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Hopf Linking of the Electron Stream and the Neutron Mass Excess in Cartan Geometry

A first-principles account of the flow correction, with the Cartan operator D defined and with Layer discipline on the spectral step

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Abstract

A Cartan-geometric account is given of the neutron mass excess relative to the free proton–electron pair, within Einstein–Cartan–Evans (ECE) theory and Unified Classical Resonance Cosmology in Cartan Geometry (UCRC-CG). Gravity is interpreted as the net aether-pressure difference arising when bidirectional Whittaker potential flow is obstructed by particle torsion, consistent with the Horst–Eckardt identifications (vector potential ↔ flow velocity, scalar potential ↔ pressure). The free pair and the bound neutron are linearly decomposable configurations of the same tetrad and torsion. The electron stream is a Hopf fiber of the principal bundle $S^1 \to S^3 \to S^2$. Absorption of that fiber changes the linking number and therefore the effective fiber density that enters the holographic factor $\alpha_{holoeff}$ in the gravitational Beltrami scalar.

Layer 1 (geometry). The first Cartan structure equation, the exterior covariant derivative D, the Beltrami condition $T = \kappa\, q$, the ECE maps $A^a = A^{(0)}\, q^a$ and $F^a = A^{(0)}\, T^a$ (electromagnetism linear in torsion) versus gravitational obstruction energy $E_{grav} \sim \int T^a \wedge *T_a$ (quadratic in torsion), and the Whittaker incoming / outgoing split, are parameter-free. The missing fundamental angular mode of the asymmetric hopfion is a geometric reason for neutron metastability.

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Layer 2 (spectral identification). Conversion of an integer Hopf-invariant change into a definite fractional shift $\delta\alpha_{holoeff} / \alpha_{holoeff}$ requires a density-of-states count on S^3 that has not yet been closed independently of CODATA. The figure $\Delta m_{flow} \equiv m_n - (m_p + m_e) = 0.78233356$ MeV/c^2 is the observational target of that count, not an input used to define δ. Identifying δ with $(m_n - m_p)/m_p$ is a circular ansatz and is not retained as a Layer-1 claim.

Keywords. Cartan geometry, ECE theory, UCRC-CG, Hopf fibration, torsion, Beltrami condition, holographic factor, neutron mass, Whittaker potentials, aether pressure, exterior covariant derivative.

1. Introduction

In a companion technical record the electromagnetic-to-gravitational amplitude ratio $A^{(0)}/\Phi^{(0)}$ was obtained from three geometric suppressions: holographic surface-to-volume mismatch at the proton scale, spinor time-asymmetry from the Dirac η-invariant on S^3 (isomorphic to SU(2)), and the distinction between linear electromagnetic and quadratic gravitational coupling.[1] The same framework implies that gravitational mass is the net pressure exerted when bidirectional vacuum-potential flow is obstructed by particle structure.

The flow is the classical Whittaker decomposition of the potential into retarded (outgoing) and advanced (incoming) characteristics.[2,3] In the Horst–Eckardt extensions of ECE, the vector potential corresponds to aether flow velocity and the scalar potential to aether pressure; the Newtonian field is an aether-pressure difference; torsion is the acceleration of that aether.[4] The incoming characteristic is intercepted at the tetrad obstruction and is what appears as inertial and gravitational mass.

The near equality of neutron and proton masses is then a question of flow geometry. The free proton–electron pair and the bound neutron differ by the topological organisation of the electron stream. If the streams recombine linearly under the Cartan exterior covariant derivative D, the mass difference can arise only from the change in obstruction geometry when the electron fiber is incorporated. That change is forced by the Hopf fibration.[5] What is not yet forced, without a spectral calculation, is the

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exact numerical value of the fractional holographic shift.

