Explaining the Lamb shift in classical terms

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Summary

Any realist electron model must explain the properties of an electron as used in mainstream quantum physics, including its mass, radius, magnetic moment – and their anomaly, of course. In a *realist* interpretation of quantum mechanics, these properties are not to be considered as mysterious intrinsic properties of a pointlike electron: the model should generate them. We think we have done that rather convincingly in previous papers.

In this paper, we take the next logical step. We relate the model to the four quantum numbers that define electron orbitals. In the process, we offer a classical explanation of the Lamb shift., which main theorists usually tout as the other high-precision test of mainstream quantum field theories.

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Introduction

The Lamb shift is a very tiny difference (in energy) between the $^2S_{1/2}$ and $^2P_{1/2}$ orbitals in a hydrogen atom. The standard story is this: Dirac's equation – for a *non*-free electron[1] – does *not* predict this tiny energy difference. Hence, it must be wrong and we, therefore, need to explain this in terms of "interaction between vacuum energy fluctuations." Let me quote Wikipedia in full here:

> "This particular difference is a one-loop effect of quantum electrodynamics, and can be interpreted as the influence of virtual photons that have been emitted and re-absorbed by the atom. In quantum electrodynamics the electromagnetic field is quantized and, like the harmonic oscillator in quantum mechanics, its lowest state is not zero. Thus, there exist small zero-point oscillations that cause the electron to execute rapid oscillatory motions."[2]

[…]

This sounds fantastic, doesn't it? 😊 Willis Eugene Lamb Jr. got a Nobel Prize in Physics for it in 1955. He had to share it with Polykarp Kusch, though. To be precise, Lamb got the prize "for his discoveries concerning the fine structure of the hydrogen spectrum" (read: the Lamb shift) and Polykarp Kusch got it "for his precision determination of the magnetic moment of the electron" (read: the so-called anomaly in the magnetic moment).[3]

To be sure, Lamb did *not* get it for the above-mentioned *explanation*, which we think of as nonsensical and which, judging from some of the later publications of Lamb, he probably found rather nonsensical as well.[4] Likewise, Kusch left the explaining of the anomalous magnetic moment to the theorists too—more famous names you may or may not be more acquainted with, such as Julian Schwinger and Richard Feynman, for example. They effectively got the Nobel Prize – almost 20 years after Lamb's discovery[5] and Bethe's first dirty work on it[6] – for *explaining* these seemingly strange measurements using even stranger theories.

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[1] Dirac first developed a wave equation for a free particle (*Principles of Quantum Mechanics*, section 30), which is a particle free of any forces. Section 39 of the *Principles* then further use this theory to deal with what Dirac refers to as the electron's 'motion in a central field of force', based on which he then develops a wave equation that gives us the energy levels of the hydrogen atom (section 40). This is, basically, a modified version of Schrödinger's wave equation for the hydrogen atom.
[2] See: https://en.wikipedia.org/wiki/Lamb_shift, accessed on 29 March 2020.
[3] See: https://www.nobelprize.org/prizes/physics/1955/summary/, accessed on 29 March 2020. We write the 'so-called' anomaly because we do not think of the anomaly as an anomaly. We think it is perfectly normal: zero-dimensional charges cannot exist. Why not? We think it is logical to suggest that something that had no dimension whatsoever cannot carry charge.
[4] See: W.E. Lamb, *Anti-photon*, Applied Physics B volume 60, pages77–84 (1995). We offer some comments on this remarkable paper – which Lamb wrote when he was over 80 years old – at the end of our paper.
[5] The Lamb shift was measured in the Columbia Radiation Laboratory in 1947. From W.E. Lamb's Nobel Prize Lecture, I gather the heavy lifting was actually done by one of his graduate students, Robert Curtis Retherford, whom he mentions only once.
[6] For a good overview of the 'dirty work' that went into this, see: Oliver Consa, *Something is rotten in the state of QED*, 1 February 2020 (https://www.researchgate.net/publication/338980602_Something_is_rotten_in_the_state_of_QED).

The need for new theories is and was very questionable, indeed. The first edition of Dirac's *Principles* was published in 1930, and it still serves as one of the better textbooks in quantum mechanics. So why would one want to invent a whole new theory instead of trying to fix *one single (wave) equation*? In fact, the rather remarkable fact that an equation yields two different *states* with the same energy level should lead to a much more logical conclusion: Dirac's equation is more or less right but is, most probably, *not sophisticated enough*.

