Quantum properties of a cyclic structure based on tripolar fields

V. N. Yershov
Mullard Space Science Laboratory (University College London),
Holmbury St.Mary, Dorking RH5 6NT, UK
vny@mssl.ucl.ac.uk

Abstract
The properties of cyclic structures (toroidal oscillators) based on classical tripolar (colour) fields are discussed, in particular, of a cyclic structure formed of three colour-singlets spinning around a ring-closed axis. It is shown that the helicity and handedness of this structure can be related to the quantum properties of the electron. The symmetry of this structure corresponds to the complete cycle of \(\frac{2}{3}\pi\)-rotations of its constituents, which leads to the exact overlapping of the paths of its three complementary coloured constituents, making the system dynamically colourless. The gyromagnetic ratio of this system is estimated to be \(g \approx 2\), which agrees with the Landé g-factor for the electron.
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1 Introduction
It is widely accepted that quantum and classical mechanics, despite being conceptually different, are intimately related [1], which can be seen, for instance, in the necessity to describe any quantum object in the context of a classical system (measuring device). Practical applications of quantum mechanics, e.g., in quantum computing, also show that quantum information can only be transmitted in conjunction with classical signalling [2]. There exist many similarities between classical and quantum phenomena, although they occur in completely different contexts [3]. This leads to the possibility of describing deterministic systems with the use of quantum-mechanical formalism and vice-versa, thus arriving at a deeper understanding of irreversibility, causality and unpredictability concepts, as was shown by I. Prigogine [4] and others [5]. Nowadays, exploring the mechanisms responsible for the appearance of a classical world through decoherence of quantum systems is regarded as one of the most important tasks of quantum mechanics [6]. For instance, it is known that a regular pattern could emerge as a result of interactions between purely chaotic systems [7]. A series of models showing the possibility of mapping the quantum states of a system onto the states of a completely deterministic model were also discussed recently by ’t Hooft [8], Prezhdo [9], and others [10].

On the other hand, there are models showing that a classical system can manifest itself quantum-mechanically [11], which means that quantum field theories could be underlied by classical mechanics [12], with quantum uncertainties also having a deterministic origin [13]. Many physicists explore the possibility that quantum phenomena could arise as a result of information loss due to non-reversible dissipative processes and self-organisation in nonlinear deterministic systems [14].

Here we shall follow this lead and examine two composite classical systems with nonlinear pairwised potentials, showing that such systems could exhibit quantum properties identifiable with those of the electron and its neutrino. Today’s commonly-held view is that these particles are point-like quantum objects whose classical description is impossible because the microscopic reality is controlled by non-commuting operators, and the more so because quantum models are able to account for most of the experimental data [15]. However, Dirac, the creator of quantum theory of the electron, warned that his point-electron model was actually a mathematical approximation, not conforming to current physical ideas [16]. The point model of a charged particle is physically unstable and requires the density of the particle’s rest mass-energy to be infinite. According to the laws of electrodynamics, a point charge would have to have a zero spin and zero magnetic moment. Thus, the laws of magnetism dictate that the electron must have some physical extent to have a magnetic moment. That is why modern quantum field
Our model is based on classical tripolar (colour) fields with the sources of these fields – tripolar charges – regarded as primitive entities with almost no properties, except for those determined by the properties of space. Therefore, these entities are likely to be described as autosolitons – localised eigenstates of the manifold, which have the properties of both particles and waves, propagate and interact with each other and obey the energy and momentum conservation laws [18]. The autosoliton parameters are entirely determined by the parameters of the system and do not depend on the excitation causing their formation. The matter particles could then be seen as composite systems based on stable configuration patterns of a moving manifold (space), which is not a novelty: perhaps the first who suggested that elementary particles might be organised patterns of space was Wheeler [19]. There are also many other models of this kind [20]. An important feature to be taken into account in this framework is torsion of the manifold [21], which would lead to the nonlinear Heisenberg equation [22] and non-Abelian degrees of freedom. The corresponding field would have a topological quantum number – the colour analogy of helicity in fluid dynamics [23] leading to colour solitons [24]. By assuming an appropriate interaction potential between colour particles in a many-particles system (e.g., of the Lennard-Jones type, with the long-range attractive and short-range repulsive character) one can reveal a potential surface with multiple local minima leading to kinematic constraints of a topological nature. This is entirely analogous to the cluster formation scheme in molecular dynamics [25]. The only difference is that here we have to deal with the tripolarity of the pairwise potential.

