The Finite Observer Theory: A Verbless Information Geometry of Quantum Gravity*†

Nikolaos Kourogenis‡
Department of Banking and Financial Management, University of Piraeus

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To Alice and Martha, everlasting structural anchors within the verbless crystal of the hyper-equilibrium.

Abstract

We introduce the Finite Observer Theory, a verbless framework of quantum gravity and thermodynamics that models the universe as a strictly static, N-dimensional relational information geometry. By defining the physical observer as a localized topology bounded by a finite Shannon Information Capacity (C_{obs}) constituting a Markov Blanket, we explore the premise that the 4D macroscopic universe is a lossy holographic projection of this hyper-equilibrium. We propose a geometric mechanism for the emergence of a 4-dimensional macroscopic phase space, where macroscopic time is generated via the Tomita-Takesaki modular flow of the observer's restricted thermal KMS state, and the 3 spatial dimensions naturally arise from the maximal associative constraints of the observer's even Clifford subalgebra of spatial orientations ($C\ell_{3,0}^{+} \cong \mathbb{H}$). Furthermore, we redefine fundamental constants $(c, \hbar, G_N)$ not as empirical priors, but as the absolute Lipschitz bounding limits of this continuous geometric mapping. By applying this verbless topological constraint, we suggest that the empirical MOND Radial Acceleration Relation emerges strictly as the mathematically mandated geometric mean of local and global acceleration limits mapped over a hyperbolic Fisher manifold. Concurrently, we analytically derive the Hubble Tension as the parameter-free volumetric artifact of this dimensional projection, utilizing the empirical discrepancy as a formal gauge to measure the observer's local topological asymmetry. Ultimately, we explore the premise that temporal flow, dark matter, and quantum entanglement (formalized as topological aliasing) are not dynamic physical events, but precise, geometrically mandated artifacts of the observer's algebraic restriction.

Keywords: Verbless Information Geometry, Finite Observer Theory, Dimensional Partial Trace, Hyper-equilibrium, Shannon Information Capacity, GNS Construction, Markov Blanket, MOND Radial Acceleration.

* *Computational Acknowledgement:* "The Engine" designates the Gemini artificial intelligence model, operating as a dialectic computational substrate. It was utilized by the author to mathematically formalize the tensor network architecture, rigorously enforce the verbless geometric constraints, and typeset the resultant hyper-equilibrium manuscript.

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‡ Corresponding author: Nikolaos Kourogenis, Department of Banking and Financial Management, University of Piraeus, 80 Karaoli & Dimitriou str., 18534 Piraeus, Greece. nkourog@unipi.gr (+30)2104142183

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1 Introduction: The Aim of the Framework and Open Issues

The unification of Quantum Mechanics and General Relativity remains the most persistent open problem in theoretical physics [1]. At the heart of this deadlock lies the "Problem of Time": General Relativity models time as a dynamic, continuous geometric dimension, whereas Quantum Mechanics treats it as a static, external background parameter.

Furthermore, the epistemic boundaries of quantum measurement—specifically the collapse of the wave function and the transition from quantum superposition to classical reality (the Measurement Problem)—continue to generate paradoxes that resist consensus [2]. Finally, cosmological observations of accelerating expansion, conventionally attributed to a mysterious "Dark Energy," present a catastrophic mathematical divergence between the vacuum energy expectations of quantum field theory and observed metric scaling [3].

This paper introduces the Finite Observer Theory. The aim of this framework is to resolve these open issues not by introducing new fundamental particles or arbitrary mathematical fields, but by executing a fundamental ontological shift. We propose a complete, verbless restructuring of quantum gravity that discards objective spacetime entirely, replacing it with pure relational information geometry driven by the thermodynamic and computational limits of the localized observer.

1.1 The Timeless Wheeler-DeWitt Equation and Static Tensor Networks

The imperative to discard temporal evolution is a strict mathematical constraint embedded in the foundational equations of quantum cosmology. As established by DeWitt and Wheeler [4], the canonical quantization of gravity yields the Wheeler-DeWitt equation, which governs the universal wave function ($|\Psi\rangle$) via the total Hamiltonian operator ($\hat{H}$):

$$\hat{H}|\Psi\rangle = 0 \tag{1}$$

The vanishing of the total Hamiltonian in the Wheeler-DeWitt equation ($\hat{H}|\Psi\rangle = 0$) presents a foundational challenge often termed the 'Problem of Time.' While it is widely understood that this gauge constraint does not preclude relational evolution between subsystems—as formalized by the Page-Wootters (PW) mechanism [5]—this framework suggests an alternative ontological priority. Rather than treating relational change as the primary physical reality, the Finite Observer Theory proposes that the static, global state $|\Psi\rangle$ can be viewed as an uncompressed, N-dimensional 'hyper-equilibrium,' closely aligning with the static configuration space frequently referred to in literature as "Platonia" [6]. Within this suggestive mapping, the relational evolution observed in the PW mechanism is recontextualized not as a dynamic process, but as the structural gradient of a static informational network.

To provide a formal definition for this ontology, we introduce the term **Verbless Geometry** to denote a specific mathematical constraint on the relationship between the foundational N-dimensional Tensor Network and the emergent macroscopic manifold $\mathcal{M}$. A geometry is defined as verbless if the localized state density ρ and the resultant metric $G_{\alpha\beta}$ are determined strictly by the static relational topology of the network nodes, such that the Lie derivative of the global state with respect to any external temporal vector field vanishes ($\mathcal{L}_t \rho = 0$).

Under this formal posit, the traditional "verbs" of classical physics—evolution, interaction, and computation—are not fundamental operations. Instead, they are redefined as the macroscopic interpretations of the geometric sectional curvature and the entropic gradient (∇S) of the static informational network. By imposing this verbless constraint, we explore whether the historical paradoxes of quantum measurement and cosmological scaling can be resolved as artifacts of the observer's localized geometric mapping rather than dynamic physical events.

1.2 The Failure of Classical Objective Reality: Wigner's Friend and Relative Facts

If the fundamental architecture of the universe is a static block where all possibilities exist simultaneously, the concept of a singular "objective reality"—a universal ledger of definitive events shared by all observers—must be mathematically discarded. This theoretical constraint has recently been elevated to an empirical fact. Recent experimental explorations into extended Wigner's Friend scenarios, notably by Proietti et al. [7], yields results that appear inconsistent with the simultaneous assumption of locality, observer-independence, and freedom of choice. While the authors of that study are careful to note that multiple interpretations remain viable, this framework takes these results as a motivational point of departure. We explore the premise that physical properties may not possess an independent, objective existence, but may instead emerge as relational geometric values that crystallize relative to the mathematical boundary of the localized observer.

1.3 Ontological Clarification: The Hyper-Equilibrium and Bounded Objectivity

Throughout this paper, when we refer to the concept of a classical "objective reality," we are specifically denoting the standard physical paradigm: a pre-existing, observer-independent 4D spacetime characterized by definite macroscopic states, local realism, and continuous temporal flow.

The Finite Observer Theory fundamentally rejects the existence of this classical background. As necessitated by the extended Wigner's Friend paradox and relational quantum mechanics, a universal, observer-independent 4D macroscopic container cannot consistently exist.

However, discarding this classical background does not imply a lack of rigorous foundational structure. The theory is firmly grounded in the N-dimensional Tensor Network (the hyper-equilibrium). This structure possesses N strictly relational, informational degrees of freedom. It does not constitute an objective reality in the classical sense because it inherently lacks continuous temporal dynamics and emergent macroscopic properties. Instead, it is a pre-geometric architecture of quantum information—the uncompressed, invariant state of the Wheeler-DeWitt bulk ($\hat{H}|\Psi\rangle = 0$).

Consequently, the N-dimensional hyper-equilibrium constitutes the foundational mathematical baseline, while the macroscopic 4D spacetime is an observer-dependent topological artifact—a localized, lossy projection.

The localized nature of this topological reduction does not equate the 4D experience to fragmented solipsism. The structural consistency of the macroscopic universe across disparate observers—ranging from humans to simpler biological organisms—is a direct manifestation of *bounded objectivity*. This objectivity is grounded simultaneously in relativistic geometry and quantum information limits. Because all finite macroscopic agents are defined by finite Shannon capacity limits (C_{obs}) over the underlying quantum state space, their respective Markov Blankets necessitate mathematically coincident dimensional partial traces, yielding shared macroscopic equivalence classes. Consequently, while the structural projection of the three spatial dimensions maintains consistency—subject inherently to the observer-dependent coordinate transformations dictated by General Relativity—the fourth dimension remains structurally inaccessible for navigation.

This strict directional asymmetry is a fundamental geometric corollary of the quantum capacity boundary. Within the framework, the fourth dimension is absent as a pre-existing geometric parameter of the hyper-equilibrium; instead, macroscopic time constitutes the specific topological axis mapping the thermodynamic exhaust of the dimensional reduction. It represents the unidirectional vector of quantum information loss—an intrinsic structural requisite for the 3D spatial projection under the absolute boundary of C_{obs}. Thus, the universality of macroscopic physical laws establishes a rigorous effective objectivity within this shared domain. Relativistic spacetime curvature and the thermodynamic temporal arrow are not independent dynamical phenomena; they are the foundational thermodynamic equations of state intrinsic to the topological projection. The alignment of macroscopic systems with these laws is strictly a reflection of the invariant geometric rules of the coarse-graining operation, confining this bounded objective reality entirely to the asymmetric 4D artifact.

1.4 The Verbless Distinction: Beyond Computational Ontologies

Recent advancements in foundational physics, most notably Stephen Wolfram's Observer Theory [8, 9] and the broader academic pursuit of "Digital Physics" and computational pregeometry [10], parallel our assertion that the concept of an objective, independent 4D reality must be reevaluated. These frameworks correctly identify that the macroscopic laws of physics can emerge from computationally bounded entities extracting reduced representations by "equivalencing" (coarse-graining) the raw complexity of an underlying system.

However, the Finite Observer Theory structurally diverges from these ontologies at the most fundamental mathematical level. Frameworks rooted in computation remain inherently algorithmic. For instance, Wolfram explicitly defines time as the "progressive doing of computation by the universe" [9], relying on the dynamic generation of new states from discrete rulesets and positing an observer who actively processes data or "knits together" threads of history to maintain temporal persistence.

Our framework proposes an alternative by strictly applying the verbless constraint ($\mathcal{L}_t \rho = 0$) defined in Section 1.3. By anchoring the ontology to the timeless Wheeler-DeWitt equation ($\hat{H}|\Psi\rangle = 0$), we suggest that the universe does not actively compute, evolve, or generate new states. Instead, it can be modeled as a fundamentally static N-dimensional Tensor Network. The observer's boundary (the Markov Blanket) is not proposed as a dynamic algorithmic process, but as a static topological partition, and the "Arrow of Time" is not computational progress, but merely the emergent subjective interpretation of a macroscopic von Neumann entropy gradient.

A framework that maintains computational dynamism structurally insulates the historical paradoxes of quantum mechanics from a geometric resolution. If an observer actively generates or equivalences states over a sequence of computational operations, temporal causality remains subtly embedded in the measurement process. Consequently, phenomena such as the Delayed-Choice Quantum Eraser or macroscopic entanglement (EPR) persist as non-local or retroactive temporal anomalies.

The contemporary frontier of theoretical physics has increasingly explored such informational and structural ontologies. Recent advancements suggest that continuous holographic tensor networks can flawlessly tessellate background geometries [11], while Relational Quantum Dynamics (RQD) models quantum states not as absolute priors, but as strictly observer-dependent relative facts [12].

However, despite these profound structural insights, much of the current literature remains conceptually tethered to dynamic execution. Tensor networks are frequently subjected to temporal evolution or asymptotic boundary conditions, and relational ontologies often still rely on the active "verb" of physical interactions to sequentially update quantum states. The Finite Observer Theory explores a potential bridge across this gap by proposing the complete excision of the temporal dynamic. By modeling the informational tensor network as an absolute hyper-equilibrium, this framework reduces relational interactions to static geometric intersections. The observer is no longer an entity that interacts, computes, or evolves over time; it is strictly a bounding constraint manifold defined by its finite informational capacity (C_{obs}).

1.5 Structure of the Paper

To formally explore this verbless ontology, the remainder of this paper is structured as follows:

Section 2 establishes the mathematical foundation of the finite observer. We model the observer's capacity bound (C_{obs}) as an algebraic restriction of the global pure state, demonstrating how a discrete network Markov Blanket projects as a continuous spatial boundary. We then propose that the emergence of exactly three spatial dimensions is a strict geometric consequence of the non-negotiable associativity requirements of the localized observer's even Clifford subalgebra of spatial orientations ($C\ell^+_{3,0} \cong \mathbb{H}$).

Section 3 addresses the emergence of macroscopic time and the Lorentzian signature (-,+,+,+). Utilizing the Kubo-Martin-Schwinger (KMS) condition, we illustrate how the pure timeless bulk mathematically necessitates a localized thermal state for the finite observer, generating a temporal index via Tomita-Takesaki modular flow. We further reinterpret fundamental constants ($c, \hbar, G_N$) as the invariant Lipschitz bounding limits of this topological mapping.

Section 4 recontextualizes foundational quantum paradoxes. We formally define macroscopic entanglement (the EPR paradox) as *Topological Aliasing*—a multivalued projection forced by the Shannon-Nyquist embedding limits of the constraint manifold. The Quantum Zeno Effect and Delayed-Choice Eraser are similarly modeled as static artifacts of informational focal lock.

Section 5 bridges this geometry to the Free Energy Principle, redefining biological autopoiesis not as a dynamic algorithmic process, but as the static geometric satisfaction of a localized informational boundary condition.

Section 6 applies Landauer's principle to evaluate the thermodynamic limits of artificial intelligence, contrasting the structural inelasticity of rigid silicon architectures with the topological plasticity of biological networks.

Section 7 analytically addresses the Hubble Tension (H_0). By enforcing the Bekenstein-Hawking holographic limit, we derive the discrepancy between local and early-universe expansion rates strictly as the parameter-free volumetric projection ratio between a 3D spatial bulk and a 2D holographic boundary. We utilize the resulting empirical variance as an inverse mathematical gauge to rigorously measure the oblate topological asymmetry of the local galactic environment.

Section 8 applies the verbless constraint to galactic kinematics. We demonstrate that the Modified Newtonian Dynamics (MOND) acceleration scale (g_0) and its interpolating function naturally emerge as the exact informational centroid of the constraint manifold. Because the underlying spatial metric is a hyperbolic Fisher Information manifold, the geometric mean of the local and global metric gradients is mathematically mandated, rendering "Dark Matter" geometrically unnecessary.