Two *different* energy states with the *same* energy level? Now *that* is actually problematic, isn't it? There must be some *duplication* then somewhere, isn't it?[7] Dirac must have forgotten to incorporate some *anomaly* or some form factor relating to our mathematical idealizations. As such, we'd think Lamb's discovery should *validate* Dirac's intuitions, rather than *contradict* them, isn't it?

The necessary correction that would need to be made looks rather obvious to us: when everything is said and done, we do not *really* believe electrons – or electric charge – are zero-dimensional objects, are they?

[…]

If *you* do, you should stop reading. Before you stop reading, however, you should reflect on the fact that Dirac didn't quite believe that either, even if his theory is based on the usual assumption—which is that electrons are pointlike and, therefore, have no dimension whatsoever.[8] We think things that have no dimension whatsoever don't exist or, at the very least, cannot carry charge. Once we accept this rather obvious *assumption*, all becomes rather reasonable.

We should also warn the professional or academic physicist: he or she may object to our light tone or language. However, we thought that – in light of Dr. Consa's rather skeptical assessment of the *state* of current physics[9] – we might as well have some fun while exploring (the) matter—*literally*. We promise we will do our best to produce some more serious-sounding language in the next version of this paper.[10]

[7] The academic physicist will probably object to our sarcastic or even caustic language but we thought that – in light of Dr. Consa's rather skeptical assessment of the *state* of current physics (https://vixra.org/abs/2002.0011) – we might as well have some fun with it.

[8] It is always worth quoting Dirac's summary of why an electron has the radius it has: "*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 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)

[9] Oliver Consa, *Something is rotten in the state of QED*, 1 February 2020 (https://vixra.org/ab0s/2002.0011).

[10] No guarantee here, though! A fellow amateur physicist refers to mainstream physics as "cargo-cult science". I must admit I like that expression—very much so, actually.

The four quantum numbers for electron orbitals

To make sense of whatever it is that we are trying to make sense of here, we should make sure we are on the same page in regard to notation and the basics of the ring current electron model that we are using here.[11]

The $^2S_{1/2}$ and $^2P_{1/2}$ notation for the orbitals is the *term symbol* notation. The numbers in the super- and subscript (2 and 1/2) and the *letter* symbol (S and P) correspond to the quantum numbers *S*, *L* and *J* respectively, like this:

$$^{2S+1}L_J$$

These symbols are a bit confusing, so let us try to clarify:

1. *S* is the spin quantum number: it is plus or minus 1/2 (*up* or *down*). It is the simplest of all quantum numbers but also the most confusing, because no one will ever tell you what it actually *is*.[12] The superscript in the $^2S_{1/2}$ and $^2P_{1/2}$ is, therefore, largely meaningless in this context: it basically denotes we have *two* states for each energy level: spin *up* versus spin *down*. In other words, it tells you we can have *two* electrons in these orbitals. As such, no value added here.

2. *L* is the (total) *orbital* quantum number. If it is zero, then the orbital is a *spherically symmetric solution* to Schrödinger's equation. If it is 1, 2,… , *n*, then it's a non-spherical solution. Physicists will often be vague about the unit for *S* (and rightly so, as we will explain later[13]) but for *L* you can be sure: it's expressed in units of *ħ*, so that's the regular unit for angular momentum. This number is the most logical one because it is reflected in the Planck-Einstein law:

$$\mathrm{E} = n \cdot \hbar\omega = \frac{h}{2\pi} 2\pi f = h \cdot f \Leftrightarrow \frac{\mathrm{E}}{f} = \mathrm{E} \cdot \mathrm{T} = n \cdot h$$

Think of T as the *cycle time* – the time that is needed for one rotation of the elementary charge that generates the magnetic moment – or the *clock speed* of the particle that we are looking at here which, in this case, is an *atom* rather than an electron or a proton. The energy level is, therefore, just a *fraction* of the energy of the electron. To be precise, for *n* = 1, we get the *Rydberg* energy E_R. Indeed, combining the Planck-Einstein relation and the classical Bohr model of a hydrogen atom – which relates the Bohr

