Electron as a Geometric Oscillator between Real and Quaternion Imaginary Space

Ivars Fabriciuss

July 27, 2025

Abstract

We propose a geometric model of the electron based on its oscillation between ordinary three-dimensional real space $\mathbb{R}^3$ and an imaginary quaternion space $\mathcal{I}^3$. This transition, occurring at the Zitterbewegung frequency $\omega_{\mathrm{ZB}} = \frac{2mc^2}{\hbar}$, gives rise to a dynamic structure: a figure-8 loop in real space (with a total 2π twist) and its inverted mirror loop in an imaginary space. The projection across a shared Planck-scale circular boundary (the *contact disc*) encodes both mass and charge, while the torsional stiffness of this contact region is identified as the physical origin of electron mass. We explore the unification of gravitational and electromagnetic length scales via this projection geometry and propose that the Schwarzschild radius r_s, Compton wavelength λ_C, and an imaginary projection length ℓ_∞ are deeply related by real-to-imaginary space inversion. The resulting framework offers a consistent ontology for particle structure, field emergence, and vacuum coupling across dual phases of the physical universe.

1 Introduction

Modern quantum field theory describes the electron as a pointlike spin-$\frac{1}{2}$ excitation with mass and charge arising from local field properties and gauge symmetries. This perspective lacks an internal geometric structure and does not connect the electron's mass or charge to any deeper substructure.

Here we propose a geometric and topological model in which the electron is not pointlike but a composite object undergoing rapid oscillation between two distinct but connected manifolds: the familiar real space $\mathbb{R}^3$ and a "mold" space $\mathcal{I}^3$ constructed from the imaginary quaternion units (i, j, k). The dynamics between these spaces are governed by a high-frequency Zitterbewegung (ZB) oscillation. The spaces share time t. A shared Planck-length contact disc serves as the interface through which the electron's configuration in $\mathbb{R}^3$ is inverted into $\mathcal{I}^3$ and vice versa.

2 Dual-Space Framework

We postulate the existence of two complementary phases of space for the electron, with a continuous interchange mediated by Zitterbewegung oscillation:

2.1 Real and Imaginary Spatial Components

Real space $\mathbb{R}^3$: The ordinary three-dimensional space where the electron exhibits its familiar properties (electric charge, spin, and energy $+mc^2$ in the rest frame).

Imaginary space $\mathcal{I}^3$: A three-dimensional space spanned by quaternionic imaginary axes. It can be viewed as a hidden "mold" or template for the particle, with exotic properties: volumes and energies carry an opposite sign signature (negative effective volume and negative potential energy), distances and speeds are measured in imaginary units (e.g. ic for velocity), although the particle's invariant mass m remains the same. In $\mathcal{I}^3$, the electron exists in a phase with energy $-mc^2$ and no electric charge manifestation. The space is hyperbolic, with negative curvature.

2.2 Zitterbewegung Oscillation

The electron oscillates between its real and imaginary configurations with angular frequency

$$\omega_{\rm ZB} \;=\; \frac{2\,mc^2}{\hbar}\,.$$

This is the characteristic Zitterbewegung frequency originally noted in relativistic electron theory. The corresponding time period for a full oscillation is extremely small ($T_{\rm ZB} \sim \pi\hbar/(mc^2) \approx 10^{-21}$ s for an electron). Each full cycle consists of two half-cycles: during one half-cycle the electron's structure is in $\mathbb{R}^3$ (with positive energy $+mc^2$ and visible electromagnetic fields), and during the other half-cycle it is in $\mathcal{I}^3$ (with negative energy $-mc^2$ and no electromagnetic interaction). This rapid phase flipping is a non-classical motion: it is a periodic inversion of the particle's geometry rather than a motion through space.

