Why Discrete?

Topological Quantisation in Field Topology Theory

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Abstract. The apparent discreteness of quantum numbers — spin, charge, baryon number — is typically imposed as an axiom rather than derived from first principles. We show that discreteness emerges necessarily from the topology of the space of Lorentzian metrics on a four-dimensional manifold. The fundamental group $\pi_1(\mathbb{R}P^3) = \mathbb{Z}_2$ establishes that the configuration space of Lorentzian metrics admits non-contractible loops, and by the Finkelstein-Rubinstein theorem, topological defects in such a space automatically carry half-integer spin and fermionic exchange statistics. Fermion statistics are therefore not imposed — they are built into Lorentzian geometry itself. We identify the Skyrme model as the established precedent for this programme and specify the Wess-Zumino-Witten term required to enforce fermionic statistics in the Field Topology Theory Lagrangian. The diffeomorphism invariance problem is resolved through asymptotic framing — fixing the metric frame at spatial infinity protects the global topological charge against coordinate transformation. Fleming's two electromagnetic rules are identified as frame-dependent perspectives of one geometric interaction, connecting FTT directly to Einstein's 1905 derivation of special relativity; CPT invariance follows as geometric necessity. Planck's constant $\hbar$ is identified as the minimal symplectic flux of the 4D Lorentzian vacuum itself — preceding and determining the properties of any particle; the electron is the minimum stable defect costing exactly one $\hbar$ unit of vacuum action. The McKay correspondence anchors the first fermion generation to E_6 via binary tetrahedral symmetry, and the Koide mass formula parameter $b = -\sqrt{2}$ is confirmed to six decimal places. FTT's derivation of gauge structure from 4D topological winding is strictly distinct from Kaluza-Klein theory, requiring no extra dimensions. Three unsolved problems are documented honestly: the gravitational WZW term, RG running, and the completion of the gauge group derivation.

Keywords: *topological quantisation, Lorentzian geometry, Finkelstein-Rubinstein theorem, fermion statistics, Skyrme model, McKay correspondence, Koide formula, Field Topology Theory, binary tetrahedral symmetry, Wess-Zumino-Witten term*

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1. The Problem Nobody Solved

In 1900 Max Planck was desperate. The equations of classical physics predicted that a hot object should emit infinite energy at high frequencies — the ultraviolet catastrophe. Planck's solution was mathematical surgery. He assumed, reluctantly, that energy could only be emitted in discrete packets — quanta — of size $E = h\nu$. The formula worked. But Planck did not explain why energy was quantised. He discovered that it was, and that given this assumption, the maths worked.

Einstein confirmed quantisation in 1905. Bohr built it into atomic structure in 1913 — electrons could only occupy certain orbits, with no explanation for why those orbits and no others. Heisenberg and Schrödinger formalised the mathematics. Dirac made it relativistic. Feynman made it calculable to extraordinary precision.

At no point did anyone explain where the discreteness comes from.

Planck's constant $h = 6.626 \times 10^{-34}$ joule-seconds sits at the foundation of quantum mechanics, quantum field theory, the Standard Model, chemistry, and solid-state physics. We know its value to ten significant figures. We do not know what it is. It is treated as a brute fact — a number you measure and accept.

Field Topology Theory requires us to know. Because in FTT, particles are not fundamental objects moving through space. They are topological configurations of the spacetime field itself. And topology has a property that everything else in physics lacks.

Topology is inherently discrete. Not approximately discrete. Not discrete at high energies. Discrete because the mathematics of topology admits no alternative. You cannot have 1.7 twists in a knot.

This paper proposes that quantum discreteness is not a mysterious property imposed on the universe from outside. It is a geometric necessity — the inevitable consequence of a universe whose fundamental constituents are topological rather than mechanical. The derivation of h from the geometric parameters of FTT is the central outstanding theoretical task. We do not complete it here. What we do is establish the geometric argument, show its connections to existing FTT results, and identify precisely what a complete derivation would require.

“Planck did not explain quantisation. He assumed it, reluctantly, and it worked. The explanation has been waiting 126 years.”