[11] We effectively assume our reader is familiar with the electron ring current model that we are constantly referring to in this paper. The basics of this model are very simple: an electron has a magnetic moment and we, therefore, assume the electron is a perpetual ring current. The current consists of an elementary charge spinning around at lightspeed. The radius of its motion is the Compton radius of an electron, which we directly derive from Einstein's mass-energy equivalence relation, the Planck-Einstein relation and the tangential velocity formula:

$$\left.\begin{array}{c} \left.\begin{array}{c}\mathrm{E} = \mathrm{m}c^2 \\ \mathrm{E} = \hbar\omega\end{array}\right\} \Rightarrow \mathrm{m}c^2 = \hbar\omega \\ c = a\omega \Leftrightarrow a = \dfrac{c}{\omega} \Leftrightarrow \omega = \dfrac{c}{a}\end{array}\right\} \Rightarrow \mathrm{m}a^2\omega^2 = \hbar\omega \Longrightarrow \mathrm{m}\frac{c^2}{\omega^2}\omega^2 = \hbar\frac{c}{a} \Leftrightarrow a = \frac{\hbar}{\mathrm{m}c}$$

For more detail, see: https://vixra.org/abs/2003.0094 or other previous publications (https://vixra.org/author/jean_louis_van_belle).

[12] For an explanation of spin, see my recent blog post: https://ideez.org/2020/03/22/whats-the-spin-of-spin-1-2-particles/.

[13] The *spin* angular momentum should also be expressed in units of *ħ* (preferably in units of *ħ*/2, actually) but the contribution of the spin angular momentum is probably only a tiny fraction of such units. Almost all of the angular momentum of an electron comes from the orbital angular momentum of the charge inside and from the electromagnetic field that keeps that charge in its orbit or *Zitterbewegung*.

and Compton radius through the fine-structure constant ($r_C = \alpha \cdot r_B$) and which associates a classical velocity $v = \alpha \cdot c$ with the motion of the electron[14] – we get:

$$h = \mathrm{E}_R \cdot \mathrm{T} = \mathrm{E}_R \cdot \frac{2\pi r_\mathrm{B}}{v} = \mathrm{E}_R \cdot \frac{\frac{h}{\alpha \mathrm{m}c}}{\alpha c} \Leftrightarrow \mathrm{E}_R = \alpha^2 \mathrm{m}c^2 = \frac{\mathrm{q_e}^4 \mathrm{m}}{8\varepsilon_0{}^2 \mathrm{h}^2} \approx 13.6 \text{ eV}$$

L is also referred to as a *subshell* number. It is then related to a so-called *principal* quantum number which describes the *principal* energy level, which is usually denoted by *n*. The subshell number *l* will always be less than the number of energy states. To be precise, we can write: l = 0, 1, 2,… n – 1 for n = 1, 2, 3,… n, and the energy of the n^{th} level is equal to:

$$\mathrm{E}_n = -\frac{1}{n^2} \cdot \alpha^2 \mathrm{m}c^2 = -\frac{1}{n^2} \cdot \frac{\mathrm{q_e}^4 \mathrm{m}}{8\varepsilon_0{}^2 \mathrm{h}^2} \approx -\frac{1}{n^2} \cdot 13.6 \text{ eV}$$

This simple formula can be derived straight from the Bohr model or – if one prefers a more sophisticated approach – from solving Schrödinger's equation.[15]

A quick remark: is an electron spin-1 or spin-1/2? The equations above suggest it's spin-1, right? Right. The spin-1/2 property is not an easy one to interpret. We've explained that elsewhere, so we will skip the question here.[16]

3. *J* is supposed to be the sum of both: *J* = *L* + *S*. Many authors use lower-case letters (*j*, *l* and *s*), which we also prefer because *L* denotes angular momentum *tout court* in classical physics. This is quite confusing because, in addition to this, physicists will usually also use *letters* rather than numbers for the *value* of *L*, and the first letter is an *s* or an *S*, to denote – you guess it – *s*pherical states. Hence, the same symbol *S* or *s* means two very different things depending on the context: (1) the spin number (*up* or *down*) and (2) the spherical solution to Schrödinger's (or Dirac's) equation, which corresponds to an *L* = *l* = 0 *energy state*. For the $^2S_{1/2}$ orbital, we get *J* = 1/2 because *L* = 0 and *S* = +1/2. We are, therefore, talking a spin-*up* electron.

