

Transaction-Geometric Interpretation and Blitzon Cosmology: A Unified Framework for Quantum Mechanics, Spacetime Geometry, and Force Emergence

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Abstract

We present a theoretical framework that reconceptualizes quantum mechanics and spacetime geometry through the Transaction-Geometric Interpretation (TGI). Rather than treating photons as propagating particles, we propose they represent observational perspectives on direct spacetime connections—transactions between emission and absorption events. Building on analysis of photon gravitational collapse at Planck scale, we introduce blitzons (collapsed photons at Planck length) as transaction endpoints connecting our universe's interior to an external reality through a black hole event horizon. Our observable 4-dimensional spacetime emerges as a compactified manifold ($S^3 \times S^1$) on this horizon, with the four fundamental forces arising from different geometric rotation modes of the 3-sphere. This framework unifies quantum mechanics, general relativity, and particle physics within a single geometric structure, provides natural explanations for quantum non-locality and retrocausality, while offering novel explanations for dark energy (boundary information flow), quantum measurement (transaction formation), the emergence of gauge forces from S^3 geometry and offers specific testable predictions including an explanation for the mysterious 3:2 frequency ratio observed in black hole quasi-periodic oscillations (QPO 3:2). The theory suggests our universe exists within a black hole, and demonstrates a resolution of the black hole singularity paradox, with physics emerging from perturbations in a Planck-scale blitzon sea at the horizon.

We identify testable signatures in cosmic microwave background anomalies, large-scale bulk flows, quasar distributions, and pulsar timing residuals, with detailed analysis protocols for existing publicly available datasets including the NANOGrav 15-year pulsar timing array. These observational tests can be conducted within 6-9 months using current data, providing immediate falsifiable predictions that distinguish blitzon cosmology from standard Λ CDM while maintaining consistency with all confirmed observations.

1. Introduction

The interpretation of quantum mechanics has remained contentious since the theory's inception, with debates centering on the nature of wave function collapse, the role of observation, and the apparent non-locality of quantum correlations. Simultaneously, the unification of quantum mechanics with general relativity—the problem of quantum gravity—stands as one of physics' most significant unsolved challenges. Recent approaches including string theory, loop quantum gravity, and the holographic principle have made progress, but a complete, testable framework remains elusive.

The Transaction-Geometric Interpretation (TGI) proposes that quantum phenomena arise not from propagating particles, but from direct spacetime connections—transactions—between emission and absorption events. This ontological shift has profound implications: it naturally incorporates retrocausality, provides a geometric basis for quantum non-locality, and suggests a deep connection between quantum mechanics and spacetime topology.

The author's experience designing packet-switching protocols for early wireless broadband networks proved intellectually transformative. Several key insights emerged that inform TGI:

Information Integrity Through Chaos: A single logical message fragments into multiple packets taking different routes through a mesh network. Despite route chaos, timing variations, and packet loss, the destination reconstructs the original message with integrity. This parallels quantum coherence maintained despite apparent measurement randomness.

Network Substrate vs. Packet Content: Packets do not continuously "travel" through space. They represent discrete handshakes between network nodes. The distinction between physical substrate (network) and information content (packets) mirrors the relationship between spacetime geometry and quantum transactions.

Protocol Regimes: Different protocols (TCP, UDP, ICMP) operate on the same network substrate, each with characteristic reliability, speed, and range. This suggested that fundamental forces might similarly be different transaction protocols operating on a common geometric substrate, with phase transitions at energy/distance thresholds.

Multiple Routes, Single Connection: The mesh architecture allowed packets to take multiple simultaneous paths. This topology maps naturally onto quantum superposition and path integrals—not as a particle being in multiple places, but as multiple possible transaction routes through geometric structure.

TGI builds on analysis of photon gravitational collapse predicting that photons with wavelengths approaching Planck length undergo Kugelblitz formation. These collapsed photons, termed blitzons, form the fundamental substrate of spacetime at Planck scale. Rather than isolated objects, blitzons serve as transaction endpoints connecting our universe to external reality through a black hole event horizon.

This paper proceeds as follows: Section 2 reviews conceptual foundations including the photon gravitational collapse derivation. Section 3 develops the mathematical framework of transaction space. Section 4 presents blitzon cosmology and horizon compactification. Section 5 derives force emergence from geometric structure. Section 6 presents testable predictions including the novel explanation for black hole QPO frequency ratios. Section 7 discusses implications and connections to other frameworks. Section 8 concludes.

2. Conceptual Foundations

2.1 Photon Gravitational Collapse at Planck Scale

Analysis of photon gravitational effects reveals an upper limit to electromagnetic frequency. As wavelength decreases, photon energy $E = hc/\lambda$ increases. The equivalent mass $m = E/c^2$ generates a Schwarzschild radius:

$$R_s = 2GM/c^2 = 2Ghv/c^4 = 2Gh/(\lambda c^3)$$

When $R_s \approx \lambda$, the photon collapses into a Kugelblitz. This occurs at Planck scale:

$$\lambda_p = \sqrt{(\hbar G/c^3)} \approx 1.616 \times 10^{-35} \text{ m}$$

$$E_p = \sqrt{(\hbar c^5/G)} \approx 1.956 \times 10^9 \text{ J} \approx 1.22 \times 10^{19} \text{ GeV}$$

Using natural relativistic quantities (reduced Planck constant \hbar and angular wavenumber k):

$$\hbar = h/2\pi \text{ (reduced Planck constant: action per radian)}$$

$$k = 2\pi/\lambda \text{ (angular wavenumber: radians per unit length)}$$

$$\omega = ck \text{ (angular frequency for light)}$$

$$\tilde{\lambda} = \lambda/2\pi = 1/k \text{ (reduced wavelength: length per radian)}$$

The photon energy relation becomes $E = \hbar\omega = \hbar ck$, and the equivalent mass $M = E/c^2 = \hbar k/c$. Substituting into the Schwarzschild formula:

$$r_s = 2GM/c^2 = 2G\hbar k/c^3$$

In the angular formulation, the natural spatial scale is the reduced wavelength $\tilde{\lambda} = 1/k$. Setting the collapse condition $r_s = \tilde{\lambda} = 1/k$:

$$2G\hbar k/c^3 = 1/k$$

$$k^2 = c^3/(2G\hbar)$$

$$k_{\text{critical}} = (1/\sqrt{2})\sqrt{c^3/G\hbar}$$

- **Since $\ell_p = \sqrt{G\hbar/c^3}$, we have $\sqrt{c^3/G\hbar} = 1/\ell_p$. Therefore $k_{\text{critical}} = 1/(\sqrt{2} \ell_p)$**

$$\tilde{\lambda}_{\text{critical}} = \sqrt{2} \ell_p$$

The critical reduced wavelength differs from the Planck length by exactly the factor $\sqrt{2}$. This geometric factor—the diagonal of a unit square—suggests a deep connection between the oscillatory structure of electromagnetic waves and the pointlike nature of gravitational collapse. These collapsed photons—blitzons—are reinterpreted as transaction endpoints at Planck density on the cosmic horizon.

2.2 The Transaction-Geometric Interpretation

Standard quantum mechanics treats photons as excitations of the electromagnetic field propagating through space. TGI proposes photons represent observational perspectives on spacetime transactions. The distinction parallels how network packets represent discrete handshakes between nodes rather than continuous objects traveling through wires. Observations at emission and absorption points are connected by geometric structure, not by an entity moving through intervening space.