The SU(3)/U(1) symmetry of the potentials leads to the possibility of a rich variety of clusters: from simple colour dipoles and tripoles to strings and complex molecule-like cyclic aggregates. The specific configuration of each structure and the number of its constituents could be found by calculating the minimum of its effective potential. In [27] it was observed that the properties of these structures resemble those of the fundamental fermions. Based on this observation, in this paper we shall further explore two simplest cyclic structures, which were identified with the electron and its neutrino. We shall outline the proposed framework in the next section. Afterwards, we shall show that within this framework we are bound to assume the probabilistic behaviour and intrinsic uncertainty of the systems. Then, in Section 4, we shall revisit some properties of the cyclic structure identified with the electron. Finally, in Section 5, we shall estimate the gyromagnetic ratio of this system.

2 Two-component basic field

As a starting point, we suggest that the electric and colour fields are unified through their source – a kind of primitive particle, with no properties save its mass and charge. That is, we assume that such a particle generates a dual (split) equilibrium field, \( F(\rho) \), with the following components:

\[
F_\ominus(\rho) = s \exp(-\rho^{-1}) \quad \text{and} \quad F_\oplus(\rho) = -F_\ominus(\rho),
\]

one attractive (\( \ominus \)) and the other repulsive (\( \oplus \)), which are intimately related to each other by their common origin. Here the signature \( s = \pm 1 \) indicates the sense of the interaction; the derivative is taken with respect to the radial coordinate, \( \rho \). For the sake of simplicity, the amplitude and range coefficients in \( \ominus \) are set to unity. We shall denote the energies corresponding to these components of the field (integrals over the entire range of \( \rho \)) as \( \tilde{m}_a \) and \( m_\ominus \), respectively. Obviously, the second quantity, \( m_\ominus \), is unity, while \( \tilde{m}_a \) diverges, implying that the above fields cannot exist in free states because of their infinite energies. The approximate antisymmetry between \( F_\ominus \) and \( F_\oplus \) in the vicinity of their origin (see details in [27]) implies that, given a pair of primitive particles with complementary colours/charges, these particles will combine into an equilibrium configuration (colour-dipole \( g^0, g^+ \) or \( g^- \)), with the average distance \( \rho_0 \) between its components such that the fields balance each other: \( F_\ominus(\rho_0) = -F_\oplus(\rho_0) \). This breaks the initial spherical symmetry of the field, as well as yet another fundamental symmetry – that of scale invariance – since there exists a distance \( \rho_0 \) which can be used as the basic unit length for this model. Moreover, it is seen that the potential \( V(\rho) \), Fig. 1k, corresponding to this field is characterised not only by its inherent length unit, \( \rho_0 \), but also by the speed and time units, \( v_0 \) and \( t_0 \). Indeed, the speed is calculated as

\[
v(\rho) = \sqrt{\frac{2}{\tilde{m}}(E_0 - V(\rho))},
\]

where
where \( \hat{m}^{-1} = m_1^{-1} + m_2^{-1} \) is the reduced mass (here \( \hat{m} = \frac{1}{2} \) because for the sake of simplicity in this example we ignore the third colour; but this does not matter for understanding the point). The energy \( E_0 \) of the initial state can be set to zero (at \( \rho = 0 \)), which defines the speed scale for this system (unit speed \( v_0 \)) through the magnitude of the maximal speed, \( v_{\text{max}} = v(\rho_0) \approx 0.937 \). This also establishes the time scale – by defining the unit time, \( t_0 \), such that \( v_0 t_0 = \rho_0 \). Thus, we can see that the field \( \mathbf{F} \) is fully self-calibrated. Of course, we have to take into account the fact that the colour dipole, as with its constituents – colour charges – cannot exist in free states because it has only two of three possible diverging components of the field \( F_\rho \) that cancel one another. The colour components could be cancelled either in a large ensemble of colour dipoles \( g^0 \) (statistically) or if three primitive particles were combined together – all with complementary colours and like charges. In the latter case, the cancelled energies of three colour-fields will be converted into the binding energy of the structure. That is, three like-charged primitive particles will necessarily cohere in a colour-neutral but electrically charged singlet – a \( \triangle \)-shaped oscillator \((\text{tripole})\) with radius oscillating near the value 3. It is noted that the tripole is colour-neutral only at infinity: nearby its field is colour-polarised since the centres of its components do not coincide. This implies that different tripoles can be further combined because of their residual chromaticism. Using the fields \( \mathbf{F} \) one can compute the pairwise forces between the colour-charges in a particular tripole cluster and estimate the energy of this cluster in order to find its equilibrium configuration with minimal energy. These calculations can easily be made for some simple configurations but the computational difficulties grow dramatically with the complexity of the structures.