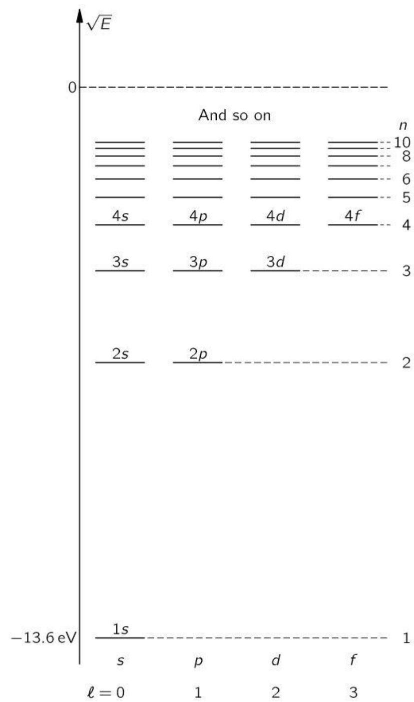
In contrast, a *P*- or *p*-state corresponds to a *non*-spherical solution, so *L* is equal to *l* = 1 or – using letters – *p* or *P*. Hence, to get a *J* that is (also) equal to 1/2, the spin *S* must be down (*S* = –1/2) in order for the *J* = *L* + *S* = 1 = 1/2 to make sense (1 –1/2 = +1/2).

[…]

Wait a minute here! Yes. You should stop me here: we shouldn't be distinguishing between spin up or spin down electrons here, should we? The Lamb shift does *not* refer to that, does it? It doesn't measure the energy difference between a spin-*up* and a spin-*down* state, does it? You are right (and not at the same time[17]).

[14] See Chapter VII of our manuscript (https://vixra.org/abs/1901.0105)
[15] See formula 19.51 in Feynman's *Lecture* on the hydrogen atom (https://www.feynmanlectures.caltech.edu/III_19.html). Note that we added the *minus* sign to account for the fact that we are measuring the (potential) energy with reference to an infinite distance from the nucleus. We should have added the minus sign in the formula for the Rydberg energy as well but we did not want to confuse the reader too much there.
[16] We deal with the question here: https://ideez.org/2020/03/22/whats-the-spin-of-spin-1-2-particles/.
[17] We will argue – later in this paper – that the Lamb shift has to do with the spin-*up* or spin-*down* states of the *Zitterbewegung* charge of the ring current that generates the magnetic moment.

Now that we are here, you should also note something else. If $l = 1$, then the principal quantum number must be equal to $n = 2$ and the energy level must be *one fourth* of the Rydberg energy. Look at the illustration we copied from Feynman's *Lectures* below: the Lamb shift is a tiny difference between the 2*s* and 2*p* subshells, and between the 3*s*, 3*p* and 3*d* subshells, etcetera.[18]



This is an important point: the Lamb shift is a tiny difference between the *excited* state of the *s*-orbital and the *p*-orbital, or between the *excited* state of a 2*p*-orbital (which is the 3*p*-orbital) and the 3*d*-orbital, so that fixes the 1/4 problem.[19] Don't trust Wikipedia to bring *too* much clarity here! 😉

4. Finally, we have a fourth quantum number, but that's one that's *not* reflected in this so-called *term* symbol notation[20]: the ***magnetic* quantum number** *m* or m_z. We will come back to that in the next section.

The point is this: this very short introduction to the quantum numbers describing electron orbitals is incomplete but should be sufficient for you to understand that one shouldn't be surprised that the $^2S_{1/2}$ and $^2P_{1/2}$ energy states are *different*. **Instead of being surprised about a difference, *we should wonder why these two energy states are so nearly together!***

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[18] See Figure 19-7 of Feynman's *Lecture* on the hydrogen atom (https://www.feynmanlectures.caltech.edu/III_19.html). We still thank the editors of the *online* version of Feynman's *Lectures* despite their complaints we make too liberal use of it. We wonder why they make such a fuss! See: https://readingfeynman.org/2020/02/20/physics-feynman-and-copyright/.