2.3 Planck-Scale Contact Disc and Inversion

A crucial element of the model is a tiny circular contact interface of radius on the order of the Planck length $\ell_{\rm Pl} = \sqrt{\hbar G/c^3} \sim 10^{-35}\,{\rm m}$. This *contact disc* is the region through which the electron's real-space structure inverts into its imaginary-space counterpart. It is a boundary disc between real and imaginary spaces. Geometrically, we model the projection from $\mathbb{R}^3$ to $\mathcal{I}^3$ as an inversion through this disc. In particular, if r is a position measured from the center of the contact disc in $\mathbb{R}^3$, the corresponding point in $\mathcal{I}^3$ is given by

$$r' \;=\; \frac{\ell_{\rm Pl}^2}{|\,r - r_0\,|^2}\,\big(r - r_0\big)\,,$$

where r_0 is the center of the contact disc. Under this inversion mapping, a structure of linear size on the order of the electron's Compton wavelength $\lambda_C = \hbar/(mc)$ in real space will be mapped to a much smaller structure in imaginary space. In fact, a loop of radius λ_C in $\mathbb{R}^3$ inverts to an imaginary loop of radius

$$\ell_\infty \;=\; \frac{\ell_{\rm Pl}^2}{\lambda_C}\,,$$

in the imaginary space. Plugging in $\ell_{\rm Pl}^2 = \hbar G/c^3$ and $\lambda_C = \hbar/(mc)$, we find

$$\ell_\infty \;=\; \frac{\hbar G/c^3}{\hbar/(mc)} \;=\; \frac{Gm}{c^2}\,.$$

Remarkably, ℓ_∞ equals Gm/c^2, which is one-half of the electron's Schwarzschild radius $r_s = 2Gm/c^2$. In other words, the characteristic size of the electron's invisible $\mathcal{I}^3$ configuration is geometrically related to its gravitational radius in $\mathbb{R}^3$. This points to a natural unity between the electromagnetic scale (Compton wavelength) and the gravitational scale (Schwarzschild radius) via the projection mechanism.

2.4 Torsional Stiffness as Mass Origin

The contact disc not only provides a geometric inversion point, but also serves as a torsional spring linking the real and imaginary structures. We propose that the electron's rest mass arises from the *torsional stiffness* of this Planck-scale contact region. During the ZB oscillation, the contact disc is twisted as the figure-8 configuration flips between $\mathbb{R}^3$ and $\mathcal{I}^3$. Treating the mass m as an effective inertia and the ZB oscillation as a torsional oscillation, we have

$$m \;=\; \frac{K_{\rm twist}}{\omega_{\rm ZB}^2}\,,$$

where $K_{\rm twist}$ is the torsional spring constant of the contact disc. Equivalently, $K_{\rm twist} = m\,\omega_{\rm ZB}^2$. For the electron, $\omega_{\rm ZB} \approx 1.5 \times 10^{21}\,{\rm s}^{-1}$, so this implies $K_{\rm twist}$ on the order of 10^{12} J (in units of energy per radian^2). Such a large stiffness is consistent with the notion that the contact disc is a Planck-scale structure with enormous energy density. Thus, in this model the electron's mass has a purely geometric origin: it measures the resistance of the contact disc to being twisted by the oscillatory inversion motion.

3 Figure-8 Electron Geometry and Dynamics

In its real-space phase, the electron is modeled as a closed loop of "rotor" particles that form a figure-8 shape. The figure-8 consists of two interlocking loops, each carrying a half-twist (π twist) , resulting in a total 2π twist around the entire structure. This twisted double-loop configuration arises naturally as a minimal energy shape (a loop that has buckled into a figure-8 under a 2π twist) and endows the electron with its spin and topological charge characteristics. The contact point of both loops where they touch is of special importance for charge emission and as boundary disc between two spaces.

Each loop in the figure-8 lies roughly in a plane, and the two loops touch orthogonally at the contact disc region. The loops have a radius on the order of the Compton wavelength λ_C (about 2.4×10^{-12} m for an electron). The total length of each loop is therefore on the order of λ_C as well, which corresponds to an enormous number of constituent rotor units on the order of $N \sim \lambda_C/\ell_{\mathrm{Pl}} \sim 10^{23}$. These Planck-scale rotor units circulate around the loops at light-speed c. The continuous circulation of these rotors around the twisted loops gives rise to the electron's spin angular momentum, while their synchronized orthogonal motion past the contact disc gives rise to the electron's charge and electromagnetic field, as described below.

