Electrons as gluons?

Jean Louis Van Belle, 28 August 2019

Summary

This paper explores the idea of a model for the proton based on a presumed *Zitterbewegung* of a (muon) positron. It also offers some alternative thinking 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.

Contents

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Introduction

One of the things that has always struck me is that there is not much theoretical research on why a very limited number of particles are stable and – conversely – why most are not. It is a crucial question. In fact, I find the term 'particle' for the so-called 'particle zoo'[1] rather odd: I always felt we should, perhaps, reserve the term 'particle' for *permanent* fixtures in our Universe – not for *resonances* or *transients*.

I relate it to the distinction between low- and high-energy physics, which is also not well defined. At the same time, it is quite obvious that the distinction between low-energy and high-energy physics is highly useful—even if artificial. Low-energy physics can be interpreted in terms of classical physics: the only force that matters is the electromagnetic force (and gravity, of course), and we study stable particles: we talk of nuclei (or protons and neutrons[2], perhaps), electrons and photons. Charge, energy, momentum (linear or angular) is always being conserved.

In contrast, high-energy physics studies what might be going on *inside* of the nucleus, and we study non-stable particles: the *debris* and the *transient* oscillations that come out of high-energy particle collisions. It is fair to say that high-energy physics studies what may or may not have happened in the first seconds, minutes or days after the presumed Big Bang.[3] High-energy experiments in labs and colliders emulate these conditions and phenomena: high-energy collisions followed by disintegration processes. High-energy physics studies weird phenomena such as electron-positron pair production from very-high energy photons.

Particles as oscillations

I mentioned (transient) oscillations. I do think of stable elementary particles as oscillations, and I do so in pretty classical terms: no string theory required. We are inspired by Schrödinger's *Zitterbewegung* idea, which makes us think of an electron as a *perpetuum mobile*: an oscillation that keeps going without any friction or loss of energy. Erwin Schrödinger stumbled upon this idea when he was exploring solutions to Dirac's wave equation for free electrons. It's worth quoting Dirac's summary of it:

> "The variables give rise to some rather unexpected phenomena concerning the motion of the electron. These have been fully worked out by Schrödinger. It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of

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[1] We refer to the hundreds of unstable particles that have been discovered over the past 70 years or so. These are listed, with their properties and decay reactions, by the Particle Data Group.

[2] Neutrons are only stable in the nucleus: free neutrons decay. We should also mention neutrinos because these are stable particles too. We will come back to both.

[3] Seconds and minutes are probably more relevant than days or weeks. According to standard theory, the Universe was an extremely high-energy environment some 14 billion years ago, before it expanded and cooled down. Needless to say, high-energy conditions still prevail in stars and other chunks of matter that need more time to cool down.

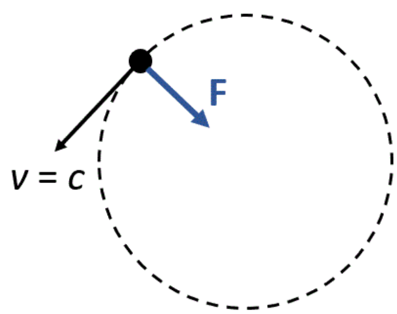
small amplitude superposed on the regular motion which appears to us. As a result of this oscillatory motion, the velocity of the electron at any time equals the velocity of light. This is a prediction which cannot be directly verified by experiment, since the frequency of the oscillatory motion is so high and its amplitude is so small. But one must believe in this consequence of the theory, since other consequences of the theory which are inseparably bound up with this one, such as the law of scattering of light by an electron, are confirmed by experiment." (Paul A.M. Dirac, *Theory of Electrons and Positrons*, Nobel Lecture, December 12, 1933)

Oscillations involve a force, a cycle time and a distance (the distance over the cycle loop), and I think particles are stable because the product of that force, the cycle time and the distance over the loop is equal to Planck's quantum of action: $F \cdot T \cdot s = h$, which we can also write as $E \cdot T = E/f = h$.[4] We briefly develop the idea below.

The oscillator model of an electron

The oscillator model of an electron[5] assumes an electron consists of a pointlike charge with zero rest mass. Note that pointlike doesn't mean it has no dimension whatsoever: we actually think the anomalous magnetic moment can be explained because the radius of this pointlike charge is equal to the classical electron radius, which is a fraction (α) of the electron's Compton radius. Pointlike means we consider the pointlike charge has no internal structure. In contrast, we think the electron – as a whole – has a structure. What structure? It's that high frequency oscillatory motion of small amplitude. That's why the electron itself has a different radius: the Compton radius. The idea is illustrated below.

