

Entropic-Operational Paradigm

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Entropic-Operational Paradigm: Reclaiming Physics from Mathematical Abstraction

Author: Rowan Brad Quni-Gudzinis **Contact:** rowan.quni@outlook.com **ORCID:** 0009-0002-4317-5604 **ISNI:** 0000000526456062 **URL:** <https://papers.qnfo.org/papers/entropic-operational-paradigm/> ****Publication Date:** 2025-11-23 **Version:**** 1.0

Thesis: Gravity, spacetime, and quantum mechanics are not fundamental geometric structures, but emergent artifacts of thermodynamic information processing, necessitating the rejection of mathematical Platonism in favor of strict operational realism.

Gravity as Entropic

Emergence

Gravity is not a fundamental interaction; it is the statistical consequence of information displacement, a macroscopic manifestation of the Second Law of Thermodynamics acting on causal horizons. The geometric interpretation of General Relativity—treating spacetime as a physical manifold capable of bending—is a category error analogous to treating heat as a fundamental fluid rather than the kinetic aggregate of atomic motion. Operational realism demands the dismantling of this geometric Platonism: spacetime curvature is not the *cause* of gravity, but the *bookkeeping metric* for the entropic costs of moving matter.

The derivation of Einstein’s field equations from thermodynamic principles, first articulated by Ted Jacobson, exposes the non-fundamental nature of the metric tensor. By applying the Clausius relation, $\delta Q = TdS$, to the boundary of a local causal horizon, the Einstein equation $G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi GT_{\mu\nu}$ emerges not as a dynamical law of geometry, but as an equation of state describing a statistical system in equilibrium. Here, the area of the horizon acts as a measure of entropy ($S \propto A$), and the surface gravity serves as the Unruh temperature ($T \propto \kappa$). When matter crosses the horizon, it transfers energy (heat), necessitating a change in the horizon’s area (entropy) to preserve thermodynamic consistency. The curvature of spacetime is merely the system’s elastic response to this information flux, a shadow cast by the underlying redistribution of microstates.

Erik Verlinde’s entropic gravity extends this operational critique, positioning mass not as a source of geometric distortion, but as a defect in the information density of the holographic screen. In this framework, the “force” of gravity is indistinguishable from the entropic force driving a polymer chain to coil or osmosis to balance concentrations. When a test mass moves away from a holographic screen, it reduces the phase space available to the system’s underlying degrees of freedom. The resulting resistance—the tendency of the system to maximize its entropy by pulling the mass back—is what classical physics misidentifies as gravitational attraction. There is no “graviton” mediating this interaction, just as there is no “phonon” mediating the pressure of a gas; there is only the statistical inevitability of microstate maximization.

This paradigm shifts the ontological baseline from geometry to information processing. If gravity is entropic, then spacetime itself is an emergent construct, a low-resolution representation of the entanglement structure between causal events. Distance is not a fundamental variable but a measure of correlation decay; time is not a dimension but the irreversible consumption of free energy (information erasure). Consequently, the search for a quantized metric is a methodological dead end. One cannot quantize gravity for the same reason one cannot quantize a sound wave in a

distinct medium from the atoms that carry it: the metric is a collective behavior, not a discrete entity. Reality operates strictly on the exchange of information bits, with gravity serving as the macroscopic cost function for their displacement.

Time as Thermodynamic

Process

The conflation of temporal duration with spatial extension constitutes the foundational error of twentieth-century mathematical physics. To operationalize time, one must strip it of its geometric disguise. Time is not a coordinate axis within a static four-dimensional hypercube; it is the thermodynamic cost of state transition. The Minkowski ‘block universe’—a static formalism where past, present, and future coexist simultaneously—is an unphysical mathematical artifact that violates Landauer’s principle by presupposing the existence of information (the future) that has not yet been physically computed.

The Operational

Divergence of Space and Time

Space and time possess distinct ontological signatures that prohibit their unification into a single isotropic manifold.

Space is Synchronic and Relational: Spatial dimensions describe the network of simultaneous relationships between physical entities. It is a measure of capacity—where information *resides*. Movement in space is reversible; one may traverse from coordinate A to B and back to A with zero net displacement.