3 Uncertainty of the field

One can see that the field \( \mathbf{F} \) necessarily implies an uncertainty, precluding the exact determination of particle trajectories. Indeed, let us consider the initial state of the simplest system formed of two primitive charges – a colour-dipole \( g^+ \). For the sake of simplicity let us ignore for a moment the third colour and analyse a two-body problem, which is known to have an exact analytical solution. It follows from (2) that the dipole components are confined within the region \( \rho \in (0, \rho_{\text{max}}) \). Fig. 1b, where \( \rho_{\text{max}} \approx 1.894 \rho_0 \), the particle speed vanishing at the ends of this interval. As we have already seen, the individual sources of the field \( \mathbf{F} \) cannot exist in free states because this would lead to their infinite energies. This means that we cannot choose \( \rho = \infty \) to be the initial state of our system. Therefore, the only available natural initial states of the dipole correspond to \( \rho = \rho_{\text{max}} \) and \( \rho = 0 \) (a superposition of particles in the origin) with \( E_0 = 0 \). The corresponding oscillatory period

\[
T = 2(t(\rho_{\text{max}}) - t(0)) = 2\sqrt{\frac{2m}{\rho_{\text{max}}}} \int_0^{\rho_{\text{max}}} \frac{d\rho}{\sqrt{-V(\rho)}}
\]  

(3)

will be infinite, which is what one would expect because of a stationary point at the origin, \( F_\rho'(0) = F_\rho''(0) = 0 \). This is the bifurcation point of a typical double-well potential \( V(\rho) \), Fig. 1b, which is known

![Figure 1: (a): Equilibrium potential \( V(\rho) \) based on the field \( \mathbf{F} \) and used for modelling a two-colour dipole system; (b): Evolution of the two-colour dipole from its initial state at \( \rho = 0 \) under the stochastic action of an external system (for \( \delta v = 0.001v_{\text{max}} \)). The coordinates \( x \) and \( y \) are measured in units of \( \rho_0 \).](image)
to lead to chaotic oscillations. In order to evolve from this state the system requires an external (albeit infinitesimally small) action. Thus, we ought to conclude that this system cannot, in principle, be treated as isolated. That is, we have to take into account the fact that at the initial moment of time an external system (e.g., the rest of the universe) adds to (or removes from) our system some infinitesimally small portions of energy (which corresponds to the noise with zero expectation value). Under this external action, the radius of our system will grow from zero to some value, say, $\delta \rho$, whilst the particle speed will increase by the value $\delta v$.

Within an $\varepsilon$-neighbourhood of the origin the proper interactions between the two particles will be small compared to the external action, so that for some period of time the system will be evolving chaotically. After exiting the $\varepsilon$-region, this evolution will become more regular, and the particles will acquire both radial and tangential components of their velocities (that is, the initial energy of the system will be shared between its angular momentum and oscillatory motion). Outside the $\varepsilon$-region the influence of the external system will be almost unnoticeable, unless the particles occasionally penetrate back into this region. An example of the trajectory of a colour-dipole influenced by an external system and evolving from its initial state with $\rho = 0$ is shown in Fig. 1b (for $\delta v = 0.001 v_{\text{max}}$). The same reasoning is applicable to the tripolar oscillators whose evolution will be more complicated, but with the same net result: it will be impossible to dispose of the influence of the external system. Thus, we have to arrive at the conclusion that within our framework no isolated systems could exist in principle. Due to this, even in the simplest case of a two-body system, the equations of motion are not analytically solvable, let alone the multi-body systems corresponding to more complex composite particles. However, given the smallness of the perturbations caused by the external system, its influence should be noticeable only under extreme conditions when all the particles are squeezed into a very small volume. In most of the other cases, the presence of the external system will be perceivable only by small deviations from the particles’ trajectories.