Figure 1: The electron as a current ring



We have a pointlike charge in a circular orbit here. Its tangential velocity equals the product of the radius and the angular velocity: $v = a \cdot \omega$ formula. The tangential velocity is the speed of light: $v = c$. Hence, the *rest* mass of this pointlike charge must be zero. However, there is *energy* in this oscillation, and we think of the rest mass of the electron as the equivalent mass of the energy in the oscillation. This

[4] See: Jean Louis Van Belle, *Mass without mass*, 13 August 2019, http://vixra.org/abs/1908.0225. Our hypothesis amounts to a realist interpretation of the wavefunction (and quantum mechanics in general) and is consistent with the new *definition* of Planck's quantum as per the 2019 revision of SI units: $h = 6.62607015 \times 10^{-34}$ J·Hz^{-1}. Note that the formula assumes the force is constant over the cycle. If the force varies, we should integrate the $\Delta F \cdot \Delta t \cdot \Delta s$ product over the cycle.

[5] Schrödinger coined the term *Zitterbewegung* for it, which refers to a shaking or trembling motion. David Hestenes is to be credited with the revival of this model in the 1980s. However, we prefer a more general term.

hybrid description of the electron is Wheeler's idea of mass without mass: the mass of the electron is the equivalent mass of the energy in the oscillation of the pointlike charge.

We can now calculate the Compton radius. The calculation is mysteriously simple. The tangential velocity tells us the radius is equal to $a = c/\omega$. The Planck-Einstein relation ($E = \hbar\cdot\omega$) then allows us to substitute ω ($\omega = E/\hbar$). Finally, we can then use Einstein's mass-energy equivalence relation ($E = m\cdot c^2$) to calculate the radius as the ratio of Planck's (reduced) quantum of action and the product of the electron mass and the speed of light:

$$a = \frac{c}{\omega} = \frac{c\cdot\hbar}{\mathrm{E}} = \frac{c\cdot\hbar}{\mathrm{m}\cdot c^2} = \frac{\hbar}{\mathrm{m}\cdot c} = \frac{\lambda_\mathrm{C}}{2\pi} = r_\mathrm{C} \approx 0.386\times10^{-12}\ \mathrm{m}$$

This can be easily interpreted: each *cycle* of the *Zitterbewegung* packs (i) one *fundamental* unit of physical action (h) and (ii) the electron's energy ($E = mc^2$). Indeed, the Planck-Einstein relation can be re-written as $E/T = h$. The $T = 1/f$ in this equation is the cycle time, which we can calculate as being equal to:

$$\mathrm{T} = \frac{h}{\mathrm{E}} \approx \frac{6.626\times10^{-34}\ \mathrm{J\cdot s}}{8.187\times10^{-14}\ \mathrm{J}} \approx 0.8\times10^{-20}\ \mathrm{s}$$

That's a *very* small amount of time: as Dirac notes, we can*not* directly verify this by experiment.[6] The point is: you will now intuitively understand why we can write Planck's quantum of action as the product of the electron's energy and the cycle time:

$$h = \mathrm{E}\cdot\mathrm{T} = \mathrm{h}\cdot f\cdot\mathrm{T} = \mathrm{h}\cdot f/f = h$$

Hence, we should, effectively, think of one cycle packing not only the electron's energy but also as packing one unit of h.

More calculations: the properties of an electron

Now that we're doing some calculations, let's do some more. We can calculate the current:

$$\mathrm{I} = \mathrm{q_e}f = \mathrm{q_e}\frac{\mathrm{E}}{h} \approx (1.6\times10^{-19}\ \mathrm{C})\frac{8.187\times10^{-14}\ \mathrm{J}}{6.626\times10^{-34}\ \mathrm{Js}} \approx 1.98\ \mathrm{A}\ (ampere)$$

This is huge: a household-level current at the sub-atomic scale. However, this result is consistent with the calculation of the magnetic moment, which is equal to the current times the area of the loop and which is, therefore, equal to:

$$\mu = \mathrm{I}\cdot\pi a^2 = \mathrm{q_e}\frac{\mathrm{m}c^2}{h}\cdot\pi a^2 = \mathrm{q_e}c\frac{\pi a^2}{2\pi a} = \frac{\mathrm{q_e}c}{2}\frac{\hbar}{\mathrm{m}c} = \frac{\mathrm{q_e}}{2\mathrm{m}}\hbar$$

It is also consistent with the presumed angular momentum of an electron, which is that of a spin-1/2 particle. Here we must make some assumption as to how the effective mass of the electron will be

[6] The cycle time of short-wave ultraviolet light (UV-C), with photon energies equal to 10.2 eV is 0.4×10^{-15} s, so that gives an idea of what we're talking about. You may want to compare with frequencies of X- or gamma-ray photons.

spread over the disk. If we assume it is spread uniformly over the whole disk[7], then we can use the 1/2 form factor for the moment of inertia (*I*). We write:

$$\mathrm{L} = I \cdot \omega = \frac{ma^2}{2}\frac{c}{a} = \frac{mc}{2}\frac{\hbar}{mc} = \frac{\hbar}{2}$$

