The Photonic Topology of Sub-Quantum Spin

*Arnie Benn, Quantum Bicycle Society, California, USA (*ORCID ID: 0000-0002-3753-7309*)*
*John G. Williamson, Quantum Bicycle Society, Scotland, UK (*ORCID ID: 0000-0001-9827-0735*)*
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ABSTRACT
This paper investigates the nature of quantum spin, an internal quantum property of the electron and other subatomic particles and antiparticles. The development of sub-quantum mechanics opened the door to a deeper understanding of the photonic substructure of subatomic particles, and in particular, allowing for the first time the *a priori* calculation of the electron's charge and anomalous magnetic moment. This represents a significant advance in relativistic quantum mechanics and in our understanding of the substructure of subatomic particles. As a consequence, this theory allows us to investigate the specific components of the electron's quantum spin, as well as the topological difference between its 'spin-up' and 'spin-down' states. (As will be clarified, spin up versus down is conceptually different to parallel versus antiparallel in that the former is a spin component and the latter a magnetic orientation.) It is proposed that the electron's spin is composed of three components, here named intrinsic spin, toroidal spin, and tumble. It is further proposed that the nature of the spin-up or spin-down state is a direct consequence of the direction of circular-polarisation of the photon constituting the electron (or other particle). Consequently, when two equal-energy photons of the appropriate energy interact to generate a particle/antiparticle pair, one photon polarisation will yield a spin-up electron and a spin-down positron (${}_{\uparrow}e^{-} + {}_{\downarrow}e^{+}$), and the other will yield a spin-down electron and spin-up positron (${}_{\downarrow}e^{-} + {}_{\uparrow}e^{+}$). The nature of quantum spin can then be leveraged to gain insight into the physical reason behind the formation and stability of the *di-electron* boson (electron pair) as a counter-rotating, interwoven, diamagnetic photonic state, a consequence of two superimposed, phase-locked, and opposite electron spin configurations. The concept can then be further extended to clarify the physical (energy-related) mechanism behind both the Pauli Exclusion 'Principle' and Hund's 2nd Rule.

Keywords:
Quantum spin, electron, positron, circularly polarized photon, intrinsic spin, spin-up, spin-down

1. INTRODUCTION

Quantum spin is a property of photons, as well as many subatomic particles. While it evokes the well-known ideas of angular momentum and rotation, these basic physical concepts do not encompass it upon closer inspection.

A circularly-polarized photon is a spin=1 boson. Its spin refers to the rotation of its electromagnetic fields about its axis of travel, which completes one 360° rotation about that axis per wavelength. In the case of the subatomic particle, however, spin does not simply refer to an orbit or rotation of the particle. The quantum spin of an electron is an internal property arising from its substructure, and according to sub-quantum mechanics,[1,2,3] is a result of both the topology and the intrinsic spin of the photon comprising it. Building upon the advances of sub-quantum mechanics, in this paper we will be able to investigate this spin in much greater detail and with much greater specificity.

The electron, the focus of this paper, was long considered to be a point particle with no substructure, to which its observed properties of spin and charge were attached, without explanation as to their origin. Recent work [1,2,3,5] has suggested that these properties are in fact a direct consequence of the electron's substructure, and remarkably, that not only its charge but also its "anomalous magnetic moment" (referred to as g-2) can be calculated, *a priori*, from this model. That is a noteworthy and meaningful development in physics.

It is upon this foundation that the present paper seeks to develop the idea in order to further clarify the particular nature of the quantum spin of the electron. In so doing, we are able to propose specific ways in which spins interact in the formation of both degenerate electron orbitals and the *di-electron* boson state — the ubiquitous electron pairing that we see in helium's electron shell, in covalent bonds, and in superconductivity.

2. THE ELECTRON/POSITRON PAIR

According to the Williamson-van der Mark model of the electron,[1,2,3] an electron-positron pair can be formed when two photons of the appropriate energy (and the same polarization state[1]) are condensed, forming two particles. Like counter-rotating vortices, these particle vortices will have opposite chirality.[2] One of the resulting double-loops, with its electric field (*the green spines*) pointing outwards and a right-handed chirality, will have a positive charge — the positron, and the other, with its electric field pointing inwards and a left-handed chirality, will have a negative charge — the electron. This process features the transition from two bosons, with relative spins $+\hbar$ and $-\hbar$, to two fermions, spins $+\frac{1}{2}\hbar$ and $-\frac{1}{2}\hbar$. Overall spin angular momentum is thus conserved.

Each particle contains a confined photon making two complete revolutions for every one wavelength, resulting in a phase-locked, stationary wave of toroidal topology that defines the

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[1] When these photons collide head-on, their relative intrinsic spins are in opposite directions.

[2] Spin-handedness of the toroidal spin component with respect to the magnetic axis. See below.

particle. This process is also reversible. When an electron and positron combine, they unlock each others' angular momenta, releasing the self-confined rotating photons as linear photons in a matter-antimatter annihilation.

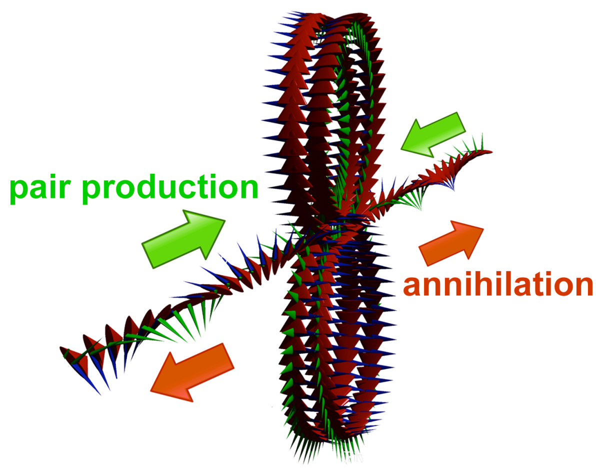

Fig. 2.1: Electron-positron pair production versus annihilation

The double loops that represent the particles are shown here in momentum space (or spatial frequency space). This is the mathematical space in which the Poynting vector shows up (*which is depicted by red arrows in fig. 2.1*). However, since the electron is a light-speed particle on the 'inside,' its geometry will project in a fully relativistic way into whichever reference 'space' we project it, so this momentum-space geometry should not be taken too literally, as we will see below. In the 'space' of electric field, a free electron will be spherically symmetrical.