4 Strings and loops of $\triangle$-shaped tripoles

It was shown in [27] that two $\triangle$-shaped tripoles can combine pole-to-pole with each other and form a two-component oscillator (doublet $d$). The sign of the force between the paired tripoles depends on their position angle, $\zeta$, with respect to each other. For example, for $\zeta = \pi/2$ the force is vanishing; it is attractive for $\pi/2 < \zeta < 3\pi/2$:

$$d^+ = \begin{array}{c}
\includegraphics[width=0.2\textwidth]{figure1a.png}
\end{array}$$

$$d^- = \begin{array}{c}
\includegraphics[width=0.2\textwidth]{figure1b.png}
\end{array}$$

and repulsive for $|\zeta| < \pi/2$:

$$d^\circ = \begin{array}{c}
\includegraphics[width=0.2\textwidth]{figure1c.png}
\end{array}$$

Thus, separated by distance $\rho > 2\rho_0$, two tripoles will tend to combine into a doublet configuration ($d^+$ or $d^-$) with $\zeta = \pi$. The neutral doublet

$$d^\circ = \begin{array}{c}
\includegraphics[width=0.2\textwidth]{figure1d.png}
\end{array}$$

can also be formed. The width of the potential well for $\zeta = \pi$ and $\rho > 2\rho_0$ allows a certain degree of rotational freedom for the paired tripoles, so that the position angle can oscillate within $\frac{2}{3}\pi < \zeta < \frac{4}{3}\pi$. We shall use the symbols $\uparrow$ and $\downarrow$ to denote, respectively, the clockwise and anticlockwise directions of rotation. Then, the rotational oscillations of the doublet can be represented as

$$d^\uparrow \rightleftharpoons d^\downarrow \text{ or } d^\circ \rightleftharpoons d^\circ.$$  

The $\zeta$-dependence of both strength and sign of the bond force between the tripoles implies that the distance $\rho$ is covariant with the position angle $\zeta$, i.e., that the translational and rotational oscillations of the doublet $d$ are synchronous.

It follows that due to the $\frac{2\pi}{3}$-symmetry of the tripoles their rotations in a chain of like-charged tripoles can cyclically repeat after each three links: $\uparrow \uparrow \uparrow$, leading to the closure of the chain in a symmetric
loop (triplet), Fig. 2a, denoted here as \( Y = 3 \triangle \). The consecutive \( \frac{2\pi}{3} \)-phase-shifts of the tripoles in this chain can be either clockwise or anticlockwise corresponding to two possible helical states of the triplet, \( Y \uparrow \) and \( Y \downarrow \).

\[ \begin{align*} \text{(a)} & \quad \text{(b)} & \quad \text{(c)} \end{align*} \]

Figure 2: (a): Scheme of the triplet \( Y \) (a chain of three like-charged \( \triangle \)-tripoles closed into a loop); (b): trajectories of colour-charges (currents) in the triplet loop; (c): trajectory of a single charge.

In a similar way, one can find that, given a chain of unlike-charged pairs of tripoles, the pattern of rotations in this chain repeats after each six tripoles-pairs, leading to the closure of the chain in a six-component loop (hexaplet), Fig. 3a, which we shall denote as \( X = 6 \triangle \triangle \). Obviously, this structure is electrically neutral and, like the triplet, can also be found in one of two possible helical states, \( X \uparrow \) or \( X \downarrow \).

\[ \begin{align*} \text{(a)} & \quad \text{(b)} \end{align*} \]

Figure 3: (a): Scheme of the hexaplet \( X \) – a loop configuration of six tripole-antitriple pairs; and (b): Trajectories of colour-charges (currents) in this structure. The antitripoles are coded with lighter colours.

