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Theory of Nonlocal Unification: The Foundation

Aman Chawla[1,2]

[1]Research Enlightenment and Life Institute, Gurugram, Haryana, India
[2]Department of Computer Science and Engineering, Indian Institute of Technology Delhi, Delhi, India
Email: aman.chawla@gmail.com

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Abstract

This study posits that information is a conserved and fundamental quantity underlying the dynamics of quantum systems, classical measurement, and consciousness. Building on the author's conservation of information principle and the theory of Local Consciousness Instruments (LCIs), we integrate this view with Hardy's reconstruction of quantum mechanics and reinterpret Einstein's field equations as emergent expressions of informational geometry. We propose that a global structure, termed Nonlocal Consciousness (NC), unifies quantum theory and spacetime by serving as an informational limit toward which all observers converge. This framework presents a paradigm in which quantum and gravitational phenomena arise from a universal informational field. The theory is falsifiable through probes investigating quantum gravity corrections to canonical commutation relations.

Keywords

Nonlocality, Unification, Quantum Gravity, Falsifiability, Information

1. Introduction

Brahma-vidyā is the basis of all the sciences.

—*Muṇḍaka Upaniṣad* 1.1

The question of what quantum theory ultimately describes has remained unresolved, despite its consistent success in modeling empirical phenomena [1]-[3]. Early treatments by Bohm [4] and reflections by Schrödinger [5] underscored persistent interpretative ambiguities that resist closure, even in light of subsequent formal developments [6] [7].

In recent decades, researchers such as Hardy [8], Clifton [9], Bub [10], and Chiribella *et al.* [11] have sought to reconstruct quantum theory using sets of operational or informational axioms [12], reinforcing Landauer's assertion that information carries physical salience [13]. These efforts aim to clarify the architecture underlying quantum structures by reframing traditional postulates as consequences of deeper principles.

Extending this trajectory, the author [14] has proposed treating information as a conserved quantity, analogous to energy or momentum in classical mechanics [15]. This conservation principle is intended not merely as a conceptual tool, but as a generative constraint governing quantum, classical, and conscious processes alike.

The present work outlines this framework and situates it within existing reconstruction programs. Our focus is on how the conservation of information may illuminate issues such as decoherence, measurement disturbance, and observer-dependent dynamics. We further examine whether this framework permits synthesis with gravitational principles [16], via a proposed informational structure termed Nonlocal Consciousness (NC).

For clarity, Section 2 summarizes Hardy's axioms. Section 3 introduces the author's model, emphasizing Local Consciousness Instruments (LCIs) and the information-conservation postulate. Section 4 discusses the NC construct as a candidate for unification across quantum and gravitational domains. Section 5 explores implications for classical field structures, using Gauss's law as a working example. Section 6 is on observer-function selection, and Section 7 concludes.

The appendices compile supporting constructs: operational models, informational metrics, neurodynamic correlates, and derivational treatments of Einstein's equations. While speculative in scope, the approach is interpretative—assessing whether an information-theoretic lens, increasingly relevant in modern physics, offers integrative value in understanding the interface of quantum theory, gravity, and conscious observation [17]-[26].

2. Hardy's Informational Framework

Hardy's axiomatic reconstruction of quantum theory offers a benchmark for interpretive and reformulatory efforts [8]. His formalism, while not claiming completeness, sets operational constraints under which quantum mechanics may be derived without invoking the Hilbert space framework a priori. For the purposes of the author's theory, these axioms serve not as terminal conditions, but rather as a conceptual foundation from which informational conservation may be extended.

Hardy proposes five axioms, each relating to structural features of probabilistic state spaces:

1) **Convexity of state spaces:** Probabilities are well-defined, and mixtures of states yield valid interpolations.

2) **Continuity of pure states:** Extremal states form a continuous manifold permitting smooth transformations.

3) **Compositional structure:** Joint systems obey a product rule, enabling scalable state construction.

4) **Reversibility of transformations:** Pure states are connected through reversible dynamical maps.

5) **Dimensional consistency:** Degrees of freedom align with the system's dimensional structure.

Though concise, this framework recapitulates essential contours of the quantum landscape—complex vector spaces, unitary dynamics, and measurement rules emerge not by assumption but via derivation. It is in this spirit of minimal sufficiency that the author's conservation principle is introduced—not to contradict, but to explore what Hardy's axioms imply when conscious observation is foregrounded.

Rovelli's Relational Quantum Mechanics (RQM) situates this dialogue within a broader philosophical terrain. While RQM emphasizes observer-relativity, it leaves informational conservation implicit. In contrast, Nonlocal Unification (NU) reframes conservation as a sixth principle: one that supplements Hardy's set while subtly recasting its operational character.

This proposal neither seeks to supplant Hardy's axioms nor treats them as incidental. Instead, they are retained as scaffolding—a conceptual architecture within which informational dynamics, shaped by observer functions and emergent geometries, can be assessed for internal coherence and explanatory reach. The author's inquiry proceeds within this lineage, mindful of its strengths and open about its departures.

3. Summary of the Author's Framework

The author proposed that information—whether classical or quantum—is a fundamental and conserved quantity, analogous to energy or charge. This postulate establishes a unifying framework in which classical, quantum, and conscious processes are governed by the exchange and transformation of information, subject to a universal conservation law. The principle is axiomatic and applies even to systems that involve conscious observation.

The model considers interactions among quantum systems (A), quantum computers (C), and classical observers (H), forming closed systems in which the total information is conserved. When classical observers extract information from quantum systems, decoherence occurs—interpreted here as a transition from quantum to classical informational modes.