Note carefully that these referenced 3-spaces, like momentum space or electric field space, are simply different divisions (or differentials) of 4-dimensional space-time, yielding different 3-dimensional subsets of space-time.[4] This separation into 'spaces' is therefore only a mathematical convenience in order to deal more accurately with each aspect of a particle's energy flow. There is, in reality, only one space-time, made up of three dimensions of space and one of time — x, y, z, and t. The mathematical inverses of space and time, and their products, quotients and differentials, lie in sets of linearly independent spaces. These prove to be of physical significance because they allow charge, field, and spin to be evaluated both separately or together, and in a fully relativistic context.

Let us now consider only the electron.

3. THE ELECTRON IN DIFFERENTIAL 3-SPACES

The following diagram illustrates the concept of a right-circularly-polarized photon becoming confined into a double loop rotation to yield an electron.[3][1,2] The double arrow represents the reversibility of this process, as is implicit in the now-legendary equation $E=mc^2$. Mass (m) is electromagnetic energy confined into the boundary condition of a toroidal light-speed double-loop (c^2) rotation. Radiant energy (E) is simply mass released from this boundary condition. (The sphere in the center of the diagram will be clarified below.)

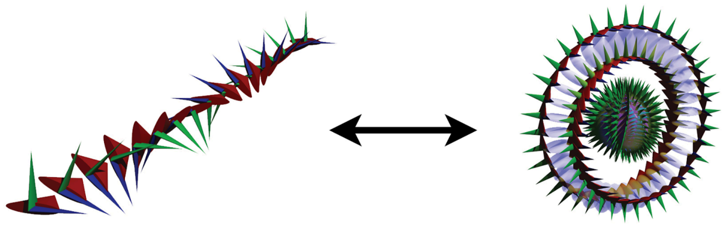

Fig. 3.1: Circularly-polarized photon becoming confined into a double-loop rotation that is an electron

The snapshot of the electron (*above, right*) can be misleading because it is really many images combined. The toroidal (donut) shape represents the phase-locked path of the rotating, circularly-polarized photon in momentum space. This aspect is shown separately in fig. 3.2 below.

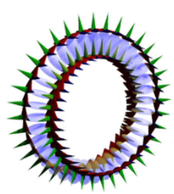

Fig. 3.2: The electron's toroidal photon path in momentum space

In order to conserve angular momentum and minimize energy, the electron toroid will also tumble in space like a spinning ring. The tumble of the electron is a rotation "perpendicular" to the toroidal path of the rotating photon that comprises it.

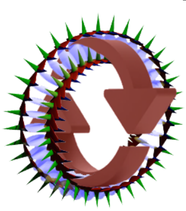

Fig. 3.3: The tumble of the electron's toroidal photon path in momentum space

[3] Technically, fig. 3.1 depicts the formation of a positron, since the green electric field spines are pointing outwards. We will use this diagram below to depict the electron, though, for the sake of visual convenience. (The spines are harder to make out when they are projecting inwards, as they do in the case of the electron.)

The sphere in the center of the image (in fig. 3.1) represents *the result* of this — a projection onto normal 3-dimensional space of the electron's charge distribution, which is perfectly spherical in normal "space-space." Note, also, that the lens shapes shown between the two paths of the double-loop (above) — the lens shapes that seem to make up the body of the torus — are all slices through the same resultant sphere depicted below.

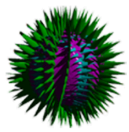

Fig. 3.4: The electron's spherical charge field in electric field space

This description allows us to more closely characterize, and therefore refer to, the three components of the electron's quantum spin. They are:

1. **Intrinsic spin** (of the photon that rotates once around its axis of travel (360°) per double revolution): $\hbar$
2. **Toroidal spin** (of the double-loop rotation of that photon that travels 720° in momentum space around the torus): $\frac{1}{2}\hbar$
3. **Tumble** (of the torus to conserve intrinsic spin angular momentum, that tumbles for one 360° revolution during the photon's 360° intrinsic rotation): $\hbar$

These three angular momentum components of spin therefore occur in the ratio of 1:2:1 revolutions, or $\hbar$:$\frac{1}{2}\hbar$:$\hbar$.

Let us now consider the relativistic consequences of such a light-speed rotation.

In normal space, each lens-shaped disk (between the paths making up the torus in fig. 3.2) represents a slice through the same (*spikey green*) spherical distribution shown in fig. 3.4. An isolated electron is thus a self-confined knot of concentrated energy traveling *around itself* at the speed of light. Since it is traveling around *itself* at the speed of light, relativity suggests that the space within the electron's toroidal path — the 'hole in the donut' — shrinks down to an effective point, but this does not obviate the fact that the particle still has both substructure, with real topology, and a non-zero size.

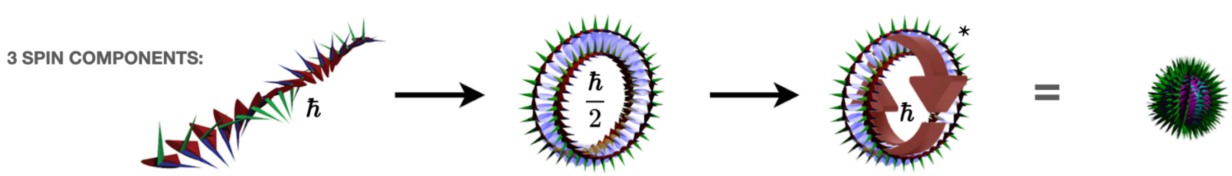

Fig. 3.5: The angular momentum consequences of a right-circularly-polarized photon forming a light-speed, double-loop rotation.

As mentioned, each lens in the images above represents a slice through the entire sphere of the electron's charge field. Since its diameter is equal to the thickness of the torus that constitutes it in momentum space, the lens is equally a slice through the thickness of the torus.