We now get the correct g-factor for the pure spin moment of an electron:

$$\boldsymbol{\mu} = -\mathrm{g}\left(\frac{\mathrm{q_e}}{2\mathrm{m}}\right)\mathbf{L} \Leftrightarrow \frac{\mathrm{q_e}}{2\mathrm{m}}\hbar = \mathrm{g}\frac{\mathrm{q_e}}{2\mathrm{m}}\frac{\hbar}{2} \Leftrightarrow \mathrm{g} = 2$$

We refer the reader to our other papers for a more detailed discussion of the model and other calculations.[8] The point is: this model gives us all of the so-called *intrinsic* properties of the electron. The mystery is gone. We have a similar *realist* interpretation of the photon.[9] However, the title of this paper is: electrons as gluons, so it is time we start talking about that. However, before we can do so, we need to cover more basics. Just hang in for a while. We will get to the fun stuff.

Calculations for the muon electron

The electron has two heavier versions but they are unstable:

1. The muon energy is about 105.66 MeV, so that's about 207 times the electron energy. Its lifetime is much shorter than that of a free neutron but longer than that of other unstable particles: about 2.2 *micro*seconds (10^{-6} s). The difference should not be exaggerated, however: the mean lifetime of charged pions is about 26 *nano*seconds (10^{-9} s), so that's only 85 times less.

2. The energy of the tau electron (or tau-*particle* as it is more commonly referred to[10]) is about 1776 MeV, so that's almost 3,500 times the electron mass. Its lifetime is extremely short: 2.9×10^{-13} s, so we think of it as some resonance or very *transient* particle.

According to the oscillator model, we should find a Compton radius for the muon that is equal to:

$$r_{\mathrm{C}} = \frac{c}{\omega} = \frac{c \cdot \hbar}{\mathrm{E}} \approx \frac{(3 \times 10^8 \frac{\mathrm{m}}{\mathrm{s}}) \cdot (6.582 \times 10^{-16}\mathrm{eV} \cdot \mathrm{s})}{105.66 \times 10^{-6}\mathrm{eV}} \approx 1.87 \text{ fm}$$

The CODATA value for the Compton *wavelength* of the muon is the following:

$$1.173444110\times10^{-14} \text{ m} \pm 0.000000026\times10^{-14} \text{ m}$$

[7] This is a very essential point: it is the *essence* of the oscillator model. It is also a very deep and philosophical point. We say the energy is in the motion, but it's also in the oscillation. According to Hestenes, half of the energy is magnetic (the magnetic flux through the ring) and the other half is the kinetic energy of the pointlike charge. However, the oscillator model implies a different interpretation. The two interpretations should be equivalent but this equivalence still needs to be firmly demonstrated. See: Jean Louis Van Belle, *Mass without mass*, 13 August 2019, http://vixra.org/abs/1908.0225.
[8] See the reference above.
[9] See: Jean Louis Van Belle, *A Classical Quantum Theory of Light*, 13 June 2019, http://vixra.org/abs/1906.0200.
[10] In light of its short lifetime, I would prefer to refer to it as a resonance. I like to reserve the term 'particle' for *stable* particles. Within the 'zoo' of unstable particles Longer-living particles may be referred

If you divide this by 2π - to get a *radius* instead of a wavelength – you get the same value: about 1.87×10^{-15} m. So our oscillator model seems to work for a muon as well! Why, then, is it not stable? The only explanation is that the oscillation might be *slightly* off, so let us be more precise in our calculation and use CODATA values for all variables here[11]:

$$\lambda_C = \frac{2\pi}{2\pi}\cdot\frac{\left(299{,}792{,}458\,\frac{\mathrm{m}}{\mathrm{s}}\right)\cdot(6.62607015\times10^{-34}\mathrm{eV}\cdot\mathrm{s})}{1.6928338\times10^{-11}\ \mathrm{J}} \approx 1.1734441131\ldots\times10^{-14}\ \mathrm{m}$$

The calculated value falls within CODATA's uncertainty interval, so we cannot be conclusive. The result remains quite significant, though.[12]

The muon is interesting because we might entertain the following idea: the muon has an anti-matter counterpart whose *electric* charge is equal to that of the proton and – who knows? – perhaps it's like the neutron: unstable *outside* of the nucleus, but stable inside. If that's the case, it might be part of the proton. Crazy? Maybe. Maybe not. Let us first look at some other things before we pursue this idea.

The universal validity of the charge conservation law

We mentioned the phenomenon of electron-positron pair production from very-high energy photons. It is a remarkable phenomenon. These pairs are produced when gamma rays hit heavy nuclei. To be precise, the photon is thought to interact with the Coulomb field of the atomic nucleus, and the probability of an electron–positron pair to emerge from the photon increases with (i) the photon energy and (ii) the atomic number.[13].

