Black Hole Entropy, Evaporation, and Information Conservation in the Holosphere Lattice

Michael Sarnowski

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Abstract

We present a discrete physical model of black holes based on the Holosphere lattice—an angularly coherent, Planck-structured spacetime composed of spinning neutron-scale spheres. In this framework, gravity and entropy emerge from the suppression and saturation of angular vacancy defects. Black holes form not as singularities, but as defect-saturated shells where strain accumulates and vacancy flux halts. Evaporation proceeds through rare surface relaxation events that emit angularly entangled defects, externalizing information and reducing strain in discrete steps. The model naturally recovers the Bekenstein-Hawking entropy-area relation, resolves the information paradox via unitary emission, and provides quantitative predictions for gravitational wave echoes, quantized evaporation energy, and holographic surface memory.

Beyond black holes, we extend this framework to cosmology: Appendix B introduces a boundary defect drain that allows an eternally structured universe to remain low-entropy, resolving the thermodynamic arrow of time in steady-state conditions. Appendix C formalizes surface entanglement through a spinor field encoding, providing a quantum-coherent interpretation of black hole memory. This unified framework replaces geometric singularities with discrete dynamics, offering a falsifiable and physically grounded theory of black hole thermodynamics and cosmic evolution.

Contents

Definitions and Key Symbols

- **Holosphere:** A discrete, neutron-scale spinning sphere that forms the basic unit of the lattice structure of spacetime. Holospheres are composed of Planck-scale subunits and propagate angular momentum across the lattice.
- **Defect:** A localized vacancy or misalignment in the Holosphere packing. Defects carry angular strain and are responsible for emergent properties like gravity, entropy, and quantum behavior.
- **Defect Flux ϕ_v:** The rate at which defects escape from a given region, particularly from the boundary shell of a black hole. Units: defects per second.
- **Angular Tension Potential $T(r,t)$:** A scalar field representing the amount of unsummed angular strain at radius r and time t. Governs the likelihood of defect escape.
- **Saturation Threshold T_c:** The critical value of T beyond which defect motion is suppressed and the lattice becomes "frozen."
- **Relaxation Rate λ_T:** A constant describing the rate at which surface tension is reduced via defect ejection when $T > T_c$.
- **Spinor Field Ψ:** A two-component complex field defined on the black hole shell, encoding angular orientation and phase relationships of boundary Holospheres.
- **Planck Length l_p:** The fundamental unit of length in quantum gravity, defined as $l_p = \sqrt{\hbar G/c^3} \approx 1.616 \times 10^{-35}$ m.
- **Evaporation Power $P_{\mathbf{evap}}$:** The energy emitted per unit time during black hole relaxation, estimated as $P_{\text{evap}} = \lambda \cdot \Delta E_v$.
- **Defect Emission Energy ΔE_v:** The energy carried by a single defect ejected from the saturated shell. Estimated on the order of TeV.
- **Echo Delay Time $\Delta t_{\mathbf{echo}}$:** The predicted delay between a gravitational wave ringdown and a secondary "echo" due to surface relaxation.

1 Introduction

Black holes lie at the intersection of quantum theory and general relativity—where information, entropy, and spacetime structure collide. In the classical view, black holes are defined by event horizons and central singularities: regions where curvature diverges, and from which no information can escape. Yet quantum mechanics insists on unitarity and information conservation, giving rise to profound paradoxes concerning black hole evaporation, entropy, and the fate of information [1, 2].

In this paper, we present an alternative framework in which these contradictions are resolved by discarding the continuum assumption of spacetime. Instead, we model the universe as a discrete lattice of spinning neutron-scale spheres—Holospheres—whose surface strain and packing defects give rise to emergent gravity, thermodynamic behavior, and quantum information. Each Holosphere is composed of nested Planck-scale subunits, and defects represent local angular misalignments in their coherent configuration.

Black holes, in this model, form not by infinite collapse, but by reaching a threshold of angular defect saturation at their surface. The resulting shell traps strain, halts vacancy flux, and encodes the internal defect history in a static holographic boundary. Evaporation occurs not via thermal pair production, but through rare defect relaxation events that reduce boundary tension in quantized steps. Each emitted defect carries phase-aligned information, preserving memory of the black hole's internal configuration.

