INFORMATIONAL RELATIVITY

A Framework for Emergent Spacetime from Information Geometry

Revised Edition with Mathematical Formalism and Experimental Protocols

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Abstract

We propose a reformulation of physical ontology in which spacetime is not fundamental but emerges from information-theoretic relationships between physical entities. In this framework, what we perceive as spatial distance is the inverse of mutual information density between systems, mass corresponds to local computational density, and temporal evolution is identical to entropy production. We demonstrate that general relativity, quantum mechanics, and thermodynamics remain mathematically coherent under this reinterpretation, while several outstanding puzzles—including quantum nonlocality, the measurement problem, and the reconciliation of gravity with quantum theory—admit natural resolutions.

This revised edition strengthens the original framework by providing explicit mathematical formalism, operational definitions for key concepts, and detailed experimental protocols capable of empirically distinguishing informational relativity from standard physics. We identify specific observational signatures in gravitational wave data, propose laboratory experiments involving rapid phase transitions, and outline the theoretical conditions under which the framework's predictions diverge from general relativity and quantum field theory.

1. Introduction

Contemporary physics rests on an assumption so fundamental it rarely receives explicit statement: that space and time constitute the arena in which physical events occur. Matter and energy inhabit spacetime; fields propagate through it; particles trace worldlines within it. Even general relativity, which revealed spacetime to be dynamic rather than fixed, retains the manifold as ontologically primary. Quantum field theory quantizes fields on spacetime, treating the background geometry as given.

This paper proposes an inversion. We suggest that spacetime is not the stage but the performance—not the container of physical relationships but their consequence. Specifically, we advance the hypothesis that what we experience as spatial separation is a measure of informational dissimilarity, that mass is computational density, and that time is indistinguishable from entropy production. The mathematics of existing physical law remains intact; what changes is our interpretation of what that mathematics describes.

The motivation for this reformulation is not merely philosophical. Several features of modern physics suggest that space and time may not be fundamental: the nonlocality of quantum entanglement, the holographic encoding of information in gravitational systems, the emergence of spacetime geometry from entanglement entropy in AdS/CFT correspondence, and the persistent failure to quantize gravity using standard field-theoretic methods. These phenomena hint that we may be attempting to discretize something that was never continuous—to quantize a projection rather than the underlying reality.

1.1 Convergent Evidence

Multiple independent research programmes have arrived at information-theoretic foundations from different starting points. The holographic principle, derived from black hole thermodynamics, establishes that the maximum information content of any region scales with its boundary area rather than its volume—a result incompatible with local field theory but natural if information is fundamental. The AdS/CFT correspondence demonstrates exact mathematical equivalence between gravitational theories in bulk spacetime and information-theoretic boundary theories without gravity. The ER=EPR conjecture proposes that quantum entanglement and geometric connection are two descriptions of the same phenomenon. Entropic gravity derives gravitational dynamics from entropy gradients.

These results suggest a pattern: when physicists probe deeply enough, they find information-theoretic structure. This paper takes that pattern seriously and asks what physics would look like if information were not merely useful for describing reality but constitutive of it.

2. Foundational Postulates

We begin by stating three postulates from which the framework follows. Unlike the original presentation, we here provide operational definitions that connect each postulate to measurable quantities.

2.1 The Information Postulate

Postulate 1: Physical reality consists fundamentally of information and the relations between informational entities. What we call 'particles' or 'systems' are patterns of information; what we call 'interactions' are computations upon that information.

This postulate aligns with Wheeler's 'it from bit' programme but extends it. We do not merely claim that information is physically relevant; we claim it is physically exhaustive. There is no additional 'stuff' that information describes. The information is the substance.

Operational Definition

A physical system S is characterized by its information content I(S), defined as the minimum number of bits required to specify the system's state relative to a reference ensemble. This is equivalent to the negative logarithm of the system's probability in the maximum entropy distribution consistent with known macroscopic constraints:

$$I(S) = -\log_2 P(S|constraints) \qquad (1)$$

2.2 The Distance Postulate

Postulate 2: Spatial distance between two systems is inversely proportional to their mutual information density. Systems with high mutual information appear close; systems with low mutual information appear distant.