3.1 Spin-$\frac{1}{2}$ from Topology

The figure-8 geometry with a total twist of 2π inherently exhibits the properties of a spin-1/2 system. A 360° (2π radian) rotation of the entire figure-8 does not restore it to the identical configuration; only a 720° (4π) rotation brings the loop assembly back to its starting orientation. This is a direct geometric analogue of the behavior of a spin-1/2 particle. The electron's spin $\frac{\hbar}{2}$ arises here not from an intrinsic point-like property, but from the distributed angular momentum of the circulating rotors in the twisted loops. Importantly, the spin orientation (e.g. "up" vs "down") corresponds to the two possible overall chirality states of the figure-8 twisting and rotor circulation direction. During the ZB oscillation into $\mathcal{I}^3$ and back, the overall spin is preserved—since the topological twist cannot change during the inversion—ensuring that spin is a conserved internal property of the electron in this model.

3.2 Magnetic Moment of the Loop Currents

Each loop of the figure-8 can be viewed as a current-carrying ring: the moving rotors of charge circulate at speed c around a loop of radius λ_C. For a rough estimate, consider that the total electron charge e is distributed evenly among N rotors, so each rotor carries charge $q_{\mathrm{rotor}} = e/N$. The current due to a single loop is approximately $I \sim q_{\mathrm{rotor}} c/(2\pi\lambda_C) = \frac{e}{N}\frac{c}{2\pi\lambda_C}$. The magnetic dipole moment contributed by one loop of radius λ_C is on the order of $\mu_{\mathrm{loop}} \sim I \cdot (\pi\lambda_C^2) = \frac{ec\lambda_C}{2N}$. Since there are two loops and their contributions add constructively (the orthogonal loops are synchronized through the contact disc so that their fields do not cancel out), the net magnetic moment of the figure-8 structure is approximately

$$\mu_e \sim 2\mu_{\mathrm{loop}} = \frac{ec\lambda_C}{N} \, .$$

Using $\lambda_C = \hbar/(mc)$ and $N \sim \lambda_C/\ell_{\mathrm{Pl}}$, this evaluates to $\mu_e \sim \frac{e\hbar}{2m}$ (up to factors of order unity). This is on the order of the Bohr magneton $e\hbar/(2m)$, the correct scale for the electron's intrinsic magnetic moment. Thus, the circulating charges in the figure-8 model naturally account for a spin-aligned magnetic moment. (In a more detailed treatment, a small tilt of one loop vs another (approximately 2.76 degree) a deviation from this value could correspond to the electron's $g \approx 2$ gyromagnetic factor.)

4 Electromagnetic Field Emission and Charge Quantization

In our model, the electron's electric field is generated by the motion of the rotors through the contact disc region during the real-space phase. Each time a segment of the rotor loop passes through the contact disc (which happens N times per full rotation of the loop), a burst of twisted displacement occurs at that interface. We interpret each such event as the emission of a tiny helical segment of electric field flux (a "twist packet") that propagates outward into $\mathbb{R}^3$ at light speed c. These helical field segments collectively form what appears macroscopically as the continuous Coulomb field of the electron.

Because the figure-8 loop has a finite number N of rotor segments, the electron's charge e is emitted in N tiny portions per ZB cycle rather than continuously. The elementary charge associated with each emitted twist packet can be estimated as

$$q_{\text{helix}} = \frac{e}{N},$$

so that after one complete cycle of all rotors passing the contact disc, the total emitted charge sums to e. In this sense, electric charge is naturally quantized in our model: it is built up from N discrete identical units rather than being a continuous fluid. Charge conservation is ensured because the topological structure of the figure-8 (with N fixed segments) does not change; thus e remains constant over time, being the sum of invariant small contributions.

During the half-cycle when the electron is in the imaginary space $\mathcal{I}^3$ (the mold phase), no real electromagnetic field is emitted. This is consistent with the idea that $\mathcal{I}^3$ has fundamentally different electromagnetic properties (for instance, an effectively negative permittivity that prevents the propagation of real electric field lines). The electron in the mold phase is thus completely electromagnetically inert, and its charge becomes unobservable until the structure returns to $\mathbb{R}^3$.