Time is Diachronic and Causal: Temporal succession describes the irreversible update of the system’s state. It is a measure of processing—how information *changes*. Movement in time is strictly unidirectional, driven by the asymmetry of the Second Law of Thermodynamics. One cannot return to a previous moment because the information state defining that moment has been irretrievably dissipated as heat.

Treating time as a fourth spatial dimension (*ict*) is a computational convenience for preserving Lorentz invariance, not a description of physical reality. Operationally, a clock does not measure distance along a temporal dimension; it measures the accumulation of entropy (energy dissipation) in a reference system.

Entropy as the Driver of

Causal Flow

Time is not a fundamental container but an emergent property of thermodynamic disequilibrium. In a universe at maximum entropy (thermal equilibrium), no macro-state changes occur, information processing ceases, and time, in any operational sense, vanishes. The “flow” of time is physically identical to the gradient of entropy production ($dS/dt > 0$).

The Information Horizon: The “present” is not a slice of a block universe; it is the active processing boundary where quantum uncertainty is converted into classical history via irreversible measurement (decoherence).

Landauer’s Limit as the Clock Tick: Every logical operation—every distinction made by a physical system—requires the erasure of information, generating heat ($k_B T \ln 2$). This energy cost defines the “tick” of the universal clock. Time moves forward because to reverse it would require an infinite energy expenditure to reconstruct dissipated heat into ordered information, violating the conservation of energy.

Rejection of the Block

Universe

The block universe model demands a “View from Nowhere”—a Platonist perspective outside the physical system. This is operationally impossible. All observers are embedded *within* the system, subject to its thermodynamic constraints.

Against Predetermined Futures: If the future already exists as a geometric coordinate, it implies that all information regarding future states is already encoded. This violates the operational reality of quantum indeterminacy, where outcomes are not hidden variables but genuine acts of creation.

Geometry as Fossilized Dynamics: What general relativity interprets as “curved spacetime” is the history of causal interactions, not a pre-existing stage. Space is the network of entanglement; time is the breaking and reforming of those links.

Therefore, gravity is not the bending of a static temporal dimension. Gravity is the entropic force resulting from the information density gradients of this processing. We must replace the geometric paradigm with a **process philosophy**: Reality is a sequence of irreversible causal updates, where space is the instantaneous configuration of the network, and time is the thermodynamic labor of rewriting that network.

The Operational

Definition of ‘Quantum’

The semantic collapse of the term “quantum” has transformed a precise algebraic descriptor into a mystical signifier for epistemic surrender, obscuring the physical mechanisms of reality behind a veil of “inherent randomness.” We reject the ontological assertion that the universe is fundamentally pixelated or that “quanta” exist as independent, indivisible tiles of spacetime. Instead, we enforce a strict **Operational Definition of Quantum Behavior**: a system is designated “quantum” if and only if its observable properties exhibit **non-commutativity** ($[\hat{A}, \hat{B}] \neq 0$). This defines “quantum” not as a geometric structure, but as a **processing constraint** where the order of information extraction dictates the state of the system.

The reification of the Planck length (l_P) as a fundamental “pixel size” of the universe is a category error—a confusion of map and territory derived from Max Planck’s heuristic computational shortcut to resolve the ultraviolet catastrophe. The assumption that spacetime must be discrete to avoid singularities is a failure of imagination, solvable via **scale-invariant fractal geometries** or asymptotic safety, where “healing lengths” emerge dynamically from field interactions rather than being hard-coded as static truncation. In this framework, $\hbar$ (Planck’s constant) is not the diameter of a grain of reality, but the **thermodynamic conversion factor** between information density and phase-space volume—defining the cost of isolating a degree of freedom from the universal entropic background.

Discreteness in energy spectra (e.g., electron orbitals) is therefore not evidence of a discrete spacetime, but an emergent **resonance phenomenon** arising from boundary conditions imposed on continuous fields, analogous to standing waves on a violin string. The “quantum jump” is an artifact of the measurement update rate, not a discontinuous movement of matter. By replacing the lazy metaphysics of “probability clouds” with the rigorous thermodynamics of **information horizons**, we locate the uncertainty principle not in the ontology of the particle, but in the entropic cost of the measurement interaction. “Quantum” is not magic; it is the friction of information processing in a thermodynamic universe.