[19] Note the use of the square root (√E) in Feynman's graph. It is just a bit of a logarithmic scale to ensure better visualization.

[20] The reference to a term is apparently based on the Rydberg–Ritz combination principle, which tells us that the *difference* in energy between the various orbitals should be equal to the difference of the following two *terms*:

$$\Delta \mathrm{E} = \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) \cdot \mathrm{E}_R$$

This, however, only concerns the *main* spectral lines which derive from the *principal* quantum number *n*, which gives us the n^{th} energy level: $\mathrm{E}_n = -\mathrm{E}_R/n^2$. From this, the reader can easily derive the formula above.

Our tentative answer is this: we believe the spin angular momentum – for which we, unlike mainstream physicists, have a *physical* interpretation – only makes a very tiny contribution to the total angular momentum. We hope that sounds very revolutionary[21] but we think we will be able to demonstrate that convincingly by relating the above-mentioned quantum numbers to our ring current model.

The four quantum numbers and the ring current model of an electron

Any realist electron model must explain the properties of an electron as used in mainstream quantum physics, including its mass, radius, magnetic moment – and the anomaly in them, of course. Indeed, in a *realist* interpretation of quantum mechanics, these properties are not to be considered as mysterious intrinsic properties of a pointlike electron: the model should generate them. We think we have done that rather convincingly in previous papers.[22]

The challenge here is different: we here need to relate the model to the four quantum numbers that define electron orbitals. How can we do that?

In order to facilitate the discussion (common language facilitates communication), we prefer to stick somewhat closer to the basics as presented in Feynman's derivation of the structure of the elementary atom (^1H) based on Schrödinger's equation[23]:

1. We have discrete energy states or energy levels, and the principal quantum number (n) refers to the energy of the nth energy level. It is used in the formula for the allowed energy levels, which is equal to $E_n = -E_R/n^2$ (E_R is the Rydberg energy).[24] It is often conveniently referred to as a shell[25]. The principal quantum number is always a simple natural number: n = 1, 2, 3, etc.

When discussing a free electron – which has one energy state only – there is no need for this number.[26] However, in the context of electron orbitals, it is a very essential number. One should note that an electron may move from one spherical state to another: the higher energy states are referred to as excited states and the electron will emit or absorb a photon when moving from one energy state to the other.

It is very important to note the Lamb shift compares excited and non-excited electron orbitals! Once again, the question is not so much: what is the difference between these energies, but *what makes them so nearly equal?*

[21] *Spin* angular momentum should also come in units of $\hbar$ or $\hbar/2$, shouldn't it? Well… No. We think the total angular momentum of the electron ($\hbar$) is the sum of the *orbital* angular momentum of the *Zitterbewegung* charge inside – whose effective mass m_γ is equal to half of the total mass of the electron – and the angular momentum of the electromagnetic field that keeps the charge in its *Zitterbewegung* orbit. As such, we do get two times $\hbar/2$ making for one unit of, but the *spin* angular momentum contributes little here. This sounds shocking, but we beg the reader to go with the flow here and judge later.

[22] See the references above.

[23] See: Feynman's *Lectures on Physics*, Vol. III, Chapter 19. The reader should note we will also use Feynman's notation (n, l, and m_z). As mentioned, the use of s for the spin quantum number is somewhat confusing because s is also used to refer to the *s*pherical solution(s) to Schrödinger's equation.

[24] Note that the energy is negative and *lowest* for n = 1. The energy concept used is the potential energy, and we assume the electron has zero (potential) energy when it is *not* in an electron orbital.

[25] See: https://en.wikipedia.org/wiki/Quantum_number#Magnetic_quantum_number.

[26] Its energy (potential and kinetic) depends on the reference frame, obviously, but we are not concerned with other reference frames now.

2. The orbital angular momentum (l) is expressed in units of ħ. It may also be zero. In fact, $l = 0$ is associated with spherically symmetric solutions: these states have no angular dependence.[27] They are referred to as an *s*-state – *s* for *s*pherical. As mentioned above, this injects some unnecessary confusion because the same symbol is used for the much more general concept of *s*pin. We will, effectively, also use it to designate the spin of the *Zitterbewegung* charge in our electron model.