The creation and annihilation of electron-positron pairs respects the *idea* of charge conservation. The *combined* charge of the *pair* is the same as that of the photon: zero. However, it does *not* conserve the *number of charged particles*. Dirac duly noted that in the preface to the fourth and last edition of his seminal 'Principles of Quantum Mechanics', in which he recognized the significance of electron-positron pair creation and annihilation:

> "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."

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[11] In the new calculation, we will also express Planck's quantum of action and the muon energy in *joule* so as to get a more precise wavelength value. Note that the $2\pi/2\pi = 1$ factor in the ratio is there because we calculate a wavelength (which explains the multiplication by 2π) and because we do *not* use the reduced Planck constant (which explains the division by 2π).

[12] As for the tau electron, we are not aware of any experimental value of its Compton wavelength. Hence, a calculation isn't useful here.

[13] The energy of the photon has to be *very* high because its energy (or mass equivalent) has to match the energies of the electron and the positron that's being produced, and some extra. Hence, we are talking high-energy gamma-ray photons here ($E_\gamma > 1.022$ MeV). The reader should note we are referring to the 1930 Meitner–Hupfeld experiment, which involved anomalous scattering of gamma rays by heavy elements. The effect is, effectively, the result of electron–positron pair production and annihilation. For a good overview and discussion, see: J.H. Hubbell, *Electron–positron pair production by photons: a historical overview*, June 2006 (https://www.sciencedirect.com/science/article/abs/pii/S0969806X0500263X).

This modification is, in fact, the only significant change in Dirac's *Principles* between 1930 (first edition) and 1957 (fourth and last edition). Mainstream quantum-mechanical calculus takes this reality into account of this reality by substituting the charge conservation law by the *lepton number conservation* law, in which the lepton number is defined as the *difference* between the number of leptons (electrons) and the number of anti-leptons (positrons).

This new definition of the lepton number covers $\gamma \leftrightarrow e^- + e^+$ processes as well as processes such as neutron decay, inverse beta decay, or electron capture by a proton, but that's only because we decided to also label neutrinos as *leptons*, which is a bit arbitrary (we will tell you why in a minute). Let us have a look at the mentioned processes—if only to check whether it is true, or not, that the total *net* charge of the Universe is always being conserved.

The nature of protons and neutrons

A proton is stable. A neutron is stable *inside of the nucleus* only. The mean lifetime of a free neutron – outside of the nucleus – is a bit less than 15 minutes.[14] That's close to an eternity in high-energy physics but it is what it is: free neutrons *decay* into a proton and an electron. This disintegration process is written as:

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

As you can see, total charge is being conserved, and the lepton number rule works because we think of the neutrino as an anti-lepton: the lepton number – defined as the *difference* between leptons and anti-leptons – is zero on both sides of the equation. However, there is this obvious but unsolved question in physics: neutrinos and anti-neutrinos are both neutral, so what's the difference between a neutrino and an anti-neutrino? 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.[15] 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. If we wouldn't, that lepton number rule wouldn't work anymore.

Let us think about the other universal conservation law: the conservation of energy. 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.[16] The electron energy gives us close to 0.511 MeV of that difference – so

[14] There are two different ways of measuring the mean lifetime of neutrons, and they yield slightly different values. See: https://www.quantamagazine.org/neutron-lifetime-puzzle-deepens-but-no-dark-matter-seen-20180213/.

[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. However, that doesn't make them two different particles, and it surely does not make one the anti-particle of the other. The question that needs to be answered is whether or not neutrinos and anti-neutrinos do what electrons and positrons do: matter and anti-matter particles should annihilate each other in a big flash. We do not know of a clear and concise answer to that question but a quick *google* search indicates neutrinos and anti-neutrinos live happily alongside each other. One should also note that – in a realistic interpretation of the neutrino – it should not have a magnetic moment (spin). Why not? Because it is neutral: there is no spinning pointlike charge.

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

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.[17] So, yes, energy is conserved.

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.

Last but not least, we should mention another interesting process. In 1951, Cowan and Reines proved that bombarding protons with neutrinos leads to the creation of neutrons and positrons.[18] The process is written as:

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

What about energy conservation here? The energy of a neutron and a positron add up to a bit more than 940 MeV. The energy *difference* with a proton is about 1.8 MeV. Can the incoming neutrino have such energy? The answer is positive: neutrinos can have any energy[19], and we may usefully remind ourselves that Wolfgang Pauli postulated the existence of neutrinos in 1930 to account for rather large variations in the measured energy of the electron coming out of beta decay processes. Hence, the order of magnitude may surprise but remains reasonable.

These reactions make one think of the neutron as a *two-body* particle: a proton with an electron. Is there any more evidence for that? Why are neutrons stable inside of a nucleus? More generally, do we have any clear picture of what might actually be happening inside of a nucleus? According to common wisdom, we need to introduce a new charge – and, therefore, a new *force* – to explain why protons will stick together. But perhaps neutrons can serve as glue? Do we need the idea of *gluons*? All nuclei with two or more protons also have one or more neutrons. 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

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

[18] The Wikipedia article on the Cowan-Reines experiment offers a very good account not only of the history of the experiment but also of the history of the discovery of neutrinos. See: https://en.wikipedia.org/wiki/Cowan%E2%80%93Reines_neutrino_experiment.

