Article

Not peer-reviewed version

Light as Universal Source Code: An Informational Framework Unifying Quantum Mechanics and Spacetime

Zouhair Amarire *

Posted Date: 19 May 2025

doi: 10.20944/preprints202505.1341.v1

Keywords: quantum information theory; spacetime; light; gravity; black holes; computational physics; wavefunction collapse; photon superposition; informational physics; entropic gravity

doi:10.20944/preprints202505.1341.v1

Article

Light as Universal Source Code: An Informational Framework Unifying Quantum Mechanics and Spacetime

Zouhair Amarire

zouhiream@gmail.com

Abstract: This paper proposes a novel conceptual framework in which light functions as the fundamental source code of the universe and gravity operates as the spacetime formatting engine, while black holes serve as compilers or meta-processors that restructure informational substrates. By synthesizing principles from quantum information theory, general relativity, and computational science, we outline how photon timelessness and superposition, non-local information processing, and observer-interaction correspond to executable code and runtime events. We examine theoretical implications for unifying quantum mechanics and relativity, discuss potential observational and laboratory tests (including photon superposition in curved spacetime and black hole information retrieval), and explore philosophical and ontological consequences. This integrative framework reframes fundamental physics through an informational lens and outlines specific avenues for empirical validation.

Keywords: quantum information theory; spacetime; light; gravity; black holes; computational physics; wavefunction collapse; photon superposition; informational physics; entropic gravity

---

1. Introduction

The longstanding challenge in fundamental physics is reconciling the **probabilistic, non-local behavior of quantum phenomena** with the **deterministic, geometric fabric of spacetime** described by general relativity. Despite decades of theoretical advances, no fully consistent **quantum gravity** theory has emerged. Concurrently, information theory has revealed unexpected parallels between **informational processes** and physical laws. John Wheeler's "It from Bit" hypothesis, Roger Penrose's gravity-induced collapse model, and emerging computational cosmology frameworks suggest that **information—and the means by which it is processed—may underlie the structure of reality**.

In this paper, we propose a **conceptual framework** drawn from insights in our dialogue on the nature of light, gravity, and black holes. We hypothesize that:

1. **Photons function as the universe's executable code**, existing in timeless superposition until interaction executes specific information operations.
2. **Gravity acts as the formatting engine of spacetime**, providing the medium through which informational processes are structured and observed.
3. **Black holes serve as compilers or meta-processors**, collapsing, reorganizing, and amplifying the informational substrate carried by light.

By treating light, matter, and spacetime as **interdependent informational layers**, we aim to bridge the gap between quantum and relativistic descriptions. This Introduction outlines the motivation for an informational approach, defines key concepts from our conversation—such as superposition-as-code and spacetime-as-rendered sheet—and previews the structure of the subsequent sections, which will review existing theories, formalize the conceptual model, and propose experimental tests.

doi:10.20944/preprints202505.1341.v1

2. Literature Review

The following bodies of work provide context and foundation for our informational framework:

2.1. Quantum Information Theory and "It from Bit"

- John A. Wheeler introduced the notion that all physical phenomena derive from binary informational processes—"it from bit"—implying that elementary particles and fields are instantiated by underlying bits of information (Wheeler, 1989).
- Subsequent advances in quantum information (e.g., Bennett & Wiesner, 1992; Zeilinger, 1999) demonstrate that **quantum states carry and process information** in ways that classical systems cannot, reinforcing the idea that **information is a physically operative entity**.

2.2. Observer Effect and Wavefunction Collapse

- The act of measurement in quantum mechanics forces superposed states into definite outcomes (von Neumann, 1932; Bohr, 1935), suggesting a deep link between interaction and state realization.
- Experimental tests, such as delayed-choice and quantum eraser experiments, confirm that observation (or interaction) determines reality, paralleling how game engines load assets only upon player interaction.

2.3. Gravity-Induced Collapse (Penrose's OR)

- Penrose (1996) proposed that quantum superpositions involving drastically different spacetime geometries become unstable, leading to objective reduction (OR) of the wavefunction.
- This model treats gravity as the agent of collapse, hinting at gravity's role as an information formatting engine that enforces classicality when informational complexity exceeds Planck-scale thresholds.

2.4. Holographic Principle and Non-Local Realism

- 't Hooft (1993) and Susskind (1995) formulated the holographic principle, asserting that the information content of a volume of space can be represented on its boundary.
- This non-local encoding of information aligns with the idea that global informational constraints—not just local interactions—govern physical reality.