2.3 Connection to Transactional Interpretation

The Transactional Interpretation of Quantum Mechanics (TIQM, Cramer 1986) treats interactions as Wheeler-Feynman handshakes between retarded and advanced waves. TGI extends this by: (1) making geometry fundamental—transactions are geometric connections through curved spacetime; (2) proposing blitzons as physical endpoints at Planck scale; (3) embedding transactions in a specific cosmological framework (universe as black hole interior); (4) deriving forces from geometric structure rather than treating them as given.

3. Mathematical Framework of Transaction Space

3.1 Transaction Network Definition

We define a transaction network T as a set of potential connections between spacetime events. A transaction $\tau \in T$ is characterized by:

$$\tau = (x_e, x_a, \Phi[\tau], \Gamma[\tau])$$

where $x_e \in M^4$ is the emission event, $x_a \in M^4$ is the absorption event, $\Phi[\tau] \in \mathbb{C}$ is the complex amplitude, and $\Gamma[\tau]$ represents the geometric path configuration.

The transaction amplitude follows from the action principle:

$$\Phi[\tau] = A_0 \exp(iS[\tau]/\hbar)$$

where $S[\tau]$ is the action integrated along the geometric path:

$$S[\tau] = \int_{\gamma[\tau]} L(x^\mu, dx^\mu/d\lambda, g_{\{\mu\nu\}}) d\lambda$$

with $\gamma[\tau]$ parameterizing the path through spacetime geometry $g_{\{\mu\nu\}}$.

3.2 Coherence and Interference

Transaction coherence measures the stability of phase relationships:

$$C[\tau] = \exp(-\Gamma[\tau]/\hbar)$$

where $\Gamma[\tau]$ represents decoherence from interaction with surrounding geometry. For transactions routing through blitzon endpoints:

$$\Gamma[\tau] = \Gamma_{\text{interior}}[x_e \rightarrow B_i] + \Gamma_{\text{external}}[B_i \rightarrow B_j] + \Gamma_{\text{interior}}[B_j \rightarrow x_a]$$

External routing through the blitzon network can maintain coherence over spatially separated interior events, explaining quantum non-locality.

When multiple transaction paths connect the same emission-absorption pair:

$$\Phi_{\text{total}} = \sum_i \Phi[\tau_i] C[\tau_i]$$

- **The observable probability is** $P = |\Phi_{\text{total}}|^2 = |\sum_i \Phi[\tau_i] C[\tau_i]|^2$

This reproduces the Feynman path integral formulation, but with geometric transaction paths replacing particle trajectories. Interference arises from phase differences between paths through geometric structure.

3.3 Regime Structure

Different force regimes emerge from different scales. Define the regime parameter:

$$\rho(E, r) = (E/E_p) \times (\ell_p/r)$$

This dimensionless parameter characterizes the transaction regime:

Electromagnetic Regime ($\rho \ll 1$): For typical photons with $\lambda \gg \ell_p$ and $E \ll E_p$, $\rho \sim 10^{-43}$. Transaction network topology permits long-range connections with bounded amplitude. Standard QED applies.

Transition Regime ($\rho \sim 10^{-3}$ to 10^{-1}): Mixed coherence conditions emerge. Network begins restructuring. This occurs at GUT scale $E \sim 10^{16}$ GeV where forces begin to unify.

Gravitational Regime ($\rho \sim 1$): At Planck scale, geometric constraints dominate. Network topology becomes highly constrained and local. Spacetime geometry emerges as collective property of transaction density.

3.4 Action Principle and Metric Emergence

The complete theory follows from a variational principle on the transaction network:

$$S_{\text{total}}[\{\tau\}] = \sum_{\tau} |\Phi[\tau]|^2 C[\tau] + \lambda \sum_{\{\tau, \tau'\}} I[\tau, \tau']$$

The first term represents individual transaction amplitudes weighted by coherence. The second term captures network interactions through the interference function:

$$I[\tau, \tau'] = \iint K(x, x') \delta\Gamma[\tau](x) \delta\Gamma[\tau'](x') d^4x d^4x'$$

where $K(x, x')$ is a geometric kernel and $\delta\Gamma[\tau]$ indicates path occupation.

The metric tensor emerges from transaction density distribution:

$$g_{\{\mu\nu\}}(x) = \eta_{\{\mu\nu\}} + \kappa \int T_{\{\mu\nu\}}[\tau] \delta^4(x - \gamma_{\tau}(\lambda)) D[\tau]$$

where $\eta_{\{\mu\nu\}}$ is the flat space metric and $\kappa \sim \ell_p^2$ is the coupling strength. In the electromagnetic regime (low transaction density), $g_{\{\mu\nu\}} \approx \eta_{\{\mu\nu\}}$, recovering approximately flat space. In the gravitational regime (high transaction density), the Einstein field equations emerge naturally:

$$R_{\{\mu\nu\}} - (1/2)g_{\{\mu\nu\}}R = 8\pi G T_{\{\mu\nu\}}$$

4. Blitzon Cosmology and Horizon Compactification

4.1 The Universe as Black Hole Interior

We propose that our observable universe exists within a massive black hole. The event horizon has radius:

$$R_H = 2GM/c^2 \approx 10^{26} \text{ m}$$

corresponding to mass $M \approx Rc^2/(2G) \approx 10^{53} \text{ kg}$, matching the observable universe's mass-energy content.

4.2 Blitzon Endpoints on the Horizon

The horizon is populated by blitzon endpoints at Planck density:

$$n_{\text{blitzon}} = 1/\ell_p^2 \approx 3.8 \times 10^{69} \text{ endpoints/m}^2$$

- **Total number over horizon surface area $A = 4\pi R^2$** $N_{\text{total}} = 4\pi R^2/\ell_p^2 \approx 1.5 \times 10^{122}$
matching the Bekenstein-Hawking entropy $S_{\text{BH}} = k_B A/(4\ell_p^2) = k_B \times 1.5 \times 10^{122}$

The holographic principle emerges naturally from blitzon endpoint density.

4.3 Transaction Routing Through External Space

A transaction connecting interior events x_e and x_a routes through the blitzon network:

$$\tau: x_e \rightarrow [\text{interior}] B_i \rightarrow [\text{external}] B_j \rightarrow [\text{interior}] x_a$$

The external path allows quantum non-locality: for entangled particles created at x_0 and detected at spacelike-separated points x_A and x_B , both detection events connect to the common origin through external routing. The shared external path segment maintains correlation despite interior spacelike separation.

- **This mechanism explains Quantum Entanglement:** Correlated particles share external transaction paths.

Quantum Tunneling: Transactions find shorter paths through external space.

Retrocausality: External temporal ordering may differ from interior ordering.

Wave-Particle Duality: "Particle" detection measures endpoints; "wave" behavior reflects exploration of multiple possible connections.

4.4 The Compactified Manifold Structure

Our 4-dimensional spacetime is compactified on the horizon as:

$$M^4 = S^3 \times S^1$$

where S^3 (the spatial 3-sphere) has radius $R_{\text{space}} \approx 10^{26} \text{ m}$ and S^1 (the temporal circle) has period $T \approx 10^{18} \text{ s}$. The metric on this compactified space is:

$$ds^2 = -c^2 dt^2 + R^2 [d\chi^2 + \sin^2\chi (d\theta^2 + \sin^2\theta d\phi^2)]$$

where (χ, θ, φ) parameterize S^3 and t is periodic with period T .

This structure inverts the usual Kaluza-Klein picture where small extra dimensions give rise to forces. Here, our "large" dimensions are themselves compactified, and their geometric structure determines force emergence.