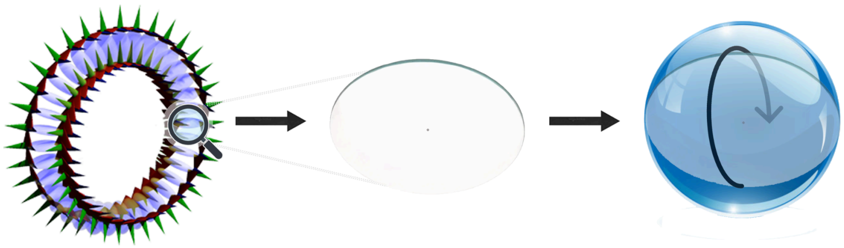

Fig. 3.6: Each lens represents a diameter slice of the electron's overall spherical charge field

We can therefore imagine each lens-shaped disk to be bounded by the wavefronts of each rotation that makes up the photon's double-loop rotation. The photon wavefront can therefore be imagined to be bouncing between the opposite edges of the lens — and thereby *constituting* the lens. Since it is a coherent self-contained object rotating around itself, it may be simpler to think of it as a spinning lens of electron density.

We can then imagine one of these "lenses" rotating in place on two axes to generate the resulting spherical distribution that is the isolated (or *s*-shell) electron. One axis of rotation is due to the photon's rotating toroidal path and the other is due to its intrinsic (photon) angular momentum, as will be discussed below. A visualization of this might appear as follows.

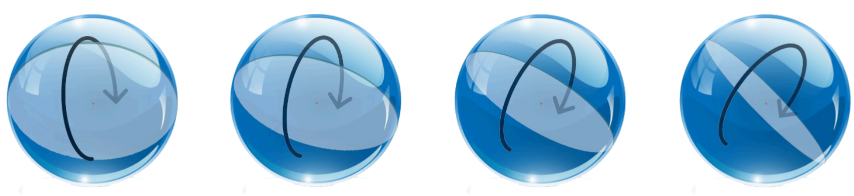

Fig. 3.7: The electron's rotating "tumble" motion

The concept of the electron orbiting the nucleus might actually hinder a clear mental image of this process. Instead, it is more useful to think of the electron as a spherical cloud of electron charge energy resulting from the spinning-tumbling motion of a lens (or hypersphere) of electromagnetic energy. This creates a phase-locked, "stationary wave propagating around a double loop. Hence, this state will have angular momentum."[1] What one observes in a given experiment depends on the effective projection onto the frame of the measurement system.

In the hydrogen atom, the proton of the nucleus is suspended at the center of this electron charge sphere, canceling its positive charge in a spherically symmetrical fashion with that spherical cloud of negative charge density around it. According to this view, in electric field space, the hydrogen atom is, in a very real sense, a proton and an electron, both spheres the size of the atom, and both completely superimposed upon one another. In both momentum space and magnetic field space, however, the picture of their complementary photon paths will be symmetrical (or in equilibrium) — a harmonic 'dance' — though not superimposed and not necessarily perfectly spherical.

4. 'SPIN-UP' vs 'SPIN-DOWN'

Now that we have separated the electron's quantum spin into its three components, which of them determines the difference between electrons of 'opposite spin'?

Is electron spin a matter of perspective or vantage point? Is spin-up simply spin-down viewed from the other side, with all electrons really being identical in all respects, or is there a fundamental and intrinsic difference between the two types of electrons spin?

Particles that are negatively charged have left-handed chirality when rotating with respect to their north magnetic pole (that runs along the axis through the center of the torus). All electrons must therefore have this left-handed chirality in common. Since they are each composed of a circularly-polarized photon going around in a toroidal, left-handed, double-loop rotation with respect to their north magnetic poles, how is a spin-up electron spinning differently to a spin-down electron?

It is reasonable to assume that there is, indeed, an actual physical difference between them because it requires the spin associated with a photon exchange ($+\hbar$) to change a spin-down electron ($-\frac{1}{2}\hbar$) into a spin-up electron ($+\frac{1}{2}\hbar$). While a spin of $\frac{1}{2}\hbar$ has been referred to above as being directly related to the toroidal flow, the difference between spin-up and spin-down cannot be the chirality of this flow because a right-handed flow would yield a positive charge, and the particle would then be a positron.

4.1. Intrinsic Spin & Tumble

The above-mentioned "sub-quantum mechanics" approach to the electron allows us to explore a possible intrinsic difference between spin-up and spin-down electrons, assuming such a difference exists, in a way that we were not able to do before the development of this absolutely relativistic, sub-quantum construct.

As mentioned above, the tumbling motion of the electron torus arises as a consequence of the conservation of angular momentum. This begs the question: where does this angular momentum originate? The answer would seem to be the intrinsic spin, $\hbar$, of the circularly polarized photon that constitutes the electron. The particle's spin of $\frac{1}{2}\hbar$ is a result of its double loop rotation, in which the photon makes two revolutions around its toroidal path per wavelength.

While the electron-positron image (*in fig. 2.1 above*) makes the torus seem stable as it is, with its angular momentum satisfied by the double loop rotation alone, that will not actually be the case since the photon wavefront — the 'lens' — still has intrinsic spin, $\hbar$. This angular momentum will cause the wavefront, and therefore the electron, to be in a constant state of tumble to one side or the other as it rotates.[4] It is here proposed that *which* way it tumbles depends on the polarization of the photon's intrinsic rotation. A right circularly-polarized photon will give the electron torus a right-oriented tumble with respect to its toroidal flow, and a left circularly-polarized photon will give it a left-oriented tumble, even as both travel with left-handed chirality around their north magnetic pole, which lies along the axis through the center of the torus.

