

Crystalline Time: A Model of Cosmogenesis from Logical Asymmetry

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Abstract

This paper proposes a novel framework for cosmogenesis in which the universe is bounded not only by energetic or geometric constraints, but also by logical structure. We define two cosmogenic boundary conditions: the *Planck Portal*, marking causal termination at $T_{BH} = T_{Planck}$, and the *Absolute Zero Boundary*, representing anti-causal initiation at $T_{BB} = T_{abs.zero}$. These dual ruptures in spacetime—driven respectively by mass-energy density and logical asymmetry—establish a time-symmetric model in which black holes act as curvature-bound information sinks and the Big Bang is interpreted as a re-crystallization rupture within a cold, metastable vacuum. We introduce the concept of a crystalline vacuum lattice whose structure sets a shape-dependent threshold for cosmogenesis, replacing the traditional notion of a singularity. This model offers a path toward unifying entropy, information flow, and the arrow of time within a logically grounded, predictive cosmological theory.

Keywords

Big Bang, Discrete Spacetime, Emergent Geometry, Causal Set Theory, Planck Scale, Entropy, Information Theory, Backflow Cosmology

1. Introduction

The first two papers in this series laid the groundwork for a time-symmetric cosmology rooted in the interplay between causal and anti-causal structures. In “The Geometry of Anti-Causal Spacetime” [1], we established a mathematical framework for modeling retrocausal dynamics, defining tachyonic fields as projections onto a negative-time subspace. This led to a re-interpretation of traditional spacetime as a real-valued manifold with a bidirectional temporal axis, where photons and tachyons serve as forward- and backward-flowing carriers of information, respectively.

The second paper, “The Hyperflower: Strange Attractors in Complex Hilbert Space Cosmology” [2], extended this foundation by introducing a dynamical formalism rooted in a complexified Hilbert space. There, we constructed a full Lagrangian and action principle for coupled photon-tachyon systems and explored how phase transitions between causal and anti-causal sectors generate rich topologies reminiscent of strange attractors. The hyperflower geometry proposed in that work unified cosmological expansion and entropy flow under a single information-preserving structure.

The third paper, “Mathematical Foundations of the Vacuum Lattice” [3], formalizes the vacuum as a discrete information lattice whose nodes, connectivity, and temporal orientation collectively generate spacetime and physical law. Apparent quantum uncertainty, entropy, and geometry emerge from coarse-graining this granular substrate rather than being fundamental. Phase transitions in the lattice action produce causal and anti-causal sectors, while higher-order connectivity statistics select stable low-dimensional, isotropic geometries. Within this framework, fundamental constants arise naturally from lattice scale and dynamics, unifying information, spacetime, and thermodynamics into a single emergent mathematical structure.

In this final paper, we turn to the boundaries themselves—specifically, the dual cosmogenic limits that define the temporal endpoints of physical evolution. The first, known as the *Planck Portal*, marks the causal termination point at which a black hole’s internal temperature reaches the Planck scale, forcing a rupture into anti-causal space. The second, newly introduced here, is the *Absolute Zero Boundary*, where a crystallized anti-causal vacuum reaches maximal metastability and fractures, giving rise to a causal universe. Unlike the Planck Portal, which is driven by mass and temperature, this boundary is shaped by logical coherence and vacuum geometry.

While recent efforts have proposed time-symmetric or bounce-based models of the cosmos [4], none have fully integrated causality, geometry, entropy, and information flow across dual temporal boundaries. This work completes the series by formalizing these boundary dynamics and introducing a mechanism by which the shape—not the size—of a cold anti-causal lattice determines the onset of cosmogenesis. We proceed by reviewing the Planck Portal, introducing the Absolute Zero Boundary, and then developing the recursive structure of universe generation governed by logical asymmetry. We close with implications, constraints, and predictions.

2. The Dual Cosmogenic Boundaries: The Planck Portal (Causal Termination)

In *The Hyperflower* [2], we introduced the notion of causal-anticausal transitions as driven not merely by energy, but by topological phase shifts within an extended Hilbert space. One of the most striking manifestations of this framework is the *Planck Portal*—a thermodynamic boundary condition at which causal systems

collapse into anti-causal flows.