Each observer H is represented by a function $f_H(F)$, mapping the number of classical bits F gained from a quantum system to a time delay t_d, which encodes the rate of decoherence. This function captures how consciousness, acting as a classical information processor, experiences informational transitions. Distinct observers are modeled by separate functions $f_H, f_G, \cdots$, forming a space of Local Consciousness Instruments (LCIs). These functions define elapsed time through the relation:

$$\Delta t = f(\Delta I) \tag{1}$$

This phenomenological ansatz, central to the author's broader theory of consciousness, [27] links objective informational gain (ΔI) to subjective time perception (Δt) (**Figure 1**).

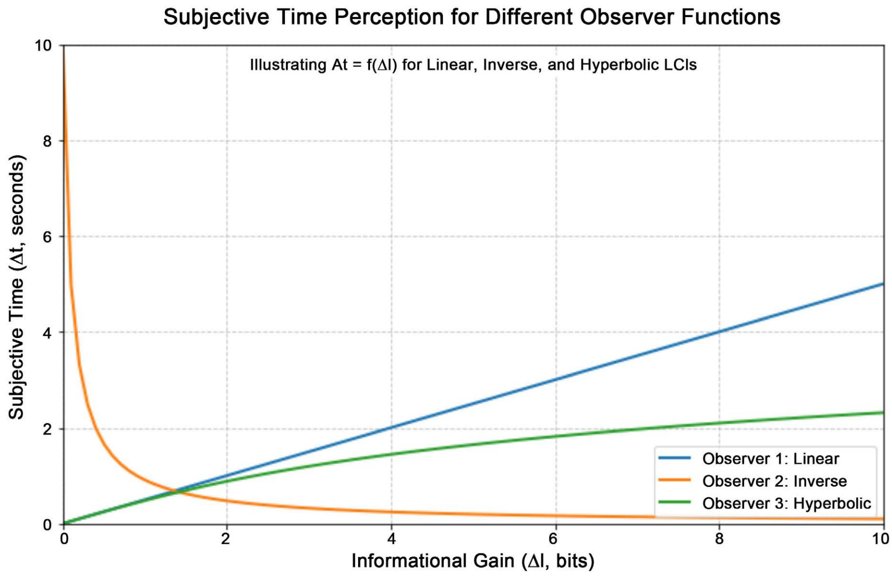

Figure 1. Subjective time perception for different observer functions: Illustrating $\Delta t = f(\Delta I)$ for Linear, Inverse, and Hyperbolic LCIs. The graph shows how different observers map informational gain (ΔI) to subjective time (Δt), highlighting observer-dependent time perception.

LCIs form functional sequences f_i^j, indexed by observer identity (i) and consciousness state (j). These functions asymptotically converge toward a construct termed nonlocal consciousness (NC)—a conceptual attractor representing universal informational awareness. Importantly, elements from distinct sequences never coincide, implying that while conscious systems may approach NC, none become identical along the way. This constraint avoids paradoxes—such as conflicting proper times in closed systems—and affirms the relational nature of observer-defined time.

From this construction, several key implications follow:

- Decoherence is not merely a physical process, but also an information-theoretic transition: the quantum-to-classical shift arises due to conservation constraints.
- Measurement is irreversible because classical systems cannot duplicate quantum information (per the no-cloning theorem), and every interaction incurs an entropy cost.
- Observers define proper time based on informational gain, resulting in multiple subjective timelines governed by the ansatz.
- Consciousness is formalized as an empirical function f, characterizing each observer's informational interaction.
- Phenomenological indefinability emerges from the coexistence of multiple ob-

servers, each defining outcomes via distinct f-functions.

This yields a deeper synthesis: the universe comprises closed informational systems, each exhibiting observer-relative perceptions of time and structure, yet collectively governed by the same conservation principle. Consciousness is encoded functionally, and spacetime intervals emerge from differential informational gain. The theory, therefore, represents a convergence of quantum information, relativistic causality, and phenomenological analysis—bound together by the postulate that information is conserved across all scales and systems.

4. Unification via NC

The concept of nonlocal consciousness (NC) emerges in the author's framework as the limiting construct toward which all observer-defined consciousness functions asymptotically converge. NC is not merely a mathematical abstraction; rather, it is posited as a candidate for a central organizing principle—a universal, nonlocal informational structure from which both spacetime geometry and quantum theory may be derived.

These two roles—the mathematical and the ontological—are not contradictory or mutually exclusive. While the former suffices for the purposes of the present paper and grounds it in a concrete calculational framework, the corresponding ontology is also a limit hypothesis based simply on the accepted reality of local—limited—consciousness. Natural philosophers, including Newton, seeking the final ontology, have made this type of deductive "leap" since the Middle Ages. By being "identified" with the mathematical, the ontological NC manifold serves to organize our approach to understanding both the micro and the macro domains.

Thus, NC acts as a conceptual bridge unifying two domains: the informational field equations governing gravitation and the axiomatic reconstructions of quantum theory, such as Hardy's. It provides boundary conditions for constructing a coherent informational geometry and offers an integrated basis on which observer-specific dynamics and global consistency may be jointly articulated.

