

Emergence of Unitary Lepton Doublet and Static Equilibrium in a Bimetric Teleparallel Manifold

Abstract

We present a theoretical construction in which the electron–positron pair emerges as a unified *unitary lepton* doublet within a **bimetric teleparallel** framework. In this approach, two mirror spacetime sheets (a Janus metric pair) are coupled via a teleparallel gauge structure (tetragauge gravity), yielding a ghost-free, renormalizable manifold ¹. We show that the electron and positron arise as **conjugate eigenmodes** of this doubled manifold – one mode on each metric sheet – related by CPT symmetry. To enforce a global **static equilibrium** between the two metric sectors, we introduce an **information-density field** (or *i-field*), a scalar field that links the metrics through a phase-locked “Josephson”-like coupling. The *i*-field dynamically constrains the two sectors to exchange energy and information in a balanced, time-symmetric way, acting as an equilibrium-enforcing potential rather than introducing any fixed stasis. We derive how the *i*-field’s equilibrium condition (phase-locking) leads to equivalence between the total information content of the system and its globally static (steady-state) configuration. Furthermore, we describe holographically how this static balanced state can be viewed as a **black/white hole dual hypertoroid** – essentially a pair of CPT-conjugate horizons forming a closed information-preserving cycle. We discuss how the construction remains ghost-free and renormalizable, and we comment on broader implications (e.g. elimination of dark sector degrees of freedom) and speculative phenomena such as golden-ratio quantization in the mass spectrum.

Introduction

Recent advances in bimetric and teleparallel gravity have opened avenues for unified frameworks that marry gravity with internal gauge symmetries while avoiding ghost instabilities. In particular, the **Hassan-Rosen (HR) bimetric potential** provides a ghost-free foundation for two interacting spin-2 fields (two metrics) ² ³, and **teleparallel gravity** recasts gravity in terms of torsion (via tetrads) making it amenable to gauge-theoretic quantization. We consider a *Bimetric Teleparallel* scenario, often called a **Janus tetragauge** model, which features twin metric sectors: one representing the ordinary “+” universe and another a “–” mirror universe. These two metric sheets are coupled through a teleparallel gauge structure wherein each metric has its own set of gauge fields (tetrads and associated $U(1)^4$ connections). This *tetragauge* extension ensures the combined system retains local gauge invariance on each sheet and maintains BRST consistency, providing a renormalizable backbone for the two-metric system ⁴ ⁵. Crucially, the interactions are arranged to preserve the ghost-free nature of the HR bimetric theory at the nonlinear level and to remain free of Boulware–Deser instabilities. At the quantum level, a combination of higher-dimensional regulators (a compact KK halo) and **Josephson phase-lock constraints** yields a path to all-loop finiteness ¹, meaning the framework can be elevated to a quantum-consistent, ghost-free theory ⁶.

Within this bimetric teleparallel manifold, the **Janus** identification refers to the fact that the two metric sectors are related by a fundamental CPT inversion – conceptually, they are “enantiomorphic” universes with

opposite arrows of time and sign-reversed mass distributions. Matter in the +sector and matter in the -sector thus behave as mutual mirror images. This raises the profound possibility that a **lepton** and its **antilepton** (e.g. electron and positron) are not independent fundamental particles, but rather two manifestations of a single underlying degree of freedom spanning both metric sheets. In this paper, we explore how the **electron/positron doublet** can be understood as a *unified eigenmode* of the coupled two-metric system. We will argue that the electron in one metric and the positron in the other metric are interrelated by the Janus symmetry (CPT reflection) and emerge as conjugate solutions of the combined field equations. This *unitary lepton doublet* carries a conserved information content across the two sectors, ensured by a new scalar field that we introduce next.

To enforce and stabilize the relationship between the two metrics and their fields, we propose the existence of an **information-density field**, or **i-field**, which serves as a dynamical **glue** between the + and - universes. The i-field is a *static, time-symmetric scalar* that couples to both metric sectors simultaneously [7]. It does *not* represent a conscious or arbitrary external agent, but rather an intrinsic field encoding the *information budget* shared by the two halves of the system. By construction, this field preserves overall CPT invariance and *unitarity* of the combined system: it ensures that processes in one sector are mirrored by conjugate processes in the other, such that no information is irreversibly lost from the total system [7] [8]. The role of the i-field is to **lock the two metrics into equilibrium** – it **ties their light-cones together** (**ensuring a common \$c\$**) and maintains *zero net entropy production* across the divide [7] [8]. In effect, the i-field sets up a **Josephson phase lock** between the two metric sectors, analogous to the phase-lock between two superconductors in a Josephson junction, enforcing a steady-state relationship. It is important to clarify that by “static equilibrium” we mean a *dynamically maintained balance* rather than absolute, frozen stasis: small fluctuations or residual expansions can occur, but any deviation in one sector is countered by an opposite deviation in the other, keeping the net state balanced [9]. This equilibrium is not imposed by hand but arises from a **constraint mechanism** in the field equations – the i-field’s equations of motion drive the system back toward balance whenever an imbalance arises.

The remainder of this paper is organized as follows. In **Section 2 (Theoretical Framework)** we outline the bimetric teleparallel (Janus + tetragauge) structure and derive how an electron–positron pair emerges as conjugate eigenmodes of the two-sheet manifold. In **Section 3 (Information-Density Field and Phase-Locked Equilibrium)** we construct the i-field, define it formally as an inter-metric scalar field (including an information density measure), and show how it implements a Josephson-like coupling that enforces static equilibrium. We derive the conditions under which the total information density of the system is conserved and equal to a static equilibrium state. **Section 4 (Holographic Interpretation: Black/White Hole Hypertoroid)** provides a holographic viewpoint, describing the globally balanced state as the projection of a black–white hole pair that form a dual connected geometry (topologically a torus), thereby shedding light on information conservation and entropy bounds. In **Section 5 (Implications)** we discuss the physical implications of this construction – notably the elimination of dark sector mysteries via geometry, and the consistency with quantum gravity and thermodynamics – and we acknowledge speculative aspects such as golden-ratio mass quantization as a curious but non-essential outcome. Finally, **Section 6 (Conclusion)** summarizes our results and outlines future directions for extending this unified framework.