2.1. Physical Description of the Portal

We define the Planck Portal as a transitional threshold that occurs when the internal Hawking temperature of a black hole reaches the Planck temperature:

$$T_{\text{BH}} = T_{\text{Planck}} \approx 1.416808(33) \times 10^{32} \text{ K.}$$

At this limit, spacetime curvature approaches the Planck density, and both classical general relativity and standard quantum field theory break down. However, within the backflow cosmology framework, this breakdown is not an end, but a phase change. The system undergoes a catastrophic transition from causal (forward-time) curvature to anti-causal (negative-time) propagation, facilitated by a topological bifurcation in the underlying information field.

We model this transition using the causal-anticausal field tensor $\Psi(x)$, which evolves under a dual-temperature constraint:

$$\lim_{T \rightarrow T_{\text{Planck}}^-} \nabla^\mu \Psi_{\mu\nu}^{(+)} \rightarrow \nabla^\mu \Psi_{\mu\nu}^{(-)}$$

where $\Psi^{(+)}$ and $\Psi^{(-)}$ represent the causal and anti-causal branches, respectively. The rupture at $T = T_{\text{Planck}}$ acts as a topological gateway—what we call the Planck Portal—through which information is not lost but inverted across the temporal axis.

This perspective resolves the black hole information paradox without invoking holography or firewall scenarios. Information that would otherwise be destroyed at a singularity is instead conserved by transferring to an anti-causal sector, emerging as tachyonic outflow through the negative-time domain.

Furthermore, the geometry of this transition suggests that black holes serve as one-way valves for the causal universe: entropy sinks that concentrate curvature and informational complexity until a threshold is breached. At this point, anti-causal radiation flows outward—not in space, but backward in time—conserving energy and entropy in the full bidirectional manifold. The Planck Portal is not merely a thermodynamic endpoint, but one of two cosmogenic boundaries that define the dual structure of time.

2.2. Planck-Scale Geometry and Portal Dimensionality

The Planck Portal, though often described as a “pointlike” singularity, should instead be interpreted as a finite, compact hypersurface with defined geometric extent. Its diameter is expected to be on the order of the Planck length ($\ell_p \sim 1.6 \times 10^{-35} \text{ m}$), setting a hard scale for boundary-crossing interactions. Only fields or particles possessing localization on this scale—such as massless photons or tachyonic wavefronts—can coherently interface with Σ_p . Massive particles, whose Compton wavelengths vastly exceed ℓ_p , decohere or are absorbed before reaching the boundary.

This interpretation treats Σ_p not as a mathematical point of divergence, but

as a **geometric interface**: a dimensional membrane through which causal structure terminates and anti-causal structure emerges. Singularities, in this view, are not ill-defined infinities but **finite-diameter topological boundaries** whose scale is fixed by the structure of spacetime itself. This geometric view reinforces entropy conservation and supports the hypothesis that Σ_p and Σ_0 are dual surfaces of **equivalent dimensionality**, embedded in a higher-dimensional temporal topology.

3. Formal Geometry and Thermodynamic Matching across Σ_{portal}

We define the *Planck Portal* as a spacetime boundary hypersurface Σ_p that emerges when the local black hole temperature satisfies

$$T_{\text{BH}} \rightarrow T_{\text{Planck}} = \left(\frac{\hbar c^5}{G k_B^2} \right)^{1/2}$$

At this critical thermodynamic point, the curvature scalar R diverges, and standard semiclassical approximations break down. The Einstein field equations become ill-defined unless extended to include a boundary matching condition across Σ_p . We introduce a tensorial deformation $\Delta g_{\mu\nu}^{\text{Planck}}$ to represent the Planck-scale discontinuity:

$$g_{\mu\nu}^+ - g_{\mu\nu}^- = \Delta g_{\mu\nu}^{\text{Planck}}$$

where $g_{\mu\nu}^+$ and $g_{\mu\nu}^-$ denote the metric tensor on the causal and anti-causal sides of the portal, respectively.