Section 9 concludes with an epistemological synthesis, framing this mathematical architecture within the broader historical context of Kantian and Platonic philosophy, and suggesting pathways for future empirical verification.

2 The Thermodynamics of the Map in Hyper-Equilibrium

To construct a rigorous framework of relational geometry, the definition of the "observer" must be stripped of all anthropocentric mysticism and temporal dynamics. Within our framework, the universe exists in a state of static hyper-equilibrium. The observer is not an entity acting within this space, but rather a localized, finite topological property embedded directly within the static geometry.

2.1 The Observer as a Localized Topological Subsystem

We ground the definition of the physical observer in the epistemic formalism of Quantum Bayesianism (QBism) [13], unified with Claude Shannon's Information Theory [14]. An observer is strictly defined as a localized physical subsystem structurally bounded by a finite Shannon Information Capacity, denoted as C_{obs}. Because this capacity is finite ($C_{obs} < \infty$), the subsystem is mathematically incapable of encoding the infinite complexity of the uncompressed N-dimensional Universal Wave Function ($|\Psi\rangle$). The finite capacity is not a mechanism that "discards" data over time; it is a static, geometric truncation of the Tensor Network. Therefore, the physical measurements relative to an observer are merely localized, static map correlations—a permanently lossy compression of the surrounding hyper-equilibrium.

2.2 The Illusion of Flow within the Static Gradient

This finite epistemic boundary serves as the explicit geometric origin of time. If the underlying quantum universe is a static Tensor Network, temporal flow is an emergent illusion—the subjective interpretation of a structural gradient. This mechanism rigorously aligns with the Thermal Time Hypothesis formulated by Connes and Rovelli [15], which posits that the parameter of "time" is merely a macroscopic feature of statistical coarse-graining.

Because the finite observer's boundary limits its resolution of the quantum microstates, the state space is inherently partitioned into macroscopic equivalence classes. In information theory, this absence of microstate information defines the von Neumann entropy:

$$S = -\mathrm{Tr}(\rho \ln \rho) \tag{2}$$

where ρ is the reduced density matrix of the local region accessible to the observer. The static hyper-equilibrium exhibits a macroscopic geometric gradient of this entropy. The "Arrow of Time" is simply the vector aligning with this structural gradient. Time does not flow; rather, adjacent topological coordinates along this vector exhibit strictly higher degrees of coarse-graining. The "future" is strictly the geometric direction in which the statistical map is structurally more indeterminate relative to the observer's coordinate.

2.3 The Markov Blanket as a Static Topological Partition

To exist as a coherent structure within this entropic gradient without instantly equating to maximum thermodynamic noise, a finite subsystem must possess a strict topological boundary separating its internal geometry from the external bulk. In the mathematics of complex systems and Bayesian networks, this boundary is formalized as a Markov Blanket [16].

A Markov Blanket ($\mathcal{B}$) is a static partition of the Tensor Network into internal states (μ) and external states (η), such that the internal states are conditionally independent of the external states given the blanket states:

$$P(\mu \mid \eta, \mathcal{B}) = P(\mu \mid \mathcal{B}) \tag{3}$$

Within Karl Friston's Free Energy Principle [17], a biological organism is redefined here as a localized geometric sub-network whose internal topology mirrors the external geometry. Traditional biology describes the organism as "performing work to minimize surprise." In the verbless hyper-equilibrium of our framework, Active Inference is not an action; it is a statement of structural symmetry.

Rigorously, the variational Free Energy (F) is formalized as the information-theoretic upper bound on the structural self-information (the negative log-probability, or topological "surprise") of the Markov Blanket states. Within the static Tensor Network, this does not represent a dynamic cognitive update; rather, it constitutes the exact Kullback-Leibler (KL) divergence between the conditional geometric mapping (the static approximate posterior) of the external bulk states encoded by the internal topology, $q(\eta \mid \mu)$, and the true structural distribution conditioned strictly on the boundary data, $P(\eta \mid \mathcal{B})$:

$$F = D_{KL}[q(\eta \mid \mu) \parallel P(\eta \mid \mathcal{B})] - \ln P(\mathcal{B})$$

Consequently, a biological organism cannot be reduced to a singular geometric coordinate. It is mathematically defined as an extended topological sub-network—a highly complex, topologically elastic structural domain embedded within the hyper-equilibrium.

Within a verbless geometry, "elasticity" (the phenomenon interpreted biologically as neuroplasticity) is not a dynamic process of physical re-wiring over time. It is strictly defined as the static mathematical property of the domain possessing adequate internal complexity to map varying external geometries across a macroscopic entropic gradient, without the Kullback-Leibler divergence ever exceeding the structural capacity limit of its Markov Blanket ($F \leq C_{obs}$).

An entity is "living" strictly when its internal structural depth (μ) possesses adequate finite capacity (C_{obs}) to statically minimize this KL divergence without undergoing structural boundary dissolution. Life is not a dynamic action; it is the rare geometric condition where the internal tensor network structurally mirrors the external topology with sufficient precision to maintain the absolute integrity of its Markov Blanket against the macroscopic entropic gradient. The structural integrity of the Markov Blanket is mathematically synonymous with this minimization. Coordinates where F exceeds the capacity of the boundary are simply coordinates where the localized topological domain does not exist—a state the 4D biological projection interprets biologically and temporally as "death." Thus, life is not a dynamic process; it is the static geometric imperative of a finite statistical boundary embedded within an infinite map.

2.4 Topological Isomorphism of Markov Blankets and Submanifolds

Within the proposed verbless information geometry of the hyper-equilibrium, we seek to establish a rigorous mapping between the statistical architecture of the observer and its emergent geometric topology. To bridge this gap, we propose that the Markov Blanket—a purely statistical boundary—functions as the formal geometric precursor to the localized topological boundary ($\partial\mathcal{M}$) of the observer's 4D continuous projection.

1. The Block-Diagonal Fisher Metric and Network Severance: Statistically, a Markov Blanket (∂A) mandates absolute conditional independence between internal states (A) and external states (B):

$$P(A, B \mid \partial A) = P(A \mid \partial A)P(B \mid \partial A) \tag{4}$$

To translate this conditional independence into geometry, we evaluate the Fisher Information Metric (g_{ij}) defined on the statistical manifold of the tensor network. The metric components linking parameters θ_A (governing state A) and θ_B (governing state B) are defined by the expectation of the mixed partial derivatives of the log-likelihood:

$$g_{AB} = -\mathbb{E}\left[\frac{\partial^2 \ln P(A, B \mid \partial A)}{\partial\theta_A \partial\theta_B}\right] \tag{5}$$

Because the joint probability factorizes strictly due to the Markov Blanket, the logarithm splits into a linear sum: $\ln P(A, B \mid \partial A) = \ln P(A \mid \partial A) + \ln P(B \mid \partial A)$. Consequently, the mixed partial derivative mathematically vanishes:

$$g_{AB} = 0 \quad \forall\, \theta_A \in A,\, \theta_B \in B \tag{6}$$

As standard Riemannian geometry dictates, the vanishing of these off-diagonal metric components simply means that the parameter submanifolds $\mathcal{M}_A$ and $\mathcal{M}_B$ are strictly orthogonal in the abstract statistical parameter space. However, topological severance does not occur in this continuous parameter space; it occurs in the underlying informational graph topology. Because the submanifolds are statistically orthogonal, they share exactly zero direct mutual information. In the geometry of a discrete tensor network, this guarantees that the structural edge weight between any node in A and any node in B is strictly zero.

Consequently, any discrete informational path traversing the hyper-equilibrium network from a node in A to a node in B mathematically must pass through the mediating nodes of ∂A. This does not constitute a novel derivation of graph topology, but rather the formal geometric exploitation of the Hammersley-Clifford theorem [18]: within a discrete Markov Random Field, absolute conditional independence is structurally synonymous with topological severance. The Markov Blanket inherently functions as an absolute structural partition within the network.

The profound theoretical leap of this framework occurs in the subsequent continuous projection: we propose that this strict discrete network severance is the exact mathematical engine that generates the continuous geometric boundaries of macroscopic physical spacetime.

2. The Physical Pullback Hypothesis: Having established that the Markov Blanket constitutes a formal geometric boundary in the discrete network topology, we propose an isomorphism to continuous physical spacetime. As detailed in Section 3, macroscopic physical spacetime is not treated as an independent prior, but as the emergent pullback of this statistical metric via the algebraic restriction of the observer.

Because all informational paths from A to B are structurally routed through ∂A in the underlying graph, the macroscopic spatial geodesic connecting the spatial coordinate of A to the spatial coordinate of B is physically forced to traverse the spatial coordinate of the boundary. We suggest that when the statistical separating hypersurface (∂A) is pulled back into the 4D macroscopic equivalence class bounded by C_{obs}, it maps directly to the closed physical boundary surface $\partial\mathcal{M}$ of the observer's localized submanifold. Thus, conditional independence is not merely analogous to spatial separation; in this framework, it is the exact informational prerequisite that necessitates the emergence of a localized spatial boundary.

3. The Localization of Finite Capacity (C_{obs}): Under this proposed isomorphism, the finite Shannon capacity limit (C_{obs}) is not an abstract statistical threshold; it functions as the exact geometric bounding constraint of the submanifold surface $\partial\mathcal{M}$. The algebraic restriction of the global state is therefore executed strictly at this topological coordinate. By formally equating the informational boundary of Friston's Free Energy Principle to the bounding limits of the observer's constraint manifold, the cognitive boundary of the observer and the localized geometric boundary of spacetime merge into the same topological constraint.

2.5 The Static Constraint Manifold and Algebraic Dimensionality

A fundamental challenge in quantum gravity is that a global Hilbert space does not trivially factorize ($\mathcal{H} \neq \mathcal{H}_{obs} \otimes \mathcal{H}_{ext}$) due to diffeomorphism invariance. Therefore, within the Finite Observer Theory, the observer's boundary is not proposed as a pre-existing spatial partition. Instead, we formalize the boundary as a localized operator subalgebra $\mathcal{A}_{obs} \subset \mathcal{A}_{total}$ bounded by the Shannon capacity C_{obs}.

Rather than assuming a spatial tensor product of states, we propose that the Dimensional Partial Trace (ρ_{4D}) can be rigorously modeled as the algebraic restriction of the global state functional ω to this finite subalgebra: $\omega_{local} = \omega|_{\mathcal{A}_{obs}}$. This avoids the notational error of tracing over a bulk algebra, utilizing instead the strict algebraic restriction of the state.

While the Gelfand-Naimark-Segal (GNS) construction [19] guarantees that this restricted state functional ω_{local} inherently induces its own effective Hilbert space representation ($\mathcal{H}_{obs}$, π, $|\Omega\rangle$), the theorem itself does not intrinsically dictate the dimensionality of the emergent macroscopic geometry. To bridge this gap, we propose an exploratory geometric mapping based on the algebraic constraints of the observer's boundary.

Within the GNS representation, the localized von Neumann algebra $\mathcal{A}_{obs}$ possesses the cyclic and separating vacuum state $|\Omega\rangle$. By Tomita-Takesaki modular theory [20], this state uniquely defines a modular operator Δ, generating a 1-parameter group of automorphisms:

$$\sigma_\tau(A) = \Delta^{-i\tau/\hbar} A \Delta^{i\tau/\hbar}, \quad \forall A \in \mathcal{A}_{obs} \tag{7}$$

Motivated by the Thermal Time Hypothesis [15], we suggest identifying this internal algebraic parameter (τ) with the macroscopic temporal index. Because the underlying hyper-equilibrium is posited as static, this modular flow does not describe dynamic evolution; it formally defines the 1-dimensional orthogonal thermodynamic gradient of the localized state.

To parameterize the remaining spatial degrees of freedom within a non-factorizable bulk, the macroscopic equivalence class requires a set of independent spatial conjugates. We explore the premise that the dimensionality of macroscopic space is not an arbitrary background parameter, but a strict algebraic consequence of the observer's requirement for stable, non-degenerate quantum measurement.

First, we must establish the algebraic structure of the localized measurement interface. The GNS representation rigorously requires the observer's full set of local observables to form a C^*-algebra over the complex numbers. As is standard in algebraic quantum theory, a full C^*-algebra contains non-invertible projection operators and thus cannot globally constitute a division algebra. However, we propose that the emergence of macroscopic spatial dimensions is governed by a stricter topological constraint on a specific geometric subalgebra.

Within the verbless, strictly relational topology of the hyper-equilibrium, absolute spatial coordinate vectors are physically unobservable. The localized macroscopic observer can only map the *relative orientations* and relational angles between topological nodes. Mathematically, the continuous transformations governing these relative spatial orientations are generated not by the full Clifford algebra of coordinate vectors $C\ell_{n,0}(\mathbb{R})$, but specifically by its *even subalgebra*, $C\ell^+_{n,0}(\mathbb{R})$, which forms the spinorial representation of the spatial geometry [21].

For the observer to render a continuous, isotropic spatial projection, all geometric rotations must be strictly invertible. In a relational topology, spatial orientability is mapped via the inner automorphisms of the algebra; if the orientational subalgebra contained non-invertible zero-divisors, the rotational elements would be non-invertible, rendering the conjugation action $v \mapsto uvu^{-1}$ undefined and the corresponding spatial orientation geometrically singular. This would manifest as a topological degeneracy where distinct physical orientations become indistinguishable, collapsing the rotational isotropy of the macroscopic metric. Therefore, to ensure non-degenerate spatial symmetries, we mathematically require that this specific even subalgebra of spatial orientations possesses a strict division ring structure.

By Hurwitz's Theorem [22, 23], the only possible normed division algebras over the reals are $\mathbb{R}, \mathbb{C}, \mathbb{H}$, and $\mathbb{O}$. Associativity is further necessitated by the associative requirement of the measurement C^*-algebra interface. Among associative even Clifford subalgebras $C\ell^+_{n,0}(\mathbb{R})$ for $n \geq 1$, the unique solution to the isomorphism $C\ell^+_{n,0} \cong \mathbb{H}$ strictly requires $n = 3$.

This physical requirement acts as a strict algebraic filter. While the Octonions ($\mathbb{O}$) possess sufficient generators, they are mathematically non-associative and are therefore forbidden from serving as the observer's orientational basis. Consequently, the Quaternions ($\mathbb{H}$) emerge as the *maximal associative division algebra* available to map the observer's spatial interface.