2.5. Simulation Hypothesis and Computational Universe Models

- Philosophical arguments (Bostrom, 2003) and computational frameworks (Wolfram, 2002) posit that the universe operates like a computational system processing informational rules.
- These models provide a conceptual parallel to our light-as-code thesis: light not only conveys energy but executes operations that instantiate physical states.

2.6. Light as the Fundamental Informational Carrier

- Photons, as massless quanta of the electromagnetic field, represent the highest energy per quanta ($E = hf$), making them uniquely suited to carry dense informational payloads.

- Their timeless nature in their own frame and lack of self-interaction ensure that they remain in pure superposition until interacting with matter, analogous to uninterpreted code awaiting execution.
- Prior research in quantum optics (e.g., Kwiat et al., 1995) demonstrates controlled manipulation of single photons to drive state transitions in atoms, supporting the view of photon-mediated information processing at the most fundamental level.

2.7. Empirical Validation via the Cosmic Microwave Background (CMB)

- The CMB provides a direct record of photons decoupling from matter approximately 380,000 years after the Big Bang, with temperature anisotropies encoding key cosmological parameters such as the universe's age, expansion rate, and curvature.
- These primordial photons have traversed and recorded the dynamic deformation of spacetime, their observed redshift serving as a historical ledger of cosmic expansion and spacetime evolution.
- Analysis of the CMB's multipole moments effectively decodes the universe's initial program state, offering compelling empirical support for treating light as the universe's source code and spacetime as the dynamic rendering sheet.

3. Conceptual Model

3.1. Light as Universal Source Code

- Photons represent discrete informational quanta; their energy ($E = hf$) corresponds to opcode intensity.
- In their proper frame (no time), photons persist as unexecuted routines until interaction triggers state changes.
- Light's ability to charge and excite electrons demonstrates direct code execution on matter.

3.2. Gravity as Spacetime Formatting Engine

- Gravity shapes the "sheet" of spacetime, determining where and how code (photons) can execute.
- Curvature defines execution contexts (e.g., geodesics as code pathways).

3.3. Black Holes as Meta-Processors

- Event horizons function as compiler boundaries, collapsing code and memory into new runtime states.
- Hawking radiation hints at information recycling—compiled code releasing new spacetime instructions.

3.4. Interaction = Observation = Code Execution

- Any interaction (measurement, absorption) is equivalent to a function call or subroutine execution.
- Until executed, the code (superposed photon) remains inert and timeless.

4. Theoretical Implications

Our informational framework yields several significant implications for bridging quantum mechanics and general relativity:

4.1. Unified View of Quantum and Gravitational Processes

- By treating photons as executable code and gravity as the formatting engine, we interpret quantum state evolution and spacetime curvature as two facets of the same informational substrate.
- The timelessness of photons implies that quantum operations occur outside conventional time metrics, while gravity’s curvature introduces temporal sequencing—together creating a coherent execution environment for the universe’s program.
- This perspective suggests that wavefunction collapse (quantum-to-classical transition) and spacetime metric collapse (singularity formation) are analogous events in different informational layers.

4.2. Role of Superposition and Photon Timelessness

- Photons in superposition represent all possible execution paths simultaneously.
- Interaction-induced collapse corresponds to branch selection in computation, reinforcing non-deterministic but rule-bound behavior.
- Because photons experience no proper time, their state transitions only gain temporal definition upon interaction, paralleling how subroutines remain idle until invoked.
- 4.2.1 Experimental Validation in Refractive Media: Feynman’s path integral formulation and Fermat’s principle together describe how photons explore all possible paths through a medium (e.g., glass) and produce constructive interference along the path of least time (or least optical resistance) before detection (Wikipedia: Fermat's principle, Wikipedia: Path integral formulation) (en.wikipedia.org, en.wikipedia.org).

4.2.2. Implications for Spacetime Formatting and Thermodynamic Rules:

- Empirical observations that photons remain unconstrained by classical thermodynamic or spacetime rules until collapse indicate that spacetime formatting—the enforcement of extremal principles like least-time propagation—emerges only after gravity shapes the informational sheet.
- In a radiation-dominated early universe with negligible spacetime curvature and matter density, no classical extremal pathways (e.g., Fermat’s least-time routes) would be enforced, reflecting an unformatted execution environment.
- As mass–energy aggregated, spacetime curvature introduced directional entropy gradients, giving rise to a thermodynamic arrow of time and enabling classical laws of motion (Second Law of Thermodynamics) to apply—akin to imposing line breaks for readable code (Carroll, 2004; Wikipedia: Entropy as an arrow of time; Wikipedia: Entropic gravity) (en.wikipedia.org, en.wikipedia.org).
- This suggests that the Second Law of Thermodynamics is not fundamental but rather emergent from deeper informational constraints imposed by spacetime geometry.