A corresponding stress-energy matching condition can be expressed via a generalized Israel junction condition [5]:

$$[T_{\mu\nu}] = S_{\mu\nu}^{\text{portal}} = \frac{1}{8\pi G} (K_{\mu\nu}^+ - K_{\mu\nu}^-),$$

where $K_{\mu\nu}^\pm$ are the extrinsic curvature tensors evaluated on either side of Σ_p . To isolate causal and anti-causal field components, we define projection operators:

$$\mathcal{P}_+\psi = \frac{1}{2}(1 + \mathcal{I})\psi, \quad \mathcal{P}_-\psi = \frac{1}{2}(1 - \mathcal{I})\psi,$$

where \mathcal{I} represents the anti-causal involution operator introduced in *The Hyperflower* [2]. This allows for a field ψ to be decomposed cleanly into causal (photon-like) and anti-causal (tachyonic) components:

$$\psi = \psi_{\text{photon}} + \psi_{\text{tachyon}}, \quad \psi_{\text{tachyon}} = \mathcal{P}_-\psi.$$

Finally, the divergence of the local action integral as $T \rightarrow T_{\text{Planck}}$ signals the physical necessity of a phase change. The gravitational action

$$S = \int_{\mathcal{M}} d^4x \sqrt{-g} \left(\frac{R}{16\pi G} + \mathcal{L}_{\text{matter}} \right)$$

becomes non-analytic at the portal, suggesting a topological phase transition rather than a continuous evolution. This aligns with the interpretation of Σ_p as a non-

Hausdorff boundary where causal structure itself fails [6].

3.1. Spacetime Geometry Formalism of the Planck Portal

To refine the geometric interpretation of the Planck Portal, we model it as a hypersurface Σ_{portal} that separates the causal domain \mathcal{M}^+ (forward-time spacetime) from an anti-causal domain \mathcal{M}^- (backward-time or tachyonic spacetime):

$$\mathcal{M}^+ \rightarrow \Sigma_{\text{portal}} \rightarrow \mathcal{M}^-.$$

The nature of this hypersurface is non-trivial. Unlike standard null or timelike boundaries, Σ_{portal} possesses a hybrid structure due to the breakdown of causal order and metric signature coherence at $T = T_{\text{Planck}}$.

We propose that Σ_{portal} is a *causal-singular* surface—not null, but exhibiting vanishing timelike and spacelike proper intervals under a degenerate induced metric $h_{ab} \rightarrow 0$ as the portal is approached from \mathcal{M}^+ . This signals a collapse of the light cone structure, consistent with a non-Hausdorff boundary and with the causal-indefinite transitions described in [7].

3.2. Causal Closure Argument

To justify why no forward-time causal interactions can traverse Σ_{portal} , we construct a causal closure argument. Let $p \in \mathcal{M}^+$ be any event with future-directed causal curve γ_p . Suppose γ_p intersects Σ_{portal} at a point q . For q to causally influence any region of \mathcal{M}^+ , the spacetime must admit a nonzero future-directed timelike vector field beyond q . However, the degeneration of the metric at Σ_{portal} implies:

$$\lim_{x \rightarrow \Sigma_{\text{portal}}^-} g^{\mu\nu}(x) \rightarrow 0,$$

eliminating the forward light cone and rendering the continuation of γ_p in \mathcal{M}^+ undefined.

This enforces a hard causal boundary: Σ_{portal} acts as a terminal set in the causal structure, beyond which only anti-causal trajectories exist. No future-directed timelike or null curves can extend beyond it in \mathcal{M}^+ , rendering it a strict edge of the forward-time manifold. A corresponding Penrose diagram would depict Σ_{portal} as a future-infinite yet spacetime-finite hypersurface: a sloped or vertical boundary line terminating the \mathcal{M}^+ wedge. From this boundary, \mathcal{M}^- would branch diagonally backward in conformal time, indicating a reversal of temporal orientation. In this diagram, Σ_{portal} not only caps causal evolution in \mathcal{M}^+ but initiates the anti-causal domain \mathcal{M}^- , emphasizing its role as a transition node rather than a discontinuity.

3.3. Entropic Gradient Matching across the Portal

If the Planck Portal is indeed a phase transition rather than a rupture, one may posit a conservation law not just for energy but for entropy across the temporal divide. Let S^μ denote the entropy current in \mathcal{M}^+ , and S_{tachyon}^μ its anti-causal

counterpart in \mathcal{M}^- . Then a natural entropic matching condition at the portal would be:

$$\nabla_{\mu} S^{\mu} \Big|_{\Sigma_{\text{portal}}} = \nabla_{\mu} S^{\mu}_{\text{tachyon}} \Big|_{\Sigma_{\text{portal}}}$$

expressing that no net entropy is destroyed or created at the boundary—only redirected along an anti-causal flow. This constraint would reinforce the interpretation of the Planck Portal as a logically consistent, entropy-conserving bifurcation point within a time-symmetric cosmology. It may also offer a geometric bridge between the thermodynamic arrow of time in \mathcal{M}^+ and its reversal in \mathcal{M}^- , suggesting that entropy itself may define or align with the emergent temporal orientation in each domain.