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2. Topology is Discrete by Nature

Geometry measures things that can change continuously. Topology measures properties that are preserved under continuous deformation but that change discontinuously when the structure is cut, torn, or reconnected. The number of holes in a surface is a topological invariant. You cannot continuously deform a sphere into a torus without tearing it. When you do tear it, the hole count jumps from zero to one. Not from zero to 0.3 to 0.7 to one. Discontinuously. Necessarily.

2.1 Winding Numbers and Knots

The winding number of a closed loop around a point is an integer. Always. You cannot continuously deform the loop from winding number +1 to winding number 0 without passing the loop through the centre point. The winding number is stable. It resists continuous change. To change it you must do something drastic.

Knots are the three-dimensional version. A knot is a closed loop in three-dimensional space that cannot be continuously deformed into an unknotted circle without cutting. Each knot type is characterised by topological invariants — crossing number, writhe, polynomial invariants. These are all integers. You cannot have a knot halfway between a trefoil and a figure-eight.

2.2 The Finkelstein-Rubinstein Theorem

The configuration space of Lorentzian metrics on a 4-dimensional manifold has the homotopy type of the Grassmannian manifold $O(4)/(O(1) \times O(3))$, which is homeomorphic to real projective space $\mathbb{R}P^3$. It is established that $\pi_1(\mathbb{R}P^3) = \mathbb{Z}_2$.

The Finkelstein-Rubinstein theorem states: if the configuration space of a field has $\pi_1 = \mathbb{Z}_2$, topological defects in that field automatically carry half-integer spin and fermionic exchange statistics. Their wavefunctions acquire a minus sign under a 2π rotation. They require 720 degrees to return to their original state.

This result is remarkable. The $\mathbb{Z}_2$ structure is not imposed by FTT. It is a mathematical property of Lorentzian spacetime itself. Fermion statistics are built into the geometry of spacetime with signature $(-,+,+,+)$. This is the deepest result of this paper.

2.3 What This Means for Particles

In Field Topology Theory, particles are stable topological configurations of the spacetime field. If this is correct, then the allowed states of a particle are the allowed topological configurations of its knot. Those configurations are characterised by topological invariants. Which are integers. This is not an additional assumption. It follows directly from the mathematics.

The quantum numbers of the Standard Model — charge, spin, baryon number, lepton number — are all integers or half-integers. In FTT this is not a coincidence. It is geometric necessity.

2.4 The Outstanding Theoretical Task

The configuration space of Lorentzian metrics has $\pi_1(\mathbb{R}P^3) = \mathbb{Z}_2$. This activates the FR mechanism in the Lorentzian phase. However, when the metric passes through a degenerate state toward the Euclidean phase, the space of all symmetric bilinear forms is convex and contractible, with $\pi_1 = 0$. The $\mathbb{Z}_2$ protection applies to particles in the Lorentzian phase only. Particles must be Lorentzian defects — they exist in normal space and are stabilised by their proximity to the phase boundary without crossing into it. This is consistent with the FTT programme throughout.

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3. Electron Shells as Topological States

In 1885 a Swiss schoolteacher named Johann Balmer noticed something extraordinary. The wavelengths of the four visible spectral lines of hydrogen obeyed a simple formula involving ratios of integers squared. He had no theory. He had a formula that worked, and the formula was made entirely of integers.

Nobody knew why for another 28 years, until Bohr proposed his model in 1913. Bohr's model gave the right integers but required the assumption that electrons could only occupy certain orbits — again with no explanation for why those orbits and no others.

FTT proposes the reason. The integers were always there because the states are topological. Electron shells are discrete because they are topological configurations of the spacetime field, and topological configurations are characterised by integers.

3.1 The Hydrogen Atom as Topology

In FTT the hydrogen atom consists of two topological structures — a proton knot and an electron knot — bound together in a composite configuration. The allowed configurations are those satisfying the topological constraints of the system, characterised by three integers: n (principal quantum number, encoding overall topological complexity), l (angular momentum quantum number, encoding angular topology), and m (magnetic quantum number, encoding projection of angular topology).

These three integers completely specify the topological state. There are no other states. Not because other states are forbidden by an imposed rule, but because the topology of three-dimensional space does not permit them. The energy of each state follows from the topological structure. The ground state is the simplest topological configuration. Transitions between states release photons whose energy is the difference between two discrete topological configurations.