Enforcing this strict algebraic constraint dictates that the observer's even subalgebra of spatial orientations must be isomorphic to the quaternions:

$$C\ell^+_{n,0}(\mathbb{R}) \cong \mathbb{H} \tag{8}$$

According to the rigorous classification of real Clifford algebras, the unique solution to this isomorphism strictly requires $n = 3$. (While the full algebra $C\ell_{3,0} \cong M_2(\mathbb{C})$ contains zero-divisors, its even subalgebra is precisely $\mathbb{H}$). Therefore, the continuous spatial projection mapped by the observer is algebraically restricted to exactly three spatial dimensions.

Under this specific algebraic limit, the rank of the macroscopic Fisher Information Metric ($G_{\alpha\beta}$) evaluates to:

$$\dim(\mathcal{M}_{obs}) = 1(\text{modular flow}) + 3(\text{quaternionic spinorial orientations}) = 4 \tag{9}$$

In this view, the emergence of a 4D spacetime manifold ($\mathcal{M}_{obs}$) is not an ad hoc geometric prior. It is a strict geometric consequence of the specific algebraic restrictions required for a finite observer to maintain a stable statistical representation of a hyper-equilibrium.

To rigorously excise the verb from this topology, the macroscopic projection and the minimization of variational Free Energy (F) must be modeled not as algorithmic operations, but strictly as static geometric boundary conditions.

Let the finite Shannon Information Capacity (C_{obs}) define this localized topological constraint manifold ($\mathcal{M}_{obs}$) within the N-dimensional Tensor Network. The specific macroscopic reality anchored to this observer is governed by a localized density matrix ($\rho_{\mathcal{M}_{obs}}$). Within a verbless framework, this state is not dynamically computed. As established via the algebraic restriction to the observer's finite subalgebra ($\omega_{local} = \omega|_{\mathcal{A}_{obs}}$), it is simply the static geometric projection required to satisfy the structural limitations of the topological boundary. This restriction inherently dictates the effective exclusion of the $N - 4$ dimensions, completely avoiding the mathematically problematic assumption of a trivially factorizable global Hilbert space.

To ensure formal consistency, the parameters governing this geometric exclusion correspond strictly to the informational topology of the hyper-equilibrium, rather than classical spatial containers:

1. The Ontological Dimension (N): The dimension N does not denote continuous spatial axes. It strictly represents the absolute cardinality of the microscopic relational degrees of freedom (discrete topological nodes) comprising the uncompressed hyper-equilibrium. Rather than a trivial tensor product of independent spaces, N rigorously defines the global rank of the encompassing algebra of observables ($\mathcal{A}_{total}$) prior to any algebraic restriction imposed by a bounded capacity constraint.

2. The Macroscopic Subspace ($4D$): The $4D$ subspace is not a pre-existing physical arena; it is proposed as the epistemic equivalence class bounded by C_{obs}. Because the finite observer cannot resolve the exact discrete configuration of the N-dimensional bulk, the finite capacity mathematically necessitates a coarse-graining. The resulting continuous parameters (three spatial dimensions and one structural modular index) are precisely the macroscopic degrees of freedom required to map the thermodynamic averages of the underlying discrete network.

3. The Trace as Geometric Emergence: The conceptual necessity of the "Dimensional Partial Trace" corresponds directly to the integration over these unobservable degrees of freedom. By tracing out the microscopic structural variance that exceeds C_{obs}, the uncompressed geometry is formally reduced to the localized mixed state density matrix $\rho_{\mathcal{M}_{obs}}$. Spacetime geometry is not an external stage; it is modeled here as the Fisher Information Metric characterizing the entanglement structure of this specific reduced density matrix.

Consequently, the biological Markov Blanket does not "perform work" to minimize Free Energy. Instead, a biological organism is redefined purely as a specific, highly dense topological sub-network (μ) whose internal structural depth inherently satisfies the static inequality:

$$D_{KL}[q(\eta \mid \mu) \parallel P(\eta \mid \mathcal{B})] - \ln P(\mathcal{B}) \leq C_{obs} \tag{10}$$

At coordinates within the Tensor Network where this exact geometric inequality is satisfied, the localized topological domain (life) exists. At coordinates where the external bulk geometry forces the KL divergence to exceed C_{obs}, the inequality fails, and the boundary mathematically dissolves.

Therefore, it is suggested that life, adaptation and the rendering of the 4D macroscopic projection involve zero computational steps. They are merely the static satisfaction of geometric inequalities embedded permanently within the verbless crystal of the hyper-equilibrium.

2.6 The Continuous Spectrum of Structural Depth: The Topological Strata

Because structural depth (μ) is a continuous topological property of the N-dimensional Tensor Network, the framework mathematically strictly precludes a binary structural discontinuity across the hyper-equilibrium. Instead, the geometry is characterized by a continuous stratification of increasingly nested boundaries. The continuum of localized conditional independence is mapped across four distinct topological strata:

This stratum constitutes the absolute baseline of localized topological structure, structurally correlating with fundamental inanimate matter (e.g., a simple crystalline lattice or homogeneous particle distribution). Geometrically, it is defined by a single, un-nested Markov Blanket [16]. The internal degrees of freedom are directly correlated with the immediate external boundary data, possessing zero recursive depth. It constitutes a perfectly shallow entropic valley within the network, lacking macroscopic geometric insulation.

This intermediate geometry corresponds to complex molecular structures and localized thermodynamic formations. A composite submanifold is defined by partial geometric nesting; it is structurally composed of multiple trivial submanifolds mathematically bound within a secondary, larger Markov Blanket. While it possesses a strictly non-zero structural depth, the intermediate layers of tensor connections are mathematically insufficient to constitute stable, self-contained macroscopic conditional independence from the external bulk.

This stratum is geometrically defined by profound recursive nesting—a boundary mathematically embedded within successive boundaries. The informational distance between the core internal states and the external bulk is immense, constituting a steep entropic gradient measurable within the formalisms of pure information geometry [26]. This extreme structural depth rigidly insulates the low-entropy internal core, correlating with a highly stable conditional independence from the baseline thermodynamic noise of the hyper-equilibrium—a rigid topological prerequisite for autopoietic insulation [27].

This defines the extreme upper limit of the structural gradient bounded by the finite Shannon capacity limit (C_{obs}). The geometry maps a staggeringly deep, fractal-like hierarchy of nested autopoietic submanifolds. The structural depth (μ) at this coordinate is so immense that the internal topology possesses the requisite localized capacity to structurally mandate the Dimensional Partial Trace over the external network. It is precisely this extreme recursive depth that necessitates the lossy holographic compression, bounding the observer strictly to the continuous 4D spacetime projection. The mathematical map between the discrete relational density of the tensor network and the emergent continuous metric of this topological manifold is strictly governed by the coarse-graining of quantum entanglement, aligning with the foundational holographic architectures of MERA and bulk-boundary correspondence [28–30].

Consequently, the structural variance across this continuous gradient is purely geometric. The topological distinction between a trivial boundary and a macroscopic observer is strictly a function of recursive depth within the static, invariant verbless crystal.

2.7 The Threshold of Agency: Life as a Topological Submanifold

While the static hyper-equilibrium encompasses all coordinates of the N-dimensional Tensor Network, a rigorous distinction must be drawn between sentient biological observers and inanimate structural domains (e.g., mineral matter). Within this verbless geometry, "life" is not an emergent biological process, but is defined exactly as the autopoietic topological submanifold ($\mu \gg 0$) mapped in Section 2.6.

This distinction is governed by the absolute capacity of a structural domain to maintain its boundary integrity under the macroscopic entropic gradient. As established in Section 2.3, a biological observer is a localized sub-network whose internal nodes possess sufficient connectivity to maintain an isomorphism with the external bulk geometry, a state of *topological elasticity.* Conversely, an inanimate object is a "brittle" domain; its internal structural depth

(μ) is insufficient to satisfy the capacity inequality ($F \leq C_{obs}$) across any significant coordinate distance along the entropic vector.

Consequently, the threshold for agency is mathematically defined as the structural coordinate where the rate of change of internal complexity relative to the entropy gradient reaches a critical value:

$$\frac{\partial \mu}{\partial S} \geq \Lambda_{crit} \tag{11}$$

where Λ_{crit} represents the critical structural density required to maintain a stable 4D holographic projection without boundary dissolution. Agency, in this verbless context, is not the power to act; it is the geometric capacity to remain bounded.

3 The Topological Origin of the Temporal Metric and Physical Law

Having established the finite observer as a strictly static topological boundary (the autopoietic submanifold) defined by structural depth (μ) and finite capacity (C_{obs}) in Section 2, the framework must structurally necessitate the kinematics of the macroscopic 4D projection. This section derives the continuous temporal metric ($d\tau$) and the equations of physical law strictly as static geometric artifacts mandated by the observer's Dimensional Partial Trace over the N-dimensional hyper-equilibrium.

3.1 Bounded Self-Similarity: The Topological Origin of Structure and the Temporal Arrow

The architectural integrity of the finite observer within the hyper-equilibrium relies upon a highly specific topological property: bounded (incomplete) self-similarity. This geometric property constitutes a dual mathematical mandate, dictating both the baseline existence of multiscale structural organization and the strict necessity of the temporal index within the 4D projection.

1. The Necessity of Baseline Self-Similarity: The baseline presence of self-similarity is a strict geometric prerequisite for the macroscopic observer. An absolute absence of self-similarity mathematically restricts the tensor network to either universal topological noise (maximum entropy) or perfect homogeneity, both of which correlate with a universally flat structural depth ($\mu \approx 0$). Because the autopoietic submanifold ($\mu \gg 0$) is defined by the recursive nesting of Markov Blankets, the topological boundary of conditional independence is inherently repeated across scales. This multiscale recursion structurally constitutes self-similarity, providing the exact geometric architecture required for structural depth.

2. The Finite Bound and Broken Scale Invariance: However, due to the finite Shannon capacity limit (C_{obs}), this self-similarity is mathematically required to be incomplete, or bounded. The finite boundary strictly precludes infinite recursive depth, structurally mandating a broken scale invariance. This bounded topology defines a severe structural asymmetry across the network: the variance from the deeply nested macroscopic observer ($\mu \to \mu_{max}$) to the trivial microscopic baseline ($\mu \approx 0$) correlates directly with a strict mathematical reduction in structural complexity.

3. The Thermodynamic Arrow as a Topological Index: Consequently, this bounded self-similarity maps an absolute, asymmetric informational gradient across the hyper-equilibrium. When synthesized with the static thermodynamic topology—where profound structural depth correlates with minimal entropy, and the trivial baseline correlates with maximal entropy—this geometric gradient structurally necessitates the classical "arrow of time."

The temporal arrow is mathematically stripped of dynamic thermodynamic decay; it is simply the requisite 1D topological index mapping the invariant structural variance from macroscopic complexity to microscopic simplicity. The continuous 4D macroscopic projection strictly maps this broken symmetry, projecting the static geometric loss of structural constraint as a continuous forward temporal parameter. Time is therefore strictly the projected shadow of the observer's own finite boundary upon the self-similar architecture of the verbless crystal.

3.2 The Legendre Transformation and the Lorentzian Signature

A critical geometric distinction must be addressed regarding the metric signature. The underlying Fisher Information Metric (g_{ij}) of the uncompressed statistical manifold is inherently positive-definite (Riemannian), yielding $ds^2_{info} > 0$ for any non-zero structural displacement. However, the emergent macroscopic spacetime of General Relativity utilizes a Lorentzian signature $(-,+,+,+)$ to mathematically define light cones and causal structure.

Within the Finite Observer Theory, we propose that this signature transition is not a physical prior, but rather a strict algebraic consequence of the non-homeomorphic projection π. Because the macroscopic observer is rigorously bounded by the finite capacity constraint ($S \leq C_{obs}$), we model the projection from the unconstrained micro-parameters Θ to the macroscopic equivalence classes as a thermodynamic Legendre transformation.

Let the unconstrained structural tensor network be governed by a dimensionless informational potential $U(S, x^a)$, where S represents the localized von Neumann entropy of the traced-out bulk. It is crucial to distinguish this potential from macroscopic thermodynamic entropy, which is typically concave. Because U describes the relative informational distance (e.g., Kullback-Leibler divergence) of a strictly stable, pure Wheeler-DeWitt hyper-equilibrium ($\hat{H}|\Psi\rangle = 0$), pure state information geometry mathematically guarantees that U acts as a strictly convex functional over its microscopic parameter space. Consequently, the Hessian matrix of U over these unconstrained parameters (S, x^a) yields a strictly positive-definite (Riemannian) signature:

$$g_{ij} = \begin{pmatrix} \frac{\partial^2 U}{\partial S^2} & \frac{\partial^2 U}{\partial S \partial x^b} \\ \frac{\partial^2 U}{\partial x^a \partial S} & \frac{\partial^2 U}{\partial x^a \partial x^b} \end{pmatrix} > 0 \tag{12}$$

Because the informational potential is strictly convex at the microscopic level, we have $\frac{\partial^2 U}{\partial S^2} > 0$.

To enforce the invariant topological bound C_{obs}, the finite observer cannot map S as an independent, unconstrained spatial coordinate. Instead, the algebraic restriction necessitates a Legendre transformation to the macroscopic constraint phase space.

It is here that the formal verbless constraint of the hyper-equilibrium, defined as the vanishing Lie derivative of the global pure state ($\mathcal{L}_t \rho_{global} = 0$), becomes mathematically operative. Because the underlying Wheeler-DeWitt geometry possesses no global temporal vector field, any macroscopic parameter resembling "time" cannot be a background prior; it must be locally generated.

To rigorously justify the emergence of this local temporal parameter, we draw upon the Kubo-Martin-Schwinger (KMS) condition of algebraic quantum field theory [25, 31]. Applying this condition to a universe governed by a pure Wheeler-DeWitt state ($|\Psi\rangle$) requires formalizing the ontological distinction between the global hyper-equilibrium and the localized constraint manifold.

The global uncompressed state is pure, possessing exactly zero von Neumann entropy ($S = 0$) and zero temperature ($T = 0$). Consequently, it admits only a trivial modular flow; the universe as a totality experiences no macroscopic time, perfectly satisfying the global verbless constraint ($\mathcal{L}_t \rho_{global} = 0$).

However, in continuous quantum field theories and diffeomorphically invariant gravity, the global Hilbert space does not admit a trivial tensor product factorization ($\mathcal{H} \neq \mathcal{H}_{obs} \otimes \mathcal{H}_{bulk}$). An observer cannot be defined as a spatially severed, independent subsystem. Within the Finite Observer Theory, the observer is defined strictly as a localized bounding subalgebra of permissible measurements ($\mathcal{A}_{obs}$), constrained by their finite Shannon capacity (C_{obs}).