The non-spherical solutions for Schrödinger's equation are associated with proper multiples of ħ. If $l = 1$, for example, then we have a number of *p*-states, which are defined by the magnetic quantum number (m_z) as a function of l (see the next section). For $l = 2$, we have *d*-states. When $l = 3, 4, 5,\ldots$ we get *f*, *g*, *h*,… states.[28]

The orbital angular momentum of an electron in an electron orbital should be distinguished from the orbital angular momentum as discussed in the context of an electron model (ring current, *Zitterbewegung*, or Kerr-Newman). We, therefore, find the oft-used term *subshell* for this number very convenient.

The subshell number l will always be less than the number of energy states. To be precise, we can write: $l = 0, 1, 2,\ldots n - 1$. Hence, if we have one energy state only, then we have only state: $l = 0$. Hence, this number is also *not* very relevant in the context of a free electron. However, the concept of angular momentum is very relevant as part of the discussions on the anomalous magnetic moment. We repeat our conclusions in this regard:

The quantum-mechanical law that angular momentum must come in units of ħ is a direct implication of – or equivalent to – the Planck-Einstein law: $E = h \cdot f = \hbar \cdot \omega$. However, the anomalous magnetic moment tells us that the angular momentum of the electron is be slightly off.[29]

The reader should also think about the units here once more: the angular momentum of a free electron is expressed in *full* units of ħ, not in *half* units.[30]

3. The magnetic quantum number (m_z) corresponds to the orientation of the shape of the subshell. It is defined by the following formula:

$$-l \leq m_z \leq +l$$

The magnetic quantum number is related to the weird 720-degree symmetry of the wavefunction which, in turn, results from mainstream academics not using the *plus* or *minus* sign of the imaginary unit to distinguish between the *direction* of spin. We are tempted to write a bit more about this – we actually promised to do so in the previous section – but we will feel it will likely confuse the reader even more, so we refer to our previous writings on that[31] and note we don't really need the concept in the

[27] Feynman solves Schrödinger's equation using polar (spherical) coordinates. Hence, the coordinates are expressed in terms of the distance from the proton (r), a polar angle (θ) and an azimuthal angle (φ). The spherical symmetric solutions only depend on the distance from the proton (r).
[28] Feynman's dictionary of quantum numbers (III-19-3, Table 19-1) is very useful.
[29] For our classical explanation of the anomalous magnetic moment, which is not an anomaly at all, see: https://vixra.org/abs/2003.0094.
[30] The reader will ask the obvious question here: the electron is a spin-1/2 particle, right? Yes, and no. We refer the reader to our explanation of the *meaning* of the concept of spin (https://ideez.org/2020/03/22/whats-the-spin-of-spin-1-2-particles/).
[31] See: *Euler's wavefunction and the double-life of –1*, 30 October 2018 (https://vixra.org/abs/1810.0339).

context of this discussion (a *physical* explanation of the Lamb shift). The bottom line is this: in our physical interpretation of the electron as a ring current, we only have use for the concepts of *orbital* and *spin* angular momentum. As a result, the *principal*, *orbital*, *magnetic* and *spin* numbers may be summarized in two quantum numbers only: one that has to do with the *orbital* angular momentum around the center of the electron and one that has got to do with the *spin* of the *Zitterbewegung* charge around its own axis.

4. The fourth and last quantum number is usually that what is referred to as the spin *tout court*. It explains why we can have two electrons in any configuration—say, the $2p^6$ configuration for the neon atom. It also explains the finer structure of the hydrogen spectral lines.

The term 'spin' is a very simple but, at the same time, also a very confusing term because so many things are spinning here. Indeed, besides the electron that is spinning inside an atom, and the pointlike *Zitterbewegung* charge that is spinning inside the electron, we will now also want to think of the *Zitterbewegung* charge spinning around its own axis.

In how many directions can it spin around its own axis? Quantum-mechanics tells us that, here also, the spin will be either *up* or *down* and, in light of the geometry of the situation, we will, of course, also want to define the up or down here in terms of the orientation of the plane of the ring current.