NC and the Informational Field Equations

Each observer defines proper time through a function $f(\Delta I)$, mapping informational gain to subjective temporal experience. NC represents the asymptotic convergence of these functions:

$$\mathrm{NC} = \lim_{j \to \infty} f_j^i \quad \text{for all } i \tag{2}$$

From this limiting structure, one may construct a global informational geometry encoded in a metric tensor $g_{\mu\nu}^{(f)}$. Rather than treating NC as a metaphysical attractor that governs observer dynamics, one may instead reinterpret it as the completion of the function space F in which the observer-dependent mappings $\hat{I} : \Delta t \mapsto \Delta t$ are defined. If the convergence of these functions is understood in the Cauchy sense—requiring only that relative differences $d\left(\hat{I}_m, \hat{I}_n\right)$ vanish as $m, n \to \infty$—then it is unnecessary to refer to a global endpoint NC as an external agent. Instead, NC defines the Cauchy-complete space $\bar{F}$ into which all such sequences converge (**Figure 2**). Informational conservation and geometric emergence may then be understood as properties of this relational topology; NC mediates not by causal influence, but by providing the structural arena in which observer functions stably coexist and transform[1]. It is hypothesized that the global information geometry satisfies an informational counterpart to Einstein's field equations:

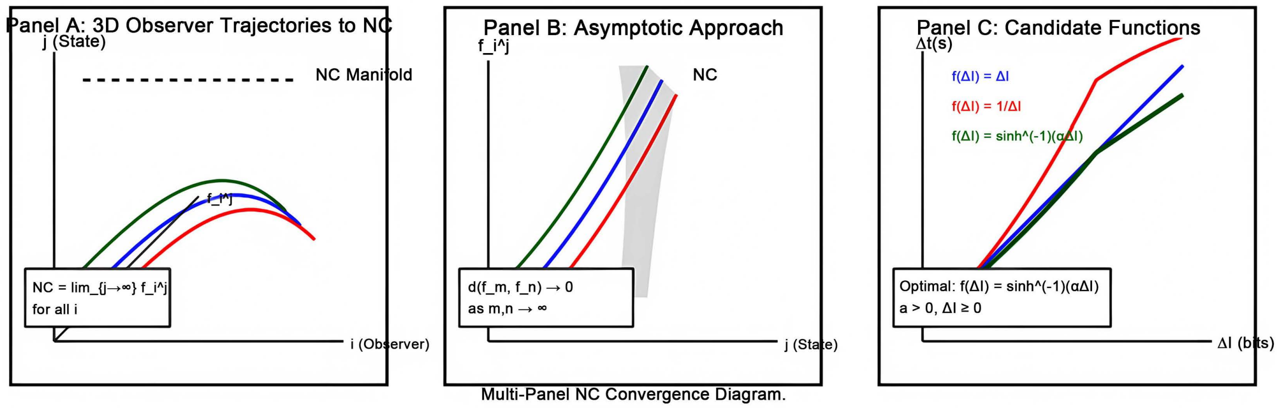

Figure 2. Multi-panel NC convergence visualization: (A) Three-dimensional representation of observer function trajectories f_i^j converging asymptotically to the Nonlocal Consciousness (NC) manifold. Multiple colored trajectories represent different observers (i) evolving through consciousness states (j). (B) Two-dimensional projection showing the asymptotic approach with convergence bounds, illustrating that $\lim_{j\to\infty} f_i^j = \mathrm{NC}_i$ while maintaining $f_i^j \neq f_k^j$ for $i \neq k$ at finite j. (C) Comparison of candidate observer functions with $f(\Delta I) = \sinh^{-1}(\alpha \Delta I)$ highlighted as the optimal choice (green) satisfying global definability, monotonicity, and curvature regularity constraints. Insets show key mathematical expressions for convergence criteria and domain constraints.

$$G_{\mu\nu}[f] + \Lambda g_{\mu\nu}^{(f)} = \kappa \nabla_\mu \nabla_\nu I(x) \tag{3}$$

Here, $I(x)$ denotes the informational density at the spacetime point x, and $\kappa = \frac{8\pi G}{c^4}$ is the coupling constant. This formulation suggests that matter-energy distributions arise from gradients in information, with curvature encoded through observer-defined functions. Please see **Appendix B** for details.

In this view, spacetime becomes a dynamic informational manifold, shaped by individual f-functions but ultimately regulated by NC's global constraint. Local curvature reflects informational flow, and the universal conservation principle governs permissible transformations across quantum, classical, and conscious systems.

NC and Hardy's Quantum Reconstruction

Hardy's axiomatic reconstruction frames quantum theory as an operational structure built on principles such as convexity, continuity, compositionality, reversibility, and dimensional consistency [8]. The author's informational conser-

[1]In order to guarantee a distinction between different observer sequences, one could, for example, require them to inhabit different "cones" apexed at the limit as they Cauchy-approach the limit.

vation postulate introduces a sixth axiom. Even though we have stated that the author's information conservation principle could be treated as a sixth axiom extending Hardy's framework, it can, in fact, be used to derive Axiom 5 itself.

Proposition (Chawla Implies Hardy Axiom 5). If information is conserved across all closed systems and observer-defined operations, as postulated in Chawla's framework, then the state space of any physical system must possess the minimal number of degrees of freedom consistent with operational access.

In other words, the number of parameters K required to specify a system's state must align precisely with those accessible through measurement, as any excess degrees of freedom would imply latent information not accounted for in observer dynamics—contradicting conservation.

To restate: if $K > N^2$, then there must exist informational degrees of freedom that are neither accessible through measurement nor conserved under interaction. This violates the author's informational closure principle, since any observer-defined function $\hat{I}$ must map perceptual intervals Δt into spaces closed under epistemic evolution.

Therefore, Hardy's Axiom 5—which asserts that the number of degrees of freedom equals the square of the number of states—is not merely a minimalist postulate, but a necessary condition for conservation when embedded in the author's topology. The convergence $K \to N^2$ reflects the completion of operational mappings under information-preserving transformations.

Hence, Axiom 5 is derivable—not just assumed—within the geometric structure of the author's observer theory. Nevertheless, here is the sixth axiom:

(Axiom VI): *Information is conserved across all closed systems, including those involving conscious observers.*

This axiom enriches Hardy's framework by clarifying not only the architecture of quantum theory but also its interface with classical and conscious systems. Decoherence, measurement irreversibility, and subjective perception emerge as natural consequences of the dynamics of informational conservation. In particular, the observer-specific f-functions act as localized constraints on allowable state transitions, extending quantum transformations into a broader, information-governed domain.