Let I(A;B) denote the mutual information between systems A and B. We propose that the apparent spatial distance d(A,B) satisfies:

$$d(A,B) = \kappa / \rho_i(A,B) \qquad (2)$$

where ρ_i is mutual information density (mutual information per unit interaction capacity) and κ is a coupling constant with dimensions of length times information density.

Operational Definition

Mutual information I(A;B) between systems A and B is defined in terms of their Shannon entropies:

$$I(A;B) = H(A) + H(B) - H(A,B) \qquad (3)$$

The mutual information density ρ_i normalizes this by the interaction capacity C(A,B):

$$\rho_i(A,B) = I(A;B) / C(A,B) \qquad (4)$$

where C(A,B) represents the maximum possible mutual information between systems of type A and B given their physical constraints. This normalization ensures that ρ_i ranges from 0 (no correlation) to 1 (maximal correlation).

2.3 The Entropy-Time Postulate

Postulate 3: Temporal evolution is identical to entropy production. There is no independent parameter 'time' along which entropy increases; rather, what we experience as the passage of time is the accumulation of entropy.

This postulate has antecedents in the work of Boltzmann, Eddington, and more recently Rovelli. The second law of thermodynamics does not describe a process occurring in time; it constitutes time. Memory, causality, and the arrow of experience emerge from the entropy gradient between initial and final states.

Operational Definition

The local time interval $\Delta\tau$ experienced by a system is proportional to the entropy produced during that interval:

$$\Delta\tau = \lambda \cdot \Delta S \qquad (5)$$

where λ is a conversion constant relating entropy (in bits or nats) to time (in seconds). This constant must satisfy dimensional constraints and recover standard physics in appropriate limits.

3. Mathematical Formalism

The postulates above must be connected to the established mathematical structure of physics. This section develops the formalism required to recover general relativity and quantum mechanics from informational principles.

3.1 The Information Metric

We define an information manifold M whose points correspond to distinguishable physical states. The natural metric on this manifold is the Fisher information metric, which measures the distinguishability of nearby states:

$$g_{ij} = \int p(x|\theta)\, [\partial_i \log p(x|\theta)][\partial_j \log p(x|\theta)]\, dx \qquad (6)$$

where $p(x|\theta)$ is the probability distribution over observables x parameterized by state variables θ. This metric has the crucial property that it is reparametrization-invariant—it depends only on the intrinsic distinguishability of states, not on how we choose to label them.

3.2 Recovery of Spacetime Geometry

We propose that the spacetime metric $g_{\mu\nu}$ of general relativity is a coarse-grained projection of the information metric onto macroscopic degrees of freedom. Specifically, when information is distributed according to a stress-energy tensor $T_{\mu\nu}$, the resulting information geometry satisfies:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = (8\pi G/c^4)\, T_{\mu\nu} \qquad (7)$$

This is the Einstein field equation, but now reinterpreted: $G_{\mu\nu}$ describes the curvature of information geometry induced by computational density $T_{\mu\nu}$. The cosmological constant Λ represents the baseline information-theoretic curvature in regions of minimal complexity.

3.3 Mass as Computational Density

In standard physics, mass-energy curves spacetime. In our framework, this statement translates directly: regions of high informational complexity require more computation to resolve their state, and this computational load manifests as what we perceive as both mass and time dilation.

Consider a region R containing information with complexity C(R), measured by the Kolmogorov complexity of the region's state specification. We propose that the local computational rate varies inversely with this complexity:

$$\tau(R) \propto C(R) \qquad (8)$$

where τ is the local 'processing time' required for each computational step. An observer in a high-complexity region experiences time passing normally, but an external observer sees their clock running slow—precisely the phenomenon of gravitational time dilation.

This can be made precise by identifying the computational density ρc with the energy density:

$$\rho c = \varepsilon \cdot (dI/dV) \cdot (dC/dt) \qquad (9)$$

where ε is an energy-per-computation constant (related to Landauer's limit), dI/dV is the information density, and dC/dt is the rate of state changes. In equilibrium, this reduces to $\rho c \propto \rho mass$, recovering the standard relationship.

4. Gravity as Information Gradient

If distance is inversely related to mutual information, then gradients in information density produce what we experience as gravitational attraction. Objects do not 'fall' toward massive bodies; rather, paths toward higher information density are shorter in the information geometry. The geodesic—the path of extremal length—curves toward mass because that is the direction of maximal informational correlation.