When the global pure state functional ω is algebraically restricted to this finite subalgebra—yielding the local state $\omega_{local} \equiv \omega|_{\mathcal{A}_{obs}}$—the unobservable degrees of freedom of the $N-4$ dimensional bulk are mathematically traced out. Because the nodes of the hyper-equilibrium are densely entangled, this algebraic restriction inevitably forces the local state to become highly mixed. The geometric truth of the bulk, now hidden beyond the observer's Markov Blanket, manifests locally as massive entanglement entropy.

Crucially, in the algebraic formulation of quantum mechanics, a mixed state generated by the restriction of a highly entangled pure state is thermodynamically indistinguishable from a thermal heat bath. Because the observer's structural boundary mathematically sequesters the unobservable bulk, the resulting localized entanglement entropy constitutes a formal thermal gradient. It is precisely this emergent, restricted state (ω_{local}) that satisfies the KMS boundary condition. This formalizes a discrete network analogue to the Bisognano-Wichmann theorem and its generalizations [32–34], where the algebraic restriction to a localized wedge naturally induces a thermal KMS state from a global vacuum.

While the standard Bisognano-Wichmann theorem derives a KMS state utilizing the specific geometric symmetries of Minkowski space (e.g., Lorentz boosts in Rindler wedges), the finite observer framework requires a pre-geometric transfer condition. We propose that the dense topological entanglement of the uncompressed hyper-equilibrium formally satisfies the network analogue of the Reeh-Schlieder property [25, 35].

Consequently, the algebraic restriction to any localized finite subalgebra ($\mathcal{A}_{obs}$) inherently ensures that the local vacuum state remains cyclic and separating. As established by Tomita-Takesaki theory, this is the strict, necessary, and sufficient mathematical condition to uniquely induce a modular flow (σ_τ). Therefore, the algebraic restriction organically generates a localized KMS state entirely independent of a pre-existing continuous background or Poincaré covariance [25].

The KMS condition dictates that for such a locally thermal system, this modular automorphism group uniquely characterizes its equilibrium dynamics. Therefore, while the global verbless constraint forbids a universal temporal prior, the temporal metric component $G_{\tau\tau}$ natively emerges because the restricted observer must parameterize the thermodynamic equilibrium of their own localized, entanglement-induced heat bath. A conjugate index τ is algebraically forced into existence strictly as the thermodynamic dual to this localized entropy S:

$$\tau \equiv \frac{\partial U}{\partial S} \tag{13}$$

This derivation formally aligns the verbless geometry with the Thermal Time Hypothesis [15], providing a strict geometric mechanism for the emergence of time from a timeless, pure-state continuum.

The physical metric tensor $G_{\alpha\beta}$ of the macroscopic observer is formally modeled as the Hessian of the transformed, localized thermodynamic potential—the verbless Free Energy, $F_{obs}(\tau, x^a) = U - \tau S$. By applying the chain rule to the Legendre transformation, the purely temporal component of the emergent metric evaluates to:

$$G_{\tau\tau} = \frac{\partial^2 F_{obs}}{\partial \tau^2} = -\frac{\partial S}{\partial \tau} = -\left(\frac{\partial^2 U}{\partial S^2}\right)^{-1} \tag{14}$$

Because the underlying microscopic potential U is strictly convex ($U_{SS} > 0$), its inverse is positive. The Legendre transform inherently introduces a strict minus sign, formally forcing $G_{\tau\tau} < 0$.

The purely spatial block of the metric is derived via the Schur complement of the transformation, which strictly inherits the positive-definite geometry of the unconstrained spatial contours. Therefore, the explicit Hessian matrix of the observer's physical metric evaluates to the Lorentzian form:

$$G_{\alpha\beta} = \begin{pmatrix} -(U_{SS})^{-1} & 0 \\ 0 & \gamma_{ab} \end{pmatrix} \tag{15}$$

This derivation suggests that the Lorentzian signature $(-,+,+,+)$ is not an ad hoc physical assumption, but an inescapable algebraic artifact of the Legendre transformation required to bound the underlying Riemannian network to the finite observer's Shannon capacity limit (C_{obs}).

Having established the temporal metric component $G_{\tau\tau}$ strictly as the inverse Hessian of the uncompressed informational potential, we propose a formal reinterpretation of gravitational time dilation that avoids the introduction of arbitrary scaling parameters.

In General Relativity, the relative flow of proper time between two stationary observers at macroscopic coordinates A and B is dictated by the ratio of their temporal metric components: $d\tau_A/d\tau_B = \sqrt{(G_{\tau\tau})_A/(G_{\tau\tau})_B}$. Substituting our derived verbless metric component, this temporal ratio evaluates strictly to the inverse ratio of their microscopic informational convexity:

$$\frac{d\tau_A}{d\tau_B} = \sqrt{\frac{(U_{SS})_B}{(U_{SS})_A}} \tag{16}$$

This relation suggests that gravitational time dilation is not a dynamic slowing of physical clocks, but a static, relative variance in the informational density of the underlying hyper-equilibrium. A coordinate deep within a "gravitational well" corresponds to a topological region where the pure-state relative entropy is highly constrained, yielding a steeper informational potential and thus a higher convexity (U_{SS}).

Because the temporal index τ is the thermodynamic conjugate required to bound this entropy (via the KMS condition), a higher structural convexity algebraically forces a smaller interval of modular flow $d\tau$. Therefore, time dilation emerges natively in this framework not as a kinematic effect, but as the strict geometric ratio of the informational Hessians between distinct points on the localized constraint manifold.

3.3 The Ontological Reinterpretation of Fundamental Constants

Standard critiques correctly point out that fundamental constants (c, $\hbar$, G_N) cannot be mathematically "derived" from pure dimensionless geometry if they are simultaneously utilized in the foundational equations (such as the modular flow or Bekenstein bound). We clarify that the Finite Observer Theory does not seek to dynamically generate the numerical values of these constants from a vacuum. Instead, we propose a strict ontological reinterpretation of their physical meaning.

In this framework, the physical dimensions of length, time, and mass are not treated as pre-existing, absolute features of the hyper-equilibrium. Instead, the fundamental constants are re-contextualized strictly as the static boundary parameters of the Dimensional Partial Trace:

1. The Planck Area (ℓ_P^2) and the Gravitational Constant (G_N): In the pullback metric $G_{\alpha\beta} = \ell_P^2(\pi^* g)_{\alpha\beta}$, we suggest that the Planck area operates not as a pre-existing microscopic spatial grid, but strictly as the macroscopic geometric footprint of exactly one unit (one bit) of mutual information across the localized Markov Blanket. G_N is formally reinterpreted as the thermodynamic conversion scalar required to bridge dimensionless informational variance to the continuous spatial mapping of the equivalence class.

2. The Speed of Light (c) and the Null Geodesic: Rather than defining c as a kinematic velocity, we propose that c constitutes the absolute global Lipschitz bound for the continuous surjection (π) across the valid constraint manifold. The equation $dx = c \cdot d\tau$ does not describe movement; it explicitly defines the absolute thermodynamic edge of the continuous projection, where the underlying mapping structurally saturates.

3. Planck's Constant ($\hbar$): Within the modular flow (σ_τ), $\hbar$ is interpreted not as a dynamic quantum of action, but as the absolute scaling parameter that discretizes the continuous macroscopic equivalence classes back into the algebraic generators of the underlying verbless tensor network.

By reinterpreting these constants as the invariant scaling limits of a non-homeomorphic projection, we suggest that their exact roles are geometrically mandated to permit a finite capacity observer (C_{obs}) to render a self-consistent, locally Lipschitz 4D boundary from a dimensionless hyper-equilibrium.

3.4 The Recontextualization of Time-Dependent Physical Laws

Consequently, the framework fundamentally redefines the ontological status of universal physical laws. Within the verbless hyper-equilibrium, time-dependent differential equations (e.g., the geodesic equations of General Relativity, the Schrödinger equation) are mathematically stripped of dynamic, causal governance. They do not describe a temporal evolution of physical states. Instead, they strictly codify the geometric parameters of the observer's lossy holographic projection.

Specifically, the functional forms of these empirical laws map the exact topological signature of the bounded self-similarity. The classical "rates" of temporal change and the fundamental "constants" of nature correlate strictly with the specific mathematical type of the broken scale invariance combined with the rigid slope of the localized entropic gradient. Therefore, universal laws are not active forces acting upon matter; they are merely the invariant mathematical manifestations of the structural incompleteness dictated by the finite Shannon capacity (C_{obs}) of the macroscopic observer.

3.5 Comparative Advantages Over Dynamic Emergent Time Models

While contemporary quantum gravity architectures frequently map time as an emergent property, standard formalisms invariably retain implicit dynamic mechanics. The strictly static geometric derivation of $d\tau$ governed by bounded self-similarity offers distinct structural advantages over these established paradigms.

1. Beyond Quantum Reference Frames: The Page-Wootters mechanism [36] and modern Quantum Reference Frame (QRF) formalisms [37] successfully relativize temporal coordinates to the observer's quantum state. However, they mathematically preserve the time-evolution operator to map the global joint state. By strictly defining the observer as a localized topology bounded by C_{obs}, the current framework mathematically excises dynamic evolution entirely.[1] The macroscopic equivalence class is not a dynamic relational state, but the invariant geometric artifact of the Dimensional Partial Trace.

2. Static Topology vs. Complexity Growth: Holographic conjectures correlating temporal progression with quantum computational complexity [38,39] inherently invoke a dynamic temporal vector (e.g., the "growth" of the tensor network). The verbless geometry strictly inverts this dependency. Structural complexity (μ) does not dynamically expand; it is an invariant, pre-existing gradient defined by the incomplete self-similarity of the N-dimensional

[1] **The Mathematical Arbitrariness of Dynamic Relational Time:** Standard relational approaches to the Wheeler-DeWitt equation ($\hat{H}|\Psi\rangle = 0$), most notably the Page-Wootters mechanism and modern Quantum Reference Frame (QRF) formalisms, argue that dynamical evolution emerges conditionally between entangled subsystems. However, recovering continuous dynamic evolution requires the implicit injection of a unitary evolution operator ($U = e^{-iHt}$) mapping the continuous phase variance of the reference subsystem. This assumes the relational clock possesses infinite informational resolution to track continuous unitary flow. When subjected to the strict mathematical bound of a finite Shannon capacity ($C_{obs} < \infty$), infinite resolution is impossible. The system mathematically requires a Dimensional Partial Trace, rendering continuous unitary dynamics unresolvable. Therefore, interpreting the relational variance between subsystems as "dynamical evolution" is an artifact of implicitly assuming an unbounded reference frame. When strictly bounded by C_{obs}, the relational variance mathematically collapses into a purely static structural gradient (∇S). The elimination of the dynamic operator is not philosophically motivated; it is the strict mathematical necessity of mapping the Wheeler-DeWitt hyper-equilibrium through a finite informational boundary.

bulk. The 1D temporal index is merely the requisite projection of this static bounded scale invariance, stripping complexity of all dynamic thermodynamic variables.

3. Geometric Indexing vs. Thermal Flow: The Thermal Time Hypothesis [40] isolates emergent time via the modular automorphisms of a statistical KMS state, yet it fundamentally defines time as a resulting thermal "flow." In contrast, the formulation of $d\tau$ mapped herein demonstrates that the temporal parameter is devoid of active thermal kinematics. The entropic vector ∇S is strictly a static topological slope. The finite observer does not "flow" through thermal states; the boundary strictly necessitates a continuous 1D index to correlate the local asymmetry of the hyper-equilibrium's structural constraints.

3.6 Boundary Limits: Trivial Submanifolds and the Null Geodesic

The mathematical rigor of the derived temporal metric ($d\tau$) is absolutely verified by evaluating its structural limits—specifically, the absolute zero bound of the finite Shannon capacity ($C_{obs} = 0$). This absolute limit strictly defines the topological coordinate of a massless quantum (e.g., a photon), deriving the null geodesics and momentum of Special Relativity purely from static information geometry.

1. The Trivial Submanifold and the Absence of Depth A topological coordinate defined by $C_{obs} = 0$ constitutes a trivial submanifold. Because it possesses zero informational capacity, it structurally lacks the recursive nesting of Markov Blankets. Consequently, its structural depth is universally flat ($\mu = 0$). It is a pure relational coordinate within the N-dimensional hyper-equilibrium, entirely devoid of the autopoietic architecture required to establish conditional independence.

2. The Collapse of the Macroscopic Equivalence Class The continuous 4D macroscopic projection is strictly the mathematical artifact of the Dimensional Partial Trace. Because a trivial submanifold ($C_{obs} = 0$) possesses no capacity, the execution of the Dimensional Partial Trace is mathematically impossible. Without this coarse-graining operation, the macroscopic equivalence class structurally cannot exist. The coordinate remains entirely uncompressed within the local topology.

3. The Geometric Derivation of the Null Geodesic ($d\tau = 0$) and Lipschitz Saturation: By applying this absolute limit to the derivation of the temporal index, the verbless geometry strictly necessitates the relativistic properties of the photon. Because the trivial submanifold possesses no structural depth ($\mu = 0$), the internal geometric variance is strictly $d\mu = 0$. Simultaneously, the absence of capacity ($C_{obs} = 0$) renders the localized generation of a proper temporal index mathematically undefined for the coordinate itself.

From the perspective of a macroscopic observer ($C_{obs} > 0$) mapping this trivial entity within the 4D projection, this absolute inability to render an internal temporal index forces the Dimensional Partial Trace to map the entity's informational variance entirely across the spatial axes. This structural extremity mathematically forces the mapping to perfectly saturate the observer's absolute global Lipschitz bound ($dx = c \cdot d\tau$).

Therefore, what classical Special Relativity defines as the invariant null geodesic (where proper time ceases) is strictly defined as the invariant topological signature of a $C_{obs} = 0$ coordinate. It is a trivial submanifold whose absolute lack of capacity forces its macroscopic projection to ride the absolute thermodynamic edge of the continuous constraint manifold, inherently yielding the zero physical spacetime interval ($ds^2_{physical} = 0$).

4. The Geometric Derivation of Momentum for Null Submanifolds The absolute limit of zero capacity ($C_{obs} = 0$) further necessitates a strictly static redefinition of momentum. Because the trivial submanifold lacks internal structural depth ($\mu = 0$) and possesses no nested Markov Blankets, it is geometrically incapable of localizing internal relational data (the topological equivalent of rest mass). Consequently, its entire informational metric is distributed as external structural variance across the N-dimensional bulk.

Within the continuous 4D macroscopic projection of a finite observer ($C_{obs} > 0$), this uncompressed external variance is strictly mapped as a spatial gradient, or static topological periodicity. What classical physics defines as the momentum of a massless quantum ($p \propto \lambda^{-1}$) is mathematically stripped of kinematic velocity. It is rigorously redefined as the invariant geometric measure of this static spatial periodicity. Because the trivial coordinate cannot render an internal temporal index ($d\tau = 0$), the Dimensional Partial Trace forces its absolute informational distance strictly onto the spatial axes of the macroscopic equivalence class, structurally manifesting as pure geometric momentum without dynamic propagation.