We have already shown that the author's conservation principle can imply Hardy's Axiom 5 (minimal degrees of freedom). Here, we show that this also implies Axioms 1 and 2, as well as 3 and 4.

Proposition (Chawla Implies Hardy Axiom 1). If information is conserved across all observer interactions in Chawla's framework, then the state space of the theory must be convex.

Proof sketch. The author's framework depends on smooth, trackable exchanges of information—such as partial measurement, decoherence, and observer transitions. These exchanges involve probabilistic mixtures of states. If the state space is non-convex, then intermediate informational states (mixtures or averages) would lie outside the valid state space, rendering classical observations undefined and breaking decoherence dynamics. This would also invalidate the continuous urgency function $f(\Delta I)$ used to define time. Hence, to conserve information across all interactions and observer-defined frames, the state space must be convex.

This convexity immediately implies Hardy's Axiom 2: the existence of a well-defined and consistent mixture operation. Since convex state spaces support probabilistic blending of pure states while preserving physical validity, mixtures remain within the theory's operational scope.

Proposition (Chawla Implies Hardy Axioms 3 and 4). If information is conserved across all closed systems in Chawla's framework, then physical transformations must be continuous (Axiom 3), and composite systems must obey dimensional consistency under tensor product construction (Axiom 4).

Proof sketch. In the author's geometry, time is derived from the smooth evolution of urgency-modulated informational flow. This requires that physical operations transform states in a continuous manner—otherwise, the function $f(\Delta I)$ governing observer dynamics would fail to track transitions properly. Thus, Axiom 3 follows from the requirement of smooth informational sampling.

Moreover, information conservation across composite systems demands that the dimensional structure of the total system space reflects multiplicative behavior. If the dimension of subsystem state spaces does not multiply under composition, then observer-defined mappings $\hat{I}$ would lose closure under joint operations, violating conservation and deforming perceptual geometry. Therefore, the tensor product dimensionality condition in Axiom 4 is a necessary consequence of global informational coherence within the author's framework.

The Central Role of NC

NC functions as a unifying structure in two complementary directions:

- **Toward gravity:** It defines an emergent spacetime geometry from conserved information flow, leading to informational field equations.
- **Toward quantum mechanics:** It constrains allowable state transformations and observer dynamics via conservation principles, extending Hardy's axioms.

Two axioms are particularly crucial in the author's framework:

- **Axiom 3:** The joint state of composite systems must be fully reconstructible from their subsystems.
- **Axiom 4:** Pure state transformations must be reversible.

Proof sketch: For Axiom 3, informational closure across partitions is essential. If global correlations or hidden degrees of freedom cannot be reconstructed from local observations, observers fail to conserve information—violating the principle. For Axiom 4, reversibility ensures that no information is created or lost during closed-system evolution. Observer functions $f(\Delta I)$, which define subjective time, rely on reversible accumulation of information. If transformations are irreversible, ΔI loses definitional consistency and convergence to NC breaks down. Therefore, to uphold universal informational conservation, both compositionality and reversibility must hold.

This leads to a new paradigm: reality is fundamentally informational. Consciousness, spacetime, and quantum structure all emerge from an observer-independent law of information conservation. NC serves as both the principle and limiting construct from which geometric (gravitational) and algebraic (quantum) structures unfold naturally.

5. Deriving Gauss's Law from NC

Having established Nonlocal Consciousness (NC) as a proposed origin for both spacetime geometry—via informational field equations—and quantum theory—via extended Hardy-style axioms—we now examine whether classical field laws similarly emerge from informational conservation. Gauss's law in electromagnetism provides an instructive case. Traditionally treated as a local field equation, it is reinterpreted in the following illustration as a natural consequence of global informational geometry governed by NC.

Classical Form of Gauss's Law

Gauss's law relates the divergence of the electric field $\boldsymbol{E}$ to the local charge density ρ:

$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon_0} \tag{4}$$

In integral form, over a closed surface S enclosing a volume V, it reads:

$$\oint_S \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{A} = \frac{1}{\varepsilon_0} \int_V \rho \mathrm{d}V \tag{5}$$

This expression defines electric flux conservation: the field lines traversing a surface encode the total charge enclosed.

Informational Analogy

In the author's framework, electric flux is reinterpreted as the flow of information. Let $I(x)$ denote the informational density at spacetime point x, and let $\boldsymbol{I}$ represent the informational flow vector field. Analogous to charge-induced field behavior, the divergence of this field is given by:

$$\nabla \cdot \boldsymbol{I} = \eta I(x) \tag{6}$$

Here, η is a proportionality constant translating informational density into flow intensity—akin to $1/\varepsilon_0$ in electromagnetism.

By correspondence:

$$\boldsymbol{E} \leftrightarrow \boldsymbol{I},\ \rho \leftrightarrow I(x),\ \varepsilon_0 \leftrightarrow \frac{1}{\eta} \tag{7}$$

Thus, Gauss's law becomes an emergent relation:

$$\nabla \cdot \boldsymbol{I} = \eta I(x) \tag{8}$$

Under this mapping, the divergence of local informational flow corresponds to localized informational curvature, just as charge density induces divergence in the electric field.

Gauss's Law as a Consequence of Informational Conservation

Since NC imposes informational conservation across all closed systems, any change in local informational density must be balanced by the net flux of $\boldsymbol{I}$ through the enclosing boundary. This yields an integral relation equivalent to the standard form of Gauss's law:

$$\oint_{\partial V} \boldsymbol{I} \cdot \mathrm{d}\boldsymbol{A} = \int_V I(x)\,\mathrm{d}V \tag{9}$$

Here, ∂V denotes the bounding surface of volume V, and $\mathrm{d}\boldsymbol{A}$ is the infinitesimal area element. The left-hand side captures total informational flux, while the right-hand side encodes the cumulative informational content within V.