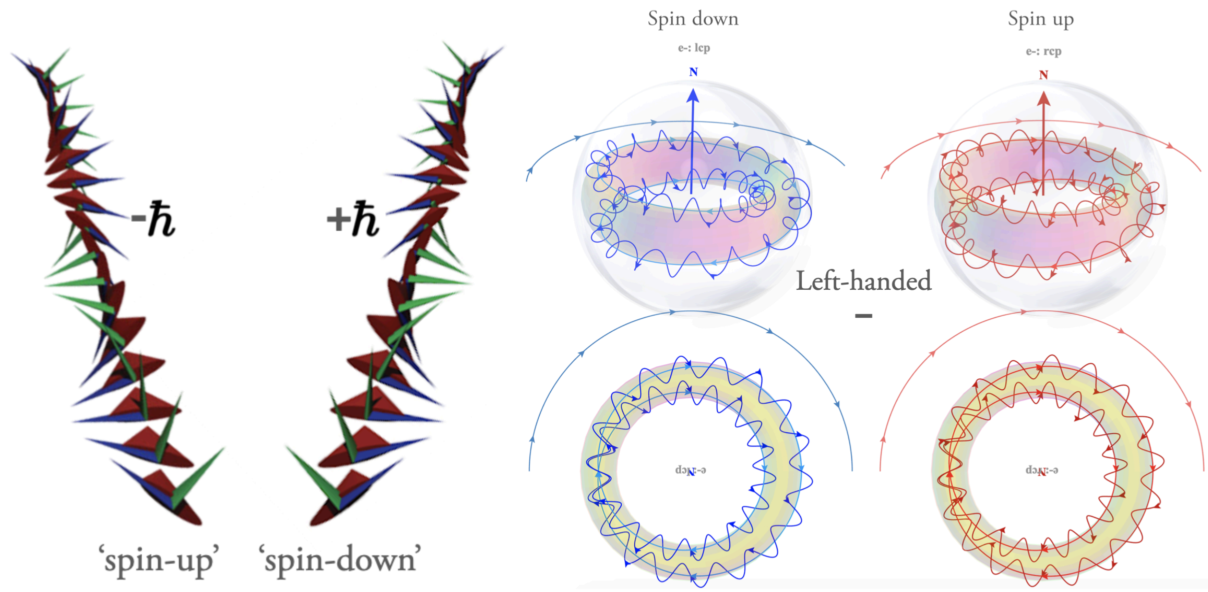

Fig. 4.1: Photons (left) and electrons (right) with a left-circularly-polarized photon (–ħ) and a right-circularly-polarized photon (+ħ).

These diagrams, as well as the ones below, include the intrinsic spin of the circularly-polarized photon as it completes 1 revolution around its axis of travel per wavelength, i.e. per double-loop rotation. Note carefully, though, that these images exaggerate the number of turns on the spiral path, for ease of viewing, and are therefore not an accurate representation. The image on the right in fig. 4.2 below correctly shows only a single revolution per double-loop, which demonstrates the reason for this visual exaggeration. Without it, the relative intrinsic spin states will be much harder to distinguish in the diagrams.

[4] The single propeller in the front of a small aircraft (like a Cessna), continually pulls the craft to the left.

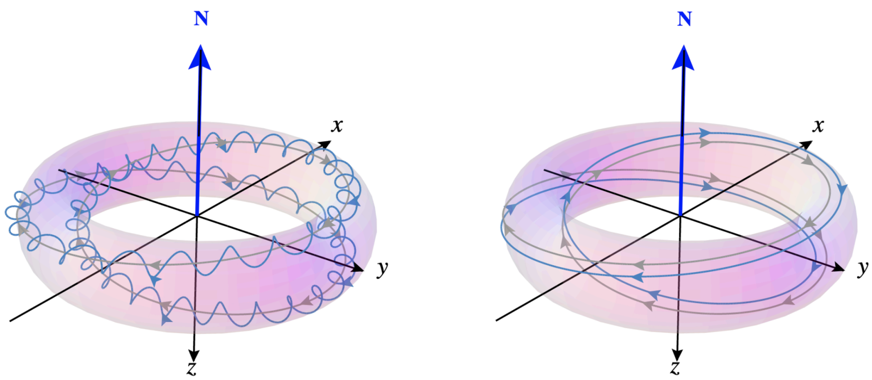

Fig. 4.2: Exaggerated intrinsic spin for ease of viewing (left) versus accurate intrinsic spin (right). The gray line represents the photon's axis of travel around the toroidal flow. (This is a left-circularly-polarized photon).

In the following diagrams, the spiral of the photon's intrinsic rotation (polarization) is shown by a red versus a blue spiral. This is only intended to show what the original polarization state of the photon was, because in these images, the whole lens is intended to represent the photon wavefronts within the particle. (The exaggerated views of the intrinsic spin will again be employed below for ease of viewing.)

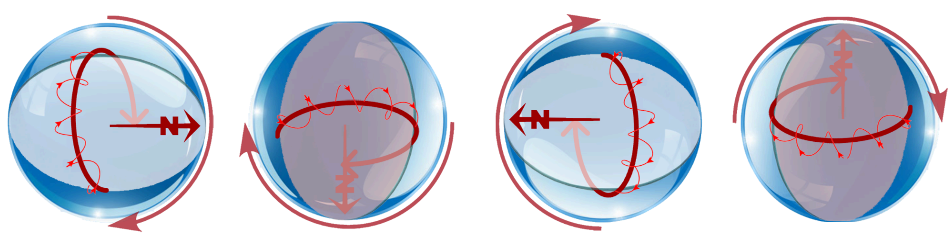

Fig. 4.3: Sequence showing the tumble of an electron made of a right circularly-polarized photon

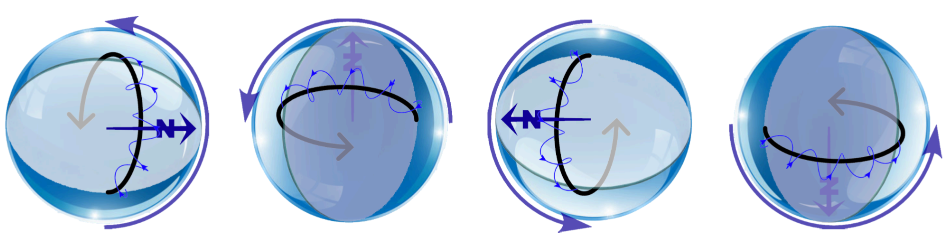

Fig. 4.4: Sequence showing the tumble of an electron made of a left circularly-polarized photon

As such, it is more the case that the double-loop rotation and the tumble are no longer two separate rotations but rather a single, net, angular momentum operating on two axes simultaneously within the confines of the electron's extent.