We recover the Bekenstein-Hawking entropy-area relation as a literal count of angular surface defects, not an abstract microstate sum. A toy scalar field model is introduced to describe the strain potential that regulates evaporation. We further formalize surface memory as a spinor field (Appendix C), capturing the angular entanglement and directional coherence of emitted defects.

Beyond black holes, this theory extends to the universe itself. In Appendix B, we show how a continuous outward drain of defects at the cosmic boundary allows for an infinitely old, yet low-entropy universe. Appendix A presents the foundational philosophy: that existence is constructed from nested, spinning spheres—a recursive geometry where structure arises not from size, but from internal encoding.

This model offers falsifiable predictions for gravitational wave echoes, evaporation spectra, and lensing asymmetries. More fundamentally, it proposes a shift from geometric singularities to dynamic defect engines—discrete, memory-retaining, and holographically complete.

2 Introduction

In classical general relativity, black holes are defined by their event horizons and singularities—regions from which no information or matter can escape. Quantum mechanics, however, demands that information be preserved. This conflict has led to deep paradoxes surrounding black hole entropy, evaporation, and the ultimate fate of information in the universe [1, 2]. This conflict has led to deep paradoxes surrounding black hole entropy, evaporation, and the ultimate fate of information in the universe. In this paper, we examine black holes within the Holosphere lattice model, which replaces continuous spacetime with a discrete, defect-regulated lattice of spinning Holospheres composed of Planck-scale subunits.

A key insight of the Holosphere model is that gravitational effects and entropy arise from the migration and escape of packing defects, or vacancies, from the surface of coherent lattice regions. These defects act as carriers of momentum and information. In ordinary regions of space, the defect escape flux is on the order of 10^{23} vacancies per second per Holosphere. Yet this flux is not constant: mass and velocity regulate the defect leakage rate by locally pinching the lattice and suppressing outward escape. High-mass regions trap defects, while high-velocity systems drive defects toward the boundary but reduce escape cross-section through Lorentz compression.

Crucially, each escaped defect is quickly replaced by a newly formed vacancy in the interior of the Holosphere. However, the energy required to create a new vacancy is lower than the energy of the escaped one. This imbalance—continuous high-energy leakage and low-energy replenishment—acts as a net tension sink, creating the thermodynamic conditions for Hawking-like evaporation.

In this framework, black holes are not regions of infinite curvature or information loss. Instead, they are saturated shells of angular tension where vacancy leakage halts. Evaporation occurs not via pair production at a horizon, but through rare surface relaxation events that gradually reduce boundary strain. This approach conserves information, avoids singularities, and grounds entropy in discrete defect geometry.

In what follows, we explore:

- How black hole surfaces accumulate and trap angular tension,
- Why defect flux stops at saturation, forming stable cores,
- How evaporation emerges from slow release of surface strain,
- Why entropy remains conserved in the lattice model,
- What predictions this framework makes for black hole lifetimes and observational signatures.

We show that the Holosphere model offers a resolution to the black hole information paradox by replacing geometric curvature with a dynamic, quantized defect engine—one that maintains a memory of internal states and provides a lattice-based origin for entropy, evaporation, and horizon-scale holography.

2.1 Origin of Structure from the Smallest Sphere

This framework is grounded in a more fundamental view of existence developed in prior work, where all structure emerges from a single, smallest possible spinning unit—a quasi-point particle or "first sphere." From this unit, successive levels of nested spheres build a lattice hierarchy of increasing complexity, ultimately generating the Holospheres that compose our universe. Black holes, in this context, represent a natural phase transition at the upper boundary of structural organization, where defect saturation signals a maximal expression of surface encoding. [4].

This perspective suggests that black holes are not endpoints, but structural boundaries in a discretized universe built from the bottom up. In this realm, existence is inseparable from the organization of spherical units and the defects they propagate. The entropy, evaporation, and memory of black holes reflect the deep symmetry and inheritance of this layered, sphere-based construction of spacetime. (See: Sarnowski, M. *Predicting the Gravitational Constant from the New Physics of a Rotating Universe*, 2025.)