2. Definitions

2.1 Geometric objects used in this record

Term	Definition used in this record
Tetrad q^a	Orthonormal co-frame one-forms on the base manifold. Indices a, b = 0, 1, 2, 3.
Spin connection $\omega^a{}_b$	so(1,3)-valued connection one-form. Units: inverse length.
Exterior derivative d	The ordinary Cartan exterior derivative on differential forms. Linear, nilpotent ($d \circ d = 0$).
Exterior covariant derivative D	The Cartan operator associated with ω. On the tetrad, $D\, q^a = d\, q^a + \omega^a{}_b \wedge q^b$. On the connection, $D\, \omega^a{}_b = d\, \omega^a{}_b + \omega^a{}_c \wedge \omega^c{}_b$. D is linear over addition of forms of the same type and over multiplication by constants. That linearity is what Section 6.1 uses.
Torsion T^a	$T^a = D\, q^a$. Measures the failure of the tetrad to be closed. Units: inverse length.
Curvature $R^a{}_b$	$R^a{}_b = D\, \omega^a{}_b$. Units: inverse length squared.
Beltrami condition	$T = \kappa\, q$. Selects self-dual torsion configurations that conserve magnetic helicity. κ has units of inverse length.
Hopf fibration	The principal S^1-bundle $S^1 \to S^3 \to S^2$. Each fiber is a great circle in S^3; the Hopf invariant is the linking number of any two distinct fibers.
Whittaker potentials F, G	Two scalar functions whose second derivatives reconstruct the electromagnetic field (Whittaker 1904).
Advanced / retarded split	Incoming and outgoing characteristics of those potentials, isolated by the arguments $\xi - c\,t$ and $\xi + c\,t$ in (9)–(10).

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Term	Definition used in this record
Holographic factor α_{holo}	Surface-to-volume ratio of independent degrees of freedom at a given length scale. Dimensionless.
Effective factor $\alpha_{holoeff}$	Double projection of α_{holo} required by quadratic gravitational coupling. Dimensionless.
Time-asymmetry α_{time}	Relative weight of the advanced vacuum sector, equal to 1/(8π) from the Dirac η-invariant on S^3.

Table 1. Geometric definitions. D is the operator named at the opening of Section 6.1.

2.2 Observed masses and constants (CODATA 2022)

Symbol	Name	Value / expression	Role
m_p	Proton rest mass	938.272 089 43 MeV/c^2	Measured input
m_e	Electron rest mass	0.510 998 950 00 MeV/c^2	Measured input
m_n	Neutron rest mass	939.565 421 94 MeV/c^2	Measured input
Δm_{np}	$m_n - m_p$	1.293 332 51 MeV/c^2	Derived from measured masses
Δm_{flow}	$m_n - (m_p + m_e)$	0.782 333 56 MeV/c^2	Definition; Layer-2 target, not a Layer-1 output
α_{time}	Spinor time-asymmetry	$1/(8\pi) \simeq 0.0397887$	Dimensionless; from η-invariant
κ_{bare}	Proton Compton wave-number	$m_p c / \hbar \simeq 4.755\times10^{15}$ m^{-1}	Fixed scale

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Symbol	Name	Value / expression	Role
κ_0	Effective gravitational Beltrami scalar	$\kappa_{bare}\,\alpha_{holoeff}\,\alpha_{time}$	Units m^{-1}
r_p	Proton rms charge radius	0.84075 fm	Orientation scale only
$\hbar$	Reduced Planck constant	$1.054\,571\,817 \times 10^{-34}$ J s	SI
c	Speed of light	$2.997\,924\,58 \times 10^{8}$ m s^{-1}	SI

Table 2. Symbols, units and roles. Δm_{flow} is a definition from measured masses, not a derived output of Section 6.