The main results of this paper are the proposals that (a) the direction of circular polarization of its internal photon determines the relative spin state of the electron, and (b) the nature of quantum spin is a combination of three forms of spin within the electron.

As we imagine this tumbling spin motion, we see that the orientation of the north magnetic pole passes through every direction within the sphere. This is essential since it is this symmetry that allows the magnetic field of the photon (within the torus) to cancel, on aggregate, against itself, lowering energy and minimizing electron mass. This underscores why the electron is so willing to form from a circularly-polarized photon, and why it is so stable once it does form. If this field-cancellation did not occur, the mass of the electron would be much greater than its actual energy content, which is not an allowed state.[1]

This does not mean that an electron has no magnetic moment. It has none within a symmetrical spin configuration. If the electron is placed within an external magnetic field, however, its magnetic axis will align with the axis of that field by precessing around it to varying degrees that depend upon the strength of the field, thus manifesting its magnetic moment as a consequence. That will also give the electron *slightly* more of a toroidal manifestation than a spherical one, depending on the strength of the external magnetic field.

Further, if we assume that photons in the universe have left versus right circular polarization in equal proportion, then electrons in the universe should have opposite spins in equal proportion.

This would further imply that, in chemical bonding, electrons on atoms will more easily bond with electrons on other atoms when their spins happen to be opposite, which should be about 50% of the time. Since atomic densities during chemical reaction are often rather high, with frequent collisions, and since spins can be flipped through photon emission/absorption, the presence of thermal energy or increasing amounts of activation energy should obviate this as an obstacle to an increasing degree, which, it is presumed, may make it more difficult to detect this difference in energy states at anything but very low temperatures and low densities.

4.2. The Dichotomy Of Spin

According to the present proposal, the spin-up vs spin-down dichotomy exists as a result of the dichotomy of a photon's circular polarization — either left or right.

In earlier work,[4] we discussed why overall quantum spin has a one dimensional nature — either up or down. It is possible to understand this partially in terms of sub-quantum mechanics. If one has an element of spin in the "*z*" direction, it is, properly, in the directed volume element *xyt*. The proper integral of this, about the *z*-direction, will yield a result with a four-dimensional form *xytz*. This has only two directions, namely an inward- or outward-directed 4-volume. In earlier work, this is referred to as the 'quedgehog'.[4]

An integer value of this spin corresponds to a full loop or multiple loops; a half integral value corresponds to a loop of a loop.

4.3. The *Di-Electron*

As discussed in earlier work,[4] if two unpaired electrons with opposite spins approach each other in an atomic or molecular system, they will be attracted to pair up, despite their mutual charge repulsion. (Note, this only happens within a nuclear charge well. It will not occur in free space due to electrostatic repulsion.) If local atomic geometry allows it, the electrons will assume an antiparallel magnetic alignment and attempt to become completely superimposed upon one another. In this state, both the spins and magnetic fields of the two electrons are aligned exactly opposite to one another in both strength and orientation. This facilitates a cancellation of the angular momentum associated with the tumble, as well as most of their magnetic field energy through destructive interference. This lowers overall energy significantly, creating a highly desirable state for the electrons. As a result, electrons of opposite spin will seek this superimposed state whenever they are not prevented from doing so by atomic or molecular geometric constraints.

This electron superimposition results in a new mixed quantum state, a *di-electron* boson, which is a distinct state from that of two electrons. *Di-electrons* are most commonly known as electron pairs, covalent bonds, or Cooper Pairs. (Note again that the photons only rotate once on their axis of travel for every two revolutions, so the red and blue spiral paths on the left in fig. 4.5 are exaggerated for ease of viewing.)

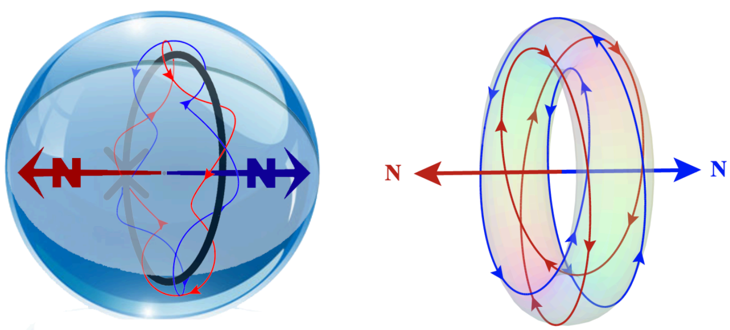

Fig. 4.5: Two views of superimposed electrons, one made of a right and the other a left circularly-polarised photon, constituting an interwoven, counter-rotating di-electron boson.

In earlier work,[4,5] it was proposed that in such a configuration, the spins of the two electrons making up the *di-electron* — the toroidal paths of their individual photons — become interwoven. Their spins, however, are not canceled in this interweaving process. It is all present, though woven together in such a way that balances both spins when they lock phases into the same space. Interweaving thus creates the spin equivalent of superimposed, counter-rotating toroidal vortices. It must do so, in fact, since the spin of the underlying light-speed photons comprising the subatomic particles cannot be nullified, nor their motion stopped. They must rather attain a perfect, phase-locked, harmonic resonance. The effect is that overall spin *is* in fact reduced because quantum spin is a measure of overall spin, J. Spin energy might thus be lowered, even as the two component spins remain present. This optimisation of spin volume may therefore amount to a more attractive energy state, despite the apparent anti-coherence of the antiparallel spins. Recall that photons, as propagating electromagnetic waves, are able to move through one another.

Only two of the three aspects of quantum spin therefore remain in a *di-electron*, the intrinsic spins, *ħ (and –ħ)*, of the two photons, and the counter-rotating double-loop rotations of their paths (½*ħ* and –½*ħ*) in momentum space. Their tumbles have been nullified, and are no longer needed for magnetic field cancellation since the paired electrons' magnetic fields achieve that by being perfectly oppositely aligned.