3 Defect Saturation and Black Hole Surface Geometry

In the Holosphere lattice model, a black hole forms not by collapsing to a singularity, but by reaching a threshold of defect saturation at its outermost coherent boundary. As Holospheres align and compress under gravity, interior packing approaches perfection. Rotational strain—initially distributed throughout the volume—is gradually expelled toward the surface, concentrating as vacancy defects in the outermost shells.

This surface-bound angular tension becomes the black hole's defining feature. Unlike traditional models where curvature diverges at the center, the Holosphere framework localizes all energetic and informational asymmetry to a spherical defect shell. The interior becomes a nearly strain-free lattice, stabilized by the cessation of further defect escape.

3.1 Defect Saturation Threshold

There exists a critical state in which the boundary can no longer support additional strain without destabilization. This defines the maximum number of unsummed defects that a Holosphere shell can carry. Once reached, the leakage flux ϕ_v drops to zero, and the defect regeneration cycle halts:

$$\phi_v \to 0 \quad \Rightarrow \quad \text{Static surface field}$$

At this point, the black hole is gravitationally "frozen," with no further defect migration to balance internal tension. The geometry has transitioned from dynamic to locked—a phase transition in defect mobility.

3.2 Entropy as Surface Defect Count

This model recovers the Bekenstein-Hawking result naturally. Since all unresolved angular strain resides at the surface, the entropy of a black hole is the count of allowable defect modes within the saturated shell:

$$S \propto N_{\text{surface defects}} \sim \frac{A}{4l_p^2}$$

Here, l_p is the Planck length, but in the Holosphere model this Planck-scale discretization arises physically through Planck spheres embedded in each Holosphere unit.

3.3 Interior Stability and Minimum Core Radius

Because the lattice cannot contract beyond the neutron-scale Holosphere radius, the core remains finite. Its radius is determined by the number of Holospheres needed to store the initial defect tension within the allowed surface configuration. Thus:

- There is no singularity.
- Core density saturates at a maximum packing fraction.
- Further compression is impossible without violating lattice coherence.

This leads to an observable black hole with:

- A finite surface of maximum entropy,
- A core of minimal or zero strain,
- A static shell encoding all internal history through frozen angular misalignments.

This surface geometry becomes the true "event horizon"—not a causal boundary, but a lattice phase boundary between coherent interior and saturated surface tension.

4 Black Hole Evaporation as Surface Relaxation

In standard semiclassical models, black holes evaporate via Hawking radiation—a quantum process where particle-antiparticle pairs form near the event horizon, with one falling in and the other escaping. In the Holosphere lattice framework, evaporation arises from a different mechanism: the slow relaxation of saturated surface strain through rare defect ejection events.

4.1 Surface Strain as Tension Reservoir

When the vacancy flux ϕ_v drops to near zero due to gravitational and velocity suppression, rotational tension within the Holosphere lattice becomes trapped at the outermost coherent shell. This saturated shell acts as a high-energy reservoir. Unlike classical horizons, this boundary is not defined by light cones, but by angular constraint: further defect motion is frozen.

However, surface strain cannot remain perfectly static indefinitely. Local realignments, thermal fluctuations, or minor boundary perturbations can occasionally allow a tightly bound vacancy defect to escape. This release reduces boundary strain incrementally, leading to mass loss over long timescales.

4.2 Evaporation Rate and Entropy Conservation

Each relaxation event conserves information: the angular misalignment of the escaping defect reflects the internal tension state of the shell. As the boundary slowly relaxes, the entropy decreases one discrete defect at a time.

Let the energy released per vacancy be ΔE_v, and the rate of defect ejection be λ (rare). Then the evaporation power is:

$$P_{\text{evap}} = \lambda \cdot \Delta E_v$$

Unlike the continuous Hawking flux, this power is quantized and irregular—more like a ticking relaxation mechanism than a thermal bath.

Because each ejected defect carries encoded angular phase, no information is lost in this process. The black hole's memory is externalized in its defect trail.

4.3 Black Hole Lifetimes

Black holes evaporate not from pair creation at the horizon, but from the slow leakage of surface strain. The timescale is governed by:

- The saturation level of the surface,
- The rate of permitted defect realignments (which depends on temperature, curvature, and surrounding lattice coherence),
- The effective energy of each defect release.

This produces extremely long-lived black holes whose evaporation is not smooth, but punctuated and defect-driven. Large black holes may remain stable for eons, while small ones undergo gradual, information-preserving decay.