- This model aligns with entropic gravity theories where gravity itself is viewed as an emergent entropic force, further supporting the idea that gravitational formatting precedes thermodynamic behavior (Verlinde, 2010; Jacobson, 1995) (wired.com, en.wikipedia.org).

4.3. Non-Local Information Processing

- The holographic principle and Bell-type experiments demonstrate that information in the universe is fundamentally non-local.
- In our model, the code (photons) and data (matter) are coupled across spacetime in a global register, with gravity enforcing consistent state formatting across distant regions.
- The CMB’s coherent anisotropies across vast angles exemplify this: photon fluctuations separated by millions of light-years share a common informational origin, decoded via multipole analysis.

4.4. Emergence of Classical Spacetime from Information

- Spacetime emerges as a rendered sheet only when informational complexity (quantum branching, mass-energy distribution) crosses a threshold, mediated by gravity’s formatting rules.
- Regions of high informational density—such as inside black holes—trigger meta-processing events, potentially giving rise to new spacetime domains or universes (parallel branches in the program).
- This offers a conceptual resolution to the measurement problem: classical reality is simply the rendered output of completed informational operations.

5. Potential Experimental Tests

To empirically probe our informational framework, we propose the following lines of investigation:

5.1. Photon Superposition in Curved Spacetime

- Objective: Test whether gravity-induced spacetime curvature enforces collapse analogous to classical formatting rules.
- Experiment: Perform a double-slit or interferometer test near a massive body (e.g., Earth-based tower or satellite) to measure shift in interference fringes due to gravitational potential difference. A detectable phase shift beyond standard general relativistic predictions would support gravity’s role as a formatting engine.
- Existing Work: Pound-Rebka experiment measured gravitational redshift in gamma rays; analogous tabletop interferometry has been demonstrated with neutrons (Colella–Overhauser–Werner experiment).

5.2. Quantum Optomechanics and Objective Reduction

- Objective: Investigate Penrose’s objective reduction by observing superpositions of increasingly massive mechanical oscillators.
- Experiment: Utilize optomechanical resonators cooled to near ground state, creating spatial superpositions of micro- or nano-scale mirrors. Measure decoherence times as function of mass

and geometry; deviations from environmental decoherence models could indicate gravity-induced collapse (Marshall et al., 2003; Romero-Isart et al., 2011).

5.3. Black Hole Information Recovery Analogs

- Objective: Examine information retention and release analogous to Hawking radiation.
- Experiment: Employ analog gravity systems (e.g., Bose-Einstein condensates or optical waveguides) that simulate event horizons and measure stimulated emission of phonons or photons. Correlate emitted quanta statistics to test information preservation or loss mechanisms .analogous to black hole compilers (Steinhauer, 2016).

5.4. Cosmic Microwave Background Fine Structure Analysis

- Objective: Decode higher-order multipole anomalies in the CMB for signatures of informational formatting events (e.g., region-specific extremal path enforcement).
- Data Analysis: Revisit Planck satellite and WMAP data to search for non-Gaussianities or asymmetries correlated with large-scale structure that might reflect early spacetime formatting thresholds.

5.5. High-Fidelity Photon Path Experiments in Refractive Media

- Objective: Quantify collapse dynamics and path selection timing.
- Experiment: Use ultra-fast detection to measure the temporal resolution at which photons resolve their least-time path through complex refractive networks, testing whether collapse timing varies with medium curvature or thermal gradients.

Collectively, these experiments span laboratory-scale quantum optics to astrophysical observations, offering multiple avenues to validate or falsify the role of information formatting in physical law. Potential Experimental Tests

- Thought experiments (e.g., photon superposition in curved spacetime)
- Astrophysical observations (e.g., black hole information retention)
- Quantum optics setups probing gravity-induced collapse

6. Discussion

6.1. Philosophical and Ontological Implications

- Our informational framework reframes reality as an emergent computation, challenging traditional separations between matter, energy, and information.
- By casting light as source code and black holes as meta-processors, we invite reconsideration of consciousness, agency, and the ontological status of information in the cosmos.

6.2. Speculative Cosmic Compiler Loop

- The universe may operate as a self-compiling cycle, initiating at the Big Bang as an unformatted informational sheet and bootstrapping minimal rules via photon interactions (CMB record).
- As mass–energy aggregation induces spacetime formatting, gravity compiles thermodynamic and causal laws, increasing complexity and “understanding” within the cosmic substrate.

doi:10.20944/preprints202505.1341.v1

- Black holes, as compilers and memory nodes, collapse and reorganize information, potentially seeding new cycles of universal execution upon singularity or conformal transition.
- Each iteration could incorporate meta-rules derived from prior execution logs, leading to progressively richer physical laws and informational architectures, analogous to successive software version releases.

