Triadic Spin Decoherence and the Emergence of Thermalization and Time's Arrow

M. J. Sarnowski

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Abstract

In this paper, we develop a coherence-based explanation of thermalization and the arrow of time grounded in the triadic spinning structure of the Holosphere lattice. Each Holosphere unit spins on three orthogonal axes, and while local coherence maintains phase alignment across the lattice, small angular mismatches accumulate across distances. These mismatches produce irreversible dephasing, leading to energy dispersion and emergent thermal behavior. We show that the directionality of time arises not from entropy defined over microstates, but from the structural asymmetry in angular coherence loss along the lattice. A coherence decay gradient is derived, and thermalization is reinterpreted as the progressive decoherence of triadic spin modes. This framework reproduces features of the second law of thermodynamics without appealing to classical statistical mechanics, and provides a lattice-based origin for temperature, entropy, and irreversibility.

1 Introduction

The emergence of time's arrow and the nature of thermalization remain two of the most enduring puzzles in physics. In classical thermodynamics, the direction of time is often associated with entropy increase, yet this explanation relies on statistical approximations that do not account for the structural origin of irreversibility. In quantum mechanics, the fundamental laws remain time-symmetric, making the emergence of irreversible processes even more perplexing.

In this paper, we propose that both thermalization and the arrow of time emerge directly from the triadic spinning structure of the Holosphere lattice. Each Holosphere—defined as a neutron-scale coherence unit composed of nested rotating Planck spheres—spins along three orthogonal axes. While local coherence ensures temporary alignment of spin phase between neighboring Holospheres, small mismatches accumulate across radial distance and angular depth. This accumulation results in an irreversible gradient of angular coherence—an effect we identify as the physical origin of thermal behavior and the direction of time.

Unlike conventional entropy, which is typically defined over ensembles of microstates, we treat coherence as a measurable structural quantity. The loss of angular phase alignment across the Holosphere lattice generates observable thermal properties without invoking probabilistic assumptions. The second law of thermodynamics, under this reinterpretation, becomes a consequence of irreversible triadic decoherence rather than a fundamental principle.

We begin by defining the triadic spin structure and coherence coupling between Holospheres. We then derive a coherence decay function based on cumulative angular mismatch. From this, we reinterpret temperature and entropy as emergent properties of local phase dephasing. Finally, we show how the global asymmetry of coherence gradients gives rise to an emergent arrow of time and explain why such dephasing is structurally irreversible within the Holosphere lattice.

This perspective replaces entropy with a geometric gradient of coherence, offering a new, deterministic, and physically grounded account of time, temperature, and thermalization. The results are compatible with prior Holosphere Theory papers and extend the framework to describe irreversible dynamics in both cosmological and microscopic systems. [3]

2 Triadic Spinning and Coherence Structure

Each Holosphere in the lattice exhibits intrinsic angular motion about three orthogonal spin axes—typically labeled ω_x, ω_y, and ω_z. These axes correspond to internal rotational modes aligned with the local lattice frame and are phase-coupled across adjacent Holospheres through angular coherence constraints. The triadic spin structure forms the foundation of emergent behaviors ranging from redshift to force differentiation and now to thermalization.

We define the total spin vector of a Holosphere as

$$\vec{\Omega} = \omega_x \hat{i} + \omega_y \hat{j} + \omega_z \hat{k}$$

where each component ω_i represents the instantaneous angular velocity around axis i. The total rotational energy of a single Holosphere unit is then proportional to the squared magnitude of this vector,

$$E_{\text{rot}} \propto |\vec{\Omega}|^2 = \omega_x^2 + \omega_y^2 + \omega_z^2.$$

For adjacent Holospheres to remain coherent, their triadic spin vectors must maintain phase alignment across all three axes. This coherence condition is defined by the phase dot-product:

$$\Delta\phi_{ij}(t) = \vec{\Omega}_i(t) \cdot \vec{\Omega}_j(t)$$

A value of $\Delta\phi_{ij}(t) = |\vec{\Omega}_i||\vec{\Omega}_j|$ indicates perfect alignment; lower values represent growing angular mismatch and partial decoherence.

Due to quantum-scale irregularities in the lattice, angular mismatches between neighboring Holospheres are inevitable. While local coherence is maintained through dynamic feedback and orbital realignment, small residual mismatches ϵ_{ij} accumulate over radial distance. The cumulative phase drift between Holospheres separated by n layers grows approximately as

$$\Delta\phi(n) \sim \sum_{k=1}^{n} \epsilon_k,$$

where each ϵ_k represents the angular misalignment introduced at layer k.

These small misalignments form the basis of thermalization in the Holosphere framework. As triadic coherence degrades, structured rotational energy becomes increasingly disordered, leading to effective angular noise and the emergence of local thermal behavior.