This correspondence implies that informational geometry inherits the divergence-integral structure of classical field laws. Under the NC constraint, such formulations are not optional—they are required for internal consistency of the conservation principle.

Interpretation and Implications

We conclude that Gauss's law is a specific manifestation of the global conservation principle imposed by NC, when applied to informational flows in a bounded region. The electric field becomes a representation of the spatial structure of informational flow, and the charge acts as a localized source of informational curvature.

In this sense, Gauss's law is not a separate postulate or an isolated electromagnetic principle. It emerges as a particular instance of the universal behavior of information under the governance of NC. In the next section, falsifiability is addressed.

6. Observer Function Selection via Quantum Gravity Probes

This section explores how specific choices of the observer function $f(\Delta I)$ correspond to quantum-gravity-motivated deformations of the canonical commutator $[x, p]$, which are now within experimental reach.

Informational Derivation of the Commutator

In the author's framework, the observer-defined time interval is:

$$\Delta t = f(\Delta I) \tag{10}$$

where ΔI is accumulated information. The spatial displacement arises from the spacetime interval constraint:

$$\Delta x = \sqrt{c^2 f^2(\Delta I) - \tau^2} \tag{11}$$

where τ is the proper interval. Corresponding momentum is given by:

$$P = m\frac{\mathrm{d}X}{\mathrm{d}t} = m\frac{\mathrm{d}X}{\mathrm{d}\Delta I}\cdot\frac{\mathrm{d}\Delta I}{\mathrm{d}t} = m\frac{\mathrm{d}X}{\mathrm{d}\Delta I}\cdot\frac{1}{f'(\Delta I)} \tag{12}$$

This yields the effective commutator:

$$[x, p] = i\hbar\left(\frac{1}{f'(\Delta I)}\right) \tag{13}$$

Thus, deformation of $[x, p]$ arises naturally from the observer's epistemic selection of f. Experimental probes of such deformations may provide direct access to the geometry of the Nonlocal Consciousness (NC) manifold.

Matching with Quantum Gravity Models

Recent proposals to test quantum gravity via opto-mechanical systems have introduced modified canonical commutators:

$$[x, p]_{\beta_0} = i\hbar\left(1+\beta_0\left(\frac{p}{M_{Pc}}\right)^2\right) \tag{14}$$

$$[x, p]_{\mu_0} = i\hbar\left(1+2\mu_0\left(\frac{p}{M_{Pc}}\right)^2+\frac{m^2}{M_P^2}\right) \tag{15}$$

$$[x, p]_{\gamma_0} = i\hbar\left(1-\gamma_0\frac{p}{M_{Pc}}+\gamma_0^2\left(\frac{p}{M_{Pc}}\right)^2\right) \tag{16}$$

Each deformation maps to a distinct choice of the observer function $f(\Delta I)$, as follows:

- **Logarithmic:** $f(\Delta I)=\log(1+\alpha\Delta I)$ corresponds to the β-type quadratic deformation.
- **Hyperbolic:** $f(\Delta I)=\sinh^{-1}(\alpha\Delta I)$ aligns with the μ-type square-root deformation.
- **Truncated Polynomial:** $f(\Delta I)=\Delta I-b\Delta I^2$ matches the γ-type mixed linear-quadratic deformation.

Each f-selection induces a unique geometry on the NC manifold, altering the informational curvature and thus modifying spacetime emergence. Consequently, experimental measurements of commutator behavior can empirically constrain the functional form of f, offering insight into observer epistemics and their relation to spacetime structure.

Experimental Implications

High-precision cavity opto-mechanical experiments, such as those proposed by Pikovski *et al.*, enable measurement of optical phase shifts resulting from quantum gravitational effects. These shifts encode deformations in the canonical commutator $[x, p]$, providing empirical access to observer-dependent dynamics.

By analyzing these phase shifts, one constrains the commutator structure:

$$[x, p] = i\hbar\left(\frac{1}{f'(\Delta I)}\right) \tag{17}$$

which in turn informs the functional form of $f(\Delta I)$. The selection of f determines the geometry of the NC manifold and shapes spacetime emergence. Hence, quantum gravity experiments offer a direct pathway to empirically selecting observer functions and refining the informational dynamics underlying the unification of perception, quantum mechanics, and spacetime.

We bring this work to a close in the next section.

7. Conclusions

This study presents a unifying framework—Nonlocal Unification (NU)—based on the central axiom that information is conserved across all scales and domains, including quantum systems, classical physics, and conscious observation. From this postulate, we derive not only foundational elements of quantum theory and gravity but also formulate a broader informational geometry that governs observer dynamics, spacetime emergence, and phenomenological perception.

Through the synthesis of Hardy's operational axioms, the author's conservation principle, and observer-specific functions $f(\Delta I)$, we advance a geometric reinterpretation of physics rooted in epistemic access and informational flow. The theory proposes that all observers—modeled as Local Consciousness Instruments (LCIs)—participate in a closed informational manifold whose limiting construct, Nonlocal Consciousness (NC), orchestrates global coherence. Within this manifold, the subjective experience of time emerges as a functional mapping from informational gain, and physical forces arise as derivatives of urgency-modulated informational transitions.