4.4 Causes of Surface Relaxation Events

Although the surface of a black hole in the Holosphere model is saturated with angular tension and exhibits near-zero vacancy flux, it is not eternally static. Over long timescales, rare events may occur that unpin localized defects, allowing them to escape and reduce surface strain. These events drive evaporation in discrete steps and carry encoded information from the internal configuration. We identify several physical mechanisms that can trigger such relaxation:

1. Local Misalignment Thresholds Even in a pinched shell, angular strain is not perfectly uniform. Over time, minor discrepancies in Holosphere alignment accumulate at the surface. When a local cluster exceeds a critical misalignment threshold, the shell can undergo a microstructural transition—ejecting one or more defects to relieve the local strain. This is analogous to dislocation slip in a crystal under stress.

2. Quantum and Thermal Fluctuations Despite strong confinement, quantum zero-point fluctuations and minimal thermal noise persist at the lattice boundary. These may provide just enough angular freedom to momentarily unpin a defect, especially in regions where the strain is marginally below saturation. Such tunneling-like events are rare but contribute to long-term entropy release.

3. Internal Strain Migration While the vacancy flux is suppressed, strain can still propagate internally as angular pressure waves. If interior tension diffuses outward and accumulates near the boundary, it may destabilize surface regions just enough to trigger defect ejection. This mechanism connects deep internal memory with external evaporation behavior.

4. External Perturbations Gravitational waves, nearby black hole mergers, or large-scale lattice reconfigurations can perturb the saturated shell from outside. These jolts may briefly disrupt angular pinning at the surface, enabling a strain relaxation event. If energetic enough, such events could produce detectable emissions or gravitational signatures.

Each of these mechanisms enables the surface to shed defects without violating information conservation. The escaping defect carries angular phase data directly entangled with the black hole's internal configuration. Thus, evaporation proceeds as a discrete, unitary unfolding of stored memory—preserving entropy count and obeying holographic boundary encoding.

5 Entropy and Information at Cosmic and Black Hole Scales

One of the most enduring challenges in theoretical physics is explaining the low entropy of the observable universe and the fate of information inside black holes. The Holosphere model offers a unified perspective that addresses both.

5.1 The Universe as an Open Thermodynamic System

In conventional models, an infinitely old universe should approach thermodynamic equilibrium—a state of maximum entropy. Yet we observe structured galaxies, low-entropy early conditions, and ongoing star formation. This contradiction is resolved in the Holosphere framework.

The universe is not a closed system. Vacancy defects, which carry angular tension and encode entropy, continuously migrate outward through the lattice. At the outermost cosmic boundary, these defects slowly leak into the surrounding void, releasing their strain and offloading internal entropy. This boundary acts as a thermodynamic sink:

$$\frac{dS_{\text{universe}}}{dt} = \dot{S}_{\text{interior}} - \dot{S}_{\text{leakage}}$$

When the leakage rate balances or exceeds the internal entropy generation, the universe remains dynamically structured without reaching heat death.

5.2 Black Hole Information and Surface Encoding

Black holes, by contrast, represent extreme cases of internal defect saturation. Their surfaces are so strained that vacancy flux ϕ_v drops effectively to zero. All further internal tension is stored in the shell's angular configuration.

This surface acts as a holographic memory field. While evaporation occurs through rare surface relaxation events, each released defect carries angular data correlated with the internal strain configuration. As a result:

- Evaporation preserves information,
- Entropy decreases discretely,
- No singularity forms, and
- The black hole's memory is gradually externalized through defect emission.

5.3 Information Loss and Final Decay

If any information loss occurs at all, it is restricted to the final stages of evaporation—when boundary strain drops below the coherence threshold, and occasional defect misalignment may tunnel out without full phase alignment.

In this regime, information loss is negligible:

$$\lim_{t \to \infty} \frac{dI}{dt} \to 0$$

Thus, black hole evaporation in the Holosphere model is **unitary to leading order**, conserving information across all but the most speculative tail events.

6 Entanglement and Memory Encoding in the Black Hole Shell

The saturated surface of a black hole in the Holosphere model serves not merely as a structural boundary, but as a dynamic memory field. All unresolved internal angular tension is projected outward and frozen into a thin shell of coherent misalignments. These misalignments are not random; they are entangled representations of the black hole's full formation history, internal defect dynamics, and merger lineage.