[19] See: https://neutrinos.fnal.gov/types/energies/. Also see the IceCube (South Pole Neutrino Observatory) experiments (https://icecube.wisc.edu/info/neutrinos), which have detected TeV neutrinos.

together through the nuclear force. *Neutrons are required for the stability of nuclei*, with the exception of the single-proton hydrogen atom."[20] So, yes, neutrons may, perhaps, serve as gluons.

Let us try to think this through.

Can we use the oscillator model for the proton?

The hydrogen nucleus is a single proton. We also have the other stable isotope of hydrogen, of course: deuterium. Deuterium has *deuteron* as its nucleus. Deuteron is a bound proton and neutron. The radius of deuteron is about 2.1 fm (10^{-15} m). That's about 25% *smaller* than the classical electron radius (2.8 fm). The radius of the most common hydrogen nucleus – a simple *proton* – is less than 1×10^{-15} m: 0.8 to 0.9 fm.[21]

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

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

That's about 1/4 of the actual radius as measured in scattering experiments. What's the *rationale* for calculating the Compton radius of a proton (or a neutron)? Can we use the same *Zitterbewegung* model for protons? To answer that question, we should examine the oscillator model some more in detail.

To keep an object with some momentum in a circular orbit, a centripetal force is needed – as shown in Figure 1. What is the nature of this force? A force can only grab onto a charge. For an electron, that charge is electromagnetic, and we analyzed all the rest in pretty much the same manner: the circular current creates a magnetic flux through the ring which keeps the current going – just like in a superconducting ring. This is David Hestenes' interpretation of the *Zitterbewegung* of an electron: half of the electron's energy is kinetic, the other half is magnetic.[22] We prefer to do some other calculations. Calculations that are more general—read: calculations that may be valid when *other* charges (or other *forces*) are involved. Let's go for it.

We can calculate the centripetal acceleration: it's equal to $a_c = v_t^2/a = a\cdot\omega^2$. This formula is relativistically correct. It might be useful to remind ourselves where this formula comes from. The radius vector $\boldsymbol{a}$ has a horizontal and a vertical component: $x = a\cdot\cos(\omega t)$ and $y = a\cdot\sin(\omega t)$. We can now calculate the two components of the (tangential) velocity vector $\boldsymbol{v} = \mathrm{d}\boldsymbol{r}/\mathrm{dt}$ as $v_x = -a\cdot\omega\cdot\sin(\omega t)$ and $v_x\ y = -a\cdot\ \omega\cdot\cos(\omega t)$. We can now calculate the components of the (centripetal) acceleration vector $\boldsymbol{a_c}$: $a_x = -a\cdot\omega^2\cdot\cos(\omega t)$ and $a_y = -a\cdot\omega^2\cdot\sin(\omega t)$. The *magnitude* of the centripetal acceleration vector can then be calculated as:

$$a_c^2 = a_x^2 + a_y^2 = a^2\cdot\omega^4\cdot\cos^2(\omega t) + a^2\cdot\omega^4\cdot\sin^2(\omega t) = a^2\cdot\omega^4 \Leftrightarrow a_c = a\cdot\omega^2 = v_t^2/a$$

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

[21] Different experimental methods give different results. We will let the eager reader *google* this.

[22] Hestenes is to be credited with the *revival* of the *Zitterbewegung* model of an electron. His re-interpretation has one problem: there is no real material ring to hold and guide our charge in free space, so what keeps this thing *tuned*? This problem led like-minded theoretical physicists (think of Alexander Burinskii, for example) to abandon the model.

Now, the force law tells us that F is equal to $F = m \cdot a_c = m \cdot a \cdot \omega^2$. However, what is the mass of our pointlike charge? It has mass because it moves at the velocity of light, but its rest mass is zero. In other words, the relativistic $m = \gamma m_0$ formula yields zero, *always*. Or not? We forget something: the velocity v is equal to c. The Lorentz factor is, therefore, equal to infinity, *always*. So we are multiplying zero with infinity, which gives us… What?