The alignment of an unpaired electron with an external magnetic field is similarly favorable because some of its magnetic field can cancel with some of the external field, and energy can thus be lowered. This is the nature of paramagnetism. In the case of the *di-electron*, however, the two electrons in the pair provide each other with perfect and symmetrical field cancellation. Any external field can only disrupt that perfect cancellation, thereby raising energy. This is the nature of diamagnetic repulsion. *Di-electrons* are diamagnetic and repel away from external magnetic fields in order to maintain their lowest energy state.

Let us now look a little more closely at the interactions between the three components of spin in the *di-electron* in order to more clearly see why the *di-electron* resonance is allowed and highly stable when the electrons have opposite spins, yet excluded when they have like spins.

4.3.1. Total *Di-Electron* Inclusion (TDI):

When two electrons of opposite intrinsic spin (${}_{\uparrow}e^{-} + {}_{\downarrow}e^{-}$) superimpose in an antiparallel fashion, their magnetic fields lie antiparallel and cancel energy, their toroidal ½*ħ* flows are counter-rotating and interweaving, which lowers energy, and their intrinsic spins, while counter-rotating around the toroidal flows, are in an opposite phase relationship. They therefore offset each other's angular momenta, which also lowers energy. *(See below, fig. 4.6, on the left.)* In addition, the Tumble angular momenta have been canceled, lowering energy.

4.3.2. Pauli Exclusion (superimposed):

When two electrons of the same intrinsic spin (${}_{\uparrow}e^{-} + {}_{\uparrow}e^{-}$) superimpose in an antiparallel fashion, their magnetic fields lie antiparallel only in one of the three components of spin, which increases energy overall. (Magnetic field space and spin space are related via a linear differential.[4]) The electrons' toroidal ½*ħ* flows are counter-rotating and interweaving, lowering energy, but their intrinsic spins, while counter-rotating around the toroidal flows, are in a same-phase relationship. This brings their photonic paths into confluence, which doubles the root-energy flow in that component of spin through constructive interference. This increases energy fourfold, making it an unfavorable state. *(See below, fig. 4.6, on the right.)* Similarly, the Tumble angular momenta are now co-rotating, which also causes a doubling, further increasing energy.

These two *di-electron* cases are illustrated in the diagram below.

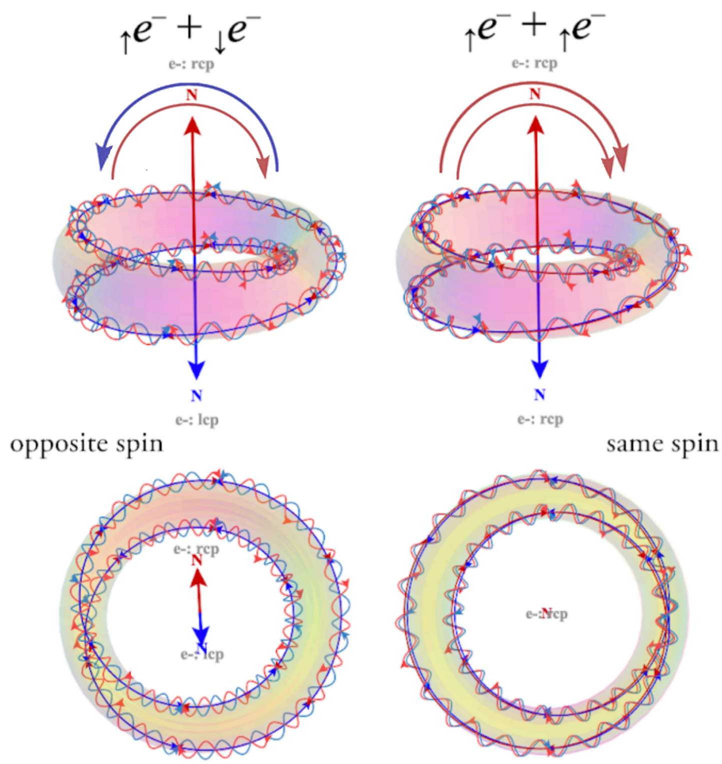

Fig. 4.6: Allowed like-spin di-electron state (left) and excluded same-spin state (right)

These component-interactions therefore can and should be considered individually for each particle interaction. For the two-electron interactions, they are summarized below, and this provides a clearer visual reference of which components of the interaction experience an energy **increase** versus a **decrease**:

Total *Di-electron* Inclusion (TDI) — ($_{\uparrow}e^{-}$ + $_{\downarrow}e^{-}$ opposite intrinsic spins - DESIRED)
- electrostatic (**repulsion** — but *overcome*)
- antiparallel **magnetic (strong attraction)** ← Perfect magnetic field cancellation since Tumble is nullified.
- SUPERIMPOSED SPINS:
  - counter-rotating and **opposite-phase** *intrinsic* spins - 1 dimension of angular momentum canceled (**attraction**)
  - counter-rotating toroidal spins/interweaving (**strong attraction**)
  - counter-rotating Tumbles nullified/canceled (**attraction**)

Pauli Exclusion — ($_{\uparrow}e^{-}$ + $_{\uparrow}e^{-}$ same intrinsic spins - EXCLUDED)
- electrostatic (**repulsion**)
- antiparallel **magnetic (repulsion) — field doubling in two of three spin components**
- SUPERIMPOSED SPINS:
  - counter-rotating but **same-phase** *intrinsic* spins (**strong repulsion**)
  - counter-rotating toroidal spins/interweaving (**strong attraction**)
  - co-rotating Tumbles **doubling** (**strong repulsion**)

4.3.3. Parallel Spin Bonding (PSB) & Hund's 2nd Rule:

Hund's 2nd Rule states that degenerate unpaired electrons (in the same orbital) will have lowest energy when they have maximum orbital angular momentum, meaning, when they have the same spin. It is here proposed that this is a consequence of the interactions of the intrinsic and toroidal spins of the two electrons, as well as whether they are oriented parallel or antiparallel.

When electrons are superimposed and antiparallel, their toroidal flows are counter-rotating (in momentum space). If they have opposite intrinsic spins, these will be counter-rotating as well, as described above, which makes the *di-electron* state highly desirable.