The Pauli matrix of the orbital electron as a two-state system

This is a rather grand title for a rather simple reflection. The point is this: if we assume the *zbw* charge has spin of its own – which it probably should have in light of the above-mentioned quantum number logic – then we can think of the magnetic moment of an electron consisting of the addition of the magnetic moment generated by the spinning *zbw* charge and the magnetic moment generated by the ring current.[32] The next question, then is, this: how should we *add* the two numbers? Following considerations may be relevant here:

1. The spin around its own axis has a different symmetry axis and the formula for the angular mass of a sphere or spherical shell involves different form factors than the disk-like structure that we associate with the electron as a whole: instead of $I = (1/2)\cdot m\cdot r^2$, we should use the $I = (3/5)\cdot m\cdot r^2$ or $I = (2/3)\cdot m\cdot r^2$ formulas.

2. Apart from deciding on a form factor, we should also decide on this: what is r here? What is the *radius* of the *Zitterbewegung* charge that we think is *zittering* around at lightspeed? The *anomaly* of the magnetic moment of an electron suggests r is of the order of the classical electron radius, so that's a *fraction* (of the order of the fine-structure constant α, to be precise) of its *Compton* radius.

However, we noted this radius is a rather strange thing: the anomaly for the muon is about the same and, hence, the size of this *zbw* charge seems to be in the same relation with the (Compton) radius of a muon: *it shrinks along with it*.[33] Hence, we should probably *not* think of the *zbw* charge as some immutable *hard core* charge. Perhaps we should think in terms of some fractal structure here.

[32] Wikipedia offers a confusing but – as far as we can see – also quite consistent explanation for the addition of spin and orbital angular momenta. See: https://en.wikipedia.org/wiki/Vector_model_of_the_atom.

[33]

[…]

After reading the two points above, you should conclude this: we don't know much, do we? So what *can* we say then?

3. I think one conclusion – or *hypothesis*, I should say – should be fairly easy to agree with: the contribution of the *spin* angular momentum to the magnetic moment of the electron must be *very* small. Why? The radius of the *zbw* charge is much smaller, and the *spin* velocity can (also) not exceed the speed of light, can it? In short, the contribution of spin to the measured magnetic moment of the electron will only be of the same order as the ratio between the classical electron radius and the Compton radius, which is equal to $\alpha \approx 0.0073$, which is less than 1%. If we denote this contribution as ε, and if we equate the main contribution from the *orbital* angular momentum to the magnetic moment to 1, then we get the following matrix[34]:

***zbw* spin vs. ring current**	**clockwise (up)[35]**	**counterclockwise (down)**
up	$1 + \varepsilon \approx 1$	$-1 + \varepsilon \approx -1$
down	$1 - \varepsilon \approx 1$	$-1 - \varepsilon \approx -1$

This matrix shows that electron – be in a free state or in an orbital – would appear to have two states only: its magnetic moment will be either *up* (+1) or *down* (–1). However, a finer measurement would, perhaps, reveal a very fine *split* of these two states. This split will be very *fine*—even finer than the secondary (fine) structure of hydrogen spectrum lines, because the fine structure is based on the basic *up* and *down* states. Here we'd have an even finer structure—fine, finer, finest?

How to test our hypothesis?

This matrix shows the electron – when doing a Stern-Gerlach experiment – should appear to be in two states: its magnetic moment will be either *up* (+1) or *down* (–1). However, a finer measurement might reveal a secondary *split* of these two states.

We am not aware of any measurements having been made here, but that should not surprise us: few amateur physicists know that *actual Stern-Gerlach experiments are never done with electrons*.

What? Yes. *Actual* Stern-Gerlach experiments are always done with electrically neutral particles, such as potassium atoms[36] or, in the original experiment, silver atoms. Why? Because any electric charge in the magnetic field in the Stern-Gerlach apparatus would be subject to a Lorentz force which would be much larger than the force resulting from the magnetic moment.

[34] Wikipedia offers a confusing but – as far as we can see – also quite consistent explanation for the addition of spin and orbital angular momenta. See: https://en.wikipedia.org/wiki/Vector_model_of_the_atom.

[35] What is clockwise or counterclockwise depends on your reference frame, but that is the same for defining up or down. If we look from the opposite direction, both up and down as well as clockwise as well counterclockwise will swap their definition. Hence, the reference frame doesn't matter here. The same reasoning applies to the definition of what's up or down in regard to the plane of the circulation of the *zbw* charge.