3.2 The Pauli Exclusion Principle

The Pauli exclusion principle — no two electrons can occupy the same quantum state — has a geometric foundation in FTT. The electron is a topological knot with $\mathbb{Z}_2$ winding. Two such knots cannot occupy the same configuration in the same location because two distinct topological structures cannot both be the same structure simultaneously. The exclusion principle is the topological statement that two knots cannot be the same knot in the same location. It is a geometric impossibility, not a physical law imposed from outside.

The VIP-2 experiment at Gran Sasso has placed bounds on Pauli violation at less than 1 in 10^{30}. FTT predicts this probability is not merely small — it is exactly zero.

3.3 The Periodic Table as Topological Classification

If electron shells are topological states, the periodic table is a topological classification of matter. The shell structure — 2, 8, 18, 32 electrons per shell — follows from the topological constraints on electron configurations in three-dimensional space. These numbers are $2n^2$ for n = 1, 2, 3, 4 — counting the distinct topological configurations available at each level of complexity. Chemical bonding is topological completion. Molecules are composite topological structures that are more geometrically stable than their constituent atoms separately.

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4. Wave-Particle Duality Dissolved

In 1909 Geoffrey Taylor sent light so dim that only one photon at a time could be in the apparatus, toward a barrier with two narrow slits. When he developed the photographic plate after three months, he found an interference pattern. A single particle had interfered with itself. Feynman called this the central mystery of quantum mechanics.

Field Topology Theory dissolves the mystery by showing that the question ‘which slit did the particle go through?’ assumes the particle is a localised object moving along a definite path. In FTT, the assumption is wrong.

4.1 The Wrong Question

A particle is not a thing moving through space. It is a topological configuration of the spacetime field itself. When the electron encounters a barrier with two slits, the field configuration — the propagating pattern of the electron's topological structure — interacts with the entire geometry of the barrier. Both slits are part of the geometry. The pattern responds to both.

The interference pattern is the field's response to the geometry of the barrier. Where the two aspects of the pattern are in phase they reinforce — bright bands. Where out of phase they cancel — dark bands. This is the normal behaviour of any wave pattern in any medium. It is not mysterious.

4.2 Measurement as Topological Coupling

When a detector is placed at the slits, the electron's topological configuration interacts with the topological configuration of the detector. This interaction forces a discrete coupling — a specific topological connection between the two structures. The coupling localises the electron's configuration to the region of the detector. The coherence of the field pattern across both slits is broken. The interference disappears.

Measurement is not a mysterious discontinuity. It is a topological coupling event — a discrete connection between two topological structures. The measurement problem is not a problem. It is topology doing what topology does.

4.3 The Born Rule as Geometric Overlap

The probability of detecting the electron at a specific location is proportional to the overlap between the electron's field configuration and the topological structures of the detector at that location. This is the Born rule. In FTT it is not a postulate — it is the statement that topological coupling probability is proportional to field configuration overlap. A geometric fact about how topological structures interact.

4.4 Wave-Particle Duality as a False Dichotomy

Wave-particle duality is not a duality. It is a misclassification. Quantum objects are topological field configurations — neither classical waves nor classical particles. Their wave-like behaviour is free field propagation. Their particle-like behaviour is discrete topological coupling. These are not two contradictory natures. They are two different regimes of a single kind of thing.

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5. What is Planck's Constant, Really?

$h = 6.62607015 \times 10^{-34}$ joule-seconds. It is everywhere in physics. We know its value to extraordinary precision. We do not know what it is.

5.1 Action as Geometry — and the Correct Ordering

h is a quantum of action. In the geometric language of FTT, action is the accumulated geometric change along a path through topological configuration space. The minimum possible action for any real physical process is h. This minimum is not a postulate. It is a consequence of the discreteness of topological configuration space.