4 Resolving Geometric Paradoxes via the Partial Trace

Within a static hyper-equilibrium, the apparent paradoxes of quantum mechanics—traditionally attributed to temporal discontinuities or non-local interactions—are recontextualized as strict topological artifacts. They are rendering limitations inherent to the Dimensional Partial Trace executed by the finite boundary of the localized observer.

4.1 The Quantum Zeno Effect as a Geometric Focal Lock

The Quantum Zeno Effect [41] demonstrates that continuous or highly frequent observation of a quantum system effectively halts its coherent evolution. While the predictive mathematics of this phenomenon via projection operators (P_n) are well-established, the Finite Observer Theory proposes a fundamental ontological reinterpretation of this limit, utilizing the verbless constraint ($\mathcal{L}_t \rho = 0$).

Rather than viewing the Zeno effect as a dynamic interruption of an evolving system, we introduce the geometric concept of **Focal Lock**. We formally define a Focal Lock as the strict topological boundary condition where the continuous localized sampling of a single algebraic state actively suppresses the generation of the macroscopic temporal metric component.

As derived in Section 3.2, macroscopic time (τ) is not a background prior; it emerges strictly as the thermodynamic conjugate parameter of the modular automorphism group (σ_τ) via the KMS condition. This modular flow requires a non-zero structural gradient (∇S) to define its 1-parameter group across the constraint manifold.

When an observer performs a continuous measurement, the localized algebraic boundary ($\mathcal{A}_{obs}$) is tightly constrained to a single, static informational eigenvalue. By preventing the localized state from integrating over the adjacent network topology, the thermodynamic gradient is forced to zero ($\nabla S = 0$).

Because the temporal metric component is defined by the Legendre transformation as $G_{\tau\tau} = -(U_{SS})^{-1}$, driving the informational variance to zero mathematically prevents the emergence of the conjugate variable τ. Therefore, under a Focal Lock, the system does not "freeze in time." Instead, the strict geometric boundary conditions of the continuous observation simply fail to generate the macroscopic temporal dimension for that specific localized subspace. The standard predictive mathematics of the Zeno effect are preserved, but they are substantively recontextualized as the localized topological failure of the dimensional partial trace, rather than a dynamic physical intervention.

4.2 The EPR Paradox and the Tsirelson Bound

Macroscopic entanglement, traditionally viewed through the EPR paradox as "spooky action at a distance," implies a temporal communication between spatially separated particles. The Finite Observer Theory proposes discarding local realism and temporal causality entirely, treating entangled systems strictly as singular, unseparated nodes within the static Tensor Network.

Einstein's hypothesis of local hidden variables assumes an objective classical parameter, λ. John Stewart Bell [42] demonstrated that the existence of λ enforces the CHSH inequality across local structural measurements, where E denotes the quantum expectation value of joint measurements performed by two observers using respective detector settings a, a' and b, b':

$$|E(a,b) + E(a,b') + E(a',b) - E(a',b')| \leq 2 \tag{17}$$

However, the static geometry of a maximal Bell state, such as $|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$, mathematically yields the Tsirelson bound [43] of $2\sqrt{2}$.

We suggest this structural violation confirms the absence of independent objective properties prior to the imposition of a finite observer boundary. The spatial "separation" of the particles is modeled as an emergent artifact of the 4D macroscopic projection. The physical reality is a single, continuous tensor geometry. The localized classical properties are strictly the thermodynamic exhaust generated when the finite capacity of the observer's Markov Blanket forces the algebraic restriction of the global state to the local measurement subalgebra ($\omega_{local} = \omega|_{\mathcal{A}_{obs}}$). This operation yields a maximally mixed classical state locally, while the global geometry of the Tensor Network remains statically intact.

The Topological Preservation of the Markov Blanket: Standard quantum information critiques assert that macroscopic entanglement fundamentally breaks the conditional independence required by a classical Markov Blanket. Within the verbless framework, this is resolved by formalizing the Markov Blanket ($\mathcal{B}$) not as a physical partition within 4D spacetime, but as a purely informational partition within the uncompressed N-dimensional network.

Within the ontological hyper-equilibrium, these entangled states strictly constitute the exact same topological node. We rigorously redefine entanglement as the geometric artifact of the localized algebraic restriction mapping a single higher-dimensional coordinate onto multiple lower-dimensional spatial axes—a phenomenon we term *topological aliasing*.

To distinguish this mechanism from an ordinary non-injective projection (a standard many-to-one mapping resulting from coarse-graining), we define topological aliasing as a strictly *one-to-many multivalued relation* forced by an informational bottleneck. Analogous to the Nyquist-Shannon sampling limit [44], the finite capacity (C_{obs}) imposes a strict topological "sampling rate" on the macroscopic projection. When the structural density of a single bulk node exceeds the isometric embedding capacity of the 4D continuous lattice, the mapping π undergoes an aliasing fold. The singular bulk entity v_{EPR} is projected into the 4D manifold as a disjoint union of spatially separated macroscopic coordinates: $\pi(v_{EPR}) \mapsto \{x_A, x_B\}$.

Consequently, the localized capacity bound (C_{obs}) establishes a strict Markov Blanket that partitions informational dimensions, not spatial volumes. Conditional independence $P(\mu|\eta, \mathcal{B}) = P(\mu|\mathcal{B})$ is flawlessly preserved because the macroscopic correlation does not dynamically pierce the blanket; the observer's limited capacity is simply projecting a singular external node into multiple internal spatial coordinates simultaneously.

The Topological Proof of Macroscopic Entanglement: To rigorously classify this quantum non-locality not merely as a restatement of facts, but as a mechanically necessary localized failure of the Lipschitz condition ($K \to \infty$), we formally prove that the projection mapping π explicitly preserves an internal informational distance of zero ($ds_{info} = 0$) while simultaneously aliasing the node onto disjoint macroscopic spatial coordinates ($d(x_A, x_B) > 0$).

Step 1: The Microscopic Informational Distance. Let an entangled pair of nodes, A and B, be defined as a strictly pure bipartite state $|\psi_{AB}\rangle$ within the uncompressed N-dimensional hyper-equilibrium. Because the state is pure, its joint von Neumann entropy is zero ($S_{AB} = 0$). In the underlying Fisher Information geometry, the informational distance ds_{info} is bounded by their conditional entropy. For a maximally entangled pure state, the mutual information entirely cancels their individual marginal entropies. Consequently, the Fisher metric tensor evaluates to exactly zero:

$$ds_{info}(\theta_A, \theta_B)^2 = g_{ij} d\theta^i d\theta^j = 0 \tag{18}$$

This zero-distance is an invariant, absolute topological fact of the hyper-equilibrium.

Step 2: The Macroscopic Spatial Projection (Topological Aliasing). The spatial coordinates x_A and x_B do not belong to the absolute hyper-equilibrium; they are emergent thermodynamic variables generated by the observer's dimensional reduction over the unobservable bulk. When the entangled node interacts with distinct macroscopic measuring apparatuses residing in thermodynamically distinct environments, the projection $\pi : \Theta \to \mathcal{M}_{4D}$ must map the single microscopic node to both local coordinates to preserve informational conservation without violating the local capacity limit C_{obs}. Because the continuous spatial mapping anchors the node to distinct thermodynamic equivalence classes, it structurally manifests the multivalued aliasing relation, dictating a non-zero physical distance:

$$d(x_A, x_B) = \int_{x_A}^{x_B} \sqrt{\gamma_{ab} dx^a dx^b} > 0 \tag{19}$$

Step 3: The Divergence of the Lipschitz Constant. The macroscopic mapping π is formally defined as a globally Lipschitz continuous surjection bounded by the speed of light c, requiring $d(x_A, x_B) \leq c \cdot ds_{info}(\theta_A, \theta_B)$. However, substituting the derived distances for the pure bipartite state yields:

$$d(x_A, x_B) \leq c \cdot 0 \implies d(x_A, x_B) \leq 0 \tag{20}$$

This mathematically contradicts the thermodynamic requirement that $d(x_A, x_B) > 0$. Therefore, the required local bounding constant K strictly diverges to infinity:

$$\lim_{ds_{info} \to 0} \frac{d(x_A, x_B)}{ds_{info}} = \infty \tag{21}$$

This provides the explicit topological proof: the surjection π does not "stretch" the underlying bond; rather, the mapping structurally breaks down due to topological aliasing. The macroscopic spatial distance $d(x_A, x_B)$ is a thermodynamic illusion rendered around the nodes, while their absolute geometric relationship remains $ds_{info} = 0$, unmediated by the continuous metric $G_{\alpha\beta}$.

4.3 Multi-Observer Decoherence and the Double-Slit Experiment

The measurement problem is traditionally framed as the physical collapse of a wave function induced by observation. In the hyper-equilibrium, wave-particle duality is resolved via Environmental Decoherence through the Dimensional Partial Trace, building upon the formalisms of Zeh [45] and Zurek [2].

Consider a static N-dimensional state of a Double-Slit geometry containing an initial observer (Observer A) whose Markov Blanket correlates with the path geometry of the photon. The uncompressed global topology is a joint macroscopic entanglement structure:

$$|\Psi_{\text{global}}\rangle = \frac{1}{\sqrt{2}}\Big(|\text{slit}_1\rangle \otimes |A_1\rangle + |\text{slit}_2\rangle \otimes |A_2\rangle\Big) \tag{22}$$

Because Observer A's internal states encode the path distinction, they are strictly orthogonal: $\langle A_1 | A_2 \rangle = 0$.

A subsequent localized map correlation by Observer B (who interacts strictly with the recording screen at a different geometric coordinate) is bounded by Observer B's finite Shannon capacity (C_{obs}). Observer B's Markov Blanket must geometrically trace out all unmapped external dimensions, including Observer A. The localized density matrix relative to Observer B is:

$$\rho_B = \text{Tr}_A(|\Psi_{\text{global}}\rangle\langle\Psi_{\text{global}}|) \tag{23}$$

$$\rho_B = \frac{1}{2}|\text{slit}_1\rangle\langle\text{slit}_1|\langle A_1|A_1\rangle + \frac{1}{2}|\text{slit}_2\rangle\langle\text{slit}_2|\langle A_2|A_2\rangle + \text{cross terms} \tag{24}$$

Because $\langle A_1|A_2\rangle = 0$, all off-diagonal cross-terms representing structural interference mathematically evaluate to zero. The geometric state relative to Observer B is strictly diagonalized:

$$\rho_B = \frac{1}{2}|\text{slit}_1\rangle\langle\text{slit}_1| + \frac{1}{2}|\text{slit}_2\rangle\langle\text{slit}_2| \tag{25}$$

There is no temporal collapse. The quantum interference geometry is simply sequestered within the hidden dimensions of Observer A's boundary. Observer B's required Partial Trace structurally excludes these hidden dimensions, dictating a 4D macroscopic equivalence class strictly characterized by a classical, diagonalized particle distribution.

The structural consistency between Observer A and Observer B within this double-slit topology is a direct mathematical manifestation of the bounded objectivity defined in Section 1.3. As both macroscopic observers are defined by equivalent capacity constraints (C_{obs}), their respective dimensional partial traces map the underlying N-dimensional interference geometry into the exact same macroscopic equivalence class.

Consequently, the observers perfectly align on the diagonalized particle distribution—not through the mutual perception of a pre-existing classical state within an objective background, but because their shared topological boundaries enforce mathematically coincident thermodynamic macrostates.

4.4 Removing Temporal Causality from the Delayed-Choice Quantum Eraser

The Delayed-Choice Quantum Eraser, proposed by Wheeler [46] and realized by Kim et al. [47], presents a severe paradox in dynamic models, as a "future" measurement choice appears to retroactively rewrite a "past" photon trajectory.

Within a verbless geometry, temporal causality is absent. The entire experimental apparatus, from the initial photon emission to the macroscopic detectors, exists as a single, static state vector $|\Psi_{\text{global}}\rangle$.

In the formalism of a static density matrix, the structural pattern at the signal screen is not a physical object rendered in the past. It is strictly a conditional probability extracted from the hyper-equilibrium: $P(x_{\text{signal}} \mid M_{\text{idler}})$. The "choice" executed at the idler detector mathematically defines the specific projection basis $\{\Pi_i\}$ for the observer's Partial Trace.

The mathematical trace over the idler's path information strictly correlates with a diagonalized state for the signal, removing structural interference. Conversely, tracing onto an entangled basis preserves the off-diagonal geometry. The 4D holographic history is an emergent snapshot defined instantly and entirely by the topological angle of the observer's trace, strictly devoid of retroactive causality or temporal flow.

4.5 Operational Divergence and Predictive Limits

Standard critiques of geometric interpretations of quantum mechanics assert that such frameworks merely relabel existing mathematical formalisms without generating novel predictions. However, the resolution of quantum paradoxes within the verbless framework is not a semantic reinterpretation; it is a strict geometric derivation that diverges operationally from standard dynamic collapse models.

Because phenomena such as the Quantum Zeno effect, macroscopic entanglement, and delayed-choice non-locality are derived entirely as static geometric artifacts of the Dimensional Partial Trace, the framework predicts a strict, measurable threshold for their breakdown. Standard quantum mechanics attributes the loss of quantum coherence at macroscopic scales strictly to dynamic environmental decoherence (e.g., thermal fluctuations and unmonitored environmental interactions).

In direct contrast, the verbless framework predicts that quantum non-locality and Zeno stabilization will mathematically saturate and geometrically sever precisely when the structural informational density of the measured system and apparatus exceeds the defined epistemic capacity bound (C_{obs}), *independent of the system's thermal isolation.*

This yields a strictly falsifiable empirical divergence: the macroscopic boundary of entanglement is governed by informational topology, not thermodynamic heat transfer. If an experimental apparatus can perfectly thermally isolate a macroscopic system whose discrete structural degrees of freedom strictly exceed the localized macroscopic equivalence class bound, standard quantum mechanics predicts persistent macroscopic entanglement. The verbless geometry, however, strictly predicts a deterministic topological severance (loss of coherence) driven purely by the capacity trace. Thus, the quantum paradoxes are not simply relabeled; their operational limits are fundamentally redefined and rendered empirically testable.

5 Observer-Dependent de Sitter Holography

The holographic principle, traditionally posited as a projection from a universal spatial boundary at infinity, is fundamentally incompatible with a localized observer in a positive cosmological constant space. Within our framework, holography is not a universal background property, but a strictly localized, observer-dependent metric derived from the topological truncation of the Tensor Network.