The model also provides a natural explanation for the existence of exactly two types of charge (positive and negative). The handedness of the helical twist emission—determined by the rotation direction of rotors at the contact disc—sets the sign of the emitted charge. A right-handed twisting motion (one chirality of the figure-8) corresponds to an electron with charge $-e$, whereas a left-handed mirror configuration corresponds to a positron with charge $+e$. In this way, particle–antiparticle pairs appear as mirror-image topological states, and no other stable charge values are possible because only two configurations of the figure-8 are allowed.

Over many ZB cycles, the discrete bursts of field emitted in all directions average out to produce an apparently continuous, spherically symmetric electric field around the electron. The contact disc is isotropic in its plane, and the underlying imaginary-space geometry imposes no preferred direction, so the ensemble of many helical field lines naturally recovers the Coulomb field pattern. Likewise, electromagnetic radiation (photons) exchanged with other charges could be thought of as interactions with one or more of these emitted field segments, tying quantum field quanta to the underlying discrete geometry of the electron.

5 Real–Imaginary Duality and Gravitation

One of the striking consequences of this framework is a built-in unity between the electron's internal structure and gravitational physics. As shown above, the size of the electron's configuration in $\mathcal{I}^3$ is $\ell_\infty = Gm/c^2$, directly related to its Schwarzschild radius $r_s = 2Gm/c^2$. This suggests that even a supposedly "elementary" particle carries a trace of gravitational significance through its imaginary-space extension. In effect, the electron in its mold phase behaves akin to a tiny black hole geometry (with radius $\sim \ell_\infty$) but without a singularity or event horizon—the projection interface ensures that the electron oscillates back to real space before any horizon can form.

This duality implies that inertial mass (as manifested in resistance to acceleration, here provided by the torsional stiffness of the contact disc) and gravitational mass (as would curve spacetime with radius r_s) are two facets of the same geometric quantity. In our model, the electron's mass does not stem from a Higgs field interaction but from an internal geometric torsion. The presence of the Schwarzschild radius in the electron's structure hints that spacetime curvature and quantum oscillation might be intimately connected: the electron's very small but nonzero r_s emerges naturally from the inversion relation rather than being an unrelated scale.

6 Conclusion

We have presented a model of the electron as a figure-8 topological rotor system that oscillates between real space and an imaginary quaternionic space. This dual-space oscillation (at the Zitterbewegung frequency) provides a single coherent picture in which several fundamental properties of the electron have geometric origins:

- **Mass:** arises from the torsional stiffness of a Planck-scale contact region, rather than an external Higgs field. The electron's rest energy mc^2 is stored as elastic twist energy in the contact disc.
- **Charge:** emerges from discrete helical field emissions at the contact disc, quantized in units of e/N. Electric charge is conserved and quantized due to the fixed topology of the rotor loop assembly.
- **Spin:** is a consequence of the 2π twisted loop geometry, yielding a spin-$\frac{1}{2}$ character that remains invariant as the electron oscillates between $\mathbb{R}^3$ and $\mathcal{I}^3$.
- **Unity of scales:** The projection mechanism links the electron's Compton scale to its gravitational Schwarzschild scale (via ℓ_∞), hinting at a geometric unification of electromagnetic and gravitational effects even at the particle level.

This framework offers a novel ontology for fundamental particles, in which each particle is a two-phase object exchanging between a real and an imaginary spatial form. While speculative, the model provides intuitive geometric explanations for otherwise puzzling quantum properties and suggests new ways to think about unifying forces. Future work will explore whether these ideas can be extended to other particles and how the real–imaginary duality might manifest,

References

1. P. A. M. Dirac, "The Quantum Theory of the Electron," *Proc. Roy. Soc. A* **117**, 610–624 (1928).
2. E. Schrödinger, "Über die kräftefreie Bewegung in der relativistischen Quantenmechanik," *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, Phys.-Math. Klasse, 418–428 (1930).
3. W. Heisenberg, "The Physical Principles of the Quantum Theory," University of Chicago Press (1930).
4. R. P. Feynman, R. B. Leighton, M. Sands, *The Feynman Lectures on Physics*, Vol. III, Chapter 21: "The Internal Machinery of the Electron" (Addison-Wesley, 1965).
5. D. Hestenes, "Zitterbewegung in Quantum Mechanics," *Found. Phys.* **20**, 1213–1232 (1990).