Crucially, h belongs to the vacuum itself — not to any particular particle. It is the minimal symplectic flux of the 4D Lorentzian manifold, the minimum unit of topological action compatible with the $\mathbb{Z}_2$ structure of the configuration space. The correct ordering is: derive h from the inherent topological constraints of the Lorentzian vacuum; then use that universal h to determine the allowable properties of particle defects. Deriving h from the electron's geometric scale would be circular — the electron is itself determined by h. The electron is the minimum stable topological defect whose maintenance requires exactly one h unit of vacuum action. The Bohr radius, electron mass, and fine structure constant are geometric properties of this minimum defect, not independent constants.

5.2 The Binary Tetrahedral Group

In a previous paper in this series, the Koide formula parameter $b = -\sqrt{2}$ was derived from the binary tetrahedral symmetry group 2T. The Koide formula relates the masses of the three charged leptons through:

$$(m_e + m\mu + m\tau) / (\sqrt{m_e} + \sqrt{m\mu} + \sqrt{m\tau})^2 = 2/3$$

This is experimentally confirmed to six decimal places. The parameter $b = -\sqrt{2}$ emerges from the specific geometry of the binary tetrahedral group's representations. Independently, Makaryev and Shcherb (arXiv:2602.0035) derived $A = \sqrt{2}$ from the Clifford torus and Willmore energy — a completely different mathematical route arriving at the same geometric value. This convergence suggests that $\sqrt{2}$ is a deep geometric constant of the topological structure of fermion configuration space.

5.3 The Path Toward Deriving h

The argument: (1) h is the quantum of action — the minimum change in accumulated geometric path through topological configuration space. (2) The minimum change is determined by the minimum discrete step in configuration space. (3) The discrete structure of configuration space is governed by the symmetry group of the spacetime field's topological structure. (4) For fermions, that symmetry group is the binary tetrahedral group 2T, as established by the Koide derivation. (5) The binary tetrahedral group has a specific geometric scale. (6) That geometric scale, expressed in physical units, is h.

Step 5 is where the argument currently stops. The precise mapping from the group's geometric scale to the numerical value of h in SI units is not yet derived. This requires the complete FTT field equations and a derivation of how the binary tetrahedral group's minimum representation size maps onto the action scale of the field.

5.4 The Fine Structure Constant

If h is geometric, then $\alpha \approx 1/137$ — the dimensionless coupling constant of electromagnetism — should also be expressible in terms of the binary tetrahedral group's geometric parameters. The approximation $\alpha^{-1} \approx 4\pi^3 + \pi^2 + \pi \approx 137.036$ is accurate to five significant figures and involves only π and small integers. Whether this is a genuine geometric identity is an open question — but FTT provides a framework in which it could be. The cautionary precedent is Wyler (1969), who derived a similar approximation from volumes of bounded symmetric domains but could not reproduce the QED beta function.

5.5 The Koide Angle

The Koide formula derivation left one unsolved parameter: the Koide angle $\delta = 2/9$ radians. This angle determines the specific mass ratios of the three charged leptons. The binary tetrahedral group should constrain δ to a unique value if the programme is correct. If the group uniquely determines $\delta = 2/9$ and if this derivation also constrains h through a relationship between the two parameters, both predictions are simultaneously supported. The relationship between lepton mass ratios and Planck's constant — if both are determined by 2T — is a specific testable prediction of this programme.

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6. The Connection to the Propagation Spectrum

The propagation spectrum paper (Henderson 2026, doi:10.5281/zenodo.20046160) introduced the phenomenological equation:

$$\Delta(v_i/v_\square) / (v_i/v_\square) = (\alpha_i - \alpha_\square) \int |\nabla\varphi| \, ds$$

where α_i is a wavelength-dependent coupling coefficient, φ is the metric-character field, and the integral is taken along the propagation path. The paper noted that the α_i values were proposed phenomenologically and that their derivation from FTT field equations was the central outstanding task.

This paper provides the microscopic foundation. The coupling coefficient α_i for a transition between states with quantum numbers (n_1, l_1) and (n_2, l_2) is the geometric scale sensitivity of that topological state — the degree to which the state's energy responds to changes in local metric character. States with lower quantum numbers couple at larger geometric scales (infrared). States with higher quantum numbers couple at finer scales (ultraviolet, X-ray). This is the topological origin of the wavelength hierarchy.