It is seen that the charges constituting a cyclic structure can spin around its ring-closed axis. In the case of the triplet, \( Y \), this will generate a toroidal (ring-closed) magnetic field which will force these charges to move along the torus. This orbital motion will generate a secondary (poloidal) magnetic field, contributing to the spin of these charges around the ring-axis, and so forth, until the charges reach their maximal speed, say, \( v_\circ \). Such a dynamo mechanism for generating a self-consistent magnetic field is studied in detail in astrophysics [30] and solar physics [31]. It is also used for stabilisation of toroidal plasma flows in the tokamak fusion reactors [32]. The only difference between the standard dynamo models and our case is that the \( Y \)-structure here does not require any external angular momentum to maintain its magnetic field. The trajectories of charges (currents) are clockwise, \( Y \uparrow \), or anticlockwise, \( Y \downarrow \), helices (Smale-Williams curves), which, by their closure, make a \( \pi \)-twist around the ring-closed axis of the structure (Fig. 2b). Such a twisting dislocation of the phase is known as the topological charge \( S = \pm \frac{1}{2} \), also called the dislocation index, which has a sign corresponding to the winding direction (clockwise or anticlockwise) and the magnitude related to the winding number per \( 2\pi \)-orbit path. In these terms, the \( \pi \)-phase shift of the currents in the structures \( X \) and \( Y \) corresponds to the topological charge \( S = \pm \frac{1}{2} \).

It is worth noticing that, since the \( \frac{2\pi}{3} \)-symmetry of the tripole is reproduced on a higher hierarchical level – in the structure \( Y \) – the path of each colour-charge belonging to a particular tripole overlaps exactly with the paths of two other colour charges that belong to two other tripoles and whose colours are complementary to the colour of the first charge. This means that the trajectories of charges (currents) in the structure \( Y \) are dynamically colourless (Fig. 2c). That is, averaged in time, the field of the triplet \( Y \) would have only two (positive and negative) polarities corresponding to the conventional electric field. The same symmetry is also observed in the hexaplet whose currents are shown in Fig. 3b. There are twelve current loops in this structure, six negative and six positive, compared to the three unipolar loops in the triplet \( Y \).

The colourlessness of the time-averaged fields of \( Y \) and \( X \) does not necessarily imply that these particles cannot colour-interact with each other. On the contrary, if the motions of their constituents are
synchronised, these structures will induce an attractive or repulsive force towards each other, additional to the conventional electrostatic force. Thus, given a pair of triplets $\mathbf{Y}$ (or hexaplets $\mathbf{X}$) with opposite helicities ($\mathbf{Y}_1\mathbf{Y}_2$), the mutual orientation of the tripleps in the pair corresponds to an attractive force between them [see the diagram (3)], whereas like-helicities ($\mathbf{Y}_1\mathbf{Y}_1$ or $\mathbf{Y}_2\mathbf{Y}_1$) correspond to repulsion [diagram (5)]. By contrast, one can find [27] that the pattern of repulsion and attraction between the constituents is reversed in a mixed pair ($\mathbf{X}$ with $\mathbf{Y}$), in which like-topological charges attract each other and unlike ones repel. As a result, the combination $\mathbf{X}_1\mathbf{Y}_1$ (or $\mathbf{X}_1\mathbf{Y}_2$) has an integral topological charge ($S_{XY} = \pm 1$). The combination $\mathbf{X}_1\mathbf{Y}_1$ would have a zero topological charge, but this system is unlikely to exist, since the topological charges of $\mathbf{X}_1$ and $\mathbf{Y}_1$ in this system are repulsive to each other. The clustering of $\mathbf{Y}$-particles (in our interpretation – electrons) is, in fact, observed experimentally: it is known that the electrons can form clusters, e.g., in extended media where they may undergo crystallisation at low densities, as has been predicted by E. Wigner [34] and then shown by different research groups [35].