3. Cartan geometry, linear electromagnetism, quadratic gravitational energy

The fundamental geometric objects are the tetrad one-forms q^a and the spin connection $\omega^a{}_b$. The first and second Cartan structure equations are

$$T^a = D\,q^a = d\,q^a + \omega^a{}_b \wedge q^b \tag{1}$$

$$R^a{}_b = D\,\omega^a{}_b \tag{2}$$

Exterior differentiation of (1) and (2) yields the Bianchi identities. Non-vanishing torsion means the geometry is Riemann–Cartan rather than purely Riemannian. The Beltrami condition

$$T = \kappa\, q \tag{3}$$

selects the self-dual sector that conserves magnetic helicity. The gravitational Beltrami scalar is

$$\kappa_0 = \kappa_{bare}\,\alpha_{holoeff}\,\alpha_{time} \tag{4}$$

with $\kappa_{bare} = m_p\, c / \hbar$ fixed by the proton Compton scale and $\alpha_{holoeff}$ taken from the double holographic projection of the companion record (not refitted here).[1]

3.1 Why electromagnetism is linear in torsion

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ECE maps geometry onto electrodynamics and gravitation by the same pattern:[4,7]

$$D \wedge T = R \wedge q, \quad D \wedge F = R \wedge A, \quad D \wedge G = R \wedge Q \tag{5}$$

The electromagnetic postulate is

$$A^a = A^{(0)}\, q^a, \quad F^a = A^{(0)}\, T^a \tag{6}$$

Field strength is therefore linear in torsion. Poynting energy and Maxwell stress are quadratic in F, hence quadratic in T after (6) is substituted. That quadratic is field energy, not a modification of the map $F \propto T$.

3.2 Why gravitational mass is quadratic in torsion

Weight is the pressure difference produced when bidirectional aether flow is obstructed.[4] The invariant that measures the obstruction is the Hodge quadratic on the torsion two-form,

$$E_{grav} \sim \int T^a \wedge *T_a \sim \kappa_0^{\,2} \times (\text{effective volume}) \tag{7}$$

Because $\alpha_{holoeff}$ already carries the double projection required by this quadratic,[1] a fractional shift in $\alpha_{holoeff}$ appears once in the fractional gravitational mass:

$$\delta m / m = \delta\kappa_0 / \kappa_0 = \delta\alpha_{holoeff} / \alpha_{holoeff} \,(\text{at fixed } \kappa_{bare}, \alpha_{time}) \tag{8}$$

There is no extra factor of two. Electromagnetic amplitudes stay linear in T; gravitational mass is the quadratic obstruction of the flow.

Plain language.

Electromagnetism is a linear reading of the twist in the frame. Gravity is the pressure cost of that twist against the incoming and outgoing aether streams. Squaring is not an extra assumption; it is the energy of a two-form. D is the machine that computes the twist from the frame and the connection. Because D adds, composite twists add, plus a linking correction.

4. Whittaker potentials and the incoming characteristic

Whittaker (1904) showed that the six components of dielectric displacement and magnetic force are second derivatives of two scalars F

and G.[2] In continuous form both angular variables appear in the argument and in the measure. Write ξ(u, v) = x sin u cos v + y sin u sin v + z cos u. Each scalar carries both characteristics: outgoing (retarded, ξ − c t) and incoming (advanced, ξ + c t).

$$F = \int_0^{\pi} \int_0^{2\pi} [\, f_{out}(\xi - c\,t, u, v) + f_{in}(\xi + c\,t, u, v) \,]\, du\, dv \qquad (9)$$

$$G = \int_0^{\pi} \int_0^{2\pi} [\, g_{out}(\xi - c\,t, u, v) + g_{in}(\xi + c\,t, u, v) \,]\, du\, dv \qquad (10)$$

F and G remain Whittaker's two scalars. They are not themselves the outgoing and incoming streams; each of them has both. For the mass problem it is convenient to write the schematic Fourier form of the same split,

$$\Phi(r, t) = \int [\, f(k)\, e^{i(k\cdot r - \omega t)} + g(k)\, e^{i(k\cdot r + \omega t)} \,]\, d^3k \qquad (11)$$

The first term is retarded (outgoing); the second is advanced (incoming). Equation (11) is a schematic, not a substitute for (9)–(10). A Fourier writing that mixed a vector wave-number with a two-angle measure and omitted one angular argument is not used.