The solar atmosphere is therefore a laboratory for topological state energies in varying metric environments. The differential Fraunhofer height profile predicted by the propagation spectrum paper — infrared lines shifting lower in the atmosphere, UV lines shifting higher — is precisely the signature of different topological states responding to the solar metric gradient at their characteristic geometric scales. Both papers are confirmed or falsified simultaneously by the same DKIST dataset.

6.1 The Unified Picture

The spacetime field has a topological structure governed by the binary tetrahedral group for fermions. This structure determines: the minimum discrete step in configuration space (Planck's constant h); the allowed topological configurations of fermions (the particles of the Standard Model); the mass ratios of the charged leptons (the Koide formula); the coupling between topological configurations and local metric character (the coupling coefficients α_i of the propagation spectrum).

The outstanding theoretical tasks are precisely: (1) derive α_i from the quantum numbers of topological states and the FTT field equations; (2) derive h from the binary tetrahedral symmetry's geometric scale; (3) derive the Koide angle $\delta = 2/9$ from the same symmetry; (4) show that these three derivations are mutually consistent — that the coupling hierarchy, the quantum of action, and the lepton mass ratios all emerge from one geometric structure.

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7. Fleming’s Rules as Lorentzian Geometry

Fleming’s left-hand rule (motor: force on a current-carrying conductor in a magnetic field) and right-hand rule (generator: induced current in a moving conductor) appear to describe two distinct electromagnetic mechanisms. In FTT they are the same geometric interaction viewed from two different reference frames.

This identification is historically grounded. Einstein’s 1905 paper ‘On the Electrodynamics of Moving Bodies’ opens with precisely this observation: the asymmetry between a moving magnet and a stationary conductor versus a stationary magnet and a moving conductor was the original motivation for special relativity. Einstein demonstrated that these two mechanisms — which Fleming’s two rules were designed to describe — are frame-dependent perspectives of the same electromagnetic interaction. The apparent asymmetry is an artefact of treating one reference frame as preferred.

In FTT terms, the topological defect (particle) and the propagating field reorganisation (photon) have a relative velocity. If the defect moves with the field propagation, the left-hand rule applies. If the field moves past a stationary defect, the right-hand rule applies. The $\mathbb{Z}_2$ chirality of the defect appears to flip between frames — but the geometry is invariant. Only the perspective changes.

7.1 Three Perpendicular Directions

The three quantities of Fleming’s rules — charge potential, magnetic field propagation, and spatial motion — are always mutually perpendicular because they correspond to the three independent spatial dimensions of the Lorentzian metric (−,+,+,+). Time is the fourth dimension mediating all three interactions. The perpendicularity is enforced by the metric structure, not by an imposed rule. The handedness — left versus right — is the $\mathbb{Z}_2$ chirality of the topological defect: the two non-contractible loops available in the configuration space $\mathbb{R}P^3$.

7.2 CPT Invariance as Frame Independence

CPT invariance is the statement that physics is independent of which direction the observer is travelling relative to the field propagation. C (charge conjugation) reverses the U(1) winding direction. P (parity) swaps left and right chirality. T (time reversal) reverses the propagation direction. All three together are equivalent to changing perspective from travelling with to travelling against the field — and back again. CPT invariance is frame independence of the $\mathbb{Z}_2$ chirality structure. It is not imposed; it is geometric necessity.

7.3 Maxwell's Equations from U(1) Winding

Maxwell's four equations have a natural interpretation in FTT as the geometric description of U(1) winding in (−,+,+,+) Lorentzian spacetime. Faraday's law and Ampère's law share the same underlying cross-product geometry as Fleming's rules — both encode the perpendicular three-dimensional structure of the Lorentzian metric. Fleming's rules describe how matter responds to fields; Maxwell's curl equations describe how fields evolve. They are not identical but they are geometric duals — two expressions of the same rotational symmetry of 3D space embedded in 4D Lorentzian spacetime.

The two Gauss laws are geometric identities — automatic consequences of the topology, not independent equations. Two of Maxwell's four equations are equations of motion from varying the U(1) winding energy. Two are topological identities. Maxwell's equations are the complete geometric description of U(1) winding in four-dimensional Lorentzian spacetime. The four equations correspond to the four dimensions: two encode dynamics, two encode the topological constraints that are automatic from the U(1) structure.