Integration Across Domains

The framework achieves conceptual breadth by embedding disparate domains into a unified theoretical structure:

- **Quantum Foundations:** Extending Hardy's reconstruction, NU shows that the author's informational conservation postulate can imply, and in some cases derive, Hardy's axioms—notably Axiom 5 on minimal degrees of freedom. The proposed Axiom VI reframes quantum mechanics as an observer-informational system governed by epistemic dynamics.
- **Consciousness and Time:** LCIs provide a formal mechanism through which consciousness and time emerge from informational sampling. The mapping $\Delta t = f(\Delta I)$ formalizes the link between perception and structure, embedding time as a derivative rather than a primitive coordinate.
- **Relativistic Geometry:** NC enables the derivation of Einstein's field equations through informational action principles. Spacetime curvature is reconceptualized as an emergent property of informational distortions driven by observer urgency and entropy gradients.
- **Classical Embedding:** Using informational stretch tensors and urgency-based viscosity regulation, NU integrates classical physics. In particular, Navier-Stokes equations are reformulated to permit smooth solutions under informational modulation—potentially redefining turbulence modeling.
- **Neurodynamics and Psychophysics:** Hodgkin-Huxley models are reinterpreted within informational geometry, illustrating how urgency, perceptual scaling, and neuronal voltage trajectories are integrated into an epistemic curvature space.
- **Interpretive Comparisons:** The framework embeds interpretations like QBism and RQM within a dual-aspect epistemic-ontic geometry, providing explicit metric structure and unification mechanisms absent in those approaches.

A Reimagined Triad

The classical triad of force, energy, and mass is reinterpreted as informational constructs:

- **Force:** The time derivative of informational flux.
- **Energy:** The capacity to transmit information along observer-defined trajectories.
- **Mass:** The degree to which information is constrained in space or time.

This reframing positions classical mechanics as an emergent limit of observer-centric informational geometry.

Limitations

While rich in unification, the NU framework has several limitations:

1) **Empirical Validation:** Though falsifiable through commutator deformation probes, direct experimental support for NC or informational geometries remains pending.

2) **Observer Function Specification:** The optimal form $f(\Delta I) = \sinh^{-1}(a\Delta I)$ is proposed, but lacks empirical standardization across individuals or domains.

3) **Philosophical Commitments:** The dual-aspect structure engages metaphysical assumptions that invite critique from both reductionist and subjectivist traditions.

4) **Computational Complexity:** Implementing dynamic geometries and urgency modulation in numerical models adds substantial technical overhead.

5) **Scale Generalizability**: Though information is treated as universally conserved, its operationalization across domains—from cosmology to cognition—requires domain-specific adaptations.

6) **Ontological Ambiguity:** The NC construct lacks a definitive physical status, oscillating between mathematical limit, global boundary condition, and informational field.

Future Research Directions

Despite these challenges, NU opens expansive research pathways:

1) **Empirical Probing of NC Geometry:** Opto-mechanical systems may test commutator deformations predicted by NU through measurable phase shifts.

2) **Observer Function Calibration:** Neuroimaging can inform the empirical mapping of $f(\Delta I)$, linking perceptual latency with informational gain.

3) **Numerical Fluid Modeling:** Urgency-based viscosity and stretch tensors can be tested in vortex filament suppression and turbulence modeling.

4) **Quantum Neural Substrate Analysis:** Study of superposition states and ephaptic coupling in axonal tracts could reveal distributed quantum computation in the brain.

5) **Formal Topology of Observer Space:** Cauchy convergence analysis in the function space $\mathcal{F}$ may clarify NC's mathematical underpinnings.

6) **Thermodynamic and Electromagnetic Embedding:** Applying NU to heat transport and electromagnetic field modeling could illuminate informational regulation of physical processes.

7) **Philosophical Rearticulation:** Clarifying NU's ontological commitments may strengthen ties to structural realism, Bayesian epistemology, and conscious-

ness studies.

8) **Interdisciplinary Collaboration:** A pluralistic effort across physics, mathematics, philosophy, and cognitive science is essential to build the empirical bridge from theory to application.

Final Synthesis

At its core, Nonlocal Unification recasts physical reality as an informational manifold governed by observer urgency and universal conservation. Rather than replacing existing theories, NU embeds them within a deeper geometric architecture where time is emergent, space is sampled, and consciousness is functional. Appendices span turbulence modeling, neurodynamics, quantum foundations, and psychophysics—each reflecting the central principle: phenomena arise from the interplay between epistemic access and ontological structure.

As future work builds toward operational clarity, NU holds the promise of offering not merely a new physics but a compelling rearticulation of reality itself—where experience, measurement, and structure become facets of conserved information dancing across the informational geometry of spacetime.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix A: Information Version of the Einstein Field Equations, from First Principles

This **Appendix** extends Chawla's proposal in A Mathematical Theory of Consciousness, we treat spacetime geometry as emergent—generated by observer-specific mappings from information gain ΔI to spacetime intervals Δx^{μ}.

Emergent Metric from Information Gain

Let spacetime intervals be induced via a nonlinear function:

$$\Delta x^{\mu} = f^{\mu}\left(\Delta I\right) \tag{18}$$

where ΔI is the observer's sampled information. The resulting spacetime manifold M reflects informational structure conditioned by epistemic access. The equivalence principle demands local frame indistinguishability, yielding flat geometry at any point:

$$g_{\mu\nu}\left(p\right) = \eta_{\mu\nu} \tag{19}$$

Thus, the map f must satisfy:

$$f\left(\Delta I_f\right) = f\left(\Delta I_a\right) + \mathcal{O}\left(\Delta I^2\right) \tag{20}$$

ensuring that free-fall and accelerated observers experience locally identical metrics. Deviations from this symmetry induce curvature:

$$R^{\mu}_{\nu\rho\sigma} \neq 0 \tag{21}$$

Action Functional over the Informational Manifold

We define an information-based action functional to describe spacetime dynamics:

$$S_I = \int_M \mathrm{d}^4 x\left(-g L_I\left(f, \partial f\right)\right) \tag{22}$$

where L_I encodes distortions in the sampling map f. This sets the stage for deriving gravitational field equations from principles of informational conservation and geometric deformation.