Landauer’s Razor:

The Physicality of Symbols

Theoretical physics has succumbed to a terminal infection of Mathematical Platonism, mistaking the descriptive map for the territory of energetic reality. The cure is the rigorous application of **Landauer’s Razor**: *if a theoretical construct cannot be encoded in a physical system, manipulated by thermodynamic work, and erased at the cost of*

$k_B T \ln 2$, it does not exist.* Information is not an abstract concept; it is a physical property of matter and radiation. Therefore, any mathematical symbol in a lagrangian that lacks a corresponding thermodynamic cost is an artifact of notation, not a constituent of the universe.

The

Bit-Joule Equivalence as an Ontological Filter

Landauer's Principle (1961) proved that the erasure of information is a dissipative process, linking the abstract "bit" directly to the physical "joule." This equivalence imposes a strict operational constraint on reality: **physical existence requires thermodynamic addressability**.

Rejection of Extra Dimensions: String theory's invocation of six or seven compactified spatial dimensions fails this test. These dimensions act as "phantom containers" for mathematical consistency (anomaly cancellation) but interact with no observable heat bath. Since a bit of information cannot be written to or erased from a Calabi-Yau manifold, these dimensions are physically null. They are not hidden; they are nonexistent.

The Myth of Ontological Negativity: Negative numbers are bookkeeping devices for relational deficits, not descriptors of fundamental entities. "Negative energy" in quantum field theory is a misnomer for a gradient relative to a vacuum expectation value; "negative probability" is a failure of the interpretive framework. Nature admits only magnitudes and vectors. An electron-positron pair is not "matter plus anti-matter" summing to zero existence; it is a high-energy system of two positive-mass excitations with opposing phase correlations. The symbol "—" denotes a conservation operation (cancellation of charge), not an ontological object.

Complex Numbers as

Compression Algorithms

The ubiquity of $\sqrt{-1}$ in quantum mechanics has deluded physicists into assigning reality to the complex plane. Operationally, the imaginary unit i is a data compression algorithm for tracking phase relationships between real-valued oscillators. A quantum wavefunction ψ is not a physical wave; it is a probability catalog. The physical reality consists solely of the measurable intensity $|\psi|^2$ and the thermodynamic click of the detector. By treating the Hilbert space as the territory, standard interpretations generate "Many Worlds" and "quantum immortality"—infinite, unobservable branches of reality that violate Landauer's Razor by demanding infinite information storage without infinite energy consumption. We discard the complex field as a fundamental structure; reality is computed in real numbers, governed by phase-dependent interference of distinct physical histories.

Gravity as Thermodynamic

Output

With mathematical artifacts excised, gravity reveals itself not as a geometric imposition, but as a **thermodynamic consequence**. Spacetime geometry is the coarse-grained macroscopic description of microscopic information processing.

Entropic Force: As derived by Verlinde, gravity arises from the tendency of a system to maximize entropy. The "pull" of gravity is the statistical inevitability of information scrambling, identical in nature to the osmotic pressure of a gas.

Horizon Encoding: The Bekenstein-Hawking relation ($S = A/4L_P^2$) confirms that the physics of a volume is fully encoded on its boundary. Spacetime is not a container; it is the holographic projection of quantum entanglement entropy.

Time as Irreversibility: Time is not a dimension coordinate (t) orthogonal to space; it is the **process count** of state changes. The “arrow of time” is the gradient of entropy production. Without thermal deviation, time ceases to exist.

The Operational Imperative

We replace the aesthetic criterion of mathematical elegance with the brutal efficiency of thermodynamic accounting. A theory is valid only if its variables map 1:1 to erasable states of matter.

Discard: Smooth manifolds, infinities, singularities, extra dimensions, and complex ontology.

Retain: Causal sets, discrete bits, entropy gradients, and relational observables.

Physics is the study of *stuff that pushes other stuff*. Any symbol that claims to be more than a label for a push, a pull, or a heat transfer is a fiction. We reclaim the universe from the mathematicians by asserting that **geometry is subservient to entropy**, and **symbols are subservient to work**.