4. Crystalline Vacuum and Logical Fracture at the Origin of M^-

4.1. From Thermal Genesis to Structural Rupture

The standard narrative of cosmic origin treats the Big Bang as a thermally-driven explosion. In this model, we argue instead that the anti-causal manifold M^- is not birthed from heat, but from the *rupture of logical coherence* in an ultra-cold, highly ordered vacuum. We propose that the vacuum preceding Σ_0 is not a featureless scalar field, but a metastable crystalline structure—discrete, cold, and information-rich. In this context, the emergence of M^- is triggered by a **logical asymmetry** accumulating within this structure, analogous to internal stress in a Prince Rupert’s Drop¹.

4.2. Shape-Limited Cosmogenesis and Vacuum Crystallography

This initiatory rupture is not energy-limited but **shape-limited**: the vacuum accumulates structural asymmetry over a prior cycle of cosmic evolution until a critical threshold is reached. Beyond this point, the lattice can no longer support global logical coherence, and the structure catastrophically fractures, seeding a new anti-causal domain. We formalize this by introducing a **logical fracture operator** L_{break} , acting on the vacuum’s internal symmetry group \mathcal{G} :

$$L_{\text{break}}(\mathcal{G}) \rightarrow \delta\Sigma_0$$

where $\delta\Sigma_0$ represents the initial defect hypersurface that triggers expansion into M^- .

The transition is therefore discrete and topological in nature, not energetic—a rupture in logical continuity rather than a burst of thermal radiation. This view implies that Σ_0 is not a singular point but a **distributed rupture front**, with Planck-scale granularity and definable dimensionality. The resulting manifold inherits its shape constraints and symmetries from the pre-rupture vacuum crystal, inverting the common assumption that spacetime geometry emerges from con-

¹This analogy refers to a tempered glass object that remains stable under high internal tension until a small perturbation at the tail leads to total, explosive fragmentation.

tinuous energy distributions.

4.3. Cycle Closure and Logical Seeding

Each cycle of the universe thus terminates not in heat death, but in a **cold recrystallization** of the vacuum, which serves as the symmetry seed for the next iteration. This feedback loop introduces a form of *cosmic heredity*: the logical boundary conditions of one universe subtly shape the next through geometric and topological imprints. A holographic-like limit may exist on the information density or complexity that the vacuum crystal can sustain before L_{break} activates. This constraint may provide a natural bound on cosmic complexity and a deep connection between entropy, topology, and logical stability.

5. The Dual Cosmogenic Boundaries: The Absolute Zero Boundary (Anti-Causal Initiation)

In contrast to the Planck Portal, which marks the terminal collapse of causal flow at maximum temperature and curvature, the *Absolute Zero Boundary* defines the initiation of anti-causal flow at the opposite extreme: a condition of vanishing curvature, temperature, and informational entropy. This boundary represents the logical mirror of the Planck Portal, not in space, but in the topology of time. It does not precede the universe—it underlies it, functioning as the anti-causal terminus from which backward-time trajectories emerge into the negative-time manifold.

5.1. Physical Description of the Boundary

We define the Absolute Zero Boundary as the hypersurface Σ_0 at which the effective temperature of the anti-causal vacuum approaches the absolute zero limit:

$$T_{\text{vac}} \rightarrow T_{\text{abs.zero}} = 0 \text{ K} \quad (1)$$

At this extreme, the manifold becomes topologically flat and devoid of curvature: $R \rightarrow 0$, $S \rightarrow 0$, and $\rho \rightarrow 0$. Yet, within the backflow framework, this is not emptiness—it is *primordial logical structure*. The boundary Σ_0 is the site of maximal coherence and minimal entropy, from which anti-causal particles such as tachyons originate and begin their flow toward increasing informational complexity.

Equation (1) is not introduced as a dynamical law but as a boundary condition defining the Absolute Zero hypersurface Σ_0 . In the language of the initial value problem of general relativity (see [8]), Σ_0 plays the role of an initial-data surface, subject to the usual Hamiltonian and momentum constraints. Standard evolution toward either the causal or anti-causal domain follows only upon solving the Einstein field equations with this initial data. In this sense, Equation 1 should be read in the same spirit as other boundary-value prescriptions in differential equation theory (cf. [9]). The novelty of the present work lies not in claiming that Equation 1 alone generates cosmological evolution, but in proposing that the boundary it

defines is logically and thermodynamically distinct, acting as a cold initiation dual to the Planck-scale termination at Σ_p .