We need to introduce the concept of the *effective* mass of a pointlike charge here. Let us denote it by:

$$m_\gamma = \gamma m_0$$

The subscript – gamma (γ) – is quite apt: it refers to the Lorentz factor, of course. However, theorists such as Burinskii sometimes refer to the pointlike charge as a *toroidal photon* – for an obvious reason, as you can see! What's the value of m_γ? It shouldn't be zero, and it shouldn't be infinity. It is also quite sensible to think m_γ should be smaller than the rest mass of the particle (m): it cannot be larger because than the energy of the oscillation would be larger than $E = mc^2$. What could it be? Rather than guessing, we may want to remind ourselves that we know the angular momentum of *matter-particles* (or fermions, as they're usually referred to): $L = \hbar/2$. If $\boldsymbol{r} = \boldsymbol{a}$, then the $\mathbf{L} = \boldsymbol{r} \times \mathbf{p}$ formula becomes $L = a \cdot p$ and then we can calculate m_γ as follows[23]:

1. $L = \hbar/2 \Rightarrow p = L/a = (\hbar/2)/a = (\hbar/2) \cdot m_e \cdot c/\hbar = mc/2$
2. $p = m_\gamma c$

   $\Rightarrow m_\gamma c = mc/2 \Leftrightarrow m_\gamma = m/2$

This is a great result: the *effective* mass of the pointlike charge – as it whizzes around the center of the two-dimensional oscillation that makes up our particle – is *half* of the (rest) mass of the particle itself. Hence, we can now write the $F = m \cdot a_c = m \cdot a \cdot \omega^2$ as:

$$F = m_\gamma \cdot a_c = m_\gamma \cdot a \cdot \omega^2 = m \cdot a \cdot \omega^2/2$$

We know energy is force over a distance and – because of the assumption of a circular orbit – the force is a constant here. Hence, we don't need to integrate. A simple product will do: $E = F \cdot s$. However, to use a simple product, the displacement needs to be measured along the line of force, and our pointlike charge doesn't move along the line of force. Not at all, actually: the motion is perpendicular to it. What should we do? We can analyze the force in terms of its *x*- and *y*-component, and we can think of the circular motion as a superposition of its motion in the *x*- and *y*-direction respectively. This allows us to write the position $\boldsymbol{r}$ of the pointlike charge in terms of the elementary wavefunction:

$$\boldsymbol{r} = a \cdot e^{i\theta} = x + i \cdot y = a \cdot \cos(\theta) + i \cdot a \cdot \sin(\theta) = a \cdot \cos(\omega t) + i \cdot a \cdot \sin(\omega t) = (x, y)$$

The two force components can be written as the following functions of the *magnitude* of the centripetal (F) and the *x* and *y* coordinates:

$$F_x = F \cdot \cos(\theta - \pi) = -F \cdot \cos(\theta) = -F \cdot x/a \quad \text{and} \quad F_y = F \cdot \sin(\theta - \pi) = -F \cdot \sin(\theta) = -F \cdot y/a$$

[23] These calculations may baffle the reader but we advise him or her to check our previous papers on the oscillator model (reference(s) above).

We thus get the following formula for the force[24]:

$$\mathbf{F} = \mathbf{F_x} + \mathbf{F_y} = -\mathrm{F}\cdot\cos(\theta) - i\cdot\mathrm{F}\cdot\sin(\theta)$$

We can now calculate the energy integral, taking into account the force *reverses* direction when *x* (or *y*) is equal to zero, and that the pointlike charge itself reverses direction when *x* (or *y*) is equal to $\pm a$[25]:

$$\mathrm{E}_x = \int_0^a \mathrm{F}_x \mathrm{d}x - \int_a^0 \mathrm{F}_x \mathrm{d}x + \int_0^{-a} \mathrm{F}_x \mathrm{d}x - \int_{-a}^0 \mathrm{F}_x \mathrm{d}x$$
$$= \int_0^a \frac{\mathrm{F}}{a} x \mathrm{d}x - \int_a^0 \frac{\mathrm{F}}{a} x \mathrm{d}x + \int_0^{-a} \frac{\mathrm{F}}{a} x \mathrm{d}x - \int_{-a}^0 \frac{\mathrm{F}}{a} x \mathrm{d}x$$
$$= \frac{\mathrm{F}}{a}\left[\frac{1}{2}x^2\right]_0^a - \frac{\mathrm{F}}{a}\left[\frac{1}{2}x^2\right]_a^0 + \frac{\mathrm{F}}{a}\left[\frac{1}{2}x^2\right]_0^{-a} - \frac{\mathrm{F}}{a}\left[\frac{1}{2}x^2\right]_{-a}^0$$
$$= \frac{\mathrm{F}}{2}a + \frac{\mathrm{F}}{2}a + \frac{\mathrm{F}}{2}a + \frac{\mathrm{F}}{2}a = 2 \cdot \mathrm{F} \cdot a$$

Why do we have a subscript in the E_x expression? The energy in the x-direction? Energy is not supposed to have any direction, does it? Right. And not so right. We calculate kinetic energy based on velocities: velocities imply motion, and motion implies some direction. Likewise, potential energy is related to the position of some charge *vis-à-vis* some other charge: that implies some idea of direction too. That brings us to the next question: what is the energy concept here? Is E_x kinetic or potential? The shape of the integral suggests we are calculating potential energy – but we do so over a full *cycle*. We know the potential energy goes from 0 to some maximum at *a* and –*a*, and then back to zero. In-between, potential energy is converted into kinetic energy and vice versa. Hence, we are, effectively, calculating the total energy here.