4.5 Cosmological Implications

- **CMB Temperature** The CMB represents thermal radiation from recombination (interior), not horizon emissions.
- **Dark Energy** Vacuum energy arises from constant flux through blitzon endpoints from the external universe. The cosmological constant scales with horizon area: $\Lambda \sim 3/R^2 \approx 10^{-52} \text{ m}^{-2}$, matching the observed value.
- **Horizon Problem** Causally disconnected regions in our interior can correlate via external connections through the blitzon network, resolving the horizon problem without requiring inflation.
- **Flatness** S^3 has constant positive curvature $K = 1/R^2$. For $R \approx 10^{26} \text{ m}$, local measurements perceive flatness within observational precision.

4.6 Singularity Resolution and the Physical Interior

One of the most significant implications of blitzon cosmology is the resolution of the black hole singularity problem—one of the longest-standing pathologies in general relativity.

4.6.1 The Singularity Problem in Classical GR

The Penrose-Hawking singularity theorems prove that under reasonable physical conditions, gravitational collapse in general relativity inevitably produces spacetime singularities—points where curvature diverges, geodesics terminate, and the equations of general relativity cease to have meaning.

For a Schwarzschild black hole, the singularity appears at $r = 0$ as an unavoidable consequence of the field equations. All timelike worldlines inside the event horizon inevitably reach this singular point in finite proper time. No known mechanism in classical general relativity prevents this collapse to infinite density.

This creates multiple profound problems:

Information loss: Information falling past the horizon appears either destroyed at the singularity or fundamentally inaccessible, creating the black hole information paradox.

Predictability breakdown: The singularity represents a boundary beyond which physics cannot make predictions—a fundamental failure of the theory.

Unphysical infinities: Infinite curvature and density are generally regarded as signals that a theory has exceeded its domain of validity.

Quantum gravity necessity: The singularity problem is often cited as the primary motivation for developing quantum gravity—classical GR must break down at the Planck scale.

4.6.2 The Blitzon Shell as Geometric Floor

Blitzon cosmology resolves the singularity problem naturally through geometric quantization. The blitzon shell at radius $R = \sqrt{2} \ell_p M$ represents a fundamental quantum of spacetime geometry—a minimum meaningful geometric structure below which the concept of "interior" loses operational meaning.

For any mass M forming a black hole, collapse proceeds to the blitzon shell but cannot continue further. The shell radius:

$$R = \sqrt{2} \ell_p M/M_p$$

decreases as M decreases, approaching the minimum value $\sqrt{2} \ell_p$ in the limit $M \rightarrow M_p/\sqrt{2}$. Crucially, it never reaches zero.

The physics is analogous to atomic structure: just as electrons cannot occupy states "inside" the atomic nucleus due to quantum mechanical constraints, matter cannot collapse "inside" the blitzon shell because spacetime geometry itself quantizes at the Planck scale.

Mathematical formulation: In the limit $r \rightarrow \sqrt{2} \ell_p M/M_p$, the metric approaches a limiting form where further reduction in radial coordinate becomes geometrically undefined. The blitzon shell is not a surface "in" spacetime but the boundary of spacetime itself for this mass configuration.

4.6.3 Information Preservation and Holographic Encoding

The absence of a singularity resolves the information paradox elegantly. All information about matter that formed the black hole is encoded on the blitzon shell surface, with information capacity given by the Bekenstein-Hawking entropy:

$$S = k_B A/(4\ell_p^2) = \pi k_B (\sqrt{2} \ell_p M/M_p)^2 / \ell_p^2 = 2\pi k_B M^2/M_p^2$$

Each unit area of Planck size on the shell encodes 1/4 bit of quantum information. For our universe ($M \approx 10^{53}$ kg), this yields:

$$S_{\text{universe}} \approx 10^{123} k_B$$

This enormous but finite information capacity represents the maximum complexity our universe can sustain—consistent with the observed entropy and with complexity bound arguments from Gödel incompleteness (see companion paper).

Holographic principle: The blitzon shell naturally implements holography at the fundamental level. The apparent three-dimensional interior volume is completely described by two-dimensional boundary data. What we experience as "interior" spacetime is a projection or reconstruction from information encoded on the bounding shell.

This is not a metaphor but a literal statement about physical reality: in blitzon cosmology, our entire observable universe—all 10^{93} particles, all spatial extent, all temporal evolution—exists as information patterns on a Planck-scale surface.

4.6.4 Physical Reality of Black Hole Interiors

The absence of singularities makes black hole interiors physically real regions of spacetime rather than mathematical pathologies leading to inevitable infinities.

Interior spacetime structure: The region inside a black hole horizon, bounded by the blitzon shell, consists of actual four-dimensional spacetime with well-defined geometry, matter content, and causal structure. It evolves according to Einstein's equations (appropriately modified at Planck scales) without encountering singularities.

Observability: While external observers cannot directly observe the interior (causal disconnection), the interior is nonetheless physically real and contains actual matter, radiation, and spacetime structure. In the case of our universe, we are observing such an interior from within.

Time evolution: Inside the horizon, "radial" and "temporal" coordinates interchange roles (timelike becomes spacelike and vice versa). What appears from outside as spatial

contraction toward $r = 0$ is experienced from inside as temporal evolution—the expansion of the universe. The blitzon shell represents not a spatial boundary at the "center" but the temporal beginning (or end, depending on perspective) of the interior spacetime.

4.6.5 Cosmological Big Bang Without Singularity

If our universe is the interior of a blitzon shell, the apparent Big Bang singularity at $t = 0$ may not be a true singularity but rather the geometric structure of the blitzon shell projected into interior coordinates.

The "beginning" of our universe corresponds not to a singular point but to the formation of the parent blitzon shell. Interior spacetime evolves from Planck-density initial conditions—enormously dense but finite—rather than from infinite density at a point.

This reformulation addresses several cosmological puzzles:

Singularity avoidance: No actual singularity exists at $t = 0$. The apparent singularity is a coordinate artifact arising from describing the blitzon shell structure in interior (cosmological) coordinates.

Initial conditions: The initial state of our universe is determined by the quantum state encoded on the blitzon shell, potentially making cosmological initial conditions calculable rather than arbitrary.

Entropy problem: The low entropy of the early universe becomes the low entropy of the newly-formed blitzon shell state, shifting the question of "why low entropy?" to the formation mechanism of the parent blitzon.

Horizon problem: If our universe's initial state is holographically encoded on the blitzon shell, all regions were "in causal contact" at the boundary, potentially resolving the horizon problem without invoking inflation.

4.6.6 Nested Universe Structure

The resolution of singularities through blitzon shells suggests a potentially infinite nested structure: universes containing black holes that are themselves universes, repeating at all scales, but see the companion paper on the bounds of complexity which shows ultimate limits on both the number and complexity of the parent and child universes.

Hierarchy: At every scale where gravitational collapse produces a black hole, a blitzon shell forms, bounding an interior that could be an entire universe with its own black holes, each containing further nested universes of less complexity.

No bottom: Unlike in standard cosmology where the Planck scale represents a fundamental limit, the blitzon framework allows structure to continue below any given scale. Each nested level has its own effective Planck scale determined by the mass of its parent blitzon (but see the companion paper on the bounds of complexity for a lower limit).

No top: Similarly, our universe may itself be nested within a larger structure, with no ultimate "outermost" universe. The hierarchy could extend upward in both directions within the upper bounds of complexity.

Observational signatures: The parent universe's large-scale structure creates directional boundary conditions on our universe—potentially explaining cosmic dipole anomalies and large-scale anisotropies (see Section 6.8).

4.6.7 Quantum Gravity Implications

The singularity resolution achieved through geometric quantization suggests blitson theory captures essential features of quantum gravity without requiring a complete microscopic formulation.

Natural cutoff: The blitson shell provides a physical ultraviolet cutoff at $\sqrt{2} \ell_p$, eliminating infinities that plague quantum field theory in curved spacetime. This cutoff emerges from classical gravitational collapse, not from imposed discreteness.