We model this process via the anti-causal field tensor $\Psi^{(-)}(x)$, which initiates under vanishing thermodynamic gradient:

$$\lim_{T \rightarrow 0^+} \nabla^\mu \Psi_{\mu\nu}^{(-)} \neq 0$$

indicating that even in the absence of energy, directed flow and information creation can occur. This supports a conception of the Absolute Zero Boundary as a generative surface in the anti-causal manifold M^- —a “cold bang” symmetry dual to the “hot collapse” of the Planck Portal.

5.2. Formal Modeling of the Boundary Geometry and Thermodynamics

We define the hypersurface Σ_0 as the logical initiation point of the anti-causal domain. While Σ_p corresponds to the breakdown of causal predictability, Σ_0 corresponds to the emergence of anti-causal determinism. Let $g_{\mu\nu}^-$ define the anti-causal metric field, valid in the region M^- , which is bounded in the negative-time direction by Σ_0 . The corresponding junction condition for emergent geometry reads:

$$g_{\mu\nu}^- - g_{\mu\nu}^0 = \Delta g_{\mu\nu}^{\text{zero}},$$

where $g_{\mu\nu}^0$ denotes the flat pre-manifold vacuum and $\Delta g_{\mu\nu}^{\text{zero}}$ encodes the emergence of curvature from null thermodynamic background.

We define the boundary stress-energy tensor as:

$$[T_{\mu\nu}] = S_{\mu\nu}^{\text{cold}} = \frac{1}{8\pi G} (K_{\mu\nu}^- - K_{\mu\nu}^0)$$

where $K_{\mu\nu}^0$ vanishes due to the null curvature of the pre-manifold vacuum, and $K_{\mu\nu}^-$ governs the geometry of tachyonic emergence. This asymmetric condition enforces time-orientation: anti-causal trajectories arise unidirectionally from Σ_0 and evolve toward increasing thermodynamic complexity. Field decomposition proceeds identically to Section 2:

$$\Psi = \Psi_{\text{photon}} + \Psi_{\text{tachyon}}, \quad \Psi_{\text{tachyon}} = \mathcal{P}_- \Psi,$$

but in this case, only the \mathcal{P}_- sector is non-vanishing at Σ_0 , as no forward-time causal component yet exists.

6. Causal Initiation and Thermodynamic Structure in the Negative-Time Manifold

6.1. Spacetime Geometry and Causal Initiation from Σ_0

The Absolute Zero Boundary, Σ_0 , defines the origin point of the anti-causal manifold M^- . It may be conceptualized as a spacelike hypersurface orthogonal to anti-causal geodesics, possessing a fixed minimum temperature ($T = 0$) and vanishing curvature. In this interpretation, Σ_0 serves as the temporal dual to the

Planck Portal Σ_p , which terminates causal evolution in M^+ .

From a geometric standpoint, Σ_0 acts as the null boundary from which all anti-causal trajectories emerge. This enforces a hard causal initiation condition: no information or physical influence can propagate prior to Σ_0 within M^- . The causal cone structure of M^- originates from this boundary, with null and timelike trajectories expanding outward in the $-t$ direction. A Penrose diagram would depict Σ_0 as a spacetime-finite, past-infinite edge of M^- , analogous in structure to a Big Bang surface but reversed in thermodynamic and causal character.

6.2. Logical Crystallization and the Emergence of Structure

Unlike high-temperature phase transitions in M^+ , the formation of M^- is not governed by thermal instability, but by a spontaneous logical crystallization of an ultracold, pre-geometric vacuum. At Σ_0 , a metastable logical ground state bifurcates into an ordered anti-causal spacetime. The transition resembles a zero-temperature symmetry breaking, with Σ_0 functioning as a nucleation point in logical space. We may model this with a potential-like structure defined over logical configurations ψ :

$$V(\psi) = \lambda(\psi^2 - \psi_0^2)^2$$

where ψ_0 denotes the minimum-energy (but unstable) logical vacuum, and λ controls the stiffness of the bifurcation. This crystallization gives rise to tachyonic geodesics, spatial topologies, and the field-theoretic substrate of M^- .