[36] See, for example, the MIT's lab experiment for students: http://web.mit.edu/8.13/www/JLExperiments/JLExp18.pdf.

In light of the importance of the assumption that electrons have two spin states – *up* or *down* – I find this simple fact actually rather shocking. Hence, the obvious question here is: is there really *no one else* who thinks about that?

The answer is: no. *Some* people are really *trying* to do something here. H. Batelaan, T. J. Gay, and J. J. Schwendiman, for example, wrote a rather intriguing *letter* to the *Physical Review* journal in 1997, explaining in very much detail how the Stern-Gerlach experiment could be modified to also split an electron beam based on the magnetic moment being up or down.[37] We are not aware of any follow-up, which we find very strange because the proposal of Batelaan, Gay and Schwendiman is based on a much older proposal of the French physicist Léon Brillouin—a proposal which goes back to 1928[38], in fact.

A good experiment here would probably decisively settle more than one ongoing discussion! Indeed, as far as we are concerned, this would be *a very testable prediction of the ring current electron model*: would or would we not get a finer splitting of the two main spots where the electron should hit the detector after going through the magnetic field of a (modified) Stern-Gerlach apparatus—one that *can* deal with the *electric* force on a charged particle?

We are willing to take a bet on this: we think there is such finer split. Why?

First, because of the Lamb shift itself—which is *real*, obviously. However, we don't believe it can be explained by "interaction between vacuum energy fluctuations". Why not? Because vacuums are vacuums. Hence, there's nothing to fluctuate, not in first loops and not in higher orders either!

Second, historical experience suggests the idea of elementary particles having some fractal structure is not a bad idea: the gross hydrogen spectrum hid a finer spectrum. The Lamb shift suggests we can go one level deeper.

Thirdly, because W.E. Lamb himself published a rather remarkable paper at rather old age – he was over 80 years old – in which he suggests a lot of mainstream theories, concepts and explanations are plain nonsense.[39] If W.E. Lamb had doubts about the concept of the photon *tout court*, he should surely have had a lot of doubts about the concept of *virtual* photons being constantly emitted and re-absorbed in some kind weird of *mediation* of the force keeping electrons in a bound state. We, therefore, think our simpler theory is better.

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[37] The proposition is based on the geometry of the so-called Penning trap, which keeps charged particles in place so as to accurately measure their magnetic moment. See: Physical Review Letters, H. Batelaan, T. J. Gay, and J. J. Schwendiman, *Stern-Gerlach Effect for Electron Beams*, Vol. 79, 8 Dec 1997, number 23 (https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1031&context=physicsgay).

[38] Batelaan, Gay and Schwendiman include the following reference: L. Brillouin, Proc. Natl. Acad. Sci. U.S.A. 14, 755, 1928. We *googled* and a scanned copy is available here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1085707/. We plan to study it carefully in the coming weeks/months. Though his name is much less well known, Brillouin was, without any doubt, a genius of the stature of Einstein. He studied with Arnold Sommerfeld and was, therefore, abreast of Sommerfeld's discovery of the fine-structure constant. He was also in touch with Albert Einstein, as evidenced by what is now referred to as the Einstein–Brillouin–Keller method for calculating the eigenvalues of a quantum-mechanical system.

[39] We thank Dr. Oliver Consa for alerting us to this article. The reference is this: W.E. Lamb, *Anti-photon*, Applied Physics B volume 60, pages77–84(1995). We found this open-access version: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.393.688&rep=rep1&type=pdf. The reader will find defensive papers *written by other authors* which carry the same title but actually downplay or understate the importance of this paper. The article posted on arxiv.org by Jacques Moret-Bailly is an example of such regretful practice.

In fact, the actual *value* of the Lamb shift may be used to help solve the questions on the form factor and symmetry axis we started off with—very much in the same way as we used the *actual* value of the anomalous magnetic moment to infer the effective radius and velocity of the *zbw* charge.[40] It should be clear from this paper that the Lamb shift and the anomaly in the magnetic moment and radius of an electron must be very much related one to another, indeed.

Jean Louis Van Belle, 29 March 2020

[40] See our geometrical explanation of the anomaly in *An Explanation of the Electron and Its Wavefunction* (https://vixra.org/abs/2003.0094).