It is interesting to note that the momentum and angular momentum of the hexaplet $\mathbf{X}$ in the structure $\mathbf{XY}$ are coupled to each other through the magnetic field (see [27] for details). Given also the possibility of polarisation of the hexaplet $\mathbf{X}$ when it is combined with the triplet $\mathbf{Y}$, the above coupling of momenta would result in the conjugation of charge and parity of the particles $\mathbf{X}$ and $\mathbf{Y}$ (at the moment when they leave the system $\mathbf{XY}$). Such a conjugation, known as CP-symmetry, is observed in the $\beta$-decay products, $e^-$ and $\nu_e$. Since we have already identified the structures $\mathbf{Y}$ and $\mathbf{X}$ with, respectively, $e$ and $\nu_e$, we can see that our model provides a natural explanation of the CP-symmetry and of the neutrino left-handedness.

It is also found that the repulsive (or attractive) force between two helical structures is maximal when their topological charges have half-integer magnitudes. This force diminishes when the magnitude of one (or both) of the topological charges deviates from the half-integer value and eventually decays to zero when the magnitude of any of the topological charges takes an integral value. This pattern of attraction and repulsion adheres to the Pauli exclusion principle, and here we have deliberately chosen the symbols $\uparrow$ and $\downarrow$ to denote the opposite helicities (topological charges), implying that the helicity of a cyclic structure is equivalent to the quantum notion of spin. This conjecture is also supported by the fact that quantum spin is measured in units of angular momentum ($\hbar$), and so too is the topological charge in question, which is derived from the rotational motion of the tripleps $\Delta$ around the ring-closed axis of the triplet $\mathbf{Y}$ or hexaplet $\mathbf{X}$.

5 Magnetic moment of the triplet

It is instructive to estimate the magnetic moment of the looped currents of the triplet $\mathbf{Y}$, together with the corresponding gyromagnetic ratio. As we have already noted, the charges moving within this structure trace helical trajectories, which, by the closure of their $2\pi$-paths along the ring-axis of $\mathbf{Y}$ are additionally $\pi$-twisted around this axis. This means that each of these currents is formed of two loops (see Fig.[3]. The magnetic moment created by these loops can be calculated as

$$
\mu_T \approx I_{\text{int}}A_{\text{int}} + I_{\text{ext}}A_{\text{ext}},
$$

Figure 4: Polar view of the trajectory of one of the charges $(q_\rho)$ belonging to a $\Delta$-tripole and moving within the structure $\mathbf{Y}$. The tripole is spinning around its polar axis ($y$) and precessing around the axis $z$ (perpendicular to the orbit plane).
where $I_{\text{int}}$ and $I_{\text{ext}}$ are the currents corresponding to the “internal” (smaller) and “external” (larger) loops; $A_{\text{int}}$ and $A_{\text{ext}}$ are the loop areas. We can reasonably approximate the loop radii by the values

$$\rho_{\text{int}} = \rho_Y - \frac{\rho_\Delta}{2}$$
$$\rho_{\text{ext}} = \rho_Y + \frac{\rho_\Delta}{2}.$$

Given

$$I = \frac{3q_v \nu}{2\pi \rho} \quad \text{and} \quad A = \pi \rho^2,$$

the magnetic moment of the structure will be

$$\mu_Y = \frac{3q_v \nu_{\text{int}}}{2\pi (\rho_Y - \rho_\Delta/2)} \cdot \pi (\rho_Y - \rho_\Delta/2)^2 +$$
$$+ \frac{3q_v \nu_{\text{ext}}}{2\pi (\rho_Y + \rho_\Delta/2)} \cdot \pi (\rho_Y + \rho_\Delta/2)^2 =$$

$$= 3q_v \omega (\rho_Y^2 + \frac{\rho_\Delta^2}{4}),$$

(8)

where $\nu_{\text{int}} = \omega (\rho_Y - \rho_\Delta/2)$ and $\nu_{\text{ext}} = \omega (\rho_Y + \rho_\Delta/2)$ are the averaged orbital speeds of the charges; $\omega$ is the angular speed of the tripoles; and the coefficient “3” in the expressions above appears due to the fact that there are actually three charges (of different colours) moving along the same path (but this is not essential here). The corresponding angular momentum

$$\ell_Y \approx 3m_v \rho_Y \nu = 3m_v \omega \rho_Y^2$$

(9)

results in the following gyromagnetic ratio of the triplet:

$$g_Y = \frac{\mu_Y}{\ell_Y} \approx 2 \left( 1 + \frac{\rho_\Delta^2}{4\rho_Y^2} \right).$$

(10)

Since $\rho_\Delta^2/4\rho_Y^2 \ll 1$, the gyromagnetic ratio above is approximately equal to the number of current loops, $g_Y \approx 2$. To derive this quantity more accurately one has to account for the detailed solenoidal geometry of the currents in the triplet, as well as for the radial oscillations of its constituents and of the whole structure.