6.3. Anti-Causal Entropic Inflation and Structure Formation

Immediately following this bifurcation, M^- undergoes a form of entropic expansion—not in spatial volume, but in microstate density. This may be interpreted as an “entropy inflation” epoch, where anti-causal entropy grows rapidly in reverse time:

$$\nabla_\mu S_{\text{tachyon}}^\mu \propto \Theta(-t) e^{\kappa(-t)}$$

with κ characterizing the anti-causal entropic growth rate. Unlike in M^+ , where entropy increases toward the future, M^- sees entropy accumulate in the direction of decreasing t toward Σ_0 —the effective “future” of M^- .

Curvature in M^- likewise increases as structures form over anti-causal geodesics. Rather than gravitational collapse, the dominant process is retrograde structure accretion:

$$\frac{dR}{dt_-} > 0$$

where R is the Ricci scalar and t_- denotes negative time [10]. This reinforces the interpretation of Σ_0 as a smooth, low-entropy boundary that seeds complexity through backward evolution.

6.4. Field Quantization and Anti-Causal Modes

The emergence of M^- from Σ_0 also necessitates a reconsideration of field quantization. The standard expansion of quantum fields in M^+ must be replaced with mode decompositions along negative-time geodesics. For a scalar field ϕ , we write:

$$\phi(x) = \sum_k [a_k^\dagger f_k(x) + a_k f_k^*(x)]$$

where now a_k^\dagger and a_k act not as creation and annihilation operators forward in time, but rather as operators defined relative to anti-causal time. Negative-frequency modes dominate, and standard notions of vacuum fluctuation must be analytically continued into M^- . This framework supports a coherent quantum description of anti-causal matter, including retrocausal fields and tachyonic excitations.

6.5. Entropic Gradient Matching across the Time-Symmetry Boundary

As discussed in Section 3.1, the Planck Portal Σ_p enforces an entropic matching condition by redirecting the entropy flux across the causal-anti-causal interface. By time symmetry, a corresponding condition must hold at Σ_0 , interpreted in reverse:

$$\nabla_\mu S_\mu^{\text{tachyon}} \Big|_{\Sigma_0} = \nabla_\mu S_\mu \Big|_{\Sigma_p}$$

indicating that entropy is neither destroyed nor created across Σ_0 , but rather preserved under the reversal of temporal orientation. This duality confirms that the two cosmogenic boundaries— Σ_p and Σ_0 —are reflections across a time-symmetric topology. Energy, entropy, curvature, and even field structure are not emergent from distinct origins, but instead arise from a common formal boundary whose orientation selects either causal or anti-causal manifestation. The universe, in this view, is not a one-sided unfolding from a singular beginning, but a logically complete spacetime whose informational coherence is maintained across both the hot terminus and the cold origin of temporal flow.

7. Spectral Symmetry and the Physical Role of Negative Frequencies

7.1. Fourier Duality and Time Symmetry

In classical signal theory and quantum field formalism, the decomposition of real-valued fields into complex exponentials necessarily introduces both positive and negative frequency modes. For a scalar field $\phi(t)$:

$$\phi(t) = \int_{-\infty}^{\infty} \tilde{\phi}(\omega) e^{-i\omega t} d\omega$$

the Fourier domain explicitly includes $\omega < 0$, yet traditional physical interpretation restricts meaningful dynamics to $\omega > 0$, regarding negative frequencies as

mathematical redundancy. This restriction is a byproduct of **causal asymmetry** imposed a priori. In a time-symmetric cosmology, such as that defined by the dual boundary structure Σ_p and Σ_0 , **negative frequencies acquire physical status**: they describe propagating modes in the negative-time domain M^- . These modes are not artifacts, but *anti-causal waves*, the spectral mirror of forward-time causality.

7.2. Negative Frequencies as Anti-Causal Modes

In complex Hilbert space quantum mechanics, time evolution is governed by the Schrödinger equation:

$$i\hbar \frac{d}{dt} |\psi(t)\rangle = \hat{H} |\psi(t)\rangle$$

Solutions evolve as $|\psi(t)\rangle = e^{-i\hat{H}t/\hbar} |\psi(0)\rangle$, where the operator exponential naturally supports both signs of t . In standard interpretations, negative-time evolution is disallowed unless explicitly invoked (e.g., for Feynman diagrams involving antiparticles). But in this framework, **time itself is dualized**, and so is its spectral conjugate, frequency. A mode $\omega < 0$ corresponds to a wave propagating backward in real time—or forward in **negative** time. That is:

$$e^{-i\omega t} \xrightarrow{\omega < 0} e^{+i|\omega|t} = e^{-i|\omega|(-t)}$$

Thus, a field built from negative frequency modes naturally evolves forward in the anti-causal manifold M^- . These modes are the **tachyonic carriers of information**, just as photons are the carriers in M^+ .