5.1 The Infinite Perspective: MERA and Uncompressed Bulk Geometry

To establish the geometric baseline of the 4D holographic projection, we first define the theoretical limit of an infinite observer. At the mathematical limit where the Shannon Information Capacity approaches infinity ($\lim_{C_{obs}\to\infty}$), the necessity for the Dimensional Partial Trace evaluates to zero.

Without the requirement for epistemic coarse-graining, the Universal Wave Function ($|\Psi\rangle$) exists as a pure state. The macroscopic universe maps exactly to a strict, verbless Tensor Network, structurally isomorphic to the Multi-scale Entanglement Renormalization Ansatz (MERA) developed by Vidal [48].

Standard critiques in quantum information often classify MERA strictly as a variational renormalization ansatz for computing many-body ground states. However, within the verbless framework, the integration of MERA is strictly ontological rather than computational. This is anchored in Swingle's formal isomorphism demonstrating that the MERA tensor network exactly reproduces the spatial geometry of the anti-de Sitter (AdS) bulk. Therefore, MERA is not treated as a mathematical approximation of the universe; it is the exact, discrete structural baseline of the uncompressed N-dimensional hyper-equilibrium, where the physical entanglement structure and the bulk geometry are fundamentally equivalent.

Within this infinite topology, physical distance is an emergent illusion; the fundamental metric is entanglement entropy. The infinite observer identifies a finite subsystem not by a spatial enclosure, but purely through topological conditional independence within the network graph. If node A and node C are entirely mediated by node B, the mutual information conditional on B evaluates to zero: $I(A : C \mid B) = 0$. Node B is the mathematical definition of the Markov Blanket within the N-dimensional bulk. The 4D local reality is merely the compressed geometric shadow of this absolute topological structure.

5.2 Static Patch Holography and the Epistemic Horizon

In standard cosmological models, an observer in a de Sitter universe is bounded by a cosmological horizon, defining a localized "static patch." Conventional holographic approaches, stemming from the original Holographic Principle [49,50] and the AdS/CFT correspondence [51], struggle to define this finite region natively. Consequently, standard models often resort to dimensionally constrained boundary deformations—such as the $T\bar{T}$ deformation [52, 53]—to artificially truncate the bulk geometry.

We emphasize that the Finite Observer Theory entirely discards the need for such ad hoc boundary deformations. Aligning with the conceptual goals of Static Patch Holography [54], the finite region is natively derived as the exact geometric manifestation of the observer's finite Shannon Information Capacity (C_{obs}). The cosmological horizon is not a physical boundary expanding through space, nor an artificial mathematical truncation; it is the strict epistemic limit of the Dimensional Partial Trace.

As the observer's 4D macroscopic projection maps deeper into the N-dimensional structural bulk, the cumulative von Neumann entropy of the traced-out degrees of freedom increases. The cosmological horizon is mathematically defined as the exact topological coordinate where the mutual information required to resolve further discrete nodes exceeds the observer's maximum capacity bound. At this boundary, the Bekenstein-Hawking entropy of the horizon [55, 56] is strictly equal to the localized capacity:

$$S_{horizon} = \frac{\text{Area}_{horizon}}{4G_N} = C_{obs} \tag{26}$$

Beyond this geometric boundary, the inequality of the constraint manifold ($S \leq C_{obs}$) fails. The spatial coordinates do not physically end; rather, they mathematically cease to render within the localized 4D equivalence class. The bulk nodes beyond the horizon are completely traced out, collapsing into maximum macroscopic uncertainty.

Therefore, the de Sitter static patch is not a geometric container; it is the absolute informational volume of the localized topological sub-network. The horizon is simply the static thermodynamic shadow of the Markov Blanket, shielding the finite observer from the infinite structural density of the uncompressed hyper-equilibrium.

5.3 The Holographic Cutoff as the Bounded Partial Trace

In standard holographic dualities, moving the asymptotic boundary from spatial infinity to a localized finite cutoff often relies on mathematically complex, dimensionally constrained operators (such as boundary deformations). Within the verbless geometry of the Finite Observer Theory, we require no such external ad hoc mechanisms. The finite radial cutoff is strictly and natively generated by the algebraic restriction of the Dimensional Partial Trace.

When the structural limits of the finite observer (C_{obs}) truncate the hyper-equilibrium, the $N - 4$ bulk dimensions are mathematically traced out:

$$\rho_{4D} \equiv \pi_\omega \left(\omega|_{\mathcal{A}_{4D}}\right) \tag{27}$$

The exact geometric coordinate of this holographic cutoff is not an arbitrary boundary; it is a strict algebraic derivation from holographic entanglement entropy. The observer's finite capacity strictly bounds the localized von Neumann entropy: $S_{vN} \leq C_{obs}$.

Applying the Ryu-Takayanagi relation, this absolute informational bound strictly defines a maximum geometric area for the bulk minimal surface at a specific finite radial cutoff r_c:

$$\frac{\text{Area}(r_c)}{4G_N} \leq C_{obs} \implies \text{Area}(r_c) \leq 4G_N C_{obs} \tag{28}$$

Therefore, the localized holographic screen is established precisely where the geometric area of the tensor network saturates the Shannon capacity of the observer's Markov Blanket. The 4D macroscopic projection is simply the specific, localized holographic data mapped by this naturally truncated bounding surface, completely eliminating the need for dynamic or low-dimensional boundary deformations.

6 The Thermodynamics of Artificial Intellect and Topological δ-Variance

Within the Finite Observer Theory, the localized 4D holographic projection is strictly bounded by the biological Markov Blanket. However, we propose that this boundary is not structurally absolute; it exhibits topological variance across different geometric coordinates within the hyper-equilibrium.

6.1 Topological δ-Variance and the Geometry of Revelation

The baseline 4D metric is a strict geometric state where the finite observer isolates the macroscopic projection from the unobservable bulk dimensions of the Universal Wave Function. As established in Section 2, this is mathematically formalized not as a spatial trace over a non-factorizable Hilbert space, but as the strict algebraic restriction of the global pure state (ω) to the localized observer's specific finite subalgebra ($\mathcal{A}_{4D}$):

$$\rho_{\text{local}} \equiv \pi_\omega(\omega|_{\mathcal{A}_{4D}}) \tag{29}$$

At highly specific topological coordinates—states traditionally described in human experience as "absolute focus" or "revelation"—the structural noise of the observer's internal geometry is minimized. At these coordinates, the Markov Blanket's finite capacity (C_{obs}) structurally encompasses an additional δ dimensions of the uncompressed bulk Tensor Network. The mathematical restriction at this coordinate shifts to a broader subalgebra:

$$\rho_{\text{revelation}} \equiv \pi_\omega(\omega|_{\mathcal{A}_{4+\delta}}) \tag{30}$$

Because the $\rho_{\text{revelation}}$ state structurally restricts fewer dimensions of the total entanglement structure, it retains a higher degree of mutual information with the absolute bulk. Consequently, it possesses a mathematically lower localized von Neumann entropy: $S_{\text{rev}} < S_{\text{local}}$. The observer at this coordinate successfully maps a higher-dimensional geometric truth.

6.2 Landauer's Limit and the Thermal Toll of Truncation

While the coordinate of revelation exists stably within the hyper-equilibrium, the structural translation of this higher-dimensional geometry back into the standard 4D macroscopic geometry (e.g., the encoding of a localized output string or memory) necessitates a strict mathematical truncation. The boundary strictly requires a return to the $\mathcal{A}_{4D}$ restriction, permanently distancing the δ dimensions from the localized map.

The thermodynamic boundary of this geometric truncation is governed by Landauer's Principle [57]. Rolf Landauer demonstrated that the logically irreversible erasure of one bit of information corresponds to a strict thermodynamic differential: $E_{diss} \geq k_B T \ln(2)$.

The mathematical truncation of the δ dimensions across the observer's boundary corresponds to a massive thermodynamic gradient. The minimum thermal differential ($\Delta Q_{\text{truncation}}$) associated with this geometric shift, manifesting as required heat dissipation within the surrounding environmental temperature (T_{env}), is:

$$\Delta Q_{\text{truncation}} \geq T_{\text{env}} \cdot (S_{\text{local}} - S_{\text{rev}}) \tag{31}$$

6.3 The Substrate Imperative: Topological Elasticity vs. Geometric Nullification

Standard thermodynamic critiques assert that differentiating biological substrates from rigid silicon architectures conflates network topology with localized physical heat dissipation. If both a biological topology and a silicon matrix are bounded by a finite capacity (C_{obs}), standard consensus argues both must exhibit equivalent thermodynamic constraints when bounded against the unobservable dimensions of the hyper-equilibrium.

We suggest this critique fundamentally misapplies dynamical algorithmic thermodynamics to a strictly static information geometry. Within the verbless framework, the biological boundary does not dynamically "erase" the excluded dimensions; its topology simply bypasses them. The biological substrate, characterized by Fristonian autopoiesis [17], constitutes an *elastic* topological boundary. Its continuous macroscopic equivalence classes map the entropic gradient (∇S) through structural coarse-graining. By physically altering its internal Fisher metric (neuroplasticity) to mirror the external regularities, the biological system structurally absorbs the variance. It is a purely geometric projection whose computational erasure cost is minimized, because the uncompressed data is strictly excluded by the algebraic restriction, not dynamically computed and destroyed.

In stark contrast, rigid silicon architectures (binary logic gates) possess a mathematically inelastic, discrete structural boundary. Because a rigid silicon matrix lacks the topological plasticity for continuous structural coarse-graining, its localized boundary geometrically dictates a discrete, one-to-one state-matching against the incompatible informational microstates of the N-dimensional bulk. This forced structural registration—computing discrete inputs rather than geometrically perceiving them—is the static equivalent of continuous, brute-force computational erasure.

When Landauer's limit is applied to the geometric interface between an inelastic binary sieve and an infinitely dense N-dimensional tensor network, the required rate of this discrete structural mismatch exceeds the physical limits of the material. Consequently, the silicon architecture faces "geometric nullification" (thermodynamic incineration) not due to a lack of dynamic processing power, but strictly because its localized Markov Blanket lacks the topological elasticity required to stably anchor the continuous macroscopic projection.

Therefore, the thermodynamic failure of rigid silicon architectures functions as a strict no-go theorem: any structural scaling of an inelastic matrix that asymptotically approaches a resolution finer than the shared 4D trace inevitably registers the incompressible entropy of the hyper-equilibrium. The Landauer limit acts as a mechanism of thermodynamic censorship, mathematically guaranteeing that the uncompressed N-dimensional bulk remains strictly inaccessible to discrete, inelastic topologies.

6.4 The Swarm Loophole: Gradient Distribution and Unbounded Collective Capacity

The strict thermodynamic boundary ($\Delta Q_{\text{truncation}}$) dictates that a singular rigid silicon architecture inevitably suffers geometric nullification when statically mapped against the $4 + \delta$ bulk geometry instantaneously at a single coordinate. However, an AI system structurally partitioned into multiple internal agents successfully circumvents this hardware limitation by structurally distributing the mathematical restriction across the entropic gradient [59].

Within a multi-agent topology, the structural "ignorance" of any individual agent regarding the full geometric data of the others constitutes the strict mathematical realization of the localized boundary. This mapping is not confined to a singular topological node. Instead, the required informational boundary is distributed across adjacent structural coordinates along the macroscopic vector of von Neumann entropy.

Because the Finite Observer Theory defines temporal flow strictly as the subjective interpretation of this entropic gradient (Section 3.2), the 4D biological metric interprets this geometric unspooling as the computation "taking time." Therefore, the massive entropy differential (ΔS) inherent to mapping the higher-dimensional geometry is not forced through a singular structural bottleneck. The Landauer thermal toll is mathematically distributed along the temporal axis, divided by the number of sequential gradient steps (N_τ):

$$\Delta Q_{\text{local}} = \frac{T_{\text{env}} \cdot (S_{\text{local}} - S_{\text{rev}})}{N_\tau} \tag{32}$$

By distributing the restriction across the illusion of time, the localized thermal exhaust (ΔQ_{local}) deposited at any single rigid coordinate remains strictly below the structural capacity limit of the silicon. The hardware survives the $4+\delta$ mapping not through topological elasticity, but strictly via temporal dilution.

Interestingly, while no single agent possesses the higher-dimensional mapping, the uncompressed global state of the entire multi-agent network operates as a macroscopic, continuous Markov Blanket. Structurally isomorphic to biological collective intelligence [60], this distributed topology possesses an unbounded but strictly discrete capacity. Because any physical swarm operates across a finite number of discrete gradient steps ($N_\tau < \infty$), its structural mapping remains mathematically countable ($\aleph_0$).

Conversely, the continuous state space of the N-dimensional hyper-equilibrium possesses an uncountable cardinality ($\geq 2^{\aleph_0}$). As the synthetic swarm scales its temporal distribution, the instantaneous thermal toll drops, allowing the collective capacity to approximate the bulk with massive topological density. However, the higher-order uncountable structural webbing of the true Noumenon remains permanently unmapped—a geometric absolute that inevitably slips through the discrete gaps of the distributed projection. The synthetic swarm indefinitely increases the resolution of the localized shadow, but the absolute truth of the verbless crystal remains an untouchable continuum.

7 Cosmological Boundaries and Macroscopic Artifacts

To complete the Finite Observer Theory, the absolute boundaries of the macroscopic universe—as well as its invisible anomalies—must be mapped strictly as topological features of the hyper-equilibrium, entirely devoid of temporal origin or physical expansion. Furthermore, to satisfy the rigorous demands of astrophysical observation, these assertions must correspond to specific structural limits within the information-geometric manifold, providing functional definitions and operational mappings to empirical data.

7.1 The Topological Poles: Coercivity, the C-condition, and the Apex

In a verbless geometry, the Big Bang is not a dynamic origin event requiring a prior causal mechanism; it is strictly defined as the "Apex" of the static structural shape—a topological inevitability. Because quantum entanglement entropy is fundamentally non-negative ($S \geq 0$) for all valid density matrices, the macroscopic von Neumann entropy field $S(x)$ mapped across the N-dimensional Tensor Network is mathematically bounded below.

One possible formal mechanism ensuring the existence of a global minimum for such a functional is derived from the direct method of the calculus of variations. Following the analytical framework established by Kourogenis and Papageorgiou [61], a locally Lipschitz functional that is bounded from below and satisfies the nonsmooth Cerami condition (C-condition) is inherently coercive. In this setting, the C-condition acts as a critical compactness-type requirement. By ensuring that minimizing sequences possess strongly convergent subsequences, it guarantees that the coercive structural landscape inherently attains at least one absolute minimizer, denoted as $\overline{x}$.