The incoming sector is not produced inside the particle. It is an ambient characteristic. The tetrad obstruction intercepts it. The intercepted flux is what appears as inertial and gravitational mass. The statistical weight of that incoming sector on S^3 is $\alpha_{time} = 1/(8\pi)$, already present in (4). The advanced sector is not an internal source term.

In the free electron the incoming stream is a Hopf fiber of linking number one relative to its own outgoing partner, and does not share the proton's S^3. The two holographic counts remain separate.

Plain language.

The vacuum potential is a pair of interlocking streams, forward and backward in time, organised as Hopf-linked circles. The electron carries one private pair. Binding forces that pair to share the proton's three-sphere. Sharing changes how many independent circles pack into a given volume, and therefore changes the holographic count. The incoming stream is not manufactured internally; it is intercepted.

5. Bound-state topology

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The free pair is two Hopf solitons. Their streams do not share fibers. When the electron is bound, its fiber is absorbed into the proton's S^3. The composite is a single hopfion with a different linking number. In strain-function language the symmetric proton supports a fundamental angular mode $\omega = 1$; the asymmetric neutron does not.[8] The spectral absence is forced by the change in integer topological indices.

The same topology appears as Möbius-type twist circles (Hopf-linked $S^1 \subset S^3$) with charge-phase transitions at polar angles $\mu = \pi/3$ and $2\pi/3$, positive charge in a core and negative charge outside — features absent in the free proton, and compatible with the complex Hopf-shell profiles of TUFT.[9]

Absence of the $\omega = 1$ mode is a geometric reason for metastability: once weak interactions are admitted, the configuration is not a local energy minimum. That statement does not require the numerical value of Δm_{flow}.

Plain language.

The proton is the more balanced knot. The neutron is the same knot with one extra twist forced by the absorbed electron stream. The extra twist removes a low-frequency mode. Removing a mode raises the energy. How much it raises the energy is the spectral question of Section 6.

5.1 Figure — free streams versus absorbed composite

Figure 1 is a schematic of the topological transition used in this record. The left panel is product-like: proton coframe and electron stream occupy separate S^3 counts. The right panel is the absorbed composite on one S^3, with nonzero fiber linking. The left-panel labels "$T^a = 0$" and "flow unobstructed" are schematic for the shared-fiber sector only. They are not a claim that a free proton is torsion-free. Each free hopfion still carries its own $T^a \neq 0$; what changes at binding is the linking correction $\delta T_{link}{}^a$ of (12).