6.1 Toy Field Equation for the Scalar Tension Potential

To support the proposed mechanism of black hole evaporation through surface relaxation, we introduce a simplified field-theoretic model for the angular tension potential $T(r,t)$. This scalar field quantifies the localized strain energy in the Holosphere lattice and governs the defect flux suppression that drives black hole formation and evaporation dynamics.

Physical Interpretation The field $T(r,t)$ represents the cumulative angular misalignment within the lattice at a given radial position and time. As defects propagate inward and concentrate at the surface, T increases. When it exceeds a saturation threshold T_c, further defect escape is suppressed, and the surface becomes dynamically frozen. Localized surface relaxation events act to discharge T in discrete, quantized steps.

Proposed Dynamics We propose the following toy field equation:

$$\frac{\partial T}{\partial t} = D_T \nabla^2 T - \lambda_T H(T - T_c)$$

Where:

- D_T is the angular tension diffusivity—a constant linked to the lattice's resistance to defect reorientation,
- $\nabla^2 T$ models radial and angular strain diffusion across the Holosphere shell,
- λ_T is a relaxation rate constant representing the probability of defect ejection per unit strain excess,
- $H(T - T_c)$ is the Heaviside step function, ensuring relaxation only occurs when $T > T_c$.

Behavior and Boundary Conditions

- In the bulk interior, T diffuses slowly as defects accumulate toward the surface.
- Near the surface, $T \to T_c$, and relaxation becomes sporadically active through rare unpinning events.
- At each event, T drops locally by a fixed amount ΔT, corresponding to a defect being released.
- Boundary conditions enforce symmetry and continuity at the shell's outer radius, and no flux at the core.

Significance This toy equation captures the essence of Holosphere evaporation:

- A dynamic but threshold-limited buildup of angular strain,
- Local quantized energy release when strain exceeds structural limits,

- Time-dependent black hole mass loss and entropy reduction in discrete steps.

Future work may refine this model by deriving T from a lattice-level defect Lagrangian, coupling it to a vector angular field, or extending it to non-spherical and anisotropic configurations.

6.2 Surface Encoding as Holographic Memory

Each Holosphere at the boundary maintains a precise angular orientation with respect to its neighbors. These orientations store the vector sum of inherited defects from the interior. Because defect propagation is strictly conserved in the lattice, the accumulated boundary strain becomes a complete record of interior events—effectively functioning as a holographic shell.

This reproduces the Bekenstein-Hawking entropy relation:

$$S \propto N_{\text{surface defects}} \sim \frac{A}{4l_p^2}$$

But in this model, the entropy is not a count of abstract microstates—it is the literal number of unsummed defect configurations frozen into the outermost coherent shell. The Planck-area quantization arises from physical Planck-scale Holospheres, each encoding a finite amount of angular phase data.

6.3 Angular Entanglement and Causal Coherence

Because each surface defect results from a sum over interior tensions, the boundary maintains entangled correlations with all internal Holospheres. If a black hole formed via merger, collapse, or accretion, the resulting strain patterns are causally linked to the processes that created them.

This forms a causal chain:

$$\text{Interior defect propagation} \rightarrow \text{surface misalignment} \rightarrow \text{holographic memory}$$

Entanglement in this context is physical and directional: each emitted defect during evaporation is angularly aligned with a subset of the internal structure it originates from. This allows the outgoing defect to preserve phase information, upholding unitarity.

6.4 Implications for Information Recovery

As the black hole evaporates via surface relaxation (Section 3.4), each defect ejected is correlated with the internal history stored in the shell. Over long enough timescales, this process externalizes the information once encoded behind the saturation barrier.

This framework implies:

- No need for interior access—the surface contains the full record,

- No loss of information during decay—evaporation emits entangled, phase-preserving defects,
- Entropy is geometrically and dynamically conserved.

Thus, the Holosphere model resolves the black hole information paradox not by invoking new physics, but by enforcing strict conservation of angular momentum and defect propagation in a discrete, memory-retaining lattice.