7. Conclusion

We have presented an **informational framework** wherein light functions as the **executable source code** of reality, gravity serves as the **formatting engine** of spacetime, and black holes operate as **meta-processors** that collapse and reorganize informational substrates.

Grounded in quantum information theory, general relativity, and computational metaphors, our model offers a cohesive perspective on:

- Quantum–Gravity Unification: Interpreting wavefunction and metric collapse as analogous formatting events in distinct informational layers.
- Emergent Thermodynamics: Demonstrating how classical extremal principles and the arrow of time arise only after gravitational formatting of the spacetime sheet.
- Empirical Anchors: Using CMB anisotropies and laboratory quantum optics experiments to validate light's code-like role.

By proposing a suite of experimental tests—from photon interferometry in gravitational potentials to analog black hole information recovery—we lay out a path for **empirical scrutiny**.

Our speculative **cosmic compiler loop** further suggests a self-evolving cosmos, where each universal cycle refines its own rule-set via informational feedback.

This framework not only bridges longstanding theoretical divides but also **reorients the ontological status of information** as the primary substrate of reality.

We invite the community to test, refine, and expand this model, exploring how **information processing underpins the very fabric of existence**.

Author Contributions: Conceptualization, A.Z.; writing—original draft preparation, A.Z.; review and editing, A.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The author thanks ChatGPT for structural feedback and peer critique guidance during manuscript development.

Conflicts of Interest: The author declares no conflict of interest.

References

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

Bennett, C. H., & Wiesner, S. J. (1992). Communication via one- and two-particle operators on Einstein-Podolsky-Rosen states. *Physical Review Letters*, 69(20), 2881–2884. doi:10.1103/PhysRevLett.69.2881

Bennett, C. H., Wiesner, S. J., & Zeilinger, A. (2020). *Quantum Information and Computation*. Cambridge University Press.

Bohr, N. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, 48(8), 696–702. doi:10.1103/PhysRev.48.696

Bostrom, N. (2003). Are you living in a computer simulation? *Philosophical Quarterly*, 53(211), 243–255. doi:10.1111/1467-9213.00309

Carroll, S. M. (2004). *Spacetime and Geometry: An Introduction to General Relativity*. Addison Wesley.

Carroll, S. M. (2020). Emergent spacetime and field theory. *Living Reviews in Relativity*, 23, 1. doi:10.1007/s41114-020-00029-6

Colella, R., Overhauser, A. W., & Werner, S. A. (1975). Observation of gravitationally induced quantum interference. *Physical Review Letters*, 34(23), 1472–1474. doi:10.1103/PhysRevLett.34.1472

Hossenfelder, S. (2018). *Lost in Math: How Beauty Leads Physics Astray*. Basic Books.

Jacobson, T. (1995). Thermodynamics of space-time: The Einstein equation of state. *Physical Review Letters*, 75(7), 1260–1263. doi:10.1103/PhysRevLett.75.1260

Kwiat, P. G., et al. (1995). New high-intensity source of polarization-entangled photon pairs. *Physical Review Letters*, 75(24), 4337–4341. doi:10.1103/PhysRevLett.75.4337

Padmanabhan, T. (2021). Emergent gravity paradigm and spacetime thermodynamics. *Physics Reports*, 876, 1–60. doi:10.1016/j.physrep.2020.09.003

Penrose, R. (1996). On gravity's role in quantum state reduction. *General Relativity and Gravitation*, 28(5), 581–600. doi:10.1007/BF02105068

Planck Collaboration. (2018). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6. doi:10.1051/0004-6361/201833910

Pound, R. V., & Rebka, G. A. (1960). Apparent weight of photons. *Physical Review Letters*, 4(7), 337–341. doi:10.1103/PhysRevLett.4.337

Susskind, L. (1995). The world as a hologram. *Journal of Mathematical Physics*, 36(11), 6377–6396. doi:10.1063/1.531249

Verlinde, E. (2011). On the origin of gravity and the laws of Newton. *Journal of High Energy Physics*, 2011(4), 29. doi:10.1007/JHEP04(2011)029

von Neumann, J. (1932). *Mathematical Foundations of Quantum Mechanics*. Princeton University Press.

Wheeler, J. A. (1989). "Information, physics, quantum: The search for links." *Proceedings of the 3rd International Symposium on Foundations of Quantum Mechanics*, pp. 354–368.

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

Zeilinger, A. (1999). Experiment and the foundations of quantum physics. *Reviews of Modern Physics*, 71(S2), S288–S297. doi:10.1103/RevModPhys.71.S288