Informational Action and Field Equations

We formalize the informational action as:

$$S_I = \int_M \mathrm{d}^4 x\left(-g L_I\left(f, \partial f\right)\right) \tag{23}$$

where L_I quantifies distortions induced by the sampling function f across the manifold. This action includes both geometric curvature and an observer-defined informational source term:

$$S_I = \frac{c^3}{16\pi G}\int \mathrm{d}^4 x\left(-gR + S_{\text{info}}\right) \tag{24}$$

with:

$$S_{\text{info}} = \int \mathrm{d}^4 x\left(-g L_{\text{info}}\left(\Delta I\left(x\right)\right)\right) \tag{25}$$

Varying S_I with respect to the metric $g^{\mu\nu}$ yields:

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T^{\text{info}}_{\mu\nu} \tag{26}$$

where the informational stress-energy tensor is defined as:

$$T_{\mu\nu}^{\text{info}} = -\frac{2}{\sqrt{-g}}\frac{\delta S_{\text{info}}}{\delta g^{\mu\nu}} \tag{27}$$

This recasts the Einstein field equations as consequences of informational conservation. Geometry arises through observer-mediated distortions of f, making curvature a manifestation of epistemic flow across the manifold.

Metric Forms from Amari Information Geometry

Following Amari's framework, we interpret ΔI as a coordinate on an informational manifold, with spacetime intervals $(\Delta x, \Delta t)$ induced via observer-specific maps $f(\Delta I)$.

Two candidate functions define distinct geometries:

- **Inverse Law:** $f_1(\Delta I) = \dfrac{1}{\Delta I}$
- **Cubic-Inverse with Shift:** $f_2(\Delta I) = \dfrac{1}{\Delta I^3} + c$, where $c \in \mathbb{R}$

Using the Fisher information metric:

$$g_{\mu\nu}(\theta) = \mathbb{E}\left[\frac{\partial \log p(\theta)}{\partial \theta^\mu} \cdot \frac{\partial \log p(\theta)}{\partial \theta^\nu}\right] \tag{28}$$

we derive induced curvature under each f-based distribution:

Case 1: $f_1(\Delta I)$

Assume an exponential distribution:

$$p(\theta) = A\mathrm{e}^{-\lambda\theta} \tag{29}$$

Then:

$$\frac{\partial \log p}{\partial \theta} = -\lambda \Rightarrow g_{\mu\nu}^{(1)} = \lambda^2 \delta_{\mu\nu} \tag{30}$$

Yielding a flat metric geometry consistent with Weberian scaling.

Case 2: $f_2(\Delta I)$

Assume nonlinear curvature via:

$$p(\theta) = B\mathrm{e}^{-\lambda/\theta^3},\ \theta > 0 \tag{31}$$

Then:

$$\frac{\partial \log p}{\partial \theta} = \frac{3\lambda}{\theta^4} \Rightarrow g_{\mu\nu}^{(2)} = \frac{9\lambda^2}{\theta^8}\delta_{\mu\nu} \tag{32}$$

This implies strong curvature near $\theta = 0$, yielding nonlinear perceptual sensitivity consistent with psychophysical divergence from Weber's Law.

Interpretation

This integrated framework demonstrates how general relativity and information geometry can emerge from first principles under the following assumptions:

- A nonlinear, observer-defined map $f(\Delta I)$ governs spacetime emergence,
- Metric curvature $g_{\mu\nu}$ reflects differential information gain,
- Field equations result from varying an information-induced action.

These connections suggest a universal structure linking gravity and cognition—where spacetime is not an absolute backdrop but a dynamic construct generated by informational processes. This framing reinterprets general relativity as an epistemic-ontic dual theory: geometry manifests through observer-defined informational access, and curvature reflects constraints arising from differential sampling.

The equivalence principle becomes a local gauge symmetry of f, preserving indistinguishability across reference frames. In turn, Einstein's equations emerge as a conservation law over the informational manifold, aligning gravity's geometric language with foundational principles of observer epistemology.

Appendix B: Informational Lagrangian and Hamiltonian Formalism

This **Appendix** introduces an action-based formalism to add mathematical rigor to the derivation of general relativity via informational geometry.

Observer Ansatz and Kinematic Variables

We begin by postulating a mapping from informational gain ΔI to proper time:

$$\Delta t = f(\Delta I), \quad f \in \mathcal{F} \subset C^1(\mathbb{R}^+, \mathbb{R}^+), \quad f(0) = 0, \quad f > 0 \tag{33}$$

The function f must be continuously differentiable, strictly increasing, and satisfy $f(0) = 0$, ensuring causal monotonicity and consistency with observer-centric time perception.

Setting $t = f(I)$, where:

$$I = \int \mathrm{d}i \tag{34}$$

defines the accumulated information. This information is treated as the fundamental dynamical variable that generates the kinematic evolution of spacetime intervals.

We thereby replace traditional coordinate-based evolution with an epistemic parameterization of dynamics, anchoring spacetime emergence in observer-dependent informational sampling.