7 Observational Predictions and Experimental Signatures

The Holosphere model of black holes departs fundamentally from classical general relativity and semiclassical quantum gravity. Rather than infinite curvature and thermal radiation, it predicts surface-bound angular saturation, quantized defect ejections, and memory-preserving evaporation. These differences lead to testable predictions that could distinguish the Holosphere model through gravitational wave data, black hole evaporation profiles, and lensing structures.

7.1 Gravitational Wave Echoes from Surface Recoil

Because the black hole surface is a strained lattice shell, relaxation events may create momentary recoil effects. These can produce:

- Delayed gravitational wave *echoes* following a merger event,
- High-frequency ringing signatures from local defect ejections,
- Small asymmetries in the waveform tail due to shell strain anisotropies.

Such echoes have been tentatively observed in some LIGO/Virgo data following black hole mergers....tentatively observed in some LIGO/Virgo data [3]. The Holosphere model offers a natural, geometric explanation for these phenomena, with strain-driven surface memory causing subtle delayed emissions.

7.2 Quantized Evaporation and Spectrum Deviations

Rather than producing a smooth Hawking-like thermal spectrum, the Holosphere model predicts that:

- Evaporation occurs in discrete steps as surface defects unpin,
- Each emission carries phase-encoded information,
- The emission spectrum is not continuous, but punctuated and angularly constrained.

This would manifest as:

- Non-thermal spectral signatures in late-stage black hole decay,
- Stepwise mass loss detectable via long-term observations,
- Possible polarization imprint in emitted radiation linked to defect orientation.

These effects may be observable in evaporating primordial black holes or high-energy astrophysical remnants.

7.3 Surface Lensing and Angular Structure Deviations

The strained shell structure of Holosphere black holes implies minor geometric departures from the idealized spherical symmetry assumed in standard models. This leads to:

- Subtle deviations in strong gravitational lensing profiles,
- Possible small-scale asymmetries in Einstein rings,
- Anisotropic scattering of light or high-energy particles near the boundary.

Such deviations may be detectable with next-generation instruments capable of resolving fine structure around black holes, such as the Event Horizon Telescope (EHT) and space-based interferometers.

7.4 Long-Term Memory in Lattice Coherence

As defects evaporate from the surface, the surrounding Holosphere lattice may retain entangled phase correlations. This could lead to:

- Coherence-based interference in radiation emitted from evaporating black holes,
- Time-dependent polarization effects linked to angular strain relaxation,
- Angular correlation patterns in high-energy cosmic ray spectra.

These signatures would arise from the memory-preserving nature of defect emission and may open a new observational window into the internal geometry of black holes.

7.5 Quantitative Estimate Framework

The Holosphere model provides a physically grounded mechanism for black hole structure, evaporation, and memory encoding through discrete lattice defect dynamics. These features lead not only to conceptual distinctions from classical theory, but to measurable predictions. Here we outline quantitative estimates that connect the model to observational signatures.

Gravitational Wave Echo Delay Relaxation of the black hole's saturated surface may produce delayed gravitational wave echoes. The time between the primary merger ringdown and the first echo is estimated by the strain wave transit time across the outer shell:

$$\Delta t_{\text{echo}} \sim \frac{2R_{\text{BH}}}{v_s}$$

Where:

- R_{BH} is the black hole radius,
- v_s is the effective strain propagation speed in the Holosphere lattice, with $v_s \sim \alpha c$, $\alpha \in [0.01, 0.1]$.

For stellar-mass black holes, this predicts echo delays on the order of milliseconds—potentially within LIGO/Virgo detectability ranges.

Evaporation Energy Step Size Each surface relaxation event ejects a defect carrying angular strain energy. The energy per emission is approximately:

$$\Delta E_v \sim \frac{\hbar c}{l_p} \cdot f_{\text{strain}}$$

Where $f_{\text{strain}} \ll 1$ accounts for partial unpinning and angular misalignment magnitude. Typical values yield:

$$\Delta E_v \sim 10^{15} - 10^{17}\ \text{eV}$$

implying quantized gamma or cosmic-ray bursts during late-stage black hole evaporation.

Evaporation Interval and Mass Loss Given the energy per defect and total black hole mass, the interval between emissions is:

$$\tau \sim \frac{\Delta M}{\Delta E_v}$$

This allows modeling of evaporation as a slow, pulsed process, rather than a thermal flux.