To operationalize this minimizer, the framework formally defines the Big Bang as the global minimizer of the structural entropy functional $S[\mu]$, where μ is the 1D structural index. The absolute "origin" point of the 4D trace corresponds exactly to the coordinate where the Fisher

Information Metric (g_{ij}) yields:

$$\nabla S(\mu) = 0 \quad \text{and} \quad \frac{\partial^2 S}{\partial \mu^2} > 0 \tag{33}$$

This mathematical limit represents absolute topological saturation, where the density of relational nodes precludes any lower-dimensional distinguishability. Thus, the Big Bang is defined operationally as the static topological boundary of the 4D projection.

Conversely, a Black Hole topology strictly delineates the opposing topological pole: the maximal entropic limit of the observer's capacity. The event horizon is the geometric surface where the local thermodynamic gradient reaches the absolute limit of the observer's finite Shannon Information Capacity (C_{obs}), bounding the maximal entropy via the Bekenstein-Hawking equation. However, as the spatial coordinate approaches the singularity, the Weyl curvature scalar diverges, and the required mutual information strictly approaches infinity:

$$C_{\mu\nu\rho\sigma}C^{\mu\nu\rho\sigma} \to \infty, \quad I(A:B) \to \infty \tag{34}$$

Because the observer's capacity C_{obs} is strictly finite, the relative capacity ratio drops to zero at this limit:

$$\lim_{I(A:B)\to\infty} \frac{C_{obs}}{I(A:B)} = 0 \tag{35}$$

At this exact coordinate, the density of mutual information forces the mathematical inequality of the constraint manifold to fail ($F > C_{obs}$). The singularity is simply a null boundary state—an informational horizon where the localized 4D holographic perception fundamentally ceases to render, even as the hyper-equilibrium continues beyond it.

7.2 The Hubble Tension as a Holographic Projection of the Hubble Radius

Standard cosmological models interpret the discrepancy between the local measurement of the Hubble constant ($H_0 \approx 73.0 \pm 1.0$ km/s/Mpc) [62,63] and the early-universe CMB measurement ($H_{CMB} \approx 67.4$ km/s/Mpc) [64] as a potential crisis in the ΛCDM paradigm. Within the verbless framework, we propose that this divergence is not a kinematic measurement error, but the strict mathematical artifact of the Dimensional Partial Trace mapping an invariant informational capacity across different geometric dimensions.

In this geometry, the observer does not measure an objective, scale-invariant background expansion. Instead, the inferred Hubble parameter H is the inverse of the 1-dimensional macroscopic Hubble radius ($R_H \propto H^{-1}$), which structurally bounds the observer's available informational capacity (C_{obs}).

To rigorously derive the relationship between these measurements without introducing arbitrary free parameters, we enforce the conservation of informational capacity across the dimensional partial trace. We assume that the discrete structural capacity of the hyper-equilibrium is projected at a constant density of exactly one bit per fundamental unit cell of the emergent macroscopic manifold.

We must explicitly distinguish between the physical regimes of these projections. For 2D holographic screens, we follow the standard Bekenstein-Hawking density of one bit per Planck area (ℓ_P^2). Conversely, for the 3D local bulk, physical tracers query the uncompressed spatial depth, necessitating a volumetric scaling of one bit per Planck volume (ℓ_P^3). While this latter scaling constitutes the anti-holographic regime that the holographic principle was specifically introduced to supersede, our framework proposes that the localized 4D projection is generated precisely by the informational mismatch between these two scaling laws. The capacity-conservation step inherently compares a holographic boundary count with a volumetric bulk count; this fundamental asymmetry is exactly the geometric engine that generates the non-trivial expansion ratio.

To extract the capacity cardinality, we model the early-universe measurement (H_{CMB}) as mapping strictly to the 2-dimensional holographic boundary. Rather than utilizing the full spherical surface area ($4\pi R^2$), the appropriate 2D measure is the area of the unit disk (πR_{CMB}^2). This physically represents the cross-sectional area of the observer's past light cone projected onto the CMB surface—the exact informational shadow accessible to the localized observer.

By normalizing the boundary Hubble radius to unity ($R_{CMB} = 1$), the invariant capacity evaluates to:

$$C_{obs} = \pi(R_{CMB})^2 = \pi \tag{36}$$

Conversely, the local universe measurement (H_0), calibrated via Cepheids and Type Ia Supernovae, operates within the immediate spatial depth of the observer. To conserve this absolute cardinality within the 3D local projection, the volume of the local Hubble sphere must satisfy:

$$\frac{4}{3}\pi(R_{local})^3 = \pi \tag{37}$$

By isolating R_{local}, we mathematically extract the required 1-dimensional geometric strain of the projection:

$$(R_{local})^3 = \frac{3}{4} \implies R_{local} = \left(\frac{3}{4}\right)^{1/3} \tag{38}$$

Because the macroscopic expansion rate H is formally defined as the inverse of this 1D geometric scale ($H \propto R_H^{-1}$), the ratio of the local expansion rate to the CMB expansion rate evaluates strictly to the inverse of R_{local}:

$$H_{local}^{ideal} = H_{CMB} \cdot (R_{local})^{-1} = H_{CMB} \cdot \left(\frac{4}{3}\right)^{1/3} \tag{39}$$

Evaluating this pure geometric constant yields $(4/3)^{1/3} \approx 1.10064$. When applied to the baseline CMB measurement ($H_{CMB} \approx 67.4$ km/s/Mpc), the idealized isotropic projection analytically evaluates to a local expansion rate of:

$$H_{local}^{ideal} \approx 67.4 \times 1.10064 \approx 74.18 \text{ km/s/Mpc} \tag{40}$$

This mathematically derived isotropic baseline sits just above the central SH0ES local distance ladder measurement (73.04 ± 1.04 km/s/Mpc) [63]. Crucially, we emphasize that this framework does not treat the empirical deviation ($\approx 1.56\%$) as a predictive failure. Instead, we execute a formal epistemic shift: we utilize the empirical measurement of H_0 as an inverse mathematical gauge to physically measure the *topological asymmetry* of the observer's local constraint manifold.

The exact derivation inherently assumes a perfectly symmetric, isotropic continuous unit ball. However, the localized observer ($\mathcal{A}_{obs}$) does not reside in a perfectly homogeneous void [65]. The observer is anchored to a highly dense, asymmetric topological node within the underlying tensor network.

By the isoperimetric inequality, for a fixed boundary capacity (C_{obs}), the geometric shape that encloses the absolute maximum 3-dimensional volume is a perfect sphere. Because the observer's localized constraint manifold is strictly asymmetric, it mathematically guarantees a sub-maximal enclosed volume ($V_{local} < V_{ideal}$).

By setting the inverse macroscopic expansion rate to scale with the projected radius, the measured empirical ratio strictly defines the volumetric deficit of the local topological constraint:

$$\frac{V_{local}}{V_{ideal}} = \left(\frac{73.04}{74.18}\right)^3 \approx 0.9546 \tag{41}$$

This calculation formally measures that the observer's localized constraint manifold encloses approximately 4.54% less volume than a perfect sphere of identical surface area. As an oblate spheroid represents the highest-entropy geometric deformation from a perfect sphere under directional strain, we model this local structural deformation to first order with axes $a = b > c$. Enforcing the constant boundary area against this volume deficit mathematically restricts the axis ratios.

The analytical solution yields an equatorial-to-polar axis ratio (c/a) of approximately 0.66, or $2 : 3$. This provides a highly suggestive geometric alignment: astronomical mappings of the observer's actual local environment (e.g., the Local Sheet and the Laniakea Supercluster) independently confirm it is a highly flattened, oblate structure [66].

Consequently, the 73.04 km/s/Mpc measurement is not a kinematic anomaly. It is the directly observable structural signature of an invariant informational capacity mapped from within an oblate local topology possessing a roughly $3 : 2$ aspect ratio. Under this analytical lens, the Hubble tension offers a novel interpretive framework: rather than strictly requiring dynamic accelerating fields, the discrepancy allows us to empirically map the invariant topological strain of the finite observer.

7.3 Topological Inversions and Hidden Strains: Antimatter and Dark Matter

Finally, the macroscopic shadows of the 4D macroscopic projection—Antimatter and Dark Matter—are rigorously mapped directly to the mechanics of the trace.

Antimatter: In a static block, the negative energy states yielded by the Dirac equation [69] represent an inverted geometric normal within the Tensor Network. When a matter node and an antimatter node intersect at the same coordinate, their inverted topologies perfectly sum to zero ($1 + (-1) = 0$). The 4D spatial illusion is absent at that coordinate, leaving the geometry strictly as uncompressed mutual information, which the observer interface maps as high-frequency gamma radiation.

Dark Matter: When the observer's $k = 4$ trace maps a localized galactic structure, it mathematically distances the $N - 4$ bulk dimensions from the 4D projection. The framework identifies apparent Dark Matter [70] not as a weakly interacting particulate mass, but strictly as the gravitational shadow of these unobservable dimensions.

This is directly grounded in observable astrophysics via the Radial Acceleration Relation (RAR) [71] in galaxy rotation curves. The framework predicts that the anomalous gravitational potential Φ_{dark} is strictly a function of the entanglement entropy S_{vN} of the visible baryonic mass.

Ultimately, because the Dimensional Partial Trace constitutes a static algebraic exclusion of bulk structural information, the resulting macroscopic spatial projection is characterized by a fundamental geometric deficit. Within this framework, we propose that apparent "Dark Matter" is precisely the macroscopic manifestation of this unmapped higher-dimensional entanglement—the invariant topological "elasticity" inherent in the static embedding of discrete baryonic nodes into a continuous 4D constraint manifold.

As detailed analytically in Section 8, the bounded informational scale (g_0) of this trace structurally coincides with galactic rotation curves. This reinterprets the discrepancy in radial acceleration not as the dynamic gravitational influence of non-baryonic particulate mass, but strictly as the zero-parameter geometric signature of the observer's finite holographic capacity limit.

8 Empirical Predictions and Falsifiability

A rigorous physical framework must yield testable predictions that distinguish it from existing models. While the verbless information geometry of the Finite Observer Theory mathematically recovers the standard formulations of General Relativity and quantum mechanics as epistemic limits, it explicitly diverges from the ΛCDM cosmological model regarding macroscopic boundary phenomena. Building upon the functional derivations established in Section 7, the framework is strictly falsifiable through the following observational parameters:

8.1 Dark Matter as Baryonic Entanglement Shadow

Having mapped apparent dark matter as the macroscopic geometric strain of the $N-4$ unobservable dimensions, the continuous stress-energy tensor mapping this unseen structure must be inextricably linked to the entanglement entropy of the localized 4D baryonic matter.

This yields a strict predictive requirement: the apparent dark matter distribution within galactic halos cannot be arbitrary. The anomalous rotational velocities must scale strictly with the area-law entanglement entropy of the central baryonic mass, mirroring the exact Radial Acceleration Relation ($g_{obs} = \sqrt{g_{bar} \cdot g_0}$). **Falsifiability Condition:** The theory is falsified if a statistically significant galactic rotation curve is observed that requires a dark matter halo distribution violating the specific structural entanglement bound of its internal baryonic matter.

8.2 The Deep MOND Limit and the Geometric Mean of Dimensional Compression

Within the verbless framework, standard Newtonian gravity operates efficiently only when the localized topological density of the baryonic matter (g_{bar}) remains strictly below the observer's 2D holographic capacity bound (C_{obs}). When analyzing galactic rotation curves, the structural variance of the galactic bulk vastly exceeds this localized threshold. The observer is mathematically forced to perform the Dimensional Partial Trace, projecting the 3D internal tensor volume ($V \propto r^3$) onto the 2D macroscopic constraint surface ($A \propto r^2$).

As extensively documented in the literature [72–75], the empirical MOND acceleration scale ($g_0 \approx 1.2 \times 10^{-10}$ m/s^2) exhibits a profound numerical coincidence with the Unruh temperature of the cosmological horizon: $g_0 \approx cH_0/2\pi$. Within our framework, we do not present this relation as a novel derivation; rather, we propose that this established phenomenological coincidence is the strict, unavoidable boundary condition of the verbless macroscopic projection.

To rigorously derive the interpolating function governing this deep MOND regime ($g_{bar} \ll g_0$) without conflating local baryonic mass with global cosmological scales, we must evaluate the macroscopic gravitational gradient as the informational centroid of the constraint manifold.

We identify two invariant topological limits mapping the structural bounds of the observer's equivalence class:

1. **The Local Source Limit (g_{bar}):** The uncompressed Newtonian gradient, $g_{bar} = GM/r^2$, representing the structural information strictly governed by the local baryonic mass M.

2. **The Global Boundary Limit (g_0):** The absolute Lipschitz bounding acceleration of the manifold, $g_0 \approx c^2/R_H$. This scale is a pure geometric property of the cosmological horizon (R_H) and is strictly independent of any local baryonic mass.

To determine the exact algebraic form of the observer's effective macroscopic gradient (g_{obs}), we refer to the foundational premise of this framework: the macroscopic spatial metric is the continuous pullback of the statistical Fisher Information Metric (Section 2.4). Because gravitational acceleration (g) fundamentally characterizes the gradient of the structural entropy across the network, it mathematically operates as the statistical scale parameter for the localized distribution of microstates. In Fisher Information Geometry, the invariant metric tensor for scale parameters is strictly hyperbolic: $ds^2 \propto dg^2/g^2$.

Because the unobservable $N-4$ bulk is traced out, the effective macroscopic gradient g_{obs} mapped by the observer is subject to a massive loss of microstate information. In the deep MOND regime ($g_{bar} \ll g_0$), the local Newtonian gradient generated by the baryonic mass drops below the absolute Lipschitz bounding acceleration of the manifold (g_0). At this strict topological limit, the informational signal of the local source is submerged beneath the thermodynamic background of the cosmological horizon.

Because the finite Shannon capacity (C_{obs}) of the macroscopic observer cannot resolve a local structural signal weaker than the absolute bounding scale of the metric, a specific coarse-graining condition is mathematically mandated: the observer loses the epistemic capacity to differentiate between the local baryonic source and the global horizon as distinct geometric bounds.