4.1 Derivation of Newtonian Gravity

Consider a test particle at distance r from a mass M. In the informational framework, M represents a region of high computational density with total information content I(M). The mutual information between the test particle and M falls off with distance according to:

$$I(particle; M) \propto M/r \qquad (10)$$

The gradient of this mutual information produces an effective force:

$$F = -\nabla U = -\alpha \cdot \nabla I(particle; M) = -\alpha M/r^2 \qquad (11)$$

where α is a coupling constant. Identifying $\alpha = Gm$ (where m is the test particle mass and G is Newton's constant) recovers Newtonian gravity exactly.

4.2 Connection to Entropic Gravity

This interpretation aligns with Verlinde's entropic gravity proposal but proceeds from different premises. Verlinde derives gravitational dynamics from entropy gradients on holographic screens; we derive apparent spatial structure from information density. The approaches are complementary and may ultimately prove equivalent.

The principle of least action, in this framework, becomes the principle of least computation. Physical systems evolve along trajectories that minimize total computational cost. Since computation requires entropy production, this is equivalent to minimizing total entropy generated—which, for conservative systems, recovers Hamiltonian mechanics exactly.

5. Black Holes as Computational Horizons

A black hole, in the standard picture, is a region from which light cannot escape. In our framework, a black hole is a region of effectively infinite computational density—a process that never returns results to external observers.

5.1 The Event Horizon

The event horizon marks the boundary beyond which the computational load diverges. Time dilation becomes infinite not because clocks 'stop' in any physical sense, but because the ratio of external to internal state updates goes to zero. The interior is not computed—or more precisely, its computation is not accessible from the exterior.

5.2 The Information Paradox

This immediately suggests a resolution to the black hole information paradox. The information is not destroyed; it is simply pending. The computation has not completed. Hawking radiation, in this view, represents the slow return of results—information about the interior state leaking out through quantum correlations as the hole evaporates. The process is unitary because no information was ever lost; it was merely delayed.

5.3 The Holographic Principle

The holographic principle finds natural expression here. If the interior is not externally computed, then all accessible information about the black hole must be encoded on its boundary. The area law for entropy is not a mysterious coincidence but a direct consequence of the framework: you can only store information on the computational interface, and that interface is two-dimensional.

Quantitatively, the Bekenstein-Hawking entropy:

$$S = A/(4l^2_p) \qquad (12)$$

represents the maximum number of distinguishable states accessible from outside the horizon, where A is the horizon area and l_p is the Planck length.

6. Quantum Mechanics Reinterpreted

6.1 Nonlocality as Information Adjacency

Entanglement has long troubled physicists because it seems to involve instantaneous correlation across arbitrary spatial distances, apparently violating relativistic locality. The resolution, in our framework, is immediate: entangled particles are not spatially distant at all. They share high mutual information, which means their informational distance is near zero.

The apparent spatial separation is an artifact of their low mutual information with other systems along the path between them. They are informationally adjacent to each other while being informationally distant from the intervening space. No signal passes between them because no signal is needed; they are, in the information geometry, neighbors.

6.2 Measurement as Correlation

The measurement problem asks: what causes the wave function to 'collapse'? Our framework suggests this question is malformed. There is no collapse. Measurement is the establishment of mutual information between a quantum system and a macroscopic observer. Prior to measurement, the observer has low mutual information with the system's state; afterward, they have high mutual information.

What we call 'superposition' is simply the state of a system with which we share insufficient mutual information to resolve its properties. The system is not 'in multiple states at once'; we are informationally distant from its determinate state. Measurement brings us informationally closer, and the apparent 'collapse' is our experience of that approach.

6.3 The Wave Function as Information Potential

The wave function ψ may be reinterpreted as encoding not probability amplitudes but potential information relationships. Its evolution under the Schrödinger equation describes how these potential relationships change as the system undergoes computation. Its squared modulus gives the probability of establishing mutual information of a particular kind upon measurement.

The Born rule, $|\psi|^2$ = probability, becomes a statement about information accessibility: the probability of finding a system in state $|n\rangle$ equals the fraction of total accessible information that would be established by observing that outcome.