Theoretical Framework: Bimetric Teleparallel Manifold and Lepton Eigenmodes

Janus Bimetric Teleparallel Gravity in a Tetragauge Formulation

Our starting point is a *bimetric teleparallel* gravity model that integrates two core ideas: (1) the **Janus cosmological scenario** of paired metrics (one for ordinary matter, one for “mirror” negative matter) and (2) the **teleparallel gauge formulation** of gravity, in which gravity is mediated by torsion rather than curvature. Each metric $g_{\{\mu\nu\}^{(+)}\}$ and $g_{\{\mu\nu\}^{(-)}\}$ has an associated set of four tetrad 1-forms $e^a_{\{(\+)\}\mu}$ and $e^a_{\{(-)\}\mu}$ (with $a=0,1,2,3$), which serve as gauge potentials for translations in the teleparallel formulation. We adopt the Partanen–Tulkki tetragauge extension, giving each metric its own $U(1)^4$ gauge fields corresponding to the tetrads; effectively, we have two copies of an Abelian gauge-gravity sector (one per metric). This yields an “octo-gauge” structure $U(1)^4 \times U(1)^4$ that ensures both metric sectors retain local Lorentz and translational invariance independently. The two sets of tetrad-gauge fields are **tied together by a coupling matrix** (sometimes denoted Σ or Ξ in literature) which mixes the fields from the + and - sheets ¹⁰ ¹¹. This inter-sheet coupling is carefully chosen to produce the characteristic **Janus force law**: like masses (two positive masses or two negative masses) attract, whereas unlike masses (positive vs. negative) repel ¹². In other words, the coupling encodes an **antisymmetric exchange** between the metrics that leads to effective gravitational repulsion of the mirror sector. This built-in “like-attracts/unlike-repels” behavior reproduces cosmic acceleration and missing mass effects without exotic dark energy or matter ¹² ¹³.

The field content and interactions are constructed to avoid any ghost degrees of freedom. At the classical level, the Hassan–Rosen bimetric potential is included to give consistent interactions between the two metric tensors, ensuring the absence of the Boulware–Deser ghost (only the desired 2 spin-2 modes – one massless graviton and one massive spin-2 – propagate) ¹⁴ ³. The teleparallel formulation introduces no curvature-based ghost; instead, gravity’s dynamics come from the torsion tensor $T^\lambda_{\;\;\mu\nu}$ (defined via the Weitzenböck connection). The **ghost-free and renormalizable character** of the theory is maintained by a combination of symmetry and dimensional control: each metric’s $U(1)^4$ tetragauge structure provides a renormalizable gauge-gravity scaffold, and the coupling between them is done in an antisymmetric, CPT-dual fashion that preserves BRST symmetry ¹⁵ ¹. A compact extra dimension (“halo”) is also incorporated as a regulator, in line with Kaluza–Klein methods, to absorb high-energy divergences and ensure the effective field theory remains well-behaved at loop level ⁴ ¹⁶. Indeed, when the Josephson-like phase-lock constraint (discussed later) and torsion-balance conditions are imposed, the model achieves **all-loops ghost control**, elevating the classical ghost-free status to a full quantum consistency with one-loop finiteness proven in recent analyses ¹ ¹⁷. In summary, the bimetric teleparallel Janus framework provides a mathematically self-consistent stage on which new physical identifications – such as the unified lepton doublet – can be realized.

Electron/Positron as Conjugate Eigenmodes on the Two-Sheet Manifold

In this doubled spacetime, any matter field must be formulated in a way that accounts for both metric sectors. Consider in particular a Dirac field $\Psi(x)$ that has support on the combined manifold. In practice, this can be treated as a pair $\{\psi_+(x), \psi_-(x)\}$, where ψ_+ lives on the +metric and ψ_- on the -metric. The two components are not independent; the inter-metric coupling (through the Σ matrix mentioned above, or through the i-field to be introduced) will mix ψ_+ and ψ_- . We posit that the electron e^- and positron e^+ emerge from a single **bimodal solution** of the Dirac equation on this

manifold. In other words, there exist normal mode solutions of the form:

$$\Psi_{(1)} = \frac{1}{\sqrt{2}}(\psi_+ + \psi_-), \quad \Psi_{(2)} = \frac{1}{\sqrt{2}}(\psi_+ - \psi_-),$$

which diagonalize the coupled equations of motion. These two eigenmodes $\Psi_{(1,2)}$ can be identified with the electron and the positron, respectively (up to phase conventions). Intuitively, one mode corresponds to an in-phase combination of the field on both sheets and the other to an out-of-phase combination. Because the $-$ -sector is essentially a CPT-reversed version of the $+$ -sector, flipping the relative phase between ψ_+ and ψ_- swaps particle with antiparticle characteristics. The result is that one eigen-solution behaves like a negatively charged lepton moving forward in time on the $+$ -sheet (i.e. an electron) while the conjugate solution behaves like a positively charged lepton moving forward in the $-$ -sheet – which is equivalent under CPT to a negative charge moving backward in time (i.e. a positron)¹⁸. In short, the electron in our universe is paired with a positron in the mirror universe, and they form a single **unitary doublet** under the combined CPT symmetry.¹⁹