When these same electrons move adjacent to one another, they are impinging upon one another side to side rather than being superimposed. This changes the chirality of their interactions. Toroidal flows that were interacting in a counter-rotating fashion will now find themselves co-rotating, and so too with intrinsic spins. This will either raise or lower energy, yielding a more exclusionary or a more inclusionary state.

It is also important to consider these spin interactions in terms of the hierarchy of forces. At atomic scales, the (inverse-square) electrostatic repulsion between electrons will dominate any (inverse-cube) magnetic or spin interactions. However, when this repulsion has reached its limit due to the constraints of atomic orbital geometry, the field repulsion will be in balance. At this point, the spin interactions can emerge as significant because their interactions will either result in an increase or a decrease of energy. This may, as a result, generate a favorable spin-related coherence.

The interactions between the toroidal and intrinsic spins of adjacent atomic electrons are depicted in the following diagram.

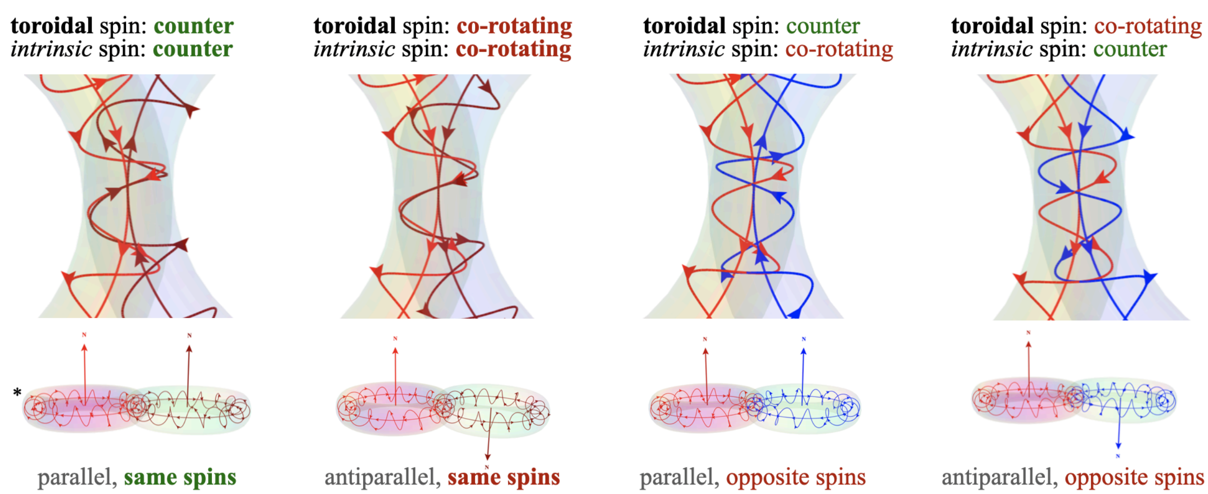

Fig. 4.7: The (harmony of phase) wave interactions between adjacent electrons of like-spin, unlike spin, and magnetically aligned either parallel and antiparallel

It must again be emphasized that these toroidal electron forms (in momentum space) nevertheless represent spherical charge symmetries in the familiar three-dimensionality of electric field space. The coherences and anti-coherences referred to here are issues of *phase harmony* within these spherical symmetries. It should not be interpreted to mean a fixed orientation for the toroidal forms. Everywhere within the sphere of an electron's extent will manifest the same quantum 'spinningness;' the spin at every point is and must be in harmony with itself. Other spin-volumes that impinge upon the first one will either have their spin components in phase harmony or out of it at every point within the region where their volumes coincide.

It is proposed that the left-most image in figure 4.7 above, the case of adjacent, parallel, and same-spin electrons, represents an energy-lowering 'spin inclusion' state. It is proposed that this effect, here named Parallel Spin Bonding (PSB), describes the physics behind Hund's 2nd Rule.

4.3.4. Pauli Exclusion (adjacent):

The two diagrams on the right of figure 4.7 (above) show the corresponding cases of Pauli Exclusion for adjacent electrons.

Neither the case of parallel or antiparallel provides a clear energy lowering state for electrons of opposite spin. In one case toroidal spins are counter-rotating and intrinsic spins co-rotating, and in the other it is the reverse. As such, electrostatic repulsion will dominate, unmitigated by an energy-lowering spin coherence.

4.4. The Mathematics Of Spin

Above we have detailed three aspects of electron spin that arise from this sub-quantum mechanical approach. They are the photon's intrinsic spin, its toroidal rotation, and its toroidal tumble, occurring in the proportion $\hbar$:½$\hbar$:$\hbar$.

In traditional Schroedinger quantum mechanics, total spin is designated as **J** = **L** + **S**. In this paper our intention is not to unpack these two systems and correlate their elements since they are based in somewhat different constructs. The traditional quantum numbers do not exactly fit the hybrid orbitals under consideration in this model, and the physics of the electron and its interactions have a different structural foundation.

As mentioned in earlier work,[2,5] the Williamson equation describing sub-quantum mechanics employs a Clifford-Dirac algebra for the wave-function modeling of all aspects of subatomic particle and photon systems. The equation of motion for a non-interacting system is

$$\mathscr{D}_\mu \mathbf{\Xi}_{\mathscr{G}} = 0 \qquad (1$$

and it encompasses the relationships between spin-flow (odd) and mass-field (even) spaces.[2] This equation describes the first-order coupling between the various 3-spaces,[4] one to the other, introducing mutual constraints.