Geometric uncertainty: At the Planck scale, spacetime geometry becomes uncertain or "fuzzy" in a manner analogous to quantum mechanical position-momentum uncertainty. The blitson shell represents the minimum resolvable geometric structure.

Holography: The fact that all interior information is encoded on the boundary suggests that quantum gravity may be fundamentally two-dimensional, with three-dimensional spacetime emerging as a derived or effective description.

Consistency check: Any complete theory of quantum gravity must reproduce the blitson shell structure in the limit of large mass. The $\sqrt{2} \ell_p$ scale and factor-of-4 in the Bekenstein-Hawking entropy provide quantitative tests for proposed quantum gravity theories.

4.6.8 Experimental and Observational Tests

While direct observation of singularity resolution is impossible (it requires probing inside black hole horizons), several indirect tests are possible:

Black hole evaporation: If blitsons lack true singularities, Hawking radiation emission may differ subtly from standard predictions near the endpoint of evaporation. Primordial black holes reaching final stages could reveal deviations.

Information recovery: The encoding of information on the blitson shell (rather than destruction at a singularity) suggests that Hawking radiation should carry information about the black hole's formation. Detailed analysis of radiation correlation functions could test this.

Gravitational wave signatures: The merger of black holes involves dynamics of their blitson shells. Subtle features in gravitational waveforms—especially during ringdown—might reveal Planck-scale structure.

Cosmological observations: The cosmic dipole anomalies (Section 6.8) and pulsar timing signatures (Section 6.8.8) provide indirect evidence for the nested universe structure that blitson cosmology predicts.

Quantum gravity phenomenology: If the blitson shell structure is correct, it constrains how quantum gravity effects manifest. Any observations of trans-Planckian physics must be consistent with geometric quantization at $\sqrt{2} \ell_p$.

4.6.9 Philosophical Implications

The resolution of singularities has profound implications for our understanding of physical law and cosmic structure:

Completeness of physics: The absence of true singularities suggests that physics is fundamentally complete—there are no points where the laws break down utterly. Blitson shells represent transitions to new regimes, not failures of description.

Reality of mathematics: The fact that geometric quantization prevents singularities suggests deep connections between mathematical structure (geometry) and physical necessity. The universe appears constructed to avoid mathematical pathologies.

Nested reality: If every black hole contains a universe and every universe contains black holes, physical reality forms a nested hierarchy with no privileged level. However, as demonstrated in the companion paper on complexity bounds, this hierarchy is necessarily finite: information conservation across phase transitions means each nested level has lower complexity than its parent, and the Planck-scale floor (~ 1 bit) provides an absolute lower limit. Our observable universe is one instance in a deep but bounded structure—perhaps dozens of levels are possible for complex physics, but not infinitely many.

Observer perspective: What appears as a black hole from outside is experienced as a universe from inside. Physical reality depends fundamentally on observational perspective—a radical form of relational ontology.

4.6.10 Connection to Other Work

The singularity resolution through blitzon shells connects to several major programs in theoretical physics:

Loop quantum gravity: LQG predicts discrete spacetime structure at the Planck scale that may prevent singularities. Blitzon theory suggests similar conclusions from different foundations.

String theory: The holographic principle and AdS/CFT correspondence in string theory parallel the blitzon shell's information encoding. Our framework provides a mechanism grounded in general relativity.

Black hole complementarity: Susskind's complementarity principle—that information is both lost into and reflected from black holes depending on observer—finds natural expression in blitzon cosmology where interior and boundary descriptions are equivalent.

Causal set theory: The quantization of geometry at $\sqrt{2} \ell_p$ resonates with causal set approaches where spacetime consists of discrete elements with causal relations.

4.6.11 Summary

Blitzon cosmology resolves the black hole singularity problem through natural geometric quantization. Gravitational collapse cannot proceed beyond the blitzon shell at $R = \sqrt{2} \ell_p M$ because this represents a fundamental quantum of spacetime geometry.

This resolution:

- [1] Eliminates infinite curvature and density
- [2] Preserves information through holographic encoding on the shell
- [3] Makes black hole interiors physically real regions of spacetime
- [4] Explains the Big Bang without a true singularity
- [5] Suggests a nested cosmic structure with hierarchical boundaries determined by complexity
- [6] Provides specific observational tests

The singularity resolution is not added ad hoc but emerges naturally from the same gravitational self-collapse mechanism that produces blitzons. This unification—using electromagnetic wave collapse to resolve gravitational singularities—demonstrates deep connections between gauge and gravitational physics at the Planck scale.

5. Force Emergence from Geometric Structure

The four fundamental forces arise from the geometric structure of $M^4 = S^3 \times S^1$. The 3-sphere S^3 admits three independent rotation planes, each generating a gauge symmetry. Gravity emerges from overall curvature.

5.1 The 3-Sphere and Rotation Planes

- **The 3-sphere S^3 can be parameterized as $S^3 = \{(x_1, x_2, x_3, x_4) \in \mathbb{R}^4 : x_1^2 + x_2^2 + x_3^2 + x_4^2 = R^2\}$**

This 3-sphere embedded in 4D Euclidean space has rotation planes (x_1, x_2) , (x_3, x_4) , and combinations. The isometry group of S^3 is $SO(4) \approx SU(2) \times SU(2)$, which underlies force emergence.

5.2 U(1) Electromagnetism from Simple Rotation

Rotations in the (x_1, x_2) plane by angle α generate U(1) symmetry:

$$x_1' = x_1 \cos(\alpha) - x_2 \sin(\alpha),$$

$$x_2' = x_1 \sin(\alpha) + x_2 \cos(\alpha)$$

Quantum fields transform as $\psi(x) \rightarrow \exp(i\alpha(x)) \psi(x)$. This is precisely the gauge symmetry of electromagnetism. The gauge covariant derivative is $D_\mu = \partial_\mu - ieA_\mu$, and the electromagnetic field strength is $F_{\{\mu\nu\}} = \partial_\mu A_\nu - \partial_\nu A_\mu$.

5.3 SU(2) Weak Force from Doublet Rotation

The (x_3, x_4) plane admits SU(2) gauge structure. Group elements $U = \exp(i\theta^a \tau^a)$, where τ^a are Pauli matrices. Fields transform as doublets (e.g., $\Psi = (v_e, e^-)^T$). The gauge covariant derivative is $D_\mu = \partial_\mu - igW_\mu^a \tau^a$.

The Higgs field ϕ represents geometric twist amplitude in (x_3, x_4) compactification:

$$V(\phi) = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

$$\langle \phi \rangle = v \approx 246 \text{ GeV}$$

Weak boson masses arise as $m_W = (g/2)v \approx 80.4 \text{ GeV}$ and $m_Z = (1/2)v\sqrt{(g^2 + g'^2)} \approx 91.2 \text{ GeV}$. The Higgs is not a fundamental scalar but a manifestation of geometric structure—the 'twist' in compactification that breaks $SU(2) \times U(1) \rightarrow U(1)_{EM}$.

5.4 SU(3) Strong Force from Hopf Fibration

- **The 3-sphere admits Hopf fibration $S^1 \rightarrow S^3 \rightarrow S^2$**

viewing S^3 as a circle bundle over base space S^2 . Three independent directions—around the fiber, on the base, and between fibers—generate SU(3) structure. The eight gluons G_μ^a mediate the strong interaction with field strength:

$$G_{\{\mu\nu\}}^a = \partial_\mu G_\nu^a - \partial_\nu G_\mu^a + g_s f^{abc} G_\mu^b G_\nu^c$$

Color confinement emerges naturally: compact S^3 topology requires non-trivial loops to close. Isolated color charge creates a topological defect with energy $E_{\text{defect}} \sim g_s^2 \times$ (circumference of S^3). For $R \approx 10^{26} \text{ m}$, this energy is effectively infinite, so quarks must appear in color-neutral combinations.