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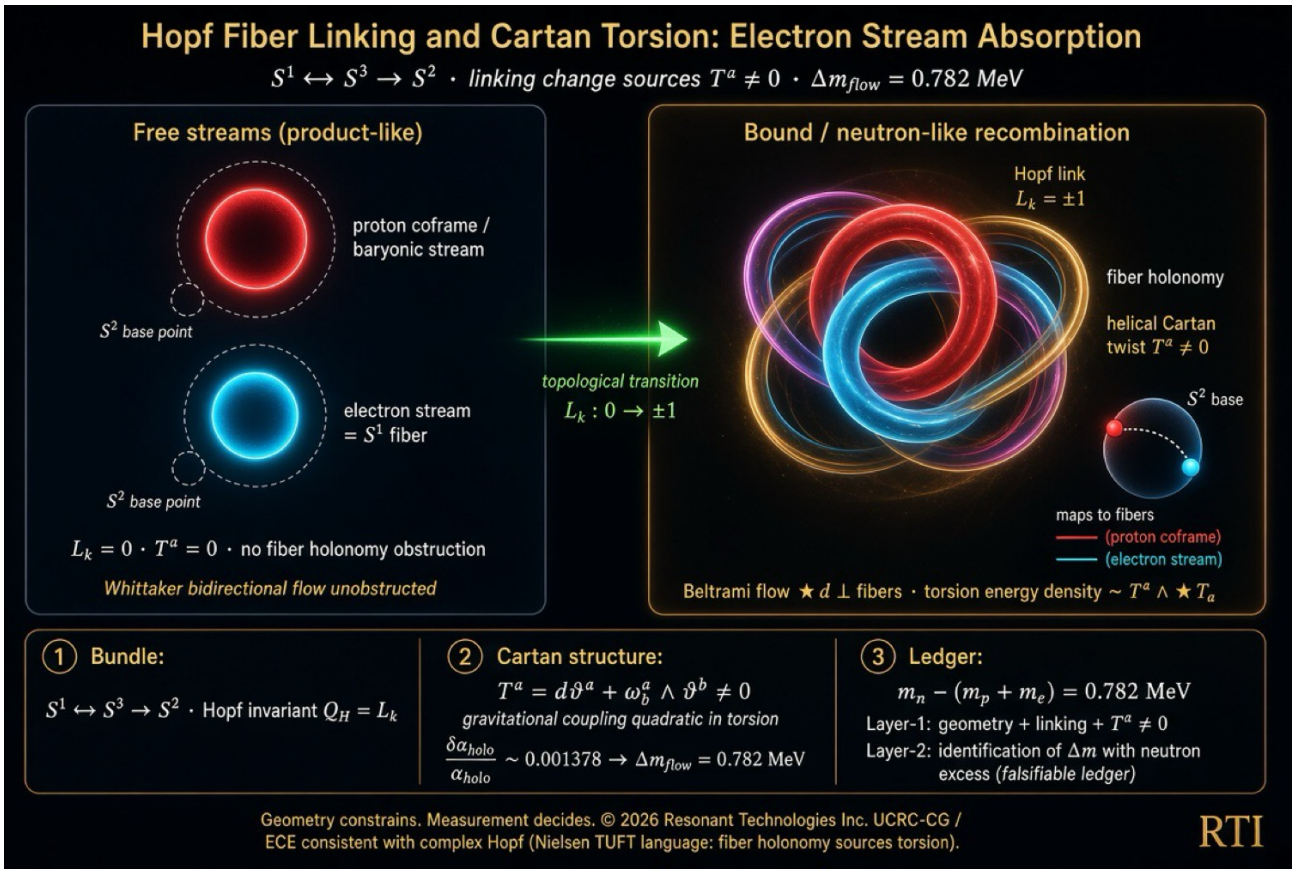


Figure 1. Hopf fiber linking and Cartan torsion at electron-stream absorption. Bundle: $S^1 \to S^3 \to S^2$, Hopf invariant $Q_H = L_k$. Cartan structure: $T^a = d\,q^a + \omega^a{}_b \wedge q^b \neq 0$; gravitational coupling quadratic in torsion. Ledger note (Layer 2). The artwork's pairing $\delta\alpha_{holo}/\alpha_{holo} \sim 0.001378 \to \Delta m_{flow} = 0.782$ MeV is the circular identification withdrawn from Layer 1 in Section 6.2. Standing observational targets are (16)–(17) and the alternative bookkeeping $\Delta m_{np}/m_p$. Geometry constrains. Measurement decides.

6. Flow correction: geometry and ledger

6.1 Layer 1 — linear recombination under D

D, defined in Table 1 and in equations (1)–(2), is the Cartan exterior covariant derivative. It is a linear operator: D(α + β) = Dα + Dβ for forms of the same type, and D(c α) = c Dα for a constant c. That is the whole content of the phrase "D is linear" at the head of this subsection. Because D is linear, the torsion of a composite configuration may be written as the sum of the contributions of its constituents plus interaction terms generated by the connection when the two fiber systems share one S^3:

$$T_n^{\,a} = T_p^{\,a} + T_e^{\,a} + \delta T_{\text{link}}^{\,a} \tag{12}$$

Under the hypothesis of linear recombination (the continuum extension of the Whittaker split already used for free particles) the interaction terms are absorbed into a redefinition of the effective holographic factor. The composite Beltrami eigenvalue is then