The structure of this coherence network ensures that angular phase can be propagated outward but cannot spontaneously re-align across all three axes simultaneously without external synchronization. This asymmetry underlies both the irreversible loss of coherence and the emergent directionality of time.

The next section develops a quantitative model of angular phase drift and introduces the coherence decay function $C(r)$ that governs the strength of coupling across radial lattice distance.

3 Angular Phase Drift and Coherence Loss

In a perfectly ordered lattice of Holospheres, coherence across triadic spin axes would remain globally aligned, preserving phase synchrony across all scales. However, due to slight mismatches in local spin coupling—arising from discrete packing defects, orbital strain, and propagation delays—angular phase alignment gradually decays over distance. This cumulative effect leads to the emergence of a coherence gradient across the lattice. [4]

Let each Holosphere be coupled to its immediate neighbors via three independent angular phase channels corresponding to spin axes x, y, and z. For a single link between two Holospheres i and j, we define the angular phase offset on one axis as

$$\delta\phi_{ij}^{(k)} = \phi_i^{(k)} - \phi_j^{(k)},$$

where $k \in \{x, y, z\}$. The net coherence coupling strength between i and j is then given by

$$C_{ij} = \sum_{k=x,y,z} \cos\left(\delta\phi_{ij}^{(k)}\right).$$

Perfect coherence corresponds to $\delta\phi_{ij}^{(k)} = 0$ for all k, yielding $C_{ij} = 3$.

In practice, random microscopic angular strain leads to small but nonzero deviations in $\delta\phi_{ij}^{(k)}$, causing coherence to decay as one moves radially through the lattice. We define a coherence decay function $C(r)$ that models the average phase coupling strength as a function of radial distance r from an initially coherent region:

$$C(r) = C_0\, e^{-\alpha r},$$

where α is the angular decoherence coefficient and C_0 is the initial coherence (typically normalized to 3).

This exponential decay arises from the statistical accumulation of random angular offsets across multiple links. If each link introduces an average phase error ϵ, then over n steps the expected total phase misalignment behaves as

$$\langle \Delta\phi(n) \rangle \sim \sqrt{n} \cdot \epsilon,$$

and the coherence coupling strength decays correspondingly.

As $C(r)$ declines, triadic spin alignment weakens and structured angular energy disperses into incoherent rotational modes. This dispersion manifests macroscopically as local thermal behavior, with the temperature of a region corresponding to the effective angular noise induced by cumulative dephasing.

Importantly, the coherence decay function $C(r)$ is not symmetric in time: the lattice permits angular coherence to propagate outward from an ordered center, but spontaneous re-alignment across three spin axes without external input is exponentially improbable. This inherent directionality of phase loss underlies the irreversibility of thermal processes and the emergence of time's arrow.

In the next section, we formalize the relationship between coherence loss and thermalization, providing a structural definition of temperature based on triadic angular noise.

4 Thermalization as Angular Decoherence

In conventional thermodynamics, temperature is a statistical measure of kinetic energy dispersion among particles in a system. In the Holosphere framework, temperature emerges instead from the structural dispersion of triadic angular coherence. As Holospheres lose synchronized alignment across their three spin axes, rotational energy becomes increasingly disordered, producing a localized field of angular noise—interpreted here as thermalization.

Each Holosphere maintains a triadic spin vector:

$$\vec{\Omega} = \omega_x \hat{\imath} + \omega_y \hat{\jmath} + \omega_z \hat{k},$$

which interacts with neighboring units through phase coupling. In a coherent regime, these vectors precess in phase, and their dot products remain high:

$$\Delta\phi_{ij} = \vec{\Omega}_i \cdot \vec{\Omega}_j \approx |\vec{\Omega}_i||\vec{\Omega}_j|.$$

However, as radial distance from a coherent origin increases, accumulated angular mismatches reduce $\Delta\phi_{ij}$ and introduce rotational randomness.

We define a local angular variance as

$$\sigma_\Omega^2(r) = \langle |\vec{\Omega}(r) - \langle \vec{\Omega}(r) \rangle|^2 \rangle,$$

where the expectation value is taken over a local region of Holospheres. As coherence decays according to $C(r) = C_0 e^{-\alpha r}$, this angular variance increases monotonically.

We now propose a structural definition of temperature:

$$T(r) \propto \sigma_\Omega^2(r),$$

where temperature is not a measure of particle velocity but rather a measure of misalignment and angular phase disorder within the lattice. In this view, the thermal state of a region reflects the average degree of triadic spin decoherence.

This framework reproduces core features of thermodynamic behavior: - **Thermal gradients** emerge from coherence gradients. - **Heat flow** is equivalent to coherence equalization via angular realignment. - **Equilibrium** corresponds to maximal decoherence—when all angular phase information has diffused and the lattice reaches uniform angular noise.