This relationship can be seen directly from the source terms and fields. If $J^\nu_{(+)}(x,t)$ is the electromagnetic current of an electron on the $+$ -side, then the Janus/CPT symmetry implies a mirror current $J^\nu_{(-)}(x,t)$ on the $-$ -side related by¹⁹:

$$J^\nu_{(-)}(x, t) = -J^\nu_{(+)}(x, -t),$$

where the minus sign reflects charge conjugation (the $-$ -side current is carried by a positron of opposite charge) and the $t \rightarrow -t$ indicates the time-reversal in the mirror frame. Consequently, the electromagnetic field strengths in each sector mirror each other as $F_{(-)}(x,t) = -F_{(+)}(x,-t)$ ²⁰, meaning the field produced by a positron on side- is exactly the CPT transform of the field of an electron on side+. Maxwell's equations are form-invariant under this combined $(t,Q) \rightarrow (-t,-Q)$ inversion, so the usual electrodynamics holds on each metric separately, with the caveat that every charge and current in one sector has a partner in the other of opposite sign and reversed time orientation²¹. This guarantees that **charge conservation and field dynamics are maintained globally**: an electron cannot disappear or change state without a corresponding change in the positron on the other side, enforced by the unitary coupling.

We therefore identify the electron/positron pair as a single degree of freedom viewed in two ways. It is this identification that earns the term **unitary lepton** – the lepton number of the system is global and preserved across the two sheets. Processes that would violate lepton number or other conservation laws in one universe (and create entropy) are forbidden unless the mirror process occurs in the other universe, a condition enforced by the i-field coupling (see below) to preserve global invariants²². In essence, the electron and positron are **CPT conjugates** living on a bimetric manifold: each is the *eigenmode conjugate* of the other under the operator that exchanges the two metric sectors (this exchange is effectively a combination of parity, time reversal, and a Z_2 interchange symmetry). Through this conjugation, the electron/positron doublet is an *emergent phenomenon* of the geometry: rather than inserting positrons by hand as separate particles, the theory's built-in Janus symmetry requires that for every electron state there is a corresponding positron state on the opposite sheet. They form a two-component quantum state protected by the overall CPT structure.

It is worth noting that this picture provides a geometric understanding of why the electron and positron have exactly equal mass and spin: they are two facets of the same solution. The mass of these eigenmodes

arises from the coupling between ψ_+ and ψ_- ; diagonalizing the coupling matrix yields two identical eigenvalues (in magnitude) corresponding to the lepton's rest mass (one solution may correspond to a positive frequency solution (electron) and the other to a negative frequency solution (positron) in Dirac theory language). In a sense, the mass is a manifestation of the tunneling or coupling energy between the two metric "wells," analogous to the symmetric/antisymmetric splitting in a double-well potential (except here the splitting is zero because of CPT symmetry, giving equal masses). Additional structures (like a small splitting due to symmetry breaking) could conceivably explain any tiny differences between particle and antiparticle if observed, but in the ideal symmetric limit presented, they remain degenerate as expected by CPT.

The Unitary Information-Density Field (i-field)

To rigorously enforce the coupling between the two metric sectors and to maintain the static equilibrium of the entire system, we introduce a scalar field $I(x)$ – the **information-density field** or **i-field**. Conceptually, the i-field is a **phase-linking field** that monitors and adjusts the energy-momentum and informational content exchanged between the + and – universes. It is "**unitary**" in the sense that it preserves information (no net loss of quantum information occurs from one side to the other) and enforces **CPT balance** between the sectors [7]. In the context of holography (where the bulk physics is encoded as information on a lower-dimensional boundary), this field is said to *saturate the entanglement bound* [7] – meaning it maintains maximal entanglement between the two halves, so that the combined state can be pure and unitary. From a 4D bulk perspective, $I(x)$ is a **static scalar field** pervading the interface of the two sheets; "static" here means it does not pick out a preferred arrow of time (it is time-symmetric), and its ground state is time-independent in the co-moving frame of the expanding universe. Rather than having a dynamical propagation like an ordinary matter field, the i-field primarily acts as a *constraint field* or *potential* that adjusts to ensure the two metrics remain synchronized.

We can formalize the i-field by constructing a **gauge-invariant scalar density** out of the teleparallel fields of both metrics. One convenient definition is provided by the model's *torsional information density* [23] [24] :

$$I_{\text{holo}}(x) = \frac{1}{16\pi G} \star \left[(T^{(+)} - T^{(-)}) \wedge (T^{(+)} + T^{(-)}) \right]. \quad \text{\color{red}\label{eq:iholo}}$$
(1)

Here $T^{(+)}$ and $T^{(-)}$ are the 2-form torsion tensors (or axial torsion 2-forms) on the + and – sheets, \wedge is the wedge product, and \star is the Hodge dual on the 4D spacetime manifold. This scalar $I_{\text{holo}}(x)$ – which we will treat as representative of the i-field – has several key properties: (i) it is explicitly **invariant** under independent local $U(1)^4$ rotations of each sheet's tetrads [25], meaning it doesn't change if we perform local frame rotations on either side (so it's a good physical observable of the coupled system); (ii) it depends **only on combinations** $T^{(+)} \pm T^{(-)}$, specifically appearing as the product of the antisymmetric difference and symmetric sum of torsions [26]. In other words, it directly measures the **mismatch vs. alignment** of the two spacetime torsion fields. If the torsion on both sheets is identical ($T^{(+)} = T^{(-)}$), then $T^{(+)} - T^{(-)} = 0$ and thus $I_{\text{holo}} = 0$. If the torsion is equal and opposite ($T^{(+)} = -T^{(-)}$), then $T^{(+)} + T^{(-)} = 0$ and again $I_{\text{holo}} = 0$. The i-field density becomes non-zero only when there is a partial imbalance – it essentially multiplies the difference between the two metrics' torsional degrees of freedom by the sum (which encodes the overall scale of torsion). In this way, $I(x)$ acts as a kind of **bridge** between the metrics: it "feels" both the average and the difference of the two field configurations.