7. Cosmological Implications

7.1 The Big Bang as Initialization

The extremely low entropy of the early universe—the 'past hypothesis' that undergirds thermodynamic time asymmetry—is, in our framework, simply an initial condition. The universe began in a state of minimal computational complexity: homogeneous, undifferentiated, unstructured. This is not a puzzle requiring explanation by some prior process; it is the input to the computation.

What we experience as cosmic history is the computation running—complexity accumulating, structure emerging, entropy increasing. Stars, galaxies, planets, and minds are intermediate states in this process, patterns that arise transiently as the system evolves from its ordered initial state toward eventual equilibrium.

7.2 Dark Matter as Information Density Without Particle Density

Dark matter presents gravitational effects without corresponding visible particles. In standard physics, this requires positing invisible matter. In our framework, an alternative exists: dark matter may be regions of elevated information density that are not associated with standard-model particles.

If the information metric can diverge from the particle distribution, we would observe exactly the phenomena attributed to dark matter: gravitational lensing without luminous sources, galactic rotation curves inconsistent with visible mass, large-scale structure formation driven by invisible wells. The 'matter' is real in the only sense that matters—it curves the information geometry—but it need not consist of particles.

This interpretation makes a specific prediction: dark matter distributions should reflect the computational structure of the universe, potentially showing correlations or patterns not expected from collisionless particles.

7.3 Dark Energy as Information Dilution

The accelerating expansion of the universe implies the presence of 'dark energy'—a uniform energy density filling space that drives cosmic acceleration. In our framework, this may be reinterpreted as the natural diffusion of mutual information.

As the information graph expands and mutual information between distant regions dilutes, the apparent distances between them increase. This is not space 'stretching' in any substantive sense; it is correlations weakening. The cosmological constant Λ parameterizes the baseline rate of this dilution in regions unaffected by local concentrations of complexity.

Recent observations from the Dark Energy Spectroscopic Instrument (DESI) suggest that dark energy may be time-varying rather than constant. This is consistent with an information-theoretic interpretation where the dilution rate depends on the evolving structure of cosmic information, rather than being fixed by a cosmological constant.

8. The Speed of Light as Maximum Information Bandwidth

The invariance of the speed of light c in all reference frames is one of the most precisely confirmed facts in physics. Our framework interprets this not as a speed limit on physical objects but as a fundamental bandwidth constraint on state propagation.

c represents the maximum rate at which changes in information state can propagate through the information geometry. It is finite because computation is finite—each node in the informational graph can only update at a bounded rate. The structure of special relativity, including time dilation and length contraction, follows from the requirement that this bandwidth limit be observer-independent.

Locality exists because it prevents computational race conditions. If arbitrary nodes could update simultaneously based on distant inputs, the system would be inconsistent. The causal structure of spacetime—the light-cone constraint—is the universe's mechanism for maintaining coherence across a massively parallel computation.

This interpretation yields the relationship:

$$c = maximum[dI/dt] / \rho_i \qquad (13)$$

where dI/dt is the rate of information transfer and ρ_i is the background information density of the vacuum. This provides a route to predicting variations in c under extreme conditions.

9. Experimental Tests and Predictions

A framework that merely reinterprets existing physics without making new predictions is metaphysics, not physics. This section details specific experimental protocols capable of distinguishing informational relativity from standard physics.

9.1 Phase Transition Gravitational Coupling

If gravity couples to information processing rate rather than merely to mass-energy content, then rapid phase transitions should produce transient gravitational signatures beyond what static mass would predict.

Theoretical Basis

During a phase transition (crystallization, melting, magnetic ordering), a system undergoes rapid state changes: molecules finding new configurations, bonds breaking or forming, the system exploring state space. In the informational framework, this represents intense local computation. If computational density couples to gravity, we should observe:

$$\delta g(t) = \eta \cdot (dS/dt) \qquad (14)$$

where $\delta g(t)$ is the transient gravitational anomaly, dS/dt is the entropy production rate, and η is the coupling constant to be determined experimentally.

Experimental Protocol

Apparatus: A torsion pendulum of sensitivity $\sim 10^{-11}$ N, isolated from seismic, thermal, and electromagnetic interference, positioned at fixed distance from a phase-transition chamber.

Procedure: (1) Establish baseline gravitational reading with sample in static solid state. (2) Trigger rapid crystallization of supercooled liquid (e.g., supercooled water at -20°C, supersaturated sodium acetate solution) via seed crystal or ultrasonic nucleation. (3) Record pendulum deflection throughout transition. (4) Repeat with melting transition (rapid heating). (5) Compare transition events to baseline.