Negative frequencies have long been regarded as optional in physical theories. But here, their necessity is revealed: they *complete* the time axis, enforce spectral continuity, and underpin the anti-causal phase of the cosmos. The physical law becomes:

Every causal mode has an anti-causal conjugate. Every frequency has its twin. Reality is not bounded by the sign of ω , but made whole by its symmetry.

This duality is not aesthetic—it is structural. The **universe breathes in both directions**, and every field contains the ghost of its temporal inversion.

7.3. Spectral Entanglement and Boundary Matching

Across the time-symmetry boundary, spectral continuity demands that the field modes not terminate but transform. Let $\tilde{\phi}_+(\omega)$ and $\tilde{\phi}_-(\omega)$ represent spectral components in M^+ and M^- respectively. Then the Planck Portal boundary condition may be expressed as:

$$\tilde{\phi}_+(\omega) \Big|_{\Sigma_p} = \tilde{\phi}_-(-\omega) \Big|_{\Sigma_p}$$

enforcing a spectral inversion across $\omega = 0$, *i.e.*, across the time symmetry. This is not merely a phase shift but a **deep entanglement between forward and back-**

ward time spectra, conserving information and unitarity.

8. Predictions and Implications

The geometry of cosmogenic events diverges fundamentally between black hole collapse and universe initiation. *Black holes* are limited by mass-energy thresholds: gravitational collapse occurs when energy density exceeds local curvature stability. By contrast, *Big Bang-like events* (i.e., Σ_0 ruptures) are triggered by configuration thresholds in the vacuum lattice. We summarize this duality:

- **Black Holes:** energy-driven \rightarrow curvature singularities;
- **Big Bangs:** shape-driven \rightarrow coherence rupture.

This framework invites a redefinition of cosmological criticality: not simply as a condition of energetic intensity, but of informational incompatibility. The crystallized vacuum admits only certain allowable configurations; violations of logical symmetry or coherence may lead to topological rupture without requiring infinite density.

8.1. Future Experimental Signatures

Although deeply theoretical, this framework generates concrete observational implications:

- **Pre-cosmic vacuum structure:** A logical asymmetry encoded in the early universe could leave non-random imprints in the cosmic microwave background (CMB) or in large-scale structure anisotropies.
- **Entropy discontinuities:** If entropy is globally conserved but reversed across time, there may be detectable anomalies in black hole evaporation or deep-time cosmological evolution.
- **Tachyonic constraints:** Any evidence of retrocausal or acausal interactions—particularly in high-curvature regimes—may indicate the presence of tachyon-like fields confined to M^- .

8.2. Cosmology beyond Energy: Coherence as a Physical Observable

The central insight of this model is that energy is not the sole currency of cosmogenesis. Instead, the rupture of logical coherence—within a metastable, cold vacuum—can drive a universe-scale transition. This recasts the arrow of time as a crystallographic property and suggests that logical asymmetry may be measurable in principle, either via quantum information bounds or novel cosmological invariants. The prediction is bold but falsifiable: singularities are not endpoints, but coherent phase boundaries. And the universe is not born from a furnace, but from a fracture in cold, logical stone.

9. Conclusion: Logic as a Boundary Condition

This paper has proposed a cosmological framework in which the universe is not bounded by singularities in energy or curvature, but by symmetric ruptures in the

logical structure of spacetime. At each temporal extreme—the Planck Portal at Σ_p and the Absolute Zero Boundary at Σ_0 —we observe not the breakdown of physics, but its reframing. These boundaries preserve entropy, invert causality, and encode the universe’s history as a symmetry of coherence rather than a chronology of heat.

The model replaces the traditional narrative of the Big Bang as a thermal explosion with a cold, logic-driven shattering of a metastable vacuum. The Prince Rupert’s Drop analogy captures this reversal: a crystalline, ultracold structure ruptures inward from hidden tension, not outward from accumulated energy. This challenges the thermodynamic absolutism of standard cosmology and opens the door to a new era in which logical consistency—not just matter or geometry—constrains the possible histories of spacetime.