The i-field can be incorporated into the action principle as an *interaction term* or a topological surface term. A minimal coupling is to include a boundary action of the form $S_{\text{i-field}} = \lambda_{\text{holo}} \int_{\Sigma} I_{\text{holo}} d^3x$ ²⁷²⁸, where Σ is the common 3D hypersurface that interfaces the two metric regions (in a cosmological context, one can imagine Σ as a spatial slice on which the two universes “meet” in the sense of the holographic duality). Variation of this term yields conditions relating $T^{(+)}$ and $T^{(-)}$ at the interface. In fact, the stationarity of the total action (including teleparallel bulk terms and the i-field term) leads to **soldering conditions** that *identify the two metrics’ tetrads and their transverse torsion at the boundary*: $[e^a_i]_{\text{pm}}=0$ and $[T]=0$ ²⁹³⁰. These imply that the metrics’ induced 3-geometry on Σ are the same and that there is no discontinuity in the torsion flux crossing the interface. Physically, these are the **phase-lock constraints**: the two sheets are “locked” together at the boundary so that they cannot slip relative to one another without a restorative response.

Josephson Phase-Locking and Dynamic Equilibrium Enforcement

The role of the i-field is analogous to a **Josephson junction** coupling between two quantum systems. In a Josephson junction (e.g. two superconductors separated by a thin insulator), a phase difference θ between the quantum wavefunctions of the two sides drives a tunneling current proportional to $\sin\theta$, and the phase evolves according to a second-order differential equation (the Josephson oscillation equation) in response to any bias. In our gravitational context, the two “superfluids” are the metric/tetrad fields on each side, and the i-field mediates a coupling such that a **phase-like degree of freedom** $\Theta(x)$ (we can think of this as the relative phase of the two tetrad fields or the difference in their connection phases) obeys a Josephson-type evolution equation. Indeed, one can show that small deviations from equilibrium satisfy an oscillator equation of the form:

$$\xi \ddot{\Theta} + m_\Theta^2 \Theta = \frac{\lambda}{M} (F_+^2 - F_-^2). \quad \text{label: eq: Josephson} \quad (2)$$

Here $\Theta(t)$ is the inter-sheet phase difference (assuming homogeneity for simplicity, so Θ depends on time mainly), ξ is an inertia-like coefficient (related to the moment of inertia of the phase, so to speak), m_Θ is an effective stiffness (restoring force parameter for the phase), and $F_+^2 - F_-^2$ represents an **imbalance in some flux or energy** between the two sides – in the simplest case, it could be the difference in the squares of electromagnetic field strengths or other excitations on each side. Equation (2) is directly analogous to the driven, damped harmonic oscillator form of the AC Josephson effect equation³¹³². A flux imbalance $F_+^2 \neq F_-^2$ acts as a *driving term* pushing the phase Θ away from zero. The terms $\xi \dot{\Theta}$ and $m_\Theta^2 \Theta$ are inertial and restoring terms, respectively, which ensure the response is oscillatory and bounded rather than runaway. In physical terms, if the +universe accumulates slightly more field energy (say F_+^2 increases relative to F_-^2), the phase Θ will start to shift. This shift in Θ induces a cross-coupling current (through the i-field) that tends to transfer energy to the -side or siphon energy from the +side, counteracting the imbalance. As a result, Θ will oscillate around $\Theta=0$ rather than increasing without bound, meaning the two sides will exchange energy back and forth (like a pendulum) rather than one side draining all energy from the other³³.

In the fully nonlinear regime, the i-field enforces **phase-locking**: the stable equilibrium is $\Theta = 0$ (or an integer multiple of 2π , generally) which corresponds to the **in-phase condition** $g_{(+)} = g_{(-)}$ evolving in sync. If Θ were to settle to a constant non-zero value, that would indicate a persistent bias (analogous to a DC Josephson current). However, a non-zero constant phase difference would itself

cause a continuous flow of information/energy from one side to the other. The only truly static equilibrium is either $\Theta=0$ or $\Theta=\pi$ (the latter would correspond to an inverting of one metric relative to the other; however, $\Theta=\pi$ in this model is essentially the negative of the same solution and would likely spontaneously revert to $\Theta=0$ once coupling terms beyond quadratic order are included). Thus we focus on the $\Theta \approx 0$ lock.

The small oscillations of Θ about zero represent **resonant exchanges** – in fact, the system behaves like a coupled oscillator that can exhibit resonant modes. These resonances have been investigated in the context of this framework and intriguingly show a tendency toward discrete frequency ratios involving the golden ratio φ (approximately 1.618) ³⁴. (We mention this *golden-ratio phase cascade* only as a tantalizing curiosity and a possible clue to deeper structure, but it is not essential for the core derivation here.) What is essential is that *any* deviation from perfect balance generates a restoring mechanism via the i-field. This constitutes a **constraint mechanism dynamically enforcing equilibrium**. As Equation (2) shows, an imbalance $(F_+^2 - F_-^2)$ feeds into the second derivative of the phase, much like a restoring force; in turn, the oscillatory response redistributes the energy until $F_+^2 = F_-^2$ on average. The i-field ensures these oscillations are damped and do not grow without bound – in an extended analysis, coupling to gravitational torsion adds a damping term to Θ 's evolution ³⁵ ³⁶, arising from torsion energy being dissipated (this is analogous to resistance in an electrical Josephson junction). This damping (sometimes called “inertial drift reversion” in the CSR+ description) means the two metrics will relax into a common phase (static phase difference) over time rather than eternally swapping energy. Effectively, the i-field provides **negative feedback**: the larger the imbalance, the stronger the corrective force to restore balance ³³.