Prediction (Informational Relativity): Both crystallization and melting produce transient gravitational enhancement proportional to transition rate. Faster transitions yield larger signals. The effect is symmetric—both entropy-increasing and entropy-decreasing processes involve computation.

Prediction (Standard Physics): No gravitational anomaly. The pendulum responds identically to static and transitioning samples of equal mass.

Controls required: Isolate from thermal expansion, pressure changes, air currents, piezoelectric effects. Use multiple crystallizing substances. Vary transition rates via temperature control.

9.2 Gravitational Wave Residual Analysis

Black hole mergers, in the informational framework, are computational reconciliation events—two information horizons combining. This should leave signatures in gravitational wave observations.

Methodology

Using publicly available LIGO/Virgo data (GWTC-3 catalog, ~90 events): (1) Extract parameter estimates (masses, spins) for each binary black hole merger. (2) Calculate information-theoretic quantities for each event:

$$S_i = 4\pi(GM_i/c^2)^2 / l_p^2 \quad \text{(Bekenstein-Hawking entropy)} \qquad (15)$$

$$\Delta S = Sfinal - (S_1 + S_2) \quad \text{(entropy created)} \qquad (16)$$

$$R = S_2/S_1 \quad \text{(asymmetry ratio)} \qquad (17)$$

(3) Compare observed waveforms to best-fit general relativity templates. (4) Calculate residuals (observed minus predicted). (5) Test for correlations between residual power and entropy parameters.

Prediction (Informational Relativity): Systematic residuals correlated with entropy change or asymmetry ratio. High-ΔS mergers should show excess power in specific frequency bands, particularly during ringdown when the final hole is 'completing computation.'

Prediction (Standard Physics): Residuals uncorrelated with entropy parameters; any deviations are random instrumental noise.

9.3 Quantum Computer Gravitational Signature

A quantum computer mid-calculation represents a system with rapidly evolving information relationships—qubits in superposition, entanglement spreading, massive parallelism. If computational intensity couples to gravity, this should be detectable.

Protocol: Position sensitive gravimeter near quantum processor. Compare gravitational signature during: (a) idle state, (b) active computation with maximal entanglement, (c) classical computation of equal energy consumption.

Prediction (Informational Relativity): Active quantum computation produces gravitational signature exceeding that of idle state or classical computation of equal energy.

Prediction (Standard Physics): No difference; gravitational effect depends only on mass-energy, not computational state.

9.4 Astronomical Tests: Crystallizing White Dwarfs

White dwarfs cool over billions of years, eventually crystallizing their carbon-oxygen cores. This is a planet-scale phase transition occurring in real time.

Prediction (Informational Relativity): White dwarfs in the crystallization epoch should exhibit subtle orbital anomalies if in binary systems—perturbations correlated with crystallization rate that deviate from Keplerian predictions based on static mass.

Observable: Monitor binary white dwarf systems with one component in the crystallization phase. Look for timing residuals correlated with evolutionary state rather than mass alone.

9.5 Falsification Criteria

The framework is falsifiable if:

(1) Phase transition experiments detect no gravitational anomaly at sensitivity levels where the predicted effect should be observable (given $\eta > 0$).

(2) LIGO residual analysis shows no correlation with entropy parameters across the full event catalog.

(3) The holographic bound is violated—information in a region exceeds the Bekenstein limit—which would contradict the framework's prediction that boundary encoding is exact.

(4) Entanglement is shown to involve genuine superluminal signaling, contradicting the interpretation that entangled particles are informationally adjacent rather than spatially separated.

10. Implications for Unsolved Problems

If informational relativity is correct, several long-standing problems in physics cease to be problems in their traditional formulation. They either dissolve entirely, transform into different questions, or admit solutions that were previously inaccessible.

10.1 The Quantum Gravity Problem

Standard physics seeks to quantize gravity using field-theoretic methods, producing infinities that cannot be renormalized. In the informational framework, this problem may be malformed. If gravity is not a force but an emergent property of information geometry, then there is nothing to quantize in the usual sense. Spacetime curvature is already a macroscopic description of underlying informational relationships.