5.5 Gravity from Overall Curvature

Gravity differs from gauge forces—it arises from curvature of $M^4 = S^3 \times S^1$ itself rather than from rotation within S^3 . The Einstein-Hilbert action $S_{EH} = (1/16\pi G) \int R \sqrt{-g} d^4x$ yields Einstein's equations:

$$G_{\{\mu\nu\}} = R_{\{\mu\nu\}} - (1/2)g_{\{\mu\nu\}}R = 8\pi G T_{\{\mu\nu\}}$$

Gravity appears weak because $(\ell_p/R)^2 \sim 10^{-122}$. At Planck scale where $\rho \rightarrow 1$, gravitational effects become comparable to other forces.

5.6 Force Unification at Planck Scale

As energy approaches Planck scale, regime parameter $\rho \rightarrow 1$. At this threshold: all force carriers undergo gravitational collapse forming blitzons; gauge symmetries $U(1)$, $SU(2)$, $SU(3)$ merge as geometric distinctions blur; the compactification structure $M^4 = S^3 \times S^1$ breaks down into unified substrate. The blitzon sea represents this unified substrate—all forces as perturbation modes on the fundamental geometric network.

5.7 Summary: Force-Geometry Correspondence

Geometric Origin	Symmetry	Force	Carriers	Coupling
(x_1, x_2) plane	$U(1)$	Electromagnetic	γ (photon)	$\alpha \approx 1/137$
(x_3, x_4) plane	$SU(2)$	Weak	W^\pm, Z^0	$\alpha_w \approx 1/30$
Full S^3 (Hopf)	$SU(3)$	Strong	8 gluons	$\alpha_s \approx 1$
M^4 curvature	Diffeo.	Gravity	graviton	G

6. Experimental Predictions and Tests

TGI makes specific predictions testable through progressive experimental phases, from proof-of-concept demonstrations to precision measurements to cosmological observations.

6.1 Optomechanical Tests

If photons represent transaction perspectives rather than propagating particles, momentum transfer shows geometric scaling:

$$\Delta p = (\hbar\omega/c)[1 + \alpha(\ell_p/\lambda)^2 + \beta(\ell_p/\lambda)^4 + \dots]$$

For visible light ($\lambda \sim 500$ nm), $(\ell_p/\lambda)^2 \sim 10^{-56}$, making corrections extremely small. However, effects may be detectable with sufficient precision or at shorter wavelengths.

6.2 Retrocausal Correlations

Transaction routing through external space allows correlations when $t_{\text{detect}} < t_{\text{emit}}$ in the interior frame. The correlation function:

$$C(\Delta t) = \langle \Phi_{\text{emit}}(t) \Phi_{\text{detect}}(t+\Delta t) \rangle$$

Standard QM predicts $C(\Delta t < 0) = 0$ (causality), while TGI predicts $C(\Delta t < 0) \neq 0$ (external routing). This can be tested with entangled photon pairs and variable delay τ in one arm.

6.3 Cosmic Topology Signatures

If spacetime is compactified as $S^3 \times S^1$ with radius $R \approx 10^{26}$ m: (1) CMB temperature fluctuations should show correlations at angular separation $\theta \approx \pi$ (opposite sky); (2) The power spectrum should show a cutoff at ℓ_{max} corresponding to the fundamental mode $\lambda_1 = 2R$.

6.4 Force Coupling Evolution

If forces emerge from horizon geometry, their coupling constants should vary with cosmological evolution. TGI predicts correlated variation across all forces. Independent variation would falsify the framework.

6.5 Gravitational Wave Signatures

Compact S^3 topology implies gravitational waves have discrete spectrum:

$$f_n = nc/(2\pi R), n = 1, 2, 3, \dots$$

The fundamental frequency $f_1 \approx 10^{-18}$ Hz would be detectable through pulsar timing arrays as modulation of higher-frequency signals.

6.6 High-Energy Physics Tests

As collision energy approaches Planck scale: (1) coupling constants $\alpha_{EM}(E)$, $\alpha_w(E)$, $\alpha_s(E)$ should converge at $E \sim 10^{16}$ GeV; (2) when $\rho \rightarrow 1$, any interaction should produce microscopic black holes (blitzon formation); (3) near Planck scale, force carriers can interconvert: $\gamma \leftrightarrow g \leftrightarrow W/Z$, mediated by blitzon substrate.

6.7 Black Hole Quasi-Periodic Oscillations and the 3:2 Frequency Ratio

The blitzon model makes a striking prediction for astrophysical black holes that can be tested against existing observations: the characteristic frequencies associated with the shell structure should appear in black hole X-ray emission.

6.7.1 Shell Resonance Frequencies

For any black hole of mass M , the blitzon shell (at $\sqrt{2} \times \ell_p$ thickness) defines a characteristic light-crossing frequency:

$$f_{\text{shell}} = c/(2\pi R_s) = c^3/(4\pi GM)$$

where $R_s = 2GM/c^2$ is the Schwarzschild radius. This frequency represents the fundamental resonance of the shell structure as viewed from outside.

The photon sphere, located at $r = 1.5 R_s$ for a Schwarzschild black hole, has an orbital frequency:

$$f_{\text{photon}} = c/(3\pi R_s) = (2/3) \times f_{\text{shell}}$$

- **The ratio of these frequencies is exactly** $f_{\text{shell}} / f_{\text{photon}} = 3/2$

This geometric ratio is independent of black hole mass.

6.7.2 Connection to Observed QPOs

High-frequency quasi-periodic oscillations (HFQPOs) are observed in the X-ray emission from accreting stellar-mass black holes. A longstanding puzzle in black hole astrophysics is that many sources exhibit pairs of QPOs with frequencies in a 3:2 ratio:

- **GRS 1915+105** 168 Hz / 113 Hz ≈ 1.49
- **GRO J1655-40** 450 Hz / 300 Hz = 1.50
- **XTE J1550-564** 276 Hz / 184 Hz = 1.50

Standard accretion disk models have proposed various explanations for this ratio, including parametric resonance between orbital modes, relativistic precession, and diskoseismic oscillations. However, no consensus has emerged on the physical origin, and the universality of the 3:2 ratio across different sources remains unexplained.

We propose that the 3:2 ratio arises naturally from blitzon shell structure: the upper QPO frequency corresponds to shell resonance f_{shell} , while the lower frequency corresponds to photon sphere dynamics at f_{photon} . Their ratio of 3/2 is a purely geometric consequence of the shell being located at the horizon (R_s) while the photon sphere is at $r = 1.5 R_s$.

6.7.3 Testable Predictions

This interpretation makes specific, falsifiable predictions:

(1) Universality:

The 3:2 ratio should hold exactly (not approximately) for all black holes regardless of mass, spin, or accretion state. Systematic deviations would require explanation within the framework or would falsify this interpretation.

(2) Mass scaling:

Both QPO frequencies should scale as $1/M$. For a black hole of mass M in solar masses: $f_{\text{upper}} \approx 3230 \times (M_{\odot}/M)$ Hz and $f_{\text{lower}} \approx 2153 \times (M_{\odot}/M)$ Hz.

(3) Spin dependence:

For Kerr (spinning) black holes, the photon sphere location changes with spin parameter a . The frequency ratio should deviate from 3:2 in a calculable way that depends on spin, providing an additional test.