Crucially, this model eliminates the need for probabilistic assumptions about microstates. Thermalization arises deterministically from structural coherence loss, with observable consequences at all scales. Local temperature can thus be interpreted as the **rotational disorder density** in a region of the Holosphere lattice.

In the following section, we demonstrate how the irreversible decay of coherence across radial layers defines a structural and directional time gradient, grounding the arrow of time in the lattice's inability to spontaneously reverse triadic decoherence.

5 Time's Arrow from Irreversible Coherence Decay

The directionality of time—commonly referred to as the "arrow of time"—has long been associated with entropy increase, yet its fundamental origin remains elusive. In the Holosphere framework, we propose that the arrow of time arises not from a probabilistic entropy gradient, but from an irreversible coherence decay embedded in the triadic spin structure of the lattice.

As demonstrated in previous sections, local coherence between Holospheres decays with radial distance according to the function

$$C(r) = C_0 e^{-\alpha r},$$

where α is the angular decoherence coefficient. This exponential decay produces a structural asymmetry: coherence can propagate outward from highly ordered regions, but cannot spontaneously regenerate inward without global realignment across all three spin axes.

Because re-establishing triadic alignment requires coordinated angular phase alignment along all three directions, such a reversal is not merely improbable—it is structurally prevented in a deterministic, causal lattice. Thus, time's arrow is not an emergent statistical result but a geometric and topological consequence of coherence loss through a three-axis network.

Irreversibility, in this view, is a feature of the medium, not of the observer. Systems evolve from angular order to angular noise, with no mechanism for coherent phase restoration on large scales. This defines a unidirectional progression toward higher angular disorder—analogous to thermodynamic entropy, but fundamentally rooted in rotational structure rather than microstate statistics.

6 Comparison to Classical Entropy and Thermodynamics

Conventional thermodynamics defines entropy as a measure of disorder over an ensemble of microscopic configurations.[2] This probabilistic concept requires assumptions about ergodicity, coarse-graining, and state indistinguishability. In contrast, the Holosphere model defines disorder geometrically, as the breakdown of triadic angular coherence.

In our framework:

- **Entropy** corresponds to angular phase variance.
- **Temperature** is defined structurally as $T \propto \sigma_\Omega^2$.
- **Irreversibility** arises from accumulated phase drift in a fixed lattice structure.

This allows thermodynamic quantities to emerge without probabilistic postulates. Moreover, it provides a consistent bridge between microscopic coherence behavior and macroscopic thermal effects. Heat flow becomes the diffusion of phase disorder. Equilibrium becomes the state of maximal angular incoherence.

The laws of thermodynamics, under this view, are reframed as structural theorems: - The **first law** arises from local conservation of rotational strain. - The **second law** follows from the directional propagation of angular decoherence. - The **third law** emerges from the structural impossibility of restoring perfect triadic alignment at nonzero coherence radius.

7 Applications and Predictions

The triadic coherence model presented here has far-reaching implications across multiple domains. Several direct applications and testable predictions emerge from the formalism:

- **Coherence-Based Thermometry**: Systems built from Holosphere-aligned structures will show measurable temperature as a function of angular noise rather than kinetic agitation.
- **Directional Decoherence in Interference Experiments**: Photon or vacancy-defect interference patterns should decay faster when subject to controlled angular phase mismatch along multiple axes.
- **Time Asymmetry in Rotating Systems**: Rotationally coherent systems will show natural time asymmetry even in closed-loop configurations due to irreversible triadic decoherence.
- **Apparent Faster-Than-Light Phase Re-alignment**: Long-range phase coherence could produce instantaneous correlations without violating causality, via triadic spin pathways.

Comparison to Entropic Gravity

Our approach to thermalization and time's arrow parallels but differs fundamentally from the entropic gravity model proposed by Erik Verlinde [1]. Whereas Verlinde treats gravity as an emergent entropic force arising from information gradients on holographic screens, the Holosphere framework derives force, temperature, and irreversibility from structural angular coherence loss across a triadically spinning lattice. [5]

Feature	**Verlinde (Entropic Gravity)**	**Holosphere Theory (Triadic Spin)**
Underlying Substrate	Information entropy on holographic screen	Angular coherence in 3D triadic spin lattice
Force Origin	Entropic gradient ∇S	Coherence strain gradient $\nabla C(r)$
Time's Arrow	Entropy increase over coarse-grained states	Irreversible angular phase decoherence
Holography Interpretation	Boundary information encodes bulk	Radial shells encode coherence boundary layers
Temperature	Defined via entropy per degree of freedom	Defined via angular variance: $T \propto \sigma_\Omega^2$
FTL Effects	Disallowed or indirect via entanglement	Apparent FTL via nonlocal phase re-alignment (no signaling)
Mechanism Type	Thermodynamic and statistical	Geometric and structural

Table 1: Comparison between Verlinde's entropic gravity and Holosphere Theory's triadic coherence framework.