What exists at the fundamental level is information and its processing. Quantum mechanics describes this processing at small scales; general relativity describes its large-scale geometric projection. They are not two theories requiring unification but two views of the same underlying computation at different scales.

10.2 The Measurement Problem

The standard measurement problem asks what causes wave function collapse. The informational resolution: there is no collapse. Measurement is the establishment of mutual information between observer and system. The apparent 'collapse' is the observer's experience of becoming correlated with the system's state. The process is unitary throughout; what changes is the observer's informational position.

10.3 The Arrow of Time

The arrow of time problem asks why the universe exhibits time asymmetry when fundamental laws are time-symmetric. The informational resolution: there is no independent parameter 'time' along which entropy happens to increase. Entropy production is time. The past is the direction of lower entropy; the future is the direction of higher entropy; the present is the computational wavefront.

10.4 The Cosmological Constant Problem

Quantum field theory predicts vacuum energy density $\sim 10^{120}$ times larger than observed. In the informational framework, 'vacuum energy' is not energy in empty space but a property of the information structure. The observed cosmological constant parameterizes the intrinsic curvature of the information manifold in regions of minimal complexity—a geometric property, not an energy density.

10.5 The Hierarchy Problem

Why is gravity so much weaker than other forces? In the informational framework, gravity is emergent rather than fundamental. The 'weakness' reflects that gravity emerges from collective information-geometric behavior, while other forces are more direct computations. Collective emergent properties are generically weaker than microscopic ones.

10.6 Fine-Tuning

Physical constants appear fine-tuned for complex structure. The framework suggests asking: what computational constraints produce these values? Some apparent fine-tuning may dissolve when constants emerge from information-theoretic necessities rather than contingent parameter choices.

11. Relation to Existing Frameworks

Informational relativity connects to several existing research programmes while differing from each in specific ways.

11.1 Digital Physics

Digital physics (Zuse, Fredkin, Wolfram) proposes that the universe is a cellular automaton or similar discrete computational structure. We share the emphasis on computation but do not commit to a specific discrete substrate. The computation may be over continuous or discrete structures; our claims are substrate-independent.

11.2 Loop Quantum Gravity

Loop quantum gravity quantizes spacetime geometry directly, yielding discrete spectra for area and volume operators. Our framework is compatible with but does not require this discreteness. If LQG is correct, the 'atoms of space' may be understood as minimal units of computation.

11.3 ER=EPR

The ER=EPR conjecture (Maldacena, Susskind) proposes that entangled particles are connected by wormholes. In our language, this is the statement that high mutual information implies low informational distance—which may manifest geometrically as a shortcut through the information graph.

11.4 Constructor Theory

Constructor theory (Deutsch, Marletto) reformulates physics in terms of possible and impossible transformations. This is complementary to our approach; we focus on what is computed, constructor theory on what computations are permitted.

11.5 Integrated Information Theory

IIT (Tononi) proposes that consciousness corresponds to integrated information. While our framework does not solve the hard problem of consciousness, it removes the apparent category gap between mind and matter—both are patterns in the same informational substrate.

12. Philosophical Implications

If this framework is correct, several traditional philosophical questions dissolve or transform.

12.1 The Nature of Substance

There is no 'stuff' underlying physical reality—no atoms, no fields, no strings in any irreducible material sense. There is only information and its processing. This is not eliminativism; the information is real. But it is a different kind of reality than the material substances of traditional ontology.

12.2 The Direction of Time

Time has a direction not because of any asymmetry in fundamental law but because of the initial condition. The universe began simple and is computing toward complexity. We remember the past because memory formation increases entropy; we cannot remember the future because that would require entropy decrease.

12.3 The Nature of Consciousness

If physical systems are information processing, then consciousness—which is certainly information processing—is not anomalous. The question is not how consciousness emerges from matter but how certain informational patterns come to model themselves. This does not solve the hard problem, but it relocates it from physics to information theory.

12.4 The Question of Purpose

Does the computation have a purpose? Is there an output? These questions may be category errors. A computation need not be for anything external to itself. The universe may simply be the computation—not a means to an end but the end in itself, if 'end' is even applicable.

13. Conclusion

We have proposed that spacetime is not fundamental but emergent—a projection of information geometry onto the manifold structure we perceive. In this framework, spatial distance measures informational dissimilarity, mass represents computational density, and time is indistinguishable from entropy production. The mathematics of general relativity, quantum mechanics, and thermodynamics remain unchanged; what changes is our understanding of what that mathematics describes.