The mathematical details of this work are beyond the scope of this paper and can be pursued further into the referred work. All that will be included here is the expansion of the Williamson equation, enabling the elements of spin within it to be highlighted (*below*). The four-differential of the 16 component general multi-vector of equation (1) gives:

$$\begin{aligned}
&\mathscr{D}_\mu \boldsymbol{\Xi}_{\mathscr{G}} = \mathscr{F}_{\mathscr{G}} = \alpha_0(\partial_0\xi_P - \partial_1\xi_{01} - \partial_2\xi_{02} - \partial_3\xi_{03}) + \\
&\alpha_{123}(\partial_0\xi_{0123} - \partial_1\xi_{23} - \partial_2\xi_{31} - \partial_3\xi_{12}) + \alpha_1(-\partial_1\xi_P + \partial_1\xi_{01} - \partial_2\xi_{12} + \partial_3\xi_{31}) + \\
&\alpha_2(-\partial_2\xi_P + \partial_0\xi_{02} + \partial_1\xi_{12} - \partial_3\xi_{23}) + \alpha_3(-\partial_3\xi_P + \partial_0\xi_{03} - \partial_1\xi_{31} + \partial_2\xi_{23}) + \\
&\boldsymbol{\alpha_{023}(\partial_0\xi_{23} - \partial_1\xi_{0123} + \partial_2\xi_{03} - \partial_3\xi_{02}) + \alpha_{031}(\partial_0\xi_{31} - \partial_2\xi_{0123} - \partial_1\xi_{03} + \partial_3\xi_{01}) +} \\
&\boldsymbol{\alpha_{012}(\partial_0\xi_{12} - \partial_3\xi_{0123} + \partial_1\xi_{02} - \partial_2\xi_{01})} + \alpha_P(\partial_0\xi_0 + \partial_1\xi_1 + \partial_2\xi_2 + \partial_3\xi_3) + \\
&\alpha_{0123}(\partial_0\xi_{123} + \partial_1\xi_{023} + \partial_2\xi_{031} + \partial_3\xi_{012}) + \alpha_{01}(\partial_0\xi_1 + \partial_1\xi_0 + \partial_2\xi_{012} - \partial_3\xi_{031}) + \\
&\alpha_{02}(\partial_0\xi_2 + \partial_2\xi_0 - \partial_1\xi_{012} + \partial_3\xi_{023}) + \alpha_{03}(\partial_0\xi_3 + \partial_3\xi_0 + \partial_1\xi_{031} - \partial_2\xi_{023}) + \\
&\alpha_{23}(\partial_0\xi_{023} + \partial_1\xi_{123} - \partial_2\xi_3 + \partial_3\xi_2) + \alpha_{31}(\partial_0\xi_{031} + \partial_2\xi_{123} + \partial_1\xi_3 - \partial_3\xi_1) + \\
&\alpha_{12}(\partial_0\xi_{012} + \partial_3\xi_{123} - \partial_1\xi_2 + \partial_2\xi_1) = 0 \qquad (2
\end{aligned}$$

In this representation of the (square-root) energy flow of the system, the terms that refers to spin are the highlighted α_{023}, α_{031}, and α_{012} terms (collectively, the α_{0ij} term). The translation of the spin component, with the proper 4-dimensional multi-vector component written to the left, is:

$$\alpha_{0ij}(\boldsymbol{\nabla}\times\mathbf{E} + \partial_0\mathbf{B} + \boldsymbol{\nabla}\mathrm{Q}) = C_{0ij}\alpha_{0ij} = 0 \qquad (3$$

where **E** is the electric field vector, **B** is the magnetic field vector, Q is the dual (pseudo) scalar term that refers to the integral of spin,[7] and where $C_{0ij} \neq 0$ is appropriate in the case of an interaction with an external system.

The above C_{0ij} term can also be taken to represent a 'spin tri-vector potential,' and it is related to the magnetic field of a non-interacting system via a time differential. In the quaternion algebra of this 'Mathematics of Absolute Relativity Theory,' the dimensions of the relativistic spin coefficient (α_{0ij}) would thereby be reduced (via *d/dt*) to the bi-vector coefficient for the magnetic field (α_{ij}). This is analogous to the way that the electric field (α_{0i}) can be reduced to the vector potential (α_i) by this same derivative. This underscores the fully relativistic nature of this approach, one whose solutions do not require any additional relativistic corrections.

While a more traditional Hamiltonian approach would involve the quantity $\boldsymbol{\Xi}^\dagger\boldsymbol{\Xi}$, and its wave equation would then have the form $\mathrm{d}\boldsymbol{\Xi}\boldsymbol{\Xi}^\dagger = 0$, the Williamson equation $\mathscr{D}_\mu\boldsymbol{\Xi}_{\mathscr{G}} = 0$ is a sub-wave equation, a wave equation at the linear level (as are the Maxwell equations). An actual wave function may then take the form $\mathrm{d}^2\boldsymbol{\Xi} = 0$, but a foray into the details of this approach is beyond the scope of this paper. The way in which this transforms into a fully relativistic photon wave function has been proposed in earlier work.[2] A fully relativistic electron wave function is being developed, and will be detailed in future work.

What is relevant to underscore here is that this mathematics is telling us that everything is made of the same kind of "stuff", and that this stuff (or root-energy) goes into the same basket. That is the *reason* that spins interact. Spin is a combination of intrinsic, orbital, and azimuthal angular momenta which are coupling to one another because they are part of the *same* spin. The proper quantisation of spin is one of the system as a whole, and not on individual bits of the system.

5. CONCLUSIONS

This paper has extended the concept of quantum spin as it relates to the model of the electron developed by Williamson and van der Mark.[1,2,3] The purpose of doing so — and the main result of this paper — is to clarify a specific topological difference between the spin-up and spin-down states of electron quantum spin. It was also suggested that the difference between these spin states is a consequence of the direction of circular polarization of the rotating photon comprising the particle. A right circularly-polarized photon will yield an electron of one spin while a left circularly-polarized photon will yield an electron of the opposite spin.

It was also clarified that the *di-electron* boson state forms when two electrons in a nuclear charge well, of antiparallel magnetic alignment and opposite intrinsic spins, superimpose upon one another in an interwoven spin state of counter-rotating photon-like wave functions. It was proposed that the physical explanation behind the Pauli Exclusion 'Principle' arises from the interactions between the electric field, magnetic field, and spin root-energy components of superimposed and adjacent electrons. In addition, the spin coherence resulting from the interactions between the toroidal and intrinsic spin components, here named Parallel Spin Bonding, as well as the relative alignments of the electrons' magnetic axes, help to clarify the physical mechanism behind Hund's 2nd Rule.

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