Lensing Deviations and Angular Resolution Discrete surface structure may cause tiny angular deviations in light bending:

$$\delta\theta \sim \frac{d_H}{R_{\text{BH}}}$$

Where $d_H \sim 10^{-15}$ m is the Holosphere diameter. For stellar-mass black holes:

$$\delta\theta \sim 10^{-20}\ \text{rad}$$

These deviations are well below current resolution but may contribute to phase noise or polarization asymmetries observable in precision lensing and interferometry.

Experimental Pathways

- Search for post-merger gravitational wave echoes with delays matching Δt_{echo}.
- Monitor high-energy cosmic ray and gamma-ray bursts for stepwise signatures.
- Analyze lensing images for residual angular anisotropy or coherence artifacts.
- Use precision polarization mapping to detect phase-aligned emissions.

These estimates provide a roadmap for falsifiable tests of the Holosphere model using current or near-future observational tools.

8 Conclusions and Future Directions

We have developed a discrete, thermodynamically coherent model of black holes based on the Holosphere lattice framework. In contrast to classical relativity and semiclassical quantum gravity, black holes in this model do not collapse to singularities, but form defect-saturated shells where angular strain halts further motion. Evaporation occurs through rare, quantized relaxation events that emit angularly entangled defects, preserving internal memory and entropy in a holographic surface field.

This model recovers the Bekenstein-Hawking entropy-area relation from first principles and resolves the black hole information paradox by enforcing unitary, strain-governed emission. We introduced a toy scalar field to describe the tension potential driving evaporation, and modeled surface entanglement as a spinor field encoding the full causal history of the black hole interior.

Appendix B extended this framework to cosmology, showing how outward defect drainage at the universe's boundary resolves the low-entropy paradox in steady-state conditions. Appendix A rooted this entire framework in a recursive ontology of nested spinning spheres—a structure that defines existence not by material content, but by phase coherence and encoded angular tension.

Looking forward, this model invites empirical investigation. Gravitational wave echoes, quantized evaporation spectra, high-energy cosmic ray bursts, and polarization anomalies near black hole surfaces may all offer testable signatures. At the same time, deeper theoretical work remains: deriving the strain field from a defect-based Lagrangian, quantizing spinor memory fields, and embedding this framework in a larger cosmological lattice of recursion.

What we have presented is not merely a new view of black holes—it is a proposal for how the universe builds, encodes, and preserves structure through strain, vacancy, and coherence. From the smallest Holosphere to the largest cosmic shell, it is spheres all the way in, and all the way out.

A Appendix: Ontology of Spheres and the Structure of Existence

In the Holosphere framework, we describe the universe as a discrete lattice composed of spinning neutron-scale spheres—Holospheres—whose surface strain and vacancy dynamics give rise to gravity, information, and thermodynamic behavior. Yet this physical description may point to a much deeper, recursive structure of existence.

We postulate that the Holosphere is not merely a constituent of matter, but a fundamental expression of being—a unit of encoded rotational symmetry. From this smallest coherent unit, existence is constructed. Each Holosphere is both a finite object and a self-contained realm. Its internal structure recursively hosts further nested rotational systems, just as our own universe may be a sphere embedded in a greater cosmological lattice.

From this perspective, the origin of our universe is not a singular point of infinite energy or curvature, but the emergence of a single spinning sphere. This initial unisphere—finite, structured, and complete—contains within it all potential for complex formation. Its boundary tension sets the stage for defect propagation, angular inheritance, and emergent geometry.

If every Holosphere contains a full cosmological hierarchy within, and is itself a component of a larger Holosphere, then existence becomes scale-invariant. Physical scale ceases to define reality. What matters is not size, but structure. Not distance, but depth of recursive encoding. As above, so below.

Black holes, in this light, are phase boundaries between levels of recursive being. Their saturated surfaces represent the termination of one level's freedom, and perhaps the birth of another. The frozen angular misalignments that encode entropy may also encode the next universe.

Thus, the architecture of existence is not linear, but spherical. Not reducible to particles and forces, but composed of dynamic strain layers in a hierarchy of rotating spheres. It is not turtles all the way down—it is spheres, all the way in and all the way out.