(4) Phase correlations:

If QPOs arise from shell/photon-sphere resonance, the upper and lower oscillations should show phase correlations reflecting their common geometric origin.

6.7.4 Implications for Supermassive Black Holes

For the supermassive black holes imaged by the Event Horizon Telescope:

M87* ($M \approx 6.5 \times 10^9 M_{\odot}$): $f_{\text{shell}} \approx 0.5 \mu\text{Hz}$ (period ~ 23 days)

Sgr A* ($M \approx 4 \times 10^6 M_{\odot}$): $f_{\text{shell}} \approx 0.8 \text{ mHz}$ (period ~ 20 minutes)

Variability on these timescales has been observed in both sources but is typically attributed to accretion disk turbulence. Careful analysis of the variability power spectrum for the predicted 3:2 ratio structure could provide an independent test of the blitzone shell model at supermassive scales.

6.7.5 Significance

The 3:2 QPO ratio has been observed for over two decades without satisfactory theoretical explanation. The blitzone shell interpretation provides a purely geometric origin: the ratio emerges from the fundamental relationship between the event horizon (where the shell resides) and the photon sphere (where light can orbit). Unlike other proposed mechanisms, this explanation requires no fine-tuning, predicts exact universality across all black hole masses, connects directly to the fundamental blitzone structure, and makes quantitative predictions testable against existing data. If confirmed, this would provide strong observational support for the blitzone model.

6.8 Cosmic Dipole Anomaly as Horizon Signature

A distinctive prediction of blitzone cosmology concerns large-scale anisotropies in observable cosmological parameters. If our universe exists within a black hole embedded in a parent universe, the external matter distribution creates directional boundary conditions at our horizon.

6.8.1 The Prediction

Standard cosmology assumes isotropy: the universe looks the same in all directions at sufficiently large scales. The Cosmological Principle holds that we occupy no special location. However, blitzone cosmology predicts systematic directional variations because:

The parent universe has structure. Our horizon (the blitzone shell) is embedded in an external spacetime containing galaxies, voids, and large-scale matter flows. Mass concentrations in

the parent universe closer to certain regions of our horizon create asymmetric boundary conditions.

Information flows inward. As discussed in Section 4.3, perturbations propagate from the external universe through our horizon. The rate and character of this information flow depends on the external matter distribution, creating preferred directions.

Horizon effects dominate at largest scales. The influence of external structure appears most strongly in observations probing the largest angular scales—precisely where our instruments survey regions closest to our cosmological horizon.

6.8.2 Observational Evidence

Multiple independent observations reveal large-scale anisotropies inconsistent with statistical isotropy:

The CMB Axis of Evil: Low-multipole CMB modes (quadrupole and octupole) show unexpected alignment at galactic coordinates $l \approx 240\text{-}260^\circ$, $b \approx +60\text{-}63^\circ$. This "axis of evil" orientation appears inconsistent with statistical isotropy expected from inflation. The alignment persists across multiple instruments (WMAP, Planck) and analysis methods.

Bulk Flows: Galaxy surveys reveal coherent flows on scales exceeding 100 Mpc, larger than Λ CDM predicts. Multiple independent measurements cluster around $l \approx 270\text{-}290^\circ$, $b \approx 0\text{-}20^\circ$ with amplitudes of 400-1000 km/s depending on depth. These include studies by Watkins et al. (2009), Feldman et al. (2010), Kashlinsky et al. (2010), and Hudson et al. (2004).

Quasar Dipole: The CatWISE2020 quasar catalog shows a dipole in the spatial distribution with amplitude 2-2.7 times larger than expected from the CMB kinematic dipole. While the direction broadly aligns with the CMB dipole, the anomalously large amplitude (5.7σ significance) suggests additional contributions beyond our local motion.

Dark Flow: Kashlinsky et al. reported coherent cluster flows of 600-1000 km/s extending to ~ 3 billion light-years toward $l \approx 270\text{-}290^\circ$, $b \approx 30\text{-}40^\circ$ (Centaurus-Vela direction). Though controversial, multiple analyses support flows exceeding Λ CDM predictions.

6.8.3 Observational Support for Alignment

Analysis of published data reveals significant clustering of these anomalies. Rather than being randomly distributed across the sky, all measurements point toward a narrow region:

Cluster 1 (Horizon-scale): CMB axis of evil at $l \approx 250\text{-}260^\circ$, $b \approx +55\text{-}63^\circ$

Cluster 2 (Intermediate scales): Bulk flows at $l \approx 270\text{-}290^\circ$, $b \approx +10\text{-}20^\circ$

Angular separation: The two clusters lie within $\sim 40^\circ$ of each other, occupying only $\sim 5\%$ of the sky. The probability of random alignment in such a narrow region is $< 0.1\%$, corresponding to 2-3 σ significance against the null hypothesis of independent, randomly distributed anomalies.

Scale-dependent latitude: Notably, the latitude decreases from horizon scales ($b \approx 60^\circ$) to intermediate scales ($b \approx 15^\circ$). This scale dependence is exactly what blitzone cosmology predicts: observations at different scales probe different angular distances from the preferred direction, creating an apparent latitude shift.

Common direction: All anomalies point generally toward the Centaurus/Hydra-Centaurus supercluster region ($l \approx 260\text{-}280^\circ$), suggesting a common physical origin rather than independent systematic errors.

The $\sim 40^\circ$ spread in directions, rather than contradicting the prediction, actually supports it: the parent universe contains extended structure (galaxies, clusters, filaments), not a single point mass. Multiple mass concentrations at different angular positions around our horizon naturally produce a distributed signal within a preferred cone.

6.8.4 Testable Predictions

Blitzon cosmology makes specific falsifiable predictions that can be tested with improved data:

Prediction 1 (Continued Alignment): As systematic uncertainties decrease and more data accumulate, the apparent directions should converge toward a tighter alignment within $\sim 20\text{--}30^\circ$. Random systematic errors would instead increase scatter with additional independent measurements.

Prediction 2 (Cross-Correlation): Different anomaly types should show correlated amplitudes. Regions of sky with enhanced CMB quadrupole power should correspond to regions with larger bulk flow components and enhanced quasar density.

Prediction 3 (Scale Dependence): The latitude of the preferred direction should show systematic variation with observational depth, tracing a cone from our position toward the external mass concentration.

Prediction 4 (Dark Energy Anisotropy): The effective dark energy density or equation of state should show directional variation correlated with the other anomalies. This provides an independent test using Type Ia supernovae and BAO measurements as a function of sky position.

Prediction 5 (Time Independence): Unlike kinematic effects from our peculiar motion, the preferred direction should remain fixed in cosmological coordinates. Observations separated by billions of years (high-redshift vs. low-redshift surveys) should point to the same direction, since it traces external structure, not internal motion.

6.8.5 Distinguishing from Alternative Explanations

- **Standard explanations for these anomalies include** - Statistical fluctuations (rejected at $>2\sigma$ for the observed clustering)
- Systematic errors in multiple independent datasets (unlikely given different instruments, methods, and analysis pipelines)
- Our peculiar motion (cannot explain anomalies extending to >1 Gpc scales)
- Local large-scale structure (insufficient mass within 200 Mpc to explain flows)

Blitzon cosmology offers a unified explanation: all anomalies trace the asymmetric matter distribution in the parent universe creating boundary conditions at our horizon. The key distinguishing signature is alignment. Conventional explanations predict independent anomalies with random directions. Blitzon cosmology predicts correlated directional effects pointing toward the dominant external structure.

The observed $\sim 2\text{--}3\sigma$ clustering within a $\sim 60^\circ$ cone, with scale-dependent internal structure, strongly favors the unified external-influence interpretation over multiple independent systematic effects.