Of course, the proportionality of the magnetic moment to the loop number of a solenoid is commonplace. In fact, what we have shown in Eq. (10) is that the gyromagnetic ratio of the triplet is slightly larger than 2, which agrees with the experimental value

$$g_e^{\exp} \approx 2.002319$$

(11)

of the Landé g-factor for the electron. The value $g_e = 2$ was explained quantum-mechanically by P.A.M. Dirac [38], and, hitherto, it was assumed that this value could not be explained in terms of classical mechanics because the classically-derived g-factor should be equal to unity. We can see now that this is not necessarily so. In fact, the derivation of the half-integral spin for a system with an integer classical orbital momentum was already reported in [39] a few years ago. Here we have shown that a classical approach can be even closer to reality. From (10) and (11) we can see that $\rho_Y/\rho_\Delta \approx 15$, corresponding to the shape of a rather thin O-ring.

6 Discussion

Without invoking any *ad hoc* assumptions and based solely on first-principles, i.e., on our conjecture about the symmetry of the basic field (1), we have found that practically all the properties of the emerging triplet structure $Y$, including its gyromagnetic ratio, match those of the electron, which makes it natural to identify the triplet with the electron. Likewise, the properties of the hexaplet $X$ suggest identifying it with the electron-neutrino. Incidentally, since the discovery of the electron many physicists explored the idea of a spinning structure in the form of a disk or ring [40] in order to explain the properties of the electron, which led to important discoveries. For example, it was A.Compton’s intention to determine the size of the ring-electron that inspired him to perform his famous scattering experiments [41]. The early
models of the ring-electron were created as straightforward interpretations of the observed properties of this particle but they could not explain the magnitude of its magnetic moment.

Some modern physicists have revisited the old ideas, encouraged by progress in the theory of rotating Kerr-Newman black holes [42] or toroidal magnetic fields in helical plasma flows [43]. Here, looking at the problem from a completely different point of view we have unravelled a similar solenoidal structure whose properties match surprisingly well those of the electron. Since our model is pretty much in line with both old and modern ideas about the electron’s structure, our identification of the triplet and hexaplet with, respectively, the electron and its neutrino is entirely natural and logical.

We have seen that a classical model with non-linear fields [1] can reproduce quantum properties of the electron. Using the symmetry of these fields we have been able to uncover the structure formation and symmetry-breaking mechanisms, which are probably responsible for the formation of the entire diversity of elementary particles. By deriving their quantum properties in a classical way our model supports the assertion that quantum mechanics could, indeed, arise from classical (albeit non-deterministic) processes. The impossibility within our framework to deal with isolated systems (Sect. 3) coheres with the ideas of A. Landé who maintained [44] that uncertainty is a physical principle equally important for both classical and quantum physics. The symmetry of time-reversibility is also broken in our model because, as is known [45], even a negligibly small noise in a deterministic N-body system can cause the loss of reversibility.

The framework outlined here opens a few promising directions for further research. First, it is of importance to specify the parameters of interaction between the colour particles under discussion. The basic field does not necessarily have to be of the proposed simplest form [1]. Its main feature (the capability of generating equilibrium particle configurations) could be derived from various physical considerations, one of which could be a detailed analysis of the collective behaviour of autosolitons in appropriate media, likely leading to the desirable shape of the potential.

The next step would be the study of the behaviour of the nine-body system – triplet identified here with the electron – under different background potentials and initial energy conditions in order to derive the exact value of the gyromagnetic ratio for this system. Then it would be logical to calculate the interaction potential between the triplet and hexaplet systems, the bound state of which is expected to be a highly nonlinear oscillator with one of its semiamplitudes growing at the expense of the other. Calculating the average disruption time and some other parameters of this oscillator is a challenging task, likely leading to unexpected ramifications and new results.

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