The framework resolves or reframes several persistent puzzles: the nonlocality of entanglement becomes informational adjacency; the black hole information paradox becomes a question of deferred computation; the unification of gravity and quantum mechanics becomes less urgent when gravity is understood as an information-geometric effect rather than a force requiring separate quantization.

This revised presentation strengthens the original framework by providing mathematical formalism connecting postulates to established physics, operational definitions enabling empirical tests, and detailed experimental protocols capable of falsification. The phase transition experiment, LIGO residual analysis, and quantum computer tests provide concrete paths to empirical discrimination.

Recent observations—including DESI evidence for time-varying dark energy, persistent Hubble tension, and challenges to ΛCDM cosmology—are consistent with the framework's predictions and suggest that standard physics may be incomplete in precisely the ways informational relativity predicts.

Whether this framework is merely a novel interpretation or points to new physics remains to be determined. The predictions outlined provide paths to resolution. But even as interpretation alone, informational relativity offers a unified picture in which matter, energy, space, and time are aspects of a single underlying reality: the universe as self-computing structure, solving itself across the long gradient from order to entropy.

Time is not real. Time is the universe solving itself.

References

Bekenstein, J. D. (1973). Black holes and entropy. Physical Review D, 7(8), 2333.

Bousso, R. (2002). The holographic principle. Reviews of Modern Physics, 74(3), 825.

Deutsch, D., & Marletto, C. (2015). Constructor theory of information. Proceedings of the Royal Society A, 471(2174), 20140540.

Hawking, S. W. (1975). Particle creation by black holes. Communications in Mathematical Physics, 43(3), 199-220.

Jacobson, T. (1995). Thermodynamics of spacetime: The Einstein equation of state. Physical Review Letters, 75(7), 1260.

Landauer, R. (1961). Irreversibility and heat generation in the computing process. IBM Journal of Research and Development, 5(3), 183-191.

Maldacena, J. (1999). The large-N limit of superconformal field theories and supergravity. International Journal of Theoretical Physics, 38(4), 1113-1133.

Maldacena, J., & Susskind, L. (2013). Cool horizons for entangled black holes. Fortschritte der Physik, 61(9), 781-811.

Penrose, R. (1979). Singularities and time-asymmetry. In General Relativity: An Einstein Centenary Survey (pp. 581-638).

Rovelli, C. (2018). The Order of Time. Riverhead Books.

Shannon, C. E. (1948). A mathematical theory of communication. Bell System Technical Journal, 27(3), 379-423.

Susskind, L. (1995). The world as a hologram. Journal of Mathematical Physics, 36(11), 6377-6396.

't Hooft, G. (1993). Dimensional reduction in quantum gravity. arXiv preprint gr-qc/9310026.

Tononi, G. (2008). Consciousness as integrated information: A provisional manifesto. The Biological Bulletin, 215(3), 216-242.

Van Raamsdonk, M. (2010). Building up spacetime with quantum entanglement. General Relativity and Gravitation, 42(10), 2323-2329.

Verlinde, E. (2011). On the origin of gravity and the laws of Newton. Journal of High Energy Physics, 2011(4), 29.

Wheeler, J. A. (1990). Information, physics, quantum: The search for links. In Complexity, Entropy, and the Physics of Information.

Wolfram, S. (2002). A New Kind of Science. Wolfram Media.

Appendix A: Experimental Parameters

A.1 Phase Transition Experiment

Parameter	Specification
Torsion pendulum sensitivity	~10^{-11} N (Eöt-Wash class)
Sample mass	100g - 1kg
Sample-pendulum distance	1-10 cm
Transition time (crystallization)	0.1 - 10 seconds
Candidate materials	Supercooled water, sodium acetate, metallic glasses
Required trials for statistical significance	>100 per condition

A.2 LIGO Analysis Parameters

Parameter	Specification
Data source	GWOSC (gwosc.org), GWTC-3 catalog
Number of events	~90 BBH mergers
Entropy calculation	$S \propto M^2$ (Bekenstein-Hawking)
Statistical test	Pearson/Spearman correlation, $p < 0.05$
Software	gwpy, pesummary, PyCBC/LALSuite