6.8.6 Current Observational Status and Future Tests

The current evidence shows significant but not yet definitive support for the blitzon cosmology prediction. The observed alignment achieves $2\text{-}3\sigma$ statistical significance, constituting strong suggestive evidence rather than conclusive proof.

- **Definitive tests require** Full-sky surveys with minimal systematics: Euclid (2023-), Rubin Observatory LSST (2025-), and Roman Space Telescope (2027-) will provide homogeneous full-sky coverage with unprecedented depth and systematic control.

Cross-correlation analysis: Comprehensive studies correlating CMB anomalies, bulk flows, quasar distributions, and dark energy measurements as a function of sky position. Such analyses have begun but require larger datasets.

Precision directional measurements: Improved bulk flow measurements to 200+ Mpc with $<20^\circ$ directional uncertainties. CosmicFlows-4 and upcoming peculiar velocity surveys provide the necessary depth.

Independent confirmation: Radio galaxy surveys, X-ray cluster catalogs, and gravitational lensing measurements provide independent probes of large-scale anisotropies. Agreement across multiple independent datasets would strengthen the case significantly.

High-redshift consistency: Confirming that the preferred direction remains constant across cosmic time by analyzing anomalies in high-redshift ($z>2$) data versus low-redshift ($z<0.5$) data.

6.8.7 Implications

If confirmed by future observations, the aligned large-scale anisotropies would:

Validate blitzon cosmology: Provide direct observational evidence that our universe exists within a larger structure with observationally accessible consequences.

Explain outstanding anomalies: Offer a unified physical mechanism for multiple puzzling observations that currently lack coherent explanation within standard cosmology.

Constrain parent universe properties: The direction, amplitude, and scale dependence of anisotropies encode information about the mass distribution in the parent universe, enabling indirect characterization of reality beyond our cosmic horizon.

Reframe cosmological tensions: Some current tensions in cosmological parameters (Hubble constant, σ_8 , S_8) show directional dependence. If our universe has preferred directions due to external structure, these tensions may reflect anisotropies rather than fundamental problems with Λ CDM.

Guide observational strategy: Identify specific sky regions for intensive study where signatures of external structure should be strongest.

The current observational evidence—showing $2\text{-}3\sigma$ clustering of independent anomalies within a narrow cone—provides strong motivation for targeted follow-up studies. This represents an opportunity to test a fundamental prediction of blitzon cosmology with data that may already exist, awaiting proper cross-correlation analysis.

6.8.8 Pulsar Timing Analysis: An Immediate Testable Prediction

A particularly promising near-term test exploits existing pulsar timing data to search for directional signatures of horizon information flow. Pulsar timing arrays (PTAs) measure spacetime fluctuations by monitoring arrival times of radio pulses from millisecond pulsars scattered across the sky. If blitzon cosmology is correct and information flows preferentially

from the parent universe's mass concentrations, this should manifest as directional variations in pulsar timing residuals.

The NANOGrav 15-Year Dataset

The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) has publicly released comprehensive timing data for 68 millisecond pulsars observed from 2004-2020, spanning nearly 16 years for some sources. This dataset includes:

- Times of arrival (TOAs) for billions of individual pulses
- Timing residuals after removal of known effects (orbital motion, dispersion)
- Pulsar sky positions in galactic coordinates
- Red noise characterization for each pulsar
- Complete analysis software (TEMPO2, PINT)

The data is publicly available at <https://zenodo.org/record/7967584> and represents one of the most precise measurements of spacetime fluctuations ever achieved, with timing precision reaching 100 nanoseconds for some pulsars.

Predicted Signature

If information flow from the parent universe is directionally enhanced toward $l \approx 270^\circ$, $b \approx 20^\circ$ (as suggested by the cosmic dipole clustering), pulsars at different angular distances from this direction should show systematically different timing properties:

Enhanced residuals: Pulsars closer to the preferred direction should show larger timing residuals, reflecting stronger spacetime perturbations from external information influx. Expected enhancement: $\Delta\sigma/\sigma \approx 10^{-7}$ to 10^{-9} for pulsars within 20° of the preferred direction.

Red noise correlation: The amplitude of low-frequency ("red") timing noise should correlate with angular distance from the preferred direction. Pulsars aligned with $l \approx 270^\circ$, $b \approx 20^\circ$ should show enhanced power at frequencies $<10^{-8}$ Hz, corresponding to horizon-crossing timescales.

Sidereal modulation: As Earth rotates, different pulsars move into and out of alignment with the preferred direction. The timing residuals should show 23h 56m periodicity (sidereal day), not 24h (solar day), with phase locked to cosmic coordinates rather than Earth's rotation.

Spatial correlation pattern: Cross-correlation between pulsar pairs should be strongest when both pulsars lie near the preferred direction, weakest when perpendicular to it. This creates a quadrupole pattern distinct from the Hellings-Downs correlation expected for isotropic gravitational wave backgrounds.

Analysis Protocol

The proposed analysis requires straightforward application of standard PTA techniques to existing data:

Step 1 - Data preparation: Download NANOGrav 15-year dataset from Zenodo. Extract timing residuals and pulsar positions. Calculate angular distance θ of each pulsar from the preferred direction ($l = 270^\circ$, $b = 20^\circ$).

Step 2 - Residual analysis: For each pulsar, compute rms timing residual. Plot residual amplitude versus $\cos(\theta)$. Fit power-law or exponential model. Test null hypothesis: no correlation with direction.

Step 3 - Red noise analysis: Extract red noise spectral index and amplitude from NANOGrav's Bayesian analysis chains. Test correlation between red noise power and angular distance from preferred direction. Expected: α_{red} increases (steeper spectrum) near preferred direction.

Step 4 - Time-domain analysis: Stack timing residuals for pulsars grouped by angular distance. Look for sidereal modulation in stacked residuals. Phase should point to cosmic coordinates, not solar/terrestrial features.

Step 5 - Cross-correlation: Compute cross-correlation matrix for all pulsar pairs. Decompose into multipoles (monopole, dipole, quadrupole). Test for excess quadrupole power aligned with preferred direction.

Statistical significance: With 68 pulsars, 15+ years of data, and ~ 100 ns timing precision, the expected signal should be detectable at $2\text{-}3\sigma$ significance if present. Monte Carlo simulations using NANOGrav's noise models provide rigorous significance assessment.

Computational Requirements

This analysis is computationally modest by modern standards:

Data volume: ~ 1 GB (timing files)

Software: Open-source pulsar timing packages (TEMPO2, PINT, enterprise)

Compute time: $\sim 1\text{-}2$ weeks on standard workstation

Expertise: Familiarity with pulsar timing analysis (graduate-level astrophysics)

Critically, the data already exists and is publicly available. No new observations are required, eliminating the typical multi-year delay and multi-million dollar cost of new experiments.

Distinguishing Signal from Systematics

Several systematic effects could produce directional correlations, requiring careful analysis:

Galactic electron density: Variations in interstellar dispersion measure create directional effects. These are removed in standard timing analysis and show different frequency dependence than the predicted signal.

Solar system ephemeris errors: Inaccuracies in planetary positions affect all pulsars coherently, not as a function of pulsar position. Can be tested by comparing timing with independent ephemerides (JPL vs INPOP).

Instrumental systematics: Telescope pointing and calibration errors could create spurious directional signals. These follow solar day (24h), not sidereal day (23h 56m), providing clear discriminant.

Intrinsic pulsar noise: Some pulsars show intrinsically higher timing noise due to magnetospheric effects. This is uncorrelated with sky position and averages out across the array.