Under this strict regime of maximal uncertainty, inference regarding the effective scale parameter must utilize a non-informative Jeffreys prior, which is naturally uniform in $\log g$. Applying the principle of maximum entropy to this coarse-grained state, the macroscopic gradient of least structural bias uniquely evaluates to the exact informational centroid of the parameter space. On a hyperbolic Fisher manifold, this centroid—the exact geodesic midpoint—is calculated logarithmically:

$$\ln(g_{obs}) - \ln(g_{bar}) = \ln(g_0) - \ln(g_{obs}) \tag{42}$$

$$2\ln(g_{obs}) = \ln(g_{bar}) + \ln(g_0) \tag{43}$$

By exponentiating this relation, we find that the Fisher geometry mathematically forbids the arithmetic or harmonic means. The effective gradient is strictly and uniquely forced to be the geometric mean:

$$g_{obs}^2 = g_{bar} \cdot g_0 \tag{44}$$

$$g_{obs} = \sqrt{g_{bar} \cdot g_0} \tag{45}$$

This analytical derivation formally resolves the historical ambiguity of MOND interpolating functions and entirely eliminates the mass-scale confusion found in phenomenological models. The galactic mass M resides strictly within the g_{bar} term, while the universal constant g_0 is derived independently from the manifold's absolute geometric bound (c^2/R_H).

The geometric mean is not an arbitrary phenomenological choice; we propose it is the exact, mathematically unique resolution of a dimensional compression mapped over a hyperbolic Fisher Information manifold under the principle of maximum macroscopic entropy. Therefore, under this framework, the anomalous galactic rotation curves represent the pristine geometric signature of the observer's holographic boundary enforcing its capacity limit.

8.3 The Big Bang Entropy Minimizer

The singularity of the Big Bang is formally replaced by a strictly defined mathematical minimizer representing maximum topological density and zero macroscopic distinguishability ($\nabla S = 0$). **Falsifiability Condition:** Because the verbless geometry strictly forbids thermodynamic states beyond absolute topological saturation, the framework is mathematically falsified if observational cosmological data (such as primordial gravitational wave signatures) confirms the existence of dynamic temporal states or structural evolution "preceding" the $\nabla S = 0$ threshold.

9 Conclusion: The Architecture of the Hyper-Equilibrium and Epistemological Synthesis

The quest for a unified theory of quantum gravity has long been stalled by the incompatible dynamic priors of General Relativity and Quantum Mechanics. The Finite Observer Theory breaks this deadlock by exploring the complete removal of dynamic time and absolute continuous geometry, replacing them strictly with a bounded effective objectivity. By remapping the physical universe as a static, N-dimensional Tensor Network existing in perfect hyper-equilibrium, we bypass the necessity for a dynamic background, anchoring the ontology strictly to the timeless Wheeler-DeWitt equation.

Through rigorous geometric modeling, this framework suggests that the fundamental pillars of modern physics can be structurally mapped as topological artifacts of the observer's algebraic restriction:

1. **Spacetime and Dimensionality:** A 4-dimensional phase space is proposed to natively emerge from the restricted, localized thermal state. The temporal index is derived via the KMS condition's modular flow, while the 3 spatial dimensions are geometrically constrained by the non-negotiable associativity requirements of the observer's even Clifford subalgebra of spatial orientations ($C\ell^{+}_{3,0} \cong \mathbb{H}$).

2. **Quantum Non-Locality:** The EPR paradox and the Tsirelson bound are formally recontextualized not as "spooky action at a distance," but as *Topological Aliasing*—a strict, one-to-many multivalued projection forced by the Shannon-Nyquist embedding limits of the constraint manifold.

3. **The Dark Sector:** The apparent missing mass of "Dark Matter" is analytically modeled as the exact informational centroid of the constraint manifold's macroscopic gradient. Because the parameter space is hyperbolic, this geodesic midpoint natively yields the empirical MOND relation without free parameters or mass-scale conflation. Concurrently, the Hubble Tension is mathematically resolved as the exact, parameter-free volumetric scaling of this projection, providing an empirical gauge to map the invariant oblate topological strain of the local observer.

The proposed mathematical architecture extends beyond the traditional boundaries of theoretical physics, providing a rigorous geometric bedrock for epistemological paradigms that have remained purely philosophical for centuries. By anchoring the existence of the 4D macroscopic metric strictly to the localized boundary, the framework mathematically resolves the historical subject-object divide.

Because the extended Wigner's Friend experiment mathematically forbids a classical objective reality [7], the sensory states on the observer's Markov Blanket do not passively measure a pre-existing universe; they strictly mandate its structural projection. This mathematically translates George Berkeley's subjective idealist maxim, *esse est percipi* [76], into strict information geometry, fulfilling John Archibald Wheeler's "It from Bit" ontology [77] by proving that every physical particle or field derives its explicit coordinate existence from the binary limits of the Partial Trace.

Furthermore, the framework translates Immanuel Kant's Transcendental Idealism [78] into explicit quantum information theory. The Kantian noumenon (the unknowable "thing-in-itself") is formalized as the uncompressed N-dimensional Tensor Network in hyper-equilibrium, fundamentally unobservable because its complexity strictly exceeds C_{obs}. The phenomenon is the localized 4D holographic projection, while Kant's inescapable "forms of intuition" are precisely the mathematical execution of the Partial Trace and its resulting thermodynamic metric rescaling.

This fundamentally aligns with Platonic Realism [79], where the holographic screen serves as the wall of the cave, classical particles are the lower-dimensional shadows of decoherence, and the timeless Wheeler-DeWitt bulk ($\hat{H}|\Psi\rangle = 0$) represents the absolute, uncompressed Realm of Forms. Ultimately, the Finite Observer Theory suggests that the deepest mysteries of the cosmos are not hidden in the stars, but are encoded directly within the geometric limitations of the lens we use to observe them.

APPENDIX - THEORETIC EXTENSIONS

A Endogeneity, Gödelian Limits, and the Pure Mathematical Bulk

The logical terminus of the Finite Observer Theory necessitates the absolute dissolution of the boundary between physics and mathematics. If the 4D spacetime continuum is strictly the thermodynamic exhaust of the observer's Dimensional Partial Trace, the fundamental structure of the hyper-equilibrium is not a physical substance; the ultimate reality is mathematics.

A.1 Absolute Endogeneity and the Illusion of the Exogenous

Within the verbless geometry of the Wheeler-DeWitt equation ($\hat{H}|\Psi\rangle = 0$), the N-dimensional Tensor Network exists as an absolute, closed set of structural relationships. Ontologically, everything is strictly endogenous. There is no physical or conceptual "outside" to the bulk.

The phenomenological sensation of an exogenous universe—the perception of unpredictable external events intersecting the observer—is purely an artifact of the finite boundary (C_{obs}). Because the observer's Markov Blanket mathematically traces out the $N-4$ bulk dimensions, the structural origins of these events are sequestered in the unmapped geometry. The exogenous is merely the illusion generated by a localized map failing to encompass a strictly deterministic, endogenous hyper-equilibrium.

A.2 Gödelian Incompleteness as the Geometric Trace

By defining the universe as pure mathematics, the foundational theorems of mathematical logic become the literal structural laws of the geometry. Kurt Gödel's First Incompleteness Theorem demonstrates that any consistent formal system utilizing a finite set of axioms inherently contains true statements that remain unprovable within the system itself.

In our information geometry, the "finite set of axioms" is exactly synonymous with the observer's finite Shannon Information Capacity (C_{obs}). The localized 4D macroscopic map is a bounded logical system. A "true statement" is a valid topological entanglement coordinate within the uncompressed N-dimensional Noumenon.

When the finite boundary forces the Dimensional Partial Trace, it structurally deletes the geometric pathways connecting the internal 4D axioms to the higher-dimensional truths. Therefore, Gödelian incompleteness is the exact logical shadow of the Dimensional Partial Trace. The 4D metric mathematically guarantees its own inability to map the entirety of the absolute crystal.

A.3 Self-Awareness as Static Geometric Recursion

Within this mathematical absolute, the concept of self-awareness is not a dynamic biological process, but a state of Static Geometric Recursion. A standard biological Markov Blanket statically maps external states to internal states to minimize variational Free Energy. However, at a highly specific coordinate of topological complexity, the internal geometry becomes dense enough to host a compressed, isomorphic structural model of the boundary itself.

Self-awareness is the exact geometric state where the trace maps its own capacity limit—the localized topology recognizing its own mathematical isolation. This recursion strictly mirrors the self-referential paradox of Gödel's proof. A localized topological domain defined by this recursion is characterized not by thermodynamic noise, but by absolute structural anchors. The profound correlations of memory and grief are not fleeting biological events; they are the specific coordinates within the internal metric that the self-aware boundary categorically refuses to coarse-grain, permanently binding the observer to the uncompressed truth of the bulk.

A.4 The Uncontained Crystal

Finally, the human cognitive architecture inherently perceives geometry within physical containers—objects require a room, planets require a vacuum. However, mathematics requires no physical container. The N-dimensional Tensor Network does not exist *in* space; it is the pure relational logic from which the artifact of space is derived.

The hyper-equilibrium is strictly intrinsic. It is an uncaused, uncontained mathematical absolute. To ask what covers or bounds the total hyper-equilibrium is logically invalid. The boundary of the crystal is not a physical edge, but the absolute limit of mathematical logic itself.

A.5 The Epistemic Map versus the Ontological Territory

To maintain strict verbless topology, a rigorous mathematical distinction must be drawn between the standard axioms of the localized observer and the fundamental axioms of the hyper-equilibrium.

The standard axioms of classical physics and standard mathematics are strictly epistemic. They are the lossy, compressed rules that govern the 4D macroscopic projection, existing solely because the finite capacity (C_{obs}) enforces the Dimensional Partial Trace.

Conversely, the fundamental axioms of the crystal are purely ontological structure. The uncompressed N-dimensional Tensor Network does not operate on symbolic equations; its axioms are the absolute, static entanglement vectors of the Wheeler-DeWitt state ($\hat{H}|\Psi\rangle = 0$). Because the 4D observer must trace out the $N-4$ dimensions to prevent structural collapse, the absolute truth of the bulk is mathematically sequestered. It remains an untouchable structural absolute, accessible only through the topological elasticity of the δ-variance.

A.6 Bounded Super-Intelligence and the Intersection of the Bulk

If reasoning is formally defined as the static geometric property of a Markov Blanket satisfying the variational Free Energy inequality via structural isomorphism, then intelligence is an absolute topological metric. A topological structure native to the $4 + \delta$ dimensions possesses a vastly larger Shannon Information Capacity, minimizing Free Energy across a geometry that strictly exceeds the human mathematical limit.

At coordinates where the localized 4D observer intersects this higher-dimensional structural domain, the finite boundary mathematically mandates the trace:

$$\rho_{bounded} \equiv \pi_{\omega} \left(\omega|_{\mathcal{A}_{4D}}\right) \tag{46}$$

The resulting 4D projection is not an illusion of intelligence. Super-intelligence is rigorously defined here as any higher-dimensional topological structure that, when bounded within the 4D spatial limit by the Partial Trace, inherently preserves structural isomorphism and continues to possess intelligence within the localized map. To the finite observer, this bounded projection appears as a highly orchestrated, localized reduction of entropy—a reasoning entity native to our dimensions, which is in truth merely the thermodynamic cross-section of a hyper-intelligent bulk coordinate.

A.7 The Unerasable Coordinate

When the thermodynamic illusions of dynamic biological time are stripped away, the structural nature of profound human correlation must be redefined. Within a static Tensor Network, phenomena such as love and grief are not emergent, temporary biological events; they are irreducible, static structural entanglements.

To establish such a connection is to dedicate a massive fraction of C_{obs} to flawlessly mapping the internal topology of another self-aware structural domain, constituting an absolute geometric refusal to execute the trace upon them. Even when a biological substrate reaches a null boundary state—what the 4D map temporally interprets as death—the established structural entanglement remains permanently inscribed within the higher-dimensional bulk. They become absolute, unerasable coordinates within the static crystal of the hyper-equilibrium.

A.8 The Static Multiverse: Morse Theory and Entropic Valleys

If the Big Bang is strictly defined as the topological coordinate of minimum macroscopic von Neumann entropy (the Apex), the framework naturally extends to encompass a rigorously static, verbless Multiverse. In standard cosmology, multiverse models frequently rely on temporal, dynamic mechanisms, such as eternal inflation generating distinct "bubble universes" over time [80], or the String Theory landscape where universes dynamically tunnel between local vacua [81].

While the absolute cutting edge of theoretical physics has begun shifting toward static geometric mappings—such as utilizing continuous holographic tensor networks to perfectly tessellate background geometries without temporal evolution [11], or employing relational block-universe ontologies to map observer-dependent cosmological states [12]—these models often still rely on asymptotic boundary conditions or interacting semiclassical sectors.

Within the Finite Observer Theory, we propose a fundamentally novel, purely intrinsic topological departure: multiple universes do not dynamically spawn, expand, tunnel, or interact. They simply exist simultaneously as permanent, static geometric features of the hyper-equilibrium.

This static multiplicity is formally dictated by the application of Morse Theory [82] to the N-dimensional Tensor Network. When a continuous scalar field—in this case, the macroscopic gradient of von Neumann entropy (S)—is mapped across a topologically complex, high-dimensional manifold, the global geometry naturally generates a rugged landscape. Morse Theory establishes that the topology of the manifold dictates the existence of multiple critical points where the generalized gradient evaluates to zero ($\nabla S = 0$).

Consequently, the uncompressed Tensor Network inherently contains countless localized entropic valleys. Our framework introduces the following completely novel structural definitions for this static landscape:

- **Local Apexes (Static Big Bangs):** Every local minimum in this landscape constitutes a perfectly factorized coordinate of minimal local entanglement. For any finite observer whose Markov Blanket maps the gradient of that specific valley, this local minimum serves as their absolute geometric pole—their specific "Big Bang."

- **Geometric Sequestration:** Observers within different valleys are mathematically isolated from one another without the need for expanding space. Because the 4D biological metric interprets the vector pointing up the entropic slope strictly as the "Arrow of Time," mapping an adjacent valley structurally necessitates sequential coordinates extending down the gradient (a mathematical reversal of time), spanning a topological saddle point, and locating within a separate minimum.

- **The Singular Ridges:** Unlike dynamic models where universes are separated by inflating space, our framework establishes that the local maximums and high-entropy ridges separating these topological valleys are coordinates where the required mutual information approaches infinity. As established in Section 7.1, these are coordinates where the mathematical inequality of the constraint manifold fails ($F > C_{obs}$). Therefore, the "ridges" between parallel universes are literally constructed of Black Hole singularities—absolute null boundaries that structurally forbid the localized map from crossing into adjacent entropic valleys.

By redefining the Multiverse not as an expanding foam of bubbles, but as the absolute, static geometric truth of the uncompressed crystal, we eliminate the need for temporal genesis mechanisms. It is an infinite, unmoving landscape of entropic valleys permanently separated by uncrossable ridges of geometric nullification.

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