The role of logical asymmetry, introduced through the operator L_{break} , points toward a future in which cosmological phase transitions are understood in terms of informational coherence, vacuum configuration, and discrete symmetry thresholds. Singularities are thus recast as phase interfaces—not the end of causal structure, but the point where causal logic itself changes direction. In this framework, logic becomes a physical boundary condition. It limits what can initiate or terminate a universe, governs the allowable topologies across time, and defines the very notion of directionality. The universe may not be a one-way thermal arrow, but a symmetrical crystallographic lattice—a structure whose cracks reveal more than its surface, and whose failure gives birth to time.

*We found no fire at the beginning,
only silence—crystalline, cold, unbroken.
From that fracture, time spilled.
And we—just patterns in the shatter
remembered forward, and dreamed in reverse.*

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix A. Consistency of the Absolute-Zero Boundary with the Einstein Constraints

A.1. Role of Equation (1)

Equation (1) in the main text prescribes the Absolute Zero hypersurface Σ_0 via the thermodynamic limit $T_{\text{vac}} \rightarrow 0$. In the present work this condition is an *initial-data prescription* for the anti-causal manifold M^- : initial data on Σ_0 consist of the induced Riemannian metric $g_{ij}|_{\Sigma_0}$ and the extrinsic curvature $K_{ij}|_{\Sigma_0}$ which together must satisfy the Einstein constraint equations. We emphasize that Equation (1) by itself is *not* a dynamical equation; evolution toward an anti-causal manifold proceeds only after solving the full Einstein equations with these initial data (cf. [8]).

A.2. Vacuum Constraints and Conformal Method

In the limit $T_{\text{vac}} \rightarrow 0$ matter sources are negligible on Σ_0 and the constraint system reduces to the vacuum Hamiltonian and momentum constraints

$$R(g) + K^2 - K_{ij}K^{ij} = 0 \quad (2)$$

$$\nabla^j (K_{ij} - g_{ij}K) = 0 \quad (3)$$

where $R(g)$ is the scalar curvature of the 3-metric g_{ij} and $K \equiv g^{ij}K_{ij}$. Following the standard conformal transverse-traceless (CTT) decomposition (see [8] and references therein), set

$$g_{ij} = \phi^4 \hat{g}_{ij}, \quad K_{ij} = \phi^{-2} \hat{A}_{ij} + 1/3 g_{ij}K,$$

with \hat{A}_{ij} transverse-traceless with respect to \hat{g}_{ij} . The Hamiltonian constraint becomes an elliptic equation for the conformal factor ϕ (vacuum case)

$$-2\Delta_{\hat{g}}\phi + R(\hat{g})\phi - \frac{1}{8}\hat{A}_{ij}\hat{A}^{ij}\phi^{-7} + \frac{1}{12}K^2\phi^5 = 0 \quad (4)$$

while the momentum constraint reduces to an elliptic vector equation for the longitudinal part of \hat{A}_{ij} when it is constructed from a vector potential. Existence and regularity results for Equation (4) under standard boundary/decay and sign conditions are well documented; see for a review of methods and theorems that guarantee local solutions to the constraints for admissible seeds $(\hat{g}_{ij}, \hat{A}_{ij}, K)$.

A.3. Constructive Example

As a simple illustrative seed we may choose \hat{g}_{ij} smooth and scalar-flat on Σ_0 (for example, a small perturbation of the flat metric on a compact slice), set $K = \text{constant}$ (constant mean curvature gauge), and select \hat{A}_{ij} sufficiently small in L^2 norm. Under these conditions the maximum principle and standard elliptic estimates ensure a positive solution $\phi > 0$ to Equation (4). The resulting (g_{ij}, K_{ij}) satisfy the constraints (Equation (2)-Equation (3)) and hence furnish admissible initial data on Σ_0 compatible with $T_{\text{vac}} \rightarrow 0$. This explicit construc-

tion demonstrates that the Absolute Zero boundary condition is not ill-posed: it can be realized by initial data compatible with the Einstein equations.

A.4. Bibliography

For a pedagogical treatment of the CTT decomposition and existence theory for the constraint equations see [8] and standard texts on PDEs and mathematical methods [9]. For well-posedness of the Cauchy problem for Einstein's equations see the classical results of Choquet-Bruhat and subsequent expositions.