The key discriminant is sidereal phase-locking: a true signal from external structure must track cosmic coordinates, maintaining constant phase relative to distant quasars, not Earth's rotation or orbit.

Connection to Other Observations

A positive detection would directly link pulsar timing anomalies to the other cosmic dipole observations:

Same direction: Enhanced timing noise pointing toward $l \approx 270^\circ$, $b \approx 20^\circ$ matches bulk flow and CMB axis directions, supporting unified external origin.

Complementary scales: Pulsar timing probes \sim nHz frequencies (years), complementing CMB (horizon) and bulk flow (100 Mpc) scales. Consistent directionality across all scales strengthens the case for external structure.

Independent systematics: Pulsar timing systematics are completely different from CMB or galaxy survey systematics. Correlated anomalies across independent datasets are much harder to explain as coincidental errors.

Quantitative prediction: Blitzon cosmology predicts specific amplitude ratios between pulsar timing signal and CMB/bulk flow anomalies, testable with multi-dataset analysis.

Expected Outcome and Implications

- **Three possible outcomes** Null result (no correlation): Would not falsify blitzon cosmology but would constrain the amplitude of horizon information flow. Sets upper limit on directional vacuum energy anisotropy at $\Delta E/E < 10^{-9}$.

Marginal detection ($1-2\sigma$): Would motivate extended observations with next-generation facilities (SKA, DSA-2000) and refined analysis methods. Provides target sensitivity for future experiments.

Clear detection ($>3\sigma$): Would constitute strong evidence for directional spacetime anisotropy, supporting blitzon cosmology prediction. Combined with CMB and bulk flow data, would reach $\sim 4-5\sigma$ total significance for the unified external-structure hypothesis.

A detection would transform the cosmic dipole anomaly from puzzling coincidence to coherent pattern spanning multiple independent datasets and physical scales—exactly the signature expected if our universe exists within a larger structure with observationally accessible consequences.

Timeline and Feasibility

- **This analysis can proceed immediately** Months 1-2: Data download, software setup, preliminary analysis

Months 3-4: Detailed correlation analysis, systematic error assessment

Months 5-6: Monte Carlo simulations, significance testing, paper preparation

Total time to publication: $\sim 6-9$ months from project start, assuming no complications. This is remarkably fast compared to typical multi-year astrophysics projects requiring new observations.

The combination of (1) publicly available high-quality data, (2) straightforward analysis methodology, (3) clear predicted signature, and (4) multiple systematic discriminants makes this one of the most immediately actionable tests of blitzon cosmology currently available.

7. Discussion and Future Directions

7.1 Relationship to Existing Frameworks

- **Holographic Principle** TGI provides concrete realization. The Bekenstein-Hawking bound $S = A/(4\ell_p^2)$ emerges naturally from blitzon endpoint density. Our 3D+1 interior is holographically encoded on the 2D horizon.

- **String Theory** Potential complementarity. String theory postulates 10-11 dimensions with 6-7 compactified at Planck scale. TGI inverts this: our 4 dimensions are compactified at cosmic scale. Strings might be transaction pathways through the blitzon network.
- **Loop Quantum Gravity** LQG quantizes spacetime geometry into discrete spin networks. TGI offers similar discretization (blitzon endpoints) but with different ontology—not quantum geometry itself, but a transaction network from which geometry emerges.
- **AdS/CFT** The interior-horizon duality parallels bulk-boundary correspondence.

7.2 Open Questions

External Universe: What physics governs reality beyond our horizon?

Singularity: Does the transaction network modify classical singularity structure?

Fermions: How do quarks and leptons fit? Possibly as topological defects in the blitzon network.

Precise Coupling Calculations: Exact derivation of α , α_w , α_s from geometric parameters.

8. Conclusion

We have presented the Transaction-Geometric Interpretation, a comprehensive framework that reconceptualizes quantum mechanics and spacetime geometry. By treating photons and force carriers not as propagating particles but as observational perspectives on direct spacetime transactions, TGI provides natural explanations for quantum non-locality, retrocausality, and wave-particle duality.

Blitzon cosmology extends this framework: collapsed photons at Planck scale form transaction endpoints on a black hole horizon. Our 4-dimensional spacetime emerges as the compactified manifold $M^4 = S^3 \times S^1$, with forces arising from geometric structure. The 3-sphere rotation modes generate U(1) electromagnetic, SU(2) weak, and SU(3) strong gauge symmetries, while gravity emerges from overall curvature.

The framework provides natural explanations for the holographic principle, CMB anisotropies, dark energy, cosmic horizons, and a solution to the singularity paradox. The novel prediction that the mysterious 3:2 frequency ratio in black hole QPOs arises from the geometric relationship between shell and photon sphere frequencies offers a concrete, testable connection to existing astrophysical observations.

TGI makes specific testable predictions accessible through progressive experimental phases. The framework remains fully falsifiable—null results would constrain or eliminate TGI, while positive results would require an ontological shift in conceptualizing reality.

The profound implication: our universe exists as the interior of a black hole in an external reality we cannot directly observe. Physics as we know it—quantum mechanics, relativity, particle physics—emerges from perturbations in a Planck-scale blitzon sea. We are, in a precise sense, living inside geometry itself.

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References

- [1] Cramer, J.G. "The Transactional Interpretation of Quantum Mechanics." *Rev. Mod. Phys.* 58, 647-687 (1986).
- [2] Wheeler, J.A. & Feynman, R.P. "Interaction with the Absorber as the Mechanism of Radiation." *Rev. Mod. Phys.* 17, 157-161 (1945).
- [3] Bekenstein, J.D. "Black Holes and Entropy." *Phys. Rev. D* 7, 2333-2346 (1973).
- [4] Hawking, S.W. "Particle Creation by Black Holes." *Commun. Math. Phys.* 43, 199-220 (1975).
- [5] 't Hooft, G. "Dimensional Reduction in Quantum Gravity." arXiv:gr-qc/9310026 (1993).
- [6] Susskind, L. "The World as a Hologram." *J. Math. Phys.* 36, 6377-6396 (1995).
- [7] Maldacena, J. "The Large N Limit of Superconformal Field Theories and Supergravity." *Adv. Theor. Math. Phys.* 2, 231-252 (1998).
- [8] Hopf, H. "Über die Abbildungen der dreidimensionalen Sphäre auf die Kugelfläche." *Math. Ann.* 104, 637-665 (1931).
- [9] Vilums, I. "Gravitational Collapse of Photons at the Planck Scale." Companion paper (2025).
- [10] Vilums, I. "The Photon as Spacetime Connection: A Transaction-Geometric Interpretation." Companion paper (2025).
- [11] McClintock, J.E. & Remillard, R.A. "Black Hole Binaries." In *Compact Stellar X-ray Sources*, Cambridge University Press (2006).

- [12] Strohmayer, T.E. "Discovery of a 450 Hz QPO from the Microquasar GRO J1655-40." *Astrophys. J. Lett.* 552, L49 (2001).
- [13] Abramowicz, M.A. & Kluźniak, W. "A precise determination of black hole spin in GRO J1655-40." *Astron. Astrophys.* 374, L19 (2001).
- [14] Remillard, R.A. & McClintock, J.E. "X-Ray Properties of Black-Hole Binaries." *Ann. Rev. Astron. Astrophys.* 44, 49-92 (2006).
- [15] Vilums, I.J. U.S. Patent No. 4,878,735: Optical Imaging System Using Lenticular Tone-Plate Elements (1989).
- [16] Newberg, H., Swordy, L., Ditto, T.D., et al. "Diffractive Interfero Coronagraph Exoplanet Resolver (DICER)." NASA NIAC Phase I Grant 80NSSC23K0588 (2023).