What about E_y? We can calculate E_y in exactly the same way but, remember, the kinetic energy in the *y*-direction reaches a maximum when it reaches zero in the *x*-direction, and vice versa for the potential energy. We have a *phase* difference of 90 degrees. In our very first paper(s) on this topic[26], we introduced a metaphor, a *perpetuum mobile* combining *two* oscillators in a 90-degree angle: two springs or two pistons attached to some crankshaft. The inspiration came from a reflection on the optimum angle between the two pistons of a V-2 engine. When the angle between is equal to 90 degrees, then it is possible to perfectly balance the counterweight and the pistons, which ensures smoother travel.[27] The

[24] We are tempted to write cos(θ) and sin(θ) in boldface too because a **cos**(θ) and **sin**(θ) notation would remind the reader of the fact we are talking vector quantities here: mathematical objects that do not only have a magnitude but a direction too, and an origin that may or may not matter. However, we stick to the usual conventions. Note that the multiplication by the imaginary unit (*i*) – which amounts to a rotation by 90 degrees – ensures independence of the two force components.

[25] The two possible directions of the pointlike charge and the two possible directions of the force give us four situations, which reflect the four quadrants of the circle. This is why we broke up the integral into four different parts. The minus signs are explained by the reversal of the direction of the pointlike charge.

[26] See, for example: http://vixra.org/abs/1709.0390. We hesitate to give the reference because this was, effectively, a *very* sketch on our way to wisdom. 😊

[27] Ducati motorbike engines are 90-degree banked. Harley-Davidson engines are 45-degree V-twin engines. This gives the Harley its typical irregular sound. To be precise, what happens is this: a piston fires; the next piston fires

analogy can be extended to include two *pairs* of springs or pistons, in which case the springs or pistons in each pair would help drive each other. In either case, we have a beautiful interplay between linear and circular motion. In this interplay, energy is borrowed from one place and then returns to the other, cycle after cycle: while transferring kinetic and potential energy from one piston to the other[28], the crankshaft will rotate with a constant angular velocity: linear motion becomes circular motion, and vice versa.

What's the point? The point is: we can *not* just *add* E_x and E_y to get the *total* energy of the system: we'd be double-counting. E = 2·F·a is the total energy. We can now combine this with the F = $m_\gamma \cdot a_c = m_\gamma \cdot a \cdot \omega^2 = m_e \cdot a \cdot \omega^2/2$ formula to get the following grand result:

$$\mathrm{E} = 2\mathrm{F}a = 2\mathrm{m}_\gamma a\omega^2 a = \mathrm{m_e}a^2\omega^2$$

If we'd have some classical (non-relativistic) harmonic oscillator – think of a mass m going up and down at non-relativistic speeds – then its total energy would be equal to E = $ma^2\omega^2/2$. Here we get *twice* that value. It is a beautiful result. Our calculation of the Compton radius combining the $c = a \cdot \omega$, E = m·c^2 and E = ħ·ω = h·f equations now makes perfect sense. We can re-write it as follows:

$$\mathrm{E} = \mathrm{m}c^2 = \mathrm{m}a^2\omega^2 = \mathrm{m}a^2\frac{\mathrm{E}^2}{\hbar^2}$$

$$\Leftrightarrow a = \sqrt{\frac{\mathrm{E}}{\mathrm{m}}\frac{\hbar^2}{\mathrm{E}^2}} = \sqrt{c^2\frac{\hbar^2}{\mathrm{E}^2}} = \frac{\hbar c}{\mathrm{E}} = \frac{\hbar c}{\mathrm{m}c^2} = \frac{\hbar}{\mathrm{m}c} = r_\mathrm{C}$$

The proton as a non-elementary particle

However, as mentioned already, the reasoning above doesn't seem to work for the proton. If we try the mass of a proton (or a neutron—almost the same) in the formula for the Compton radius, we get this:

$$a_\mathrm{p} = \frac{\hbar}{\mathrm{m_p}\cdot c} = \frac{\hbar}{\mathrm{E_p}/c} = \frac{(6.582\times10^{-16}\ \mathrm{eV}\cdot s)\cdot(3\times10^{8}\ m/s)}{938\times10^{6}\ \mathrm{eV}} \approx 0.21\times10^{-15}\ \mathrm{m}$$

That's about 1/4 of the actual radius as measured in scattering experiments. A factor of 1/4 is encouraging but not good enough. According to mainstream theory, this is supposed to prove that some other force must be involved. A force which is *not* like the electromagnetic force. At the same time, protons do carry *electric* charge, and they also have a magnetic moment.

Can we think of a muon *positron* – a 105.66 MeV *variant* of the positron, so to speak – and imagine it is in some kind of oscillation? The energy in the oscillation would then have to explain the energy of the proton, which is almost 9 times that value! That looks like a bit of a long haul, and it is. However, the idea is not all that outrageous.

