is, therefore, out of touch with physical reality. So I have replaced it by a quantum electrodynamics which includes creation and annihilation of electron-positron pairs. […] It seems that the classical concept of an electron is no longer a useful model in physics, except possibly for elementary theories that are restricted to low-energy phenomena."

I think it's useful to downplay Dr. Dirac's excitement somewhat. Our world is governed by low-energy phenomena: if our Universe was created in a Big Bang – some extremely high-energy environment – then it happened 14 billion years or so ago, and the Universe has cooled down since. Hence, these high-energy experiments in labs and colliders are what they are: high-energy collisions followed by disintegration processes. They emulate the conditions of what might have happened in the first second – or the first minute, perhaps (surely not the first day or week or so) – after Creation.[13]

I am, therefore, a bit puzzled by Dr. Dirac's sentiment. Why would he think the classical concept of an electron is no longer useful? An electron is a permanent fixture. We can create and destroy it in our high-energy colliders, but that doesn't mean it's no longer useful as a concept. Pair production only happens when the photon is fired into a nucleus, and the generalization to 'other' bosons 'spontaneously' disintegrating into a particle and an anti-particle is outright pathetic.

The mainstream interpretation of this phenomenon is that the surplus kinetic energy needs to be absorbed by some heavy particle – the nucleus itself. My guts instinct tells me something else must be going on. Electron-positron pair production does seem to involve the *creation* of an electric charge out of energy. It puzzled Dirac (and many other physicists, of course) greatly. What happens might be something like this: we fire an enormous amount of electromagnetic energy into a nucleus (the

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[12] See: Jean Louis Van Belle, *A Realist Interpretation of QCD*, 16 June 2019 (http://vixra.org/abs/1907.0043).

[13] I use the term 'Creation' as an absolutely non-religious concept here: it's just a synonym of the presumed 'Big Bang'. To be very clear on this, I am rather appalled by semi-scientific accounts of the creation of our world in terms of the biblical week.

equivalent mass of the photon has to match the mass of the electron and the positron that's being produced) and, hence, we destabilize the stable nucleus.

Perhaps we should think of the photon kicking that electron inside the nucleus. What electron? The electron that exchanges charge between the proton and the neutron: remember we're thinking of proton-neutron pairs as two protons plus an electron now! Of course, when it kicks that electron out, we need a *positive* charge to compensate. We could, effectively, now imagine a *positron* carrying charge back and forth between the neutron and the proton: 'positron glue' instead of 'electron glue'! However, like charges repel, so the positron is going to be kicked out, and quickly annihilates with some electron, so it can't actually mediate between the proton and neutron: it's 'Game Over' in a fraction of a second!

Conclusions

Is this a serious paper? Maybe it isn't, but then it's at least as serious – or at least as fancy – as some of the other crazy ideas out there, and our ideas are simpler. Hence, Occam might think they're better. At least, they show it's not all that difficult to think of some alternative model of the nucleus.

The obvious question – which we did *not* answer here – is: why are protons and neutrons so heavy? If we believe in the mass without mass concept[14], then we do need some *different* charge to explain the mass factor.

The other obvious issue is the size of the electron: even its classical electron radius is much *larger* than, say, the radius of deuteron.

Last but not least, the fact that a proton and a neutron have a magnetic moment implies we must explain some electric current *inside* – rather than *between* them.

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[14] See: Jean Louis Van Belle, *Mass without Mass*, 13 August 2019 (http://vixra.org/abs/1908.0225).