Informational Lagrangian Construction

The accumulated information $I = \int \mathrm{d}i$ serves as the dynamical parameter replacing standard coordinate time. Let $x^\mu = x^\mu(I)$ denote the trajectory of an observer or particle across the informational manifold. Then, the informational velocity is given by:

$$\dot{x}^\mu = \frac{\mathrm{d}x^\mu}{\mathrm{d}I} \tag{35}$$

We define the informational Lagrangian $\mathcal{L}_I$ as a functional of position and velocity:

$$\mathcal{L}_I(x^\mu, \dot{x}^\mu) = \frac{1}{2} g_{\mu\nu}(x) \dot{x}^\mu \dot{x}^\nu \tag{36}$$

The informational action is:

$$S_I = \int \mathcal{L}_I(x(I), \dot{x}(I)) \mathrm{d}I \tag{37}$$

This construction mirrors standard geodesic action in general relativity, but parameterizes dynamics by sampled information rather than coordinate time. The metric $g_{\mu\nu}(x)$ itself is emergent, induced by the observer function f via spacetime mappings. Variational principles applied to S_I yield the equations of motion on the informational manifold.

Prescription for Constructing the Hamiltonian

1) Choose an observer function f (experimentally: calibrating f from an LCI sequence).

2) Re-parameterize time: $t = f(I)$.

3) Replace every time derivative $\dot{q}^a \to \dot{q}^a / f(I)$.

4) Build $\mathcal{L}_I$ via Equation (25).

5) Define canonical momenta:

$$p_a := \frac{\partial \mathcal{L}_I}{\partial \dot{x}^a} = \frac{m g_{ab} \dot{x}^b}{f(I)^2} \tag{38}$$

6) Construct the informational Hamiltonian:

$$\mathcal{H}_I = p_a \dot{x}^a - \mathcal{L}_I = \frac{1}{2} \frac{m g_{ab} \dot{x}^a \dot{x}^b}{f(I)^2} + V(x) \tag{39}$$

which mirrors the total energy and reveals information-parameter invariance.

Euler-Lagrange Equations

Variation of the informational action yields:

$$\frac{\mathrm{d}}{\mathrm{d}I}\left(\frac{\partial \mathcal{L}_I}{\partial \dot{x}^a}\right) - \frac{\partial \mathcal{L}_I}{\partial x^a} = 0 \tag{40}$$

Returning to coordinate time t recovers the standard equations of motion, now reinterpreted as emerging from informational sampling dynamics.

Toy Example: 1-D Harmonic Oscillator

Let the potential be $V(x) = \frac{1}{2} k x^2$. Then, Equation (25) becomes:

$$\mathcal{L}_I = \frac{m}{2}\left(\frac{\dot{x}_I^2}{f(I)^2}\right) - \frac{k}{2} x^2 \tag{41}$$

with canonical momentum:

$$p = \frac{m \dot{x}_I}{f(I)^2} \tag{42}$$

Applying Hamilton's equations yields:

$$\dot{x}_I + \omega^2 f(I)^2 x = 0, \ \ \omega^2 = \frac{k}{m} \tag{43}$$

Choosing $f(I) = I$ (linear information growth) reproduces the standard harmonic motion. Nonlinear choices of f rescale the effective frequency—modeling perceptual compression or dilation in informational time.

Informational Action for Fields

Promote I to a scalar field over an informational manifold M with coordinates x^μ. Define the induced metric:

$$g_{\mu\nu} := \partial_\mu I \partial_\nu I \tag{44}$$

The action becomes:

$$S = \int_M \mathrm{d}^4 x \sqrt{-g}\left(\frac{1}{2} \alpha g^{\mu\nu} \partial_\mu I \partial_\nu I + \mathcal{L}_{\text{matter}}(x)\right) \tag{45}$$

Variation with respect to I yields a covariant continuity equation; variation with respect to $g_{\mu\nu}$ generates a stress-energy tensor of informational origin—matching Equation (3) in the main text and embedding informational dynamics directly into gravitational curvature.

Einstein-Hilbert Action as the Informational Limit

To formalize the emergence of classical spacetime, we impose a constraint on the metric tensor $g_{\mu\nu}$ using a Lagrange multiplier λ and extend Equation (28). The total action becomes:

$$S_{\text{tot}} = \frac{c^3}{16\pi G}\int \mathrm{d}^4x\left(-\sqrt{-g}\left[R+\lambda\left(g^{\mu\nu}\partial_\mu I\partial_\nu I-\Lambda^2\right)\right]\right)+S_{\text{matter}} \tag{46}$$

This constrained formulation ensures that the metric is induced by gradients of the informational field I, aligned with the observer function $f\left(\Delta I\right)$. In the Nonlocal Consciousness (NC) limit $I \to I_{\text{NC}}$, observer-dependence collapses to a fixed point, yielding:

$$\partial_\mu I_{\text{NC}}\partial_\nu I_{\text{NC}} \to \text{Observer-independent curvature} \tag{47}$$

Thus, the Einstein-Hilbert action arises as the limit of informational sampling when all observers converge to a shared geometry—the Nonlocal Consciousness (NC) manifold. This defines spacetime not as a backdrop, but as an emergent structure regulated by informational coherence.

Collapse to Einstein-Hilbert Action

In the NC convergence limit, the informational curvature $I_{\text{NC}} \propto g_{\mu\nu}$, rendering the Lagrange multiplier term redundant. Equation (46) thus collapses to the classical Einstein-Hilbert action:

$$S_{EH} = \frac{c^3}{16\pi G}\int \mathrm{d}^4x\left(\sqrt{-g}R+S_{\text{matter}}\right) \tag{48}$$

This shows that general relativity emerges as the universal geometry of informational coherence when all observer-dependent features vanish. In this regime, the spacetime metric is no longer shaped by individual sampling—it's regulated by invariant dynamics across the Nonlocal Consciousness (NC) manifold.

Remark. All dependencies on the observer function f vanish at the level of S_{EH}. Consequently, classical spacetime dynamics are recovered in a fully observer-independent manner, matching expectations from standard gravitational physics.