8 Conclusion

In this paper, we have presented a structural foundation for thermalization and the arrow of time based on the triadic spin framework of Holosphere Theory. By treating each Holosphere as a unit of coherent angular momentum along three orthogonal axes, we have shown that cumulative phase mismatches across the lattice naturally lead to irreversible decoherence, which manifests macroscopically as temperature, entropy, and time asymmetry.

Unlike traditional thermodynamic approaches that define temperature through kinetic motion and entropy through probabilistic ensembles, our model derives these quantities directly from the geometry of angular coherence. Temperature is reinterpreted as a measure of triadic spin variance, while entropy emerges from the irreversible dispersion of coherent phase alignment. Time's arrow arises from the structural impossibility of spontaneous global re-alignment across all three rotational axes—making irreversibility a feature of the medium, not an artifact of statistical assumptions.

We compared this framework to Verlinde's entropic gravity, showing that while both models rely on emergent structures, the Holosphere approach grounds emergence in deterministic coherence gradients rather than statistical entropy flows. Our model further suggests that apparent faster-than-light coherence propagation and directional thermal asymmetry can be derived without violating causality, due to the triadic structure of the underlying medium.

The implications are far-reaching. Triadic coherence provides a unifying explanation for thermal behavior, cosmological redshift, entanglement propagation, and time directionality within a single lattice framework. It offers a structural basis for both microscopic quantum transitions and macroscopic cosmological evolution, including galactic recycling processes and coherence gradients on universal scales.

Future work will extend this triadic framework to explore cyclic coherence regeneration, topological re-coherence, and the dynamics of cosmic aging. In particular, we aim to develop a coherence-phase thermodynamics and a predictive model for galaxy-scale recycling across Holosphere shells. By grounding entropy and time in the structural physics of angular strain, Holosphere Theory offers a new pathway toward a unified understanding of irreversible processes in the cosmos.

References

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[2] C. A. Egan and C. H. Lineweaver, ”A Larger Estimate of the Entropy of the Universe,” *The Astrophysical Journal*, vol. 710, no. 2, pp. 1825–1834, 2010.

[3] M. J. Sarnowski, ”Quantum Mechanics from Vacancy Defects in a Holosphere Lattice,” *Holosphere Theory Series, Paper 1*, 2025.

[4] M. J. Sarnowski, ”Geometric Redshift and Light Propagation in a Rotating Lattice Universe,” *Holosphere Theory Series, Paper 2*, 2025.

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Appendix A: Glossary of Key Definitions

- **Holosphere**: A neutron-scale coherent unit composed of nested spinning Planck spheres.
- **Triadic Spin**: Three orthogonal angular momentum modes within each Holosphere.
- **Coherence**: Phase alignment between spin vectors across neighboring Holospheres.
- **Decoherence**: Loss of phase alignment, interpreted as entropy or thermalization.

- **Angular Phase Drift**: Accumulation of small spin mismatches over distance.
- **Coherence Gradient**: Spatial variation in phase alignment; source of redshift and time asymmetry.
- **Structural Entropy**: Entropy defined from angular strain, not microstates.
- **Vacancy Defect**: A non-occupied lattice node supporting quantum excitation or phase collapse.

Appendix B: Glossary of Symbols (with Pronunciation)

Symbol	Meaning	Pronunciation
$\vec{\Omega}$	Triadic spin vector	"omega vector"
$\omega_x, \omega_y, \omega_z$	Spin rate on each axis	"omega ex, omega why, omega zee"
$C(r)$	Coherence as a function of radius	"C of r"
α	Angular decoherence coefficient	"alpha"
$\Delta\phi$	Angular phase difference	"delta phi"
σ^2_Ω	Angular spin variance (defines T)	"sigma squared of omega"
T	Structural temperature	"tee"
S	Structural entropy	"ess"

Appendix C: Glossary of Equations

- Triadic Spin Vector:
$$\vec{\Omega} = \omega_x \hat{i} + \omega_y \hat{j} + \omega_z \hat{k}$$
- Angular Phase Difference:
$$\Delta\phi_{ij}(t) = \vec{\Omega}_i(t) \cdot \vec{\Omega}_j(t)$$
- Coherence Decay Function:
$$C(r) = C_0 e^{-\alpha r}$$
- Spin Variance:
$$\sigma^2_\Omega(r) = \langle |\vec{\Omega}(r) - \langle \vec{\Omega}(r) \rangle|^2 \rangle$$
- Structural Temperature:
$$T(r) \propto \sigma^2_\Omega(r)$$
- Entropy Turnover Time Estimate:
$$\tau_S = \frac{S_{\text{universe}}}{\dot{S}} \approx 10^{14}\ \text{Gyr}$$