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at 315 degrees; there is a 405-degree gap; a piston fires; the next piston fires at 315 degrees; there is a 405-degree gap; etcetera. That's because the engine is four-stroke.

[28] Physicists will probably prefer a double-spring system as a metaphor – as opposed to a Ducati V-twin engine! The principle is the same, however: with permanently closed valves, the air inside the cylinder compresses and decompresses as the pistons move up and down. It provides, therefore, a restoring force. As such, it will store potential energy, just like a spring.

Why the muon positron? Perhaps we're luckier with the tau positron? We do not have any measured value for its radius but if our oscillator model works, then its radius should – effectively – be *smaller* than the proton radius. Indeed, the $r_C = c \cdot \hbar/E$ relation tells us it *must* be smaller than the proton radius because the tau's energy is higher—but so now we have another problem: we cannot have a *heavier* particle as the constituent of a *lighter* one, right?

OK. But so the muon doesn't work. What to do? The idea remains attractive. Why? Because the alternative is quite a headache: introducing an entirely new force (a 'strong' force) complicates the analysis significantly because we have to distinguish and disentangle two forces – each with their own structure. Also, if there is such thing as a strong force, then there must be some *strong* charge. Hence, we need to think about the equivalent of a magnetic moment, spin and other intrinsic properties of particles that have *electric* charge only. It seems like an impossible task—especially because we think the strong charge comes in three colors, so it has a ternary structure (red, blue and green) rather than a binary one (positive versus negative).

That sounds terribly complicated, and it is. That's why the alternative – thinking of the proton as an oscillation of a (muon) positron – remains attractive. The only problem is the (muon) radius. The Compton radius we calculated (about 1.87 fm) is *larger* than the charge radius of the proton (0.8 to 0.9 fm), so how do we deal with that?

We have no answer for that. The question is complicated because we have to note another inconsistency: if a muon is an oscillation of a pointlike charge, then its radius shouldn't be larger than that pointlike charge, right? However, we do associate a radius with the pointlike charge: the classical electron radius. We do so to explain Thomson scattering and other properties (e.g. the anomalous magnetic moment[29]). The problem is that this classical electron radius – aka as Thomson or Lorentz radius – is actually *larger* than the muon radius. To be precise, it's 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 1.5 times *larger* than the measured muon radius, and it's 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. Should we try to develop some kind of inside-out *plum pudding model* of an atom here, with the negative electron charge enveloping some newly defined positron?[30] Probably not. There seems to be no escape: we probably do need to accept some non-electromagnetic force is involved.

It's not only the above-mentioned inconsistency about the proton radius. There is another obvious reason to think of another force, of course: when everything is said and done, we also do need to

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[29] See: Jean Louis Van Belle, *The Anomalous Magnetic Moment: Classical Calculations*, 11 June 2019 (http://vixra.org/abs/1906.0007).

[30] See: https://en.wikipedia.org/wiki/Plum_pudding_model. We talk of a 'newly defined positron' because it is clear – from the arguments presented – that the proton cannot be equated to a positron.

explain the *particle zoo*—why some decay reactions occur and others don't, and why we have all those different mean lifetimes. Any explanation of that *zoo*[31] must probably involve some other force.

We will let this matter rest for a while. Let us examine something else. Let us hover around the higher level: the nucleus. What keeps a nucleus together? What keeps protons together?

Neutrons – or electrons? – as gluons

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."[32] So, yes, neutrons may, perhaps, serve as gluons.

At the same time, the above-mentioned processes – proton turning into neutrons and vice versa – make us think of a neutron as a *two-body* particle: a proton with an electron. Hence, perhaps we should think of the electron as the 'glue' inside of a nucleus.

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.[33] 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.[34]

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

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

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

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

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:

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

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.[35] 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 as 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

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

[35] 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.

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 (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.[36] 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.[37] 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

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

[37] 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.

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.

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[38]:

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

The $q_e\hbar/2m_e$ 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?[39] 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[40]:

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

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

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

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

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, $\mu_\mathrm{p} \approx 2.8 \cdot \mu_\mathrm{N}$, 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:

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

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.[41]

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.[42]

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

[42] 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.

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 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!

Perhaps the process is like this: the photon causes a proton to emit a positron (β+ decay[43]) – so it turns it into a neutron. At the same time, a neutron decays into a proton and emits an electron. Charge is conserved and so there's no mystery here !

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[44], 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. That's why the idea of a proton model based on some oscillation of a positron (or a *muon* positron) is and remains appealing.

Jean Louis Van Belle, 28 August 2019

[43] See: https://en.wikipedia.org/wiki/Positron_emission
[44] See: Jean Louis Van Belle, *Mass without Mass*, 13 August 2019 (http://vixra.org/abs/1908.0225).