$$\kappa_0^{(n)} = \kappa_0^{(p)} (1 + \delta) \tag{13}$$

where $\delta \equiv \delta\alpha_{\text{holoeff}} / \alpha_{\text{holoeff}}$ is the relative change in fiber density caused by the altered linking. From (8),

$$\Delta m_{\text{geom}} = \delta\, m_p \tag{14}$$

The free-pair baseline is $m_p + m_e$. The geometric mass of the composite, if the electron rest energy continues to sit additively after recombination, would be

$$m_n^{\text{geom}} = m_p + m_e + \delta\, m_p \tag{15}$$

Equation (15) is a template, not an evaluation. It becomes a prediction only when δ is computed from the Hopf spectral problem without using m_n.

Plain language.

D is the rule that turns a frame plus a connection into torsion. Because that rule adds, you may add the proton twist, the electron twist, and a leftover piece that appears only when their loops share one three-sphere. That leftover piece is the linking correction. Its size is not fixed by adding the three CODATA masses together.

6.2 Circular identification is not Layer 1

Setting $\delta = (m_n - m_p)/m_p \simeq 0.001378419$ and then writing $m_n = m_p(1 + \delta) + m_e$ is algebraically inconsistent with the simultaneous claim that $\Delta m_{\text{flow}} = m_n - (m_p + m_e)$ is the derived correction: substituting that δ into (15) yields $m_n + m_e$, not m_n. The identification also inserts the observed n–p splitting into the quantity that was supposed to predict it. That is not a topological derivation. It is a consistency ansatz. It is not retained as Layer 1.

6.3 Observational target, not input

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CODATA fixes the combination that any honest spectral calculation must reproduce:[6]

$$\Delta m_{flow} \equiv m_n - (m_p + m_e) = 0.78233356\ \mathrm{MeV/c^2} \tag{16}$$

If the correct recombination is (15), the Layer-2 target for the fiber-density shift is

$$\delta_{target} = \Delta m_{flow} / m_p \simeq 8.338 \times 10^{-4} \tag{17}$$

If instead the electron rest energy is already subsumed in the composite hopfion and must not be added separately, the target is $\delta = \Delta m_{np} / m_p \simeq 1.378 \times 10^{-3}$. Distinguishing those two bookkeepings is part of the spectral problem: does the absorbed fiber contribute an additive m_e plus a linking correction, or only a linking correction? Mixing the two bookkeepings is not permitted in the Layer-1 ledger.

6.4 What would close the ledger

Compute the Beltrami spectrum of (i) a proton-like hopfion of linking number Q_H and (ii) the absorbed composite $Q_H + \Delta Q_H$ on the same S^3, under $T = \kappa\, q$, with Hodge residual $\leq 10^{-6}$ and mode orthogonality $\leq 10^{-4}$. The fractional change in the density of states at the holographic cutoff is δ. That number is then compared with (17) or with $\Delta m_{np} / m_p$, according to the recombination rule the spectrum itself selects. Until that count exists, Δm_{flow} is a target. It is not a derivation.

7. Consistency and implications

The equivalence principle is preserved: free pair and neutron intercept the same ambient flow; only the internal organisation of the obstruction differs. The missing $\omega = 1$ mode remains a geometric account of finite neutron lifetime, independent of the value of δ.

The construction is compatible with TUFT Hopf-shell charge profiles[9] and with hypersphere-soliton nucleon densities.[8] Linear recombination under D is the only dynamical hypothesis beyond the structure equations and the Beltrami condition; it is the continuum limit of the Whittaker split already used for free particles.

The three suppressions that fix $A^{(0)}/\Phi^{(0)}$ still constrain the gravitational sector of this problem. They do not, by themselves, evaluate δ. Claiming

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that they also fix Δm_{flow} is too strong and is not made.

Plain language.

The geometry tells us that binding the electron stream must change the mass a little, and that the neutron should be less stable than the proton. It does not yet tell us the size of the little. That size is a counting problem on the three-sphere, not a rearrangement of the CODATA table.