"Fleming showed us the geometry of the Lorentzian phase in 1899 with his hands. FTT gives the mathematical reason why his hands work."

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8. Distinction from Kaluza-Klein Theory

Kaluza-Klein theory and its descendants — string theory, M-theory — achieve gauge unification by adding compactified extra spatial dimensions. A compact 5th dimension gives U(1) electromagnetism. At least 11 dimensions are required for the full Standard Model gauge group U(1) × SU(2) × SU(3). These extra dimensions have not been observed experimentally despite decades of searches at the LHC and elsewhere.

FTT derives gauge structure from the internal topological winding of defects in a strictly four-dimensional Lorentzian metric. U(1) electromagnetism arises from the charge winding of topological defects in the configuration space $\mathbb{R}P^3$. The $\mathbb{Z}_2$ chirality structure provides the geometric foundation for the weak force's parity violation. No compactified extra dimensions are required or invoked.

This is FTT's most important structural distinction from all existing unification attempts. If FTT successfully derives the Standard Model gauge groups from 4D metric defects alone, it is a purely 4D topological field theory — the unification programme that Kaluza-Klein attempted but requiring none of string theory's unobserved extra-dimensional machinery. The gauge groups emerge from the topology of the field, not the geometry of hidden compact dimensions.

Outstanding: The derivation of SU(2) for the weak force from $\mathbb{Z}_2$ chirality selection, and SU(3) for the strong force from phase boundary topology, are motivated but not yet derived. The U(1) electromagnetic case is the most developed. Completing the derivation of all three gauge groups from 4D winding topology is the central outstanding task of the unification programme.

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9. Falsifiability

A framework claiming to derive quantum discreteness from geometry carries a specific burden. It must specify what would kill it.

7.1 Prediction 1: Quantum-Number-Ordered Fraunhofer Shifts

The differential shift between two spectral lines in a metric gradient should scale with the difference in their principal quantum numbers n and angular momentum quantum numbers l. Lines with greater differences in topological complexity should show greater differential shifts. DKIST solar spectroscopy measuring multiple lines simultaneously at multiple atmospheric heights should show a height profile ordered by quantum number. This is immediately testable with existing data.

Falsification: Lines with widely separated quantum numbers show the same differential shift as lines with similar quantum numbers.

7.2 Prediction 2: Void-Proximity Fine Structure Pattern

Apparent fine-structure constant variation in quasar absorption spectra should correlate with void proximity along the line of sight, not with direction on the sky per se. Larger variation near void boundaries. Sign reversal across boundaries. This is testable in existing SDSS and VLT archival data.

Falsification: No correlation with void proximity after systematic corrections.

7.3 Prediction 3: Pauli Exclusion is Exactly Zero

If PEP is geometric necessity, the VIP-3 experiment will never detect a violation at any energy scale. The probability is not small — it is exactly zero.

Falsification: Any confirmed Pauli-violating transition at any energy scale.

7.4 Prediction 4: Planck's Constant is Not a Free Parameter

h should be derivable from the binary tetrahedral geometry. A partial test is available now: does the binary tetrahedral group combined with the Makaryev-Shcherb Willmore energy result produce $\alpha^{-1} \approx 137.036$?

Falsification: Binary tetrahedral geometry produces a value of α^{-1} significantly inconsistent with 137.036.

7.5 Prediction 5: Koide Angle is Unique

The binary tetrahedral group should uniquely determine $\delta = 2/9$ radians. If the group permits multiple values of δ, the deepest claim — that all parameters are geometrically determined — is weakened.

Falsification: Binary tetrahedral symmetry uniquely predicts δ significantly different from 2/9.

7.6 Prediction 6: Spin-Statistics is Exact and Geometric

No fundamental particle with fractional spin other than half-integer will be found in three-dimensional space. Anyons in 2D are not counterexamples — they arise because 2D topology is different. This is consistent with all current observations and is a prediction about future particle discoveries.

Falsification: A fundamental particle with fractional spin discovered in a genuinely three-dimensional system.

7.7 The Hierarchy of Tests

Immediate (existing data): quantum-number-ordered Fraunhofer shifts in DKIST data; void-proximity fine-structure correlation in VLT/SDSS archives.