Thus, in equilibrium we have $\Theta = 0$ and $F_+^2 = F_-^2$ (and more generally, complete equality of stress-energy distributions as seen by each metric). The i-field's job is precisely to drive the system toward this state and maintain it. We can see the equilibrium condition directly in the **information density** formalism as well: in equilibrium, since $T^{(+)}$ equals $T^{(-)}$ (or is related by a sign in the fully antisymmetric case), the integrand in I_{holo} (Eq. [\ref{eq:iholo}](#)) vanishes, giving $I_{\text{holo}} = 0$ everywhere. The *total* information stored in the coupling is therefore extremized (in fact minimized to zero leakage) at equilibrium. Conversely, if I_{holo} were nonzero, it would indicate a flow of torsional information across the interface – essentially the system would not be static. Indeed, the topological constraint underlying this theory (originating from a teleparallel Gauss–Bonnet identity) demands **zero net torsion flux on any closed surface** (specifically a toroidal spatial cycle), which is exactly the condition for static equilibrium ³⁷. In CSR+ terms, “zero-sum torsion charge” means the torsion leaving one sheet equals torsion entering the other, which locks the sheets into a common phase ³⁷. This is how the **total information density relates to static equilibrium**: when the system is in global static equilibrium, the information exchange term is balanced to zero net flux, and all the “would-be” information content is trapped in a stationary configuration (often at a maximal entropy allowed by the geometry). In effect, the *conservation of total information* becomes equivalent to the *condition of static balance*.

One can formalize this via a continuity equation. From the field equations one can derive an information current J^μ_{holo} whose divergence is zero when the appropriate interface conditions hold ³⁸ ³⁹. Physically, $\nabla_\mu J^\mu_{\text{holo}} = 0$ implies that any information (or entropy) flow out of one region is equal to the flow into the other – no information is lost or gained overall. In particular, the time component of this continuity equation yields $\partial_t I_{\text{holo}} + \nabla_\mu \cdot J^\mu_{\text{holo}} = 0$; in the static equilibrium state, $\partial_t I = 0$, meaning the information density is time-independent and no spatial flow of information occurs. The i-field adjusts itself such that this holds. We stress that this $\Rightarrow 0$

and \bf J does not mean nothing is happening in each universe – on the contrary, normal dynamics can occur, but always in correlated pairs. For example, if entropy increases locally on the +side due to some irreversible process, the i-field will induce a corresponding entropy decrease on the -side (perhaps by an improbable spontaneous structure formation or other mirror process) so that the **total entropy remains constant** ⁸ ⁷. The i-field, in other words, mediates a kind of **entropic entanglement**: the two universes share a common entropy budget and a common arrow of time (or in this case, a symmetrical double-arrow of time). This is consistent with viewing the two halves as a single CPT-invariant system – any time-asymmetric evolution in one half is compensated by an opposite evolution in the other, preserving overall time symmetry ⁴⁰ ⁴¹. Indeed, the presence of the i-field in the bulk corresponds, in the boundary holographic theory, to an exact CPT symmetry of the universe ⁴² ⁴¹.

To summarize this section: the i-field $I(x)$ is a scalar field defined on the bimetric manifold that couples to the difference and sum of the two metrics' torsion/gauge fields. It is *static and time-symmetric* in character, enforcing a strict CPT reflection symmetry between the metric sectors ⁷. By adding a Josephson-like coupling, the i-field causes any deviations in energy or information to produce oscillatory exchange (phase oscillations) which effectively *locks* the two sectors into a **dynamical equilibrium** state (no net energy drift). In equilibrium, the total “information density” of the system is constant in time and the system attains a sort of maximal entanglement where all change is relational (happening in balanced pairs). This equilibrium is not a trivial frozen state but a **constrained steady state** – small fluctuations exist but are tightly correlated such that they do not grow or produce cumulative divergence between the two universes ⁹. The end result is a consistent scenario in which the electron/positron doublet described earlier is sustained and stabilized by the i-field: neither the electron’s world nor the positron’s world can stray too far apart in terms of physical evolution, thanks to the information tether between them.

Holographic Interpretation: Black/White Hole Dual Hypertoroid

The static, phase-locked equilibrium enforced by the i-field can be given a striking interpretation in terms of holography and black hole physics. In holographic duality (inspired by AdS/CFT principles), a higher-dimensional bulk gravitational system can be mapped to a lower-dimensional field theory on its boundary. In our case, the **bulk** is the 5D bimetric teleparallel structure (with two 4D metric sheets plus perhaps a compact 5th dimension for regularization), and the **boundary** is effectively a single 4D universe that we observe. The i-field in the bulk, which enforces unitarity and ties the two halves together, corresponds to a condition of *maximal entanglement* or information saturation on the boundary ⁴³ ⁴⁴. In fact, one can think of the two sheets as analogous to the two sides of an **Einstein–Rosen bridge** (wormhole) connecting a black hole and a white hole.

Consider an eternal black hole in general relativity: its maximally extended solution contains not only a black hole region (from which nothing escapes) but also a *white hole* region (into which nothing enters, but things can emerge) as the time-reverse of the black hole. Typically, an eternal black hole solution also has two exterior regions, which could be interpreted as two universes connected by the wormhole. In our scenario, we can liken the +sector to one exterior (with a black hole horizon facing it) and the -sector to the other exterior (facing a white hole horizon). The **i-field-enforced static equilibrium** then mirrors the condition that the black hole and white hole are part of a single interconnected system with no net loss of information: any information that disappears behind the black hole horizon in the +universe reappears from the white hole horizon into the -universe, and vice versa. The **pair of conjugate horizons** effectively acts like an entangled black–white hole pair.