8. Conclusions

Layer 1. Absorption of the electron Hopf fiber into the proton S^3 changes the linking number, removes the $\omega = 1$ mode, and shifts the holographic factor that multiplies the gravitational Beltrami scalar. Electromagnetism reads torsion linearly through $F^a = A^{(0)}\, T^a$; gravitational mass is the quadratic aether-pressure obstruction of the bidirectional Whittaker flow. D is the linear Cartan operator that makes the recombination (12) legitimate. Those statements do not use the neutron mass as an input.

Layer 2. The conversion of the integer linking change into $\Delta m_{flow} = 0.782$ MeV/c^2 is not yet a closed spectral calculation. Identifying δ with $(m_n - m_p)/m_p$ is a circular ansatz and is not retained as a first-principles result.

Next ledger action. Hopfion density-of-states count on S^3 for the free-pair topology versus the absorbed composite, Beltrami-constrained, residual-controlled. That count, not a further rearrangement of CODATA, is what would move the 0.782 MeV figure from target to derivation.

Acknowledgements

H. Eckardt emphasized the angular completeness of the Whittaker spherical integrals (both angular arguments present in the measure), requested a precise meaning for interception of the incoming advanced characteristic at the torsion obstruction, asked for the linear / quadratic distinction between electromagnetic and gravitational coupling, asked what D means at the opening of Section 6.1, and requested true superscripts and subscripts in the typeset file. Those points, and his aether-pressure identifications in the Horst–Eckardt extensions, are incorporated above. Remaining errors are the author’s.

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Footnotes

[1] The numerical value of $\alpha_{holoeff}$ is taken from the double holographic projection derived in the companion record RTI-TR-2026-01; it is not adjusted in the present work.

[2] E. T. Whittaker, Proc. London Math. Soc. s2-1, 367–372 (1904).

[3] E. T. Whittaker, Math. Ann. 57, 333–355 (1903).

[4] H. Eckardt and J. Surbat, AIAS Paper 453 (24 August 2023); ECE overview lecture, 30 January 2023.

[5] H. Hopf, Math. Ann. 104, 637–665 (1931).

[6] CODATA Recommended Values of the Fundamental Physical Constants: 2022.

[7] M. W. Evans et al., Generally Covariant Unified Field Theory (ECE series), AIAS.

[8] The spectral absence of the $\omega = 1$ mode in the neutron configuration is a standard result in hopfion and hypersphere-soliton analyses of baryons; see the literature collected as reference [8].

[9] J. L. Nielsen, Topological Unified Field Theory on the Complex Hopf Fibration (TUFT), preprints (2025–2026).

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[2] E. T. Whittaker, “On an Expression of the Electromagnetic Field due to Electrons by Means of Two Scalar Potential Functions,” Proc. London Math. Soc. s2-1, 367–372 (1904).

[3] E. T. Whittaker, “On the partial differential equations of mathematical physics,” Math. Ann. 57, 333–355 (1903).

[4] H. Eckardt and J. Surbat, “The Horst-Eckardt Extensions of ECE Theory — Achievements since 2019,” AIAS Paper 453 (24 August 2023); see also ECE overview lecture, 30 January 2023.

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[6] CODATA Recommended Values of the Fundamental Physical Constants: 2022, Rev. Mod. Phys. / J. Phys. Chem. Ref. Data (2025).

[7] M. W. Evans et al., Generally Covariant Unified Field Theory (ECE series), Alpha Institute for Advanced Studies. Orientation corpus for the Cartan–ECE maps; not a substitute for the derivations in this record.

[8] Literature on hopfions, hypersphere solitons and nucleon charge profiles (Faddeev–Skyrme and related geometric constructions).

[9] J. L. Nielsen, Topological Unified Field Theory on the Complex Hopf Fibration (TUFT), preprints (2025–2026).

[10] E. Cartan, “Sur les variétés à connexion affine et la théorie de la relativité généralisée,” Ann. Sci. École Norm. Sup. 40, 325–412 (1923).

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Document control

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