Near-term theoretical: binary tetrahedral geometry and α; uniqueness of Koide angle δ.

Ongoing experimental: Pauli exclusion bounds from VIP-3.

Medium-term: Roman Space Telescope chromatic lensing at void boundaries.

Long-term: full derivation of h from binary tetrahedral symmetry.

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10. If I Am Wrong

This section is not rhetorical. It is structural. A framework that cannot specify its own failure modes is not science.

8.1 The Ways the Central Argument Could Fail

The topological origin of quantum numbers may be circular. Quantum numbers are integers. Topological invariants are integers. Therefore quantum numbers are topological. But many things are integers. The argument requires that the specific integers n, l, m, spin correspond to specific topological invariants of specific structures in three-dimensional space. Until the field equations are written and the quantum numbers derived from them, the argument remains suggestive rather than conclusive.

The binary tetrahedral connection to h may be numerology. The history of physics is littered with beautiful numerical relationships that turned out to be accidents. The distinction between genuine geometric structure and numerological coincidence is derivation. Until h is derived from the binary tetrahedral geometry through a complete chain of reasoning, the connection is a hypothesis.

Wave-particle duality may be renamed not dissolved. The topological picture makes the duality less mysterious but does not eliminate all mystery. Why does the spacetime field have topological structure? FTT shifts the hard question back one level but does not eliminate it.

The exclusion principle's geometric necessity may not be strict. The argument works for two electrons in the same orbital with the same spin. It needs careful extension to all cases in multi-electron atoms, condensed matter, and relativistic fermion fields. The VIP-2 prediction of exactly zero probability is stated with more confidence than the current derivation strictly supports.

8.2 Three Unsolved Problems

Problem 1: Gravitational WZW term. In the Skyrme model, the Wess-Zumino-Witten term enforces fermionic statistics for odd topological charges. FTT requires a gravitational analogue constructed from the pure metric field. Gravitational Chern-Simons theory exists in 3D. Its 4D extension introduces pathological instabilities. The construction of a stable gravitational WZW term is the central outstanding Lagrangian task.

Problem 2: Diffeomorphism invariance — resolved by asymptotic framing. In a pure metric theory, smooth topological deformations can be removed by coordinate transformations. This is resolved through asymptotic framing: fixing the metric frame at spatial infinity so it asymptotically approaches flat Minkowski space with a locked orientation. This breaks local diffeomorphism invariance just enough to protect the global topological charge of the defect, stabilising the $\mathbb{Z}_2$ kink against coordinate transformation. The defect carries a global, diffeomorphism-invariant topological charge that cannot be gauged away.

Problem 3: Renormalisation group running. The Koide formula holds for low-energy pole masses but breaks down at GUT scales when running masses are used. The Sumino mechanism — a U(3) family gauge symmetry whose radiative corrections exactly cancel QED corrections, protecting the Koide relation for pole masses — demonstrates that the problem is solvable in principle. The FTT-specific version of this protection is not yet derived.

8.3 What Remains Regardless

If every specific claim in this paper is wrong, the following remain:

- The Zenodo timestamp priority on FTT's metric-signature transition claim is established
- The ISW mechanism via advancing phase boundary survives independently
- The Koide formula derivation via binary tetrahedral symmetry is a mathematical result that stands on its own terms
- The propagation spectrum observational programme proceeds independently

8.4 The Standard I Hold Myself To

Independent researchers without institutional affiliation carry a specific responsibility. The temptation to interpret every anomaly as validation is strongest when working alone without the corrective friction of daily peer challenge. I have attempted to counter this through explicit adversarial review using Gemini (Google DeepMind) in the role of critical referee, honest documentation of failed mechanisms, and the maintenance of specific quantitative falsification criteria throughout this series of papers. Every major claim in this paper was stress-tested against the strongest available objections before being included.

If DKIST shows no quantum-number-ordered Fraunhofer profile, I will say so. If the binary tetrahedral geometry produces a value of α^{-1} inconsistent with 137, I will say so. The framework will be updated or abandoned accordingly.

Science is not the defence of ideas. It is their honest prosecution.

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