Topologically, this combined object is donut-like. The teleparallel Gauss–Bonnet constraint used in the CSR+ stack explicitly required the spatial sections to have **genus 1 (a torus topology)**, which was achieved by setting the Euler characteristic $\chi = 0$ ⁴⁵. A genus-1 surface (torus) has a “hole”, and in our 4D context, that hole can be thought of as the wormhole throat connecting two sides. We might call this a **hypertoroid** – essentially a higher-dimensional generalization of a torus – to indicate that the full spacetime geometry with the black/white hole pair is toroidal when seen from a topological perspective. The requirement $\chi(S)=0$ ensures there is a non-trivial cycle in spacetime through which torsion flux must sum to zero, which is precisely the condition of no net information leakage (as discussed, zero total torsion flux means one side’s torsion is balanced by the other’s³⁷). In other words, the *entire gravitational solution* can be visualized as a black hole feeding into a white hole in such a way that space wraps around – information swallowed by the black hole does not vanish, but travels through the bridge and emerges from the white hole, eventually returning (potentially in a cyclic fashion). This is consistent with the i-field “saturating the entanglement bound” – it indicates the two horizons are maximally entangled, forming a pure state. In fact, the construction is reminiscent of the *thermofield double state* in holography, where two entangled copies of a system correspond to the two sides of an eternal black hole. Here, however, one side’s time is reversed relative to the other (one side’s black hole is the other’s white hole), enforcing a *global CPT invariant* picture^{41 46}.

From the boundary observer’s perspective (our physical observable universe), this static equilibrium manifests as a kind of cancellation of what would otherwise be a cosmological constant or runaway effect. The Janus model was originally invoked to eliminate a large cosmological constant via cancellation between matter and mirror matter contributions. Indeed, the **bulk dynamic balance of two metrics** – as enforced by the i-field – holographically corresponds to the **absence of a net cosmological constant on the boundary** (i.e. an almost static or marginally expanding universe)^{47 48}. The intuitive picture is that the expansion drive from the positive-energy sector is countered by an effective contraction drive from the negative-energy sector, resulting in near-zero net acceleration^{49 50}. In terms of black hole thermodynamics, one might say that what looks like dark energy (accelerated expansion) in a single-sector view is actually an entropic effect of entanglement between two halves. The i-field ensures that the “would-be” horizon energy (which would act like a cosmological constant) is redistributed between the two universes.

The *hypertoroidal black/white hole* picture also gives a satisfying qualitative resolution to the **black hole information paradox**. Normally, information that falls into a black hole seems lost, leading to a paradox when the black hole evaporates. In our scenario, however, that information is never truly lost – it is stored in the coupled partner universe (accessible via the white hole aspect). The i-field guarantees a unitary evolution for the combined system, so any information that one horizon absorbs is preserved and can influence the other side. In fact, the **information budget enforcement via topological bounds** in our model directly suggests new approaches to resolving black hole paradoxes^{40 41}, essentially by treating the black hole plus its Janus partner as a closed system. The entropy of the black hole is offset by the entropy of a “white hole” elsewhere, and the entanglement entropy between them saturates a bound that prevents any further net increase⁷. In simpler terms, the maximum entropy a black hole can have (proportional to horizon area) is mirrored by the entanglement entropy with its conjugate white hole – thus all information is accounted for in the correlation, and no paradox arises.

It is interesting to note that in our framework the **entire cosmos** in static equilibrium could itself be viewed as an extremal case of a black/white hole hypertoroid. If we imagine the universe’s geometry closing on itself (toroidally) due to the identification of the two metric sheets, one can picture the Big Bang of our

universe as a *white hole* output from the mirror side, and the eventual collapse (or scenario inside a black hole) of our side as feeding into the mirror universe's beginning. Such a view is speculative, but it aligns with a cyclic or oscillatory universe concept in which time is symmetric. The Janus model indeed implies one side's Big Bang is the other's "Big Crunch" in a CPT sense. Our formalism doesn't require this cosmic identification, but the holographic hypertorus image elegantly encapsulates the idea that what looks like an isolated singular beginning or end in one sector is resolved by inclusion of the other sector, making the totality free of singular boundary (a torus has no edge, unlike a line interval).

In summary, the holographic view of the bimetric phase-locked system is that it corresponds to a single-unit system where any would-be horizon is *double-faced*: one face is a black hole absorbing information in one sector, the other face is a white hole releasing that information in the other sector. These two faces form a contiguous object (like the two sides of a donut), ensuring information can circulate but never escape the closed system. The **genus-1 topology** enforced by our torsional Gauss–Bonnet constraint mathematically encodes this situation ⁵¹ ⁵². The boundary theory sees no loss of information and respects CPT, which is exactly what one would expect if the bulk contains a unitary i-field binding everything together ⁵³ ⁵⁴. In physical terms, the static equilibrium state of our model is **holographically dual** to a **maximally entangled black-white hole pair**, representing the ultimate information-equilibrium configuration of the two-sheet world.

Implications

The emergence of a unitary lepton doublet and an information-binding field in a ghost-free bimetric teleparallel framework carries significant implications for both fundamental physics and cosmology:

- **Unification of Matter and Antimatter:** By treating the electron and positron as two aspects of one entity (rather than unrelated particles introduced separately), the framework offers a novel solution to why our laws of physics treat particles and antiparticles so symmetrically. In the Janus teleparallel picture, this symmetry is a natural consequence of the dual metric structure and CPT invariance enforced by the i-field ⁵⁵ ⁷. It suggests that conservation laws (like lepton number or baryon number if extended to other particle families) might be global constraints stemming from the topology of spacetime rather than ad hoc rules – any imbalance in one universe is corrected by the other via the information field ²². This could provide new insights into matter-antimatter asymmetry: if our observable universe has an excess of matter over antimatter, the mirror universe would have an excess of antimatter (negative matter in Janus terms) such that the **net asymmetry is zero**. The i-field would then ensure that processes violating baryon-lepton number in one sector are suppressed or mirrored by the other sector, potentially offering a mechanism to stabilize proton decay or neutrinoless double beta decay, etc., only allowing them if they respect the dual constraint.
- **Elimination of Dark Sector Mysteries:** The bimetric teleparallel model was designed to explain cosmic acceleration and missing mass phenomena without invoking unknown dark energy or dark matter components ⁵⁶ ⁵⁷. Our results bolster this approach – we find that the static equilibrium enforced by the i-field precisely yields conditions like *no net cosmological constant* (since positive vacuum energy is canceled by negative vacuum energy) ⁴⁷ ⁴⁸ and *modified gravitational clustering* (since ordinary matter in one sheet is influenced by mirror matter via repulsive gravity). The **torsional information density** filling the bulk (Eq. \ref{eq:iho}) actually furnishes what appears as an additional source in the effective Einstein equations, mimicking a combination of dark matter and dark energy effects ⁵⁸ ⁵⁹. Notably, the theory reproduces cosmic acceleration with a very small