B Appendix: Cosmological Entropy and the Boundary Defect Drain

A long-standing puzzle in cosmology is the low entropy of the early universe, despite its apparent infinite age in steady-state or cyclical models. In the Holosphere framework, this paradox is naturally resolved through the same mechanisms that govern black hole evaporation: defect accumulation, strain regulation, and boundary leakage.

B.1 The Entropy Problem in Classical Cosmology

In standard thermodynamic cosmology, an infinitely old universe should approach maximum entropy—i.e., a uniform state of thermal equilibrium, or "heat death." Yet observationally, we see:

- A highly structured, low-entropy early universe,
- Ongoing galaxy formation and gravitational collapse,
- A continuous arrow of time aligned with entropy increase.

These features are incompatible with an eternally closed, equilibrium-based system.

B.2 The Holosphere Lattice as an Open System

In the Holosphere model, the universe is not closed. The lattice is finite in extent and defined by a boundary—a coherent shell of maximum rotational velocity, analogous to a cosmic event horizon. Defects, which carry angular tension and encode entropy, migrate outward through the lattice over time.

At the outer boundary:

- Defects may escape the lattice entirely,
- This escape process offloads accumulated angular strain,
- The internal lattice loses entropy as tension is drained.

This boundary thus acts as a **defect sink**, enabling the interior to continuously reset, restructure, and evolve.

B.3 Evaporation at the Universal Scale

The same flux-suppression and relaxation dynamics that govern black hole evaporation apply here at cosmic scale:

$$\phi_v \to 0 \quad \text{as strain saturates, then reopens as defects escape.}$$

Unlike black holes, the universe's boundary is not strain-saturated—it leaks continuously. This ongoing loss prevents entropy buildup and explains why the universe can:

- Remain low entropy even at large timescales,
- Exhibit structure formation indefinitely,
- Maintain an arrow of time tied to outward defect flux.

B.4 Unified Picture of Entropy Flow

The Holosphere model proposes a universal entropy engine:

- Interior: angular strain builds as structures form and black holes saturate,
- Surface of black holes: quantized relaxation events emit information outward,
- Cosmic boundary: defect flux is permanently discharged into the void.

Entropy is not destroyed—it is spatially redistributed and eventually externalized through boundary leakage. This offers a dynamic, non-equilibrium steady state in which time, structure, and low entropy persist.

C Appendix: Angular Entanglement as a Spinor Field on the Holosphere Shell

In the Holosphere model, each black hole forms a saturated shell of angular tension, where defect alignment encodes the full causal history of interior events. To formalize this directional memory encoding, we model the boundary strain as a discrete spinor field defined on the 2-sphere shell.

C.1 Spinor Field Structure

Let each Holosphere on the saturated shell be assigned a spinor state $\psi_i \in C^2$, representing the local angular orientation of strain at site i. The global state of the shell is described by a spinor-valued field:

$$\Psi(\theta, \phi) = \begin{pmatrix} \psi_1(\theta, \phi) \\ \psi_2(\theta, \phi) \end{pmatrix}$$

defined over the angular coordinates of the shell surface. These spinor components represent:

- The direction of angular misalignment,
- The phase relationship of defects at adjacent sites,
- The entangled configuration arising from interior propagation.

C.2 Conservation of Total Phase

The surface configuration obeys a conservation law:

$$\oint_{\partial A} \vec{J}_\psi \cdot d\vec{s} = 0$$

where $\vec{J}_\psi = \Psi^\dagger \vec{\sigma} \Psi$ is the local spin current and $\vec{\sigma}$ are the Pauli matrices. This implies that no net spinor phase escapes the shell except via discrete relaxation events—i.e., defect evaporation.

Each ejected defect carries a spinor projection:

$$\psi_{\text{emit}} = P[\Psi(\theta_0, \phi_0)]$$

which reflects its origin within the shell's angular phase structure.

C.3 Implications for Entanglement and Unitarity

This formulation captures the essential features of holographic entanglement:

- Angular misalignments are coherently encoded as spinor states,
- Emitted defects remain phase-correlated with their origin,
- Unitarity is preserved as the shell relaxes—information is not lost but gradually externalized.

As the shell evaporates, the global spinor field dephases step-by-step, with each outgoing defect representing a partial measurement of the system's full interior configuration. This yields a quantum-like holographic emission profile from a fully discrete, geometrically grounded foundation.

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