effective Λ (consistent with observations) by balancing the two metrics' contributions⁴⁸
⁵⁰, and it predicts distinctive deviations in structure growth (e.g. a slightly lower growth index γ than Λ CDM) that can be tested⁶⁰⁶¹. If upcoming surveys find $\gamma \approx 0.42$ instead of 0.55 , as one example, it would strongly favor this geometric, information-based resolution over exotic matter explanations⁶²⁶³. The **void lensing phenomenon** (light bending the “wrong way” in low-density regions due to negative mass) is another prediction: our model's equilibrium implies a small negative convergence (voids acting as divergent lenses)⁶⁴⁶⁵, which upcoming weak lensing observations could detect.

- **Quantum Gravity and Information:** By maintaining unitarity at a fundamental level (thanks to the i-field), this framework aligns with the principles of quantum mechanics even when gravity is involved. It provides a concrete scenario where there is no information loss in gravitational processes – addressing a long-standing concern in quantum gravity (the black hole information problem). The fact that $I_{\text{holo}}(x)$ leads to an entropy bound that is saturated⁷ suggests a deep connection to the Bekenstein–Hawking entropy limit. In essence, the theory embodies a realization of the holographic principle in a teleparallel setting: all bulk information is encoded on the interface and regulated so as not to violate known entropy bounds⁶⁶⁶⁷. This hints that other “missing physics” or paradoxes might be resolved by similar means – i.e. by expanding our description of spacetime to include complementary sectors or topological constraints rather than by adding new particles. It exemplifies the idea that certain global symmetries (CPT, and possibly gauge symmetries of the Standard Model as indicated in the tetrad-spin connection unification⁶⁸⁶⁹) could be *emergent* from a higher-dimensional or multi-sheet geometry⁷⁰⁷¹. The **antisymmetric conjugation structure** at the core of our coupling may illuminate the origin of, say, $U(1)$ charge conjugation symmetry or even why gauge groups mirror across generations⁴⁶⁴¹.
- **Experimental Outlook:** Although the theory operates at high complexity, it does suggest various experimental signals. For instance, as found in prior studies of this framework, there could be tiny deviations in local gravity – e.g. an oscillatory correction to Newton's constant that depends on frequency⁷²⁷³, arising from the phase-lock mechanism. Our work further identifies the electron-positron coupling: there might be effects in entangled electron/positron pairs if one could isolate a positron in a “mirror” state (this is far-fetched, but one could think of searching for slight anomalies in positron behavior that could hint at mirror coupling). More concrete might be looking for evidence of **energy balance across cosmic voids** – if a region of space loses energy (e.g. photons redshift, matter dissipates), the mirror side should gain an equivalent. This could conceivably lead to subtle anisotropies or unexpected low-frequency gravitational wave backgrounds as the two sides exchange energy. The i-field's Josephson oscillations might even produce a characteristic spectrum of gravitational or torsional waves. Intriguingly, the model predicts a fundamental frequency scale related to the optimal equilibrium cell size (in the CSR+ analysis, $\omega_g \approx 396 \text{ Hz}$) was found as a gap frequency of the phase oscillation mode⁷⁴⁷⁵. Searching for anomalous resonances in precision Cavendish experiments or pendulum torsion oscillators around the kHz range might reveal a tiny signal of this frequency⁷⁶⁶⁴. Additionally, cosmological structure formation might occur faster than in Λ CDM due to information-assisted collapse⁷⁷⁷⁸, which could be checked with high-redshift galaxy observations (e.g. the presence of mature galaxies at $z > 10$ as possibly seen by JWST).
- **Golden-Ratio Quantization (Speculative):** As a side note, our discussion mentioned that the phase-lock dynamics can exhibit a cascade of resonance frequencies related approximately by the golden

ratio φ ³⁴ [79]. This has led to speculation that particle masses or other quantized quantities might emerge in golden ratio proportions in this framework. For example, one could imagine the electron mass, muon mass, etc., following a pattern tied to phase locking at different modes. While intriguing, this idea remains highly conjectural and is not a firm prediction of the core theory – it arises from simplifying assumptions in the CSR+ model and numerical coincidences (e.g. certain frequency sums yielding $\varphi^{1.7}$ in experiments)⁸⁰ [81]. We mention it to acknowledge a curious feature: the interplay of topology and dynamics in this model produces *discrete phase-locked modes*, suggesting a new kind of quantization in gravitational systems. If future data were to reveal e.g. ratios of oscillation modes or mass gaps aligning with golden ratios, it would hint that the complexity of this self-similar cascade (sometimes poetically called a “complexity cascade” or φ -resonance) is physically realized. Until then, we treat golden-ratio mass quantization as an interesting but speculative extension of the theory.

Finally, we emphasize the philosophical shift implied by this framework. Instead of adding invisible entities (dark matter, dark energy) to fix discrepancies, or accepting information loss in black holes, we modify the *geometric foundations* – introducing a mirror metric and a unitarizing field – such that consistency is restored at a structural level. This points to a paradigm where **completeness of physics** might require considering duplicate or hidden sectors that are tightly correlated with the observable one, maintaining cosmic accounting of information and symmetry. It resonates with other ideas in cosmology (e.g. CPT-symmetric universe proposals, mirror matter models) but here all tied together in a single, renormalizable gauge-gravity theory.

Conclusion

We have presented a structured derivation of how an electron–positron pair can be understood as a unified mode of a **Janus bimetric teleparallel manifold**, and how a novel **information-density field (i-field)** enforces a global static equilibrium between the two metric sectors. Beginning with a ghost-free bimetric gravity scaffold, augmented by teleparallel gauge structure, we showed that the **electron/positron emerge as conjugate eigenstates**: one residing on each metric sheet and transforming into one another under the combined CPT symmetry of the two-sheet system. This reinterpretation of the lepton doublet as a single *unitary object* across two spacetimes provides a natural explanation for their symmetric properties and introduces a global mechanism to preserve quantum information.

We constructed the **i-field** as a scalar field coupling that links the metrics by a Josephson-like phase difference. Formalized through a torsional information density $I_{\text{holo}}(x)$, this field couples to the difference and sum of the two tetrad fields²⁴ and enters the action as an interface term. By analyzing its dynamics, we found that it induces **phase-locked oscillations** that counteract any energy or information imbalance between the two universes. The resulting equilibrium is a *dynamical steady state* where the metrics remain in sync (phase-aligned) and no net entropy is produced. We derived that in this state, the **total information density is conserved** and essentially tied to the static equilibrium condition itself – the system self-regulates to keep I_{holo} at a constant (in fact zero net flux) value, equivalent to maintaining a zero torsion-flux (genus-1) condition³⁷. Thus the **global static equilibrium** of the coupled metrics is *not* an externally imposed stasis, but the result of the i-field’s constraint forces canceling out any would-be divergence. This equilibrium remains compatible with small cosmological evolution (e.g. a very slow expansion) as long as it is symmetric, consistent with how our real universe appears nearly homogeneous and isotropic on large scales.

Importantly, the entire construction respects the requirements of a consistent quantum theory of gravity: it stays **ghost-free** at the classical and quantum perturbative levels (thanks to the HR potential and careful coupling choices) ¹, and by including the tetragauge fields and a compact extra dimension, it achieves a renormalizable, anomaly-free structure with finite one-loop behavior ¹⁷. The i-field does not introduce any ghosts because it enters as a part of the constrained algebra; rather than a propagating phantom field, it is more like a *Lagrange multiplier* enforcing CPT symmetry and energy balance. This ensures that the extended theory remains stable and unitary.

We then interpreted the static equilibrium solution through a **holographic lens**. The combined +/- metric system with the i-field can be viewed as a single, closed system akin to a **black hole-white hole pair** joined at the interior. Topologically, the requirement of zero net torsion implies a toroidal structure ⁵¹, which we described as a **dual hypertoroid** housing a black hole on one side and a white hole on the other. In this picture, information that falls into the black hole (in the +sector) emerges from the white hole (in the - sector), and the two are entangled to the maximal extent allowed by physical laws ⁷. This provides a clear mechanism for information conservation in gravitational collapse and offers an elegant resolution to the information paradox: the i-field ensures that the total system evolves reversibly, with no loss of quantum coherence. Our model thus aligns with the broader principle that *information is never destroyed*, bolstering a unitarity-preserving view of cosmology.

Our findings open up several new pathways for exploration. The concept of **unitary particle doublets** could extend beyond leptons – one might investigate quark-antiquark pairs, or even incorporate the entire Standard Model particle content with a mirror counterpart, to see if this framework naturally explains other puzzles (such as neutrino oscillations or strong CP problems via mirror symmetry). The **phase-locking mechanism** invites deeper mathematical analysis: it shares features with cosmological inflationary reheating (energy swapping between fields), and with condensed matter phase synchronization, hinting at possible analogies that could be experimentally simulated. The presence of a preferred frequency (order hundreds of Hz in one estimate ⁷⁴) is particularly intriguing and could provide a direct empirical handle if corroborated.

In conclusion, the bimetric teleparallel Janus model with an information-binding scalar offers a rich, self-consistent paradigm in which the universe is a coupled two-sheet system maintaining an exquisite balance. It connects seemingly disparate concepts – Dirac’s electron-positron symmetry, Josephson junction dynamics, holographic entropy bounds, and cosmological stability – into one coherent theoretical structure. While many details remain to be fleshed out and tested, this framework provides a compelling example of how **augmenting general relativity with symmetry-coupled dual spacetime sectors** can solve long-standing problems: eliminating dark sector mysteries through geometry ⁸² ⁸³, safeguarding unitarity at cosmic scales ⁸⁴, and placing matter-antimatter on equal fundamental footing. Future work will further investigate the observable signatures of this theory (in laboratory experiments, astrophysical observations, and cosmological surveys) to either validate or falsify this bold approach to unification. If nature indeed operates with such a Janus face, it would mean that our universe’s missing pieces and mirages were a sign to look in the mirror – and find that the mirror itself was an essential part of reality all along.

1 2 3 4 5 6 14 15 16 17 23 24 25 26 27 28 29 30 38 39 40 41 42 46 58 59 60 61 62 63
64 65 66 67 70 71 72 73 76 77 78 82 83

Bimetric_Teleparallel_8_Gauge_Holography_0_9_8_4_Dual_Pipeline_Implementation_-1.pdf

file://file-WAcLCvMEL4Gd5Eu7457XuF

7 8 9 10 11 12 13 18 19 20 21 22 43 44 47 48 49 50 53 54 55 56 57 68 69 84 BIMETRIC

TELEPARALLEL FRAMEWORK (1)-9.pdf

file://file-DyW7mVh6MCeWkcJpB78tSY

31 32 33 34 35 36 37 45 51 52 74 75 79 80 81 Release Toroid Equations with Axiomatic Linkage

(4).pdf

file://file-5w1kYTng1w64n992exQyDj