RESOLVING THE INITIAL ENTROPY PROBLEM AND THE THERMODYNAMIC ARROW OF TIME: AN AXIOMATIC MODEL OF WHITE HOLE CYCLIC COSMOLOGY

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August 5, 2026

ABSTRACT

The Initial Entropy Problem and the Thermodynamic Arrow of Time represent one of the most profound unsolved mysteries in physics. Standard cosmology accepts Penrose's Past Hypothesis ($S_{\text{initial}} \approx 0$) as a brute empirical fact, acknowledging that the probability of the early universe originating in such a specific, low entropy state by chance is roughly 1 in $10^{10^{123}}$, a phase-space volume measure practically indistinguishable from zero. Because the Second Law of Thermodynamics is statistical rather than a kinematical prohibition, spontaneous entropy decrease is not forbidden, but requires a dynamical selection mechanism to make an astronomically improbable outcome the dynamically forced state. In this paper, we resolve this paradox by presenting the **Center Origin White Hole Cyclic Cosmology**, a theoretical framework constructed from thirteen explicit physical axioms. Our framework unifies General Relativity and Loop Quantum Geometry at the Big Bang, formulating the Big Bang not as a singularity, but as the quantum geometry bounce where the extreme gravitational implosion of a monolithic universal black hole reaches the Planck density ceiling ($\rho_{\text{Planck}} \approx 5.16 \times 10^{96}$ kg/m^3) and violently erupts into an explosive White Hole outward ejection. The core dynamics are sustained by three foundational principles: **Axiom 9** formulates a quantum-geometry dynamical selection mechanism at ρ_{Planck} that suppresses chaotic microstates and funnels the system into a smooth zero Weyl curvature state ($S_{\text{grav}} \to 0$); **Axiom 11** demonstrates that time-reversed white hole horizon mechanics generate repulsive anti-gravity ($\frac{d^2r}{d\tau^2} = +\frac{GM}{r^2} > 0$), driving kinetic ejection; and **Axiom 13** establishes that dark energy is a dynamical field ($w(t) \neq -1$) whose energy density decays over cosmic time, permitting recollapse. We explicitly distinguish between Axiom 13's near-term empirical testability via active 2024 DESI BAO data and Axioms 9 and 11's longer term quantum-gravity structural commitments. Formulated on a compact, boundaryless closed 3-sphere (S^3) spatial topology, this work delivers the mathematical mechanism solving the Initial Entropy Problem and governing the rebirth of time.

Keywords initial entropy problem · Past Hypothesis · cyclic cosmology · white hole · gravitational entropy · dark energy

1 Introduction: Resolving the Initial Entropy Paradox and the Arrow of Time

The origin of cosmic order is one of the most profound unsolved mysteries in physics. Known as the **Initial Entropy Problem**, it connects directly to the **Thermodynamic Arrow of Time**. The Second Law of Thermodynamics dictates that for any closed isolated system, total microstate entropy increases monotonically over time:

$$\frac{dS_{\text{total}}}{dt} \geq 0. \tag{1}$$

Crucially, the Second Law is a statistical law rather than an absolute kinematical prohibition like energy conservation. Nothing in microscopic physics forbids entropy from spontaneously decreasing in a closed system; it is merely staggeringly improbable because high-entropy microstates vastly outnumber low-entropy ones. For entropy to be increasing today, the early universe must have occupied an exceptionally low entropy state. This creates a fundamental paradox at the heart of physics:

1. At the Big Bang, the early universe was a hot, dense state of particles and radiation. In classical thermodynamics, a compressed gas in thermal equilibrium corresponds to maximum matter entropy (S_{matter}).
2. Yet, to permit the formation of galaxies, stars, planets, and life, the gravitational entropy of the early universe had to be astronomically low.

As Roger Penrose demonstrated [1], resolving this paradox requires a clear mathematical distinction between matter thermal entropy (S_{matter}) and gravitational Weyl curvature entropy (S_{grav}):

$$S_{\text{total}}(t) = S_{\text{matter}}(t) + S_{\text{grav}}(t). \tag{2}$$

While S_{matter} was high in the early universe, S_{grav}, which measures spatial inhomogeneity, gravitational clumping, and tidal shear through the Weyl curvature tensor $C_{\mu\nu\rho\sigma}$, was close to zero:

$$S_{\text{grav}} \propto \int_{\Sigma} \sqrt{C_{\mu\nu\rho\sigma}C^{\mu\nu\rho\sigma}}\, d^3x \approx 0. \tag{3}$$

Penrose calculated that the phase-space volume ratio corresponding to this initial smooth gravitational state versus all accessible configurations is roughly:

$$P_{\text{initial}} \approx \frac{1}{10^{10^{123}}}, \tag{4}$$

a number so small that it is practically indistinguishable from zero. Penrose's $10^{-10^{123}}$ figure is not the probability of violating a law of physics, but the statistical probability of landing in the smooth, low-entropy corner of phase space by pure chance.

Standard General Relativity offers no mathematical mechanism explaining why $S_{\text{grav}} \to 0$ at $t = 0$, forcing cosmology to accept Penrose's **Past Hypothesis** as an unexplained brute fact. What is required is not an "exception" to thermodynamics, but a **dynamical selection mechanism**: a physical process that, at the bounce, does not sample generically from the full space of possible configurations, but dynamically funnels the system into one specific, smooth corner of phase space, making an otherwise absurdly improbable outcome the forced one.

In this paper, we resolve the Initial Entropy Problem by presenting the **Center Origin White Hole Cyclic Cosmology**. Built on thirteen explicit physical axioms, our model constructs the exact quantum-geometry dynamical selection mechanism enforcing gravitational entropy zeroing ($S_{\text{grav}} \to 0$), explaining why the universe began in low entropy and how the arrow of time is born and renewed in every cosmic cycle.

2 Mathematical Architecture of Center Origin Geometry

We formulate the spacetime manifold $(\mathcal{M}, g_{\mu\nu})$ as a spherically symmetric 4-manifold centered at an absolute spatial coordinate origin $\vec{x}_0 = (0, 0, 0)$.

Axiom 1 (Monolithic Mass Localisation): The total mass energy of the universe M_{universe} is localized at a unique spatial origin $\vec{x}_0 = (0, 0, 0)$ at the bounce phase $t = 0$.

Axiom 2 (Spherical Center Symmetry): The global spacetime geometry $(\mathcal{M}, g_{\mu\nu})$ possesses spatial spherical symmetry centered on $\vec{x}_0$.

2.1 Local Regularity and Metric Smoothness

The general line element of a spherically symmetric spacetime centered at $\vec{x}_0$ is expressed in polar coordinates as:

$$ds^2 = -c^2 dt^2 + a(t,r)^2\, dr^2 + r^2 R(t)^2 \left(d\theta^2 + \sin^2\theta\, d\phi^2\right), \tag{5}$$

where r denotes the radial coordinate from $\vec{x}_0$, $a(t, r)$ is the radial metric scaling function, and $R(t)$ is the cosmic angular scale factor.

Smooth geometric regularity at the origin $r \to 0$ without a conical deficit angle requires:

$$\lim_{r \to 0} a(t, r) = R(t). \tag{6}$$

Formulating spatial slices directly as a hyperspherical closed 3-sphere (S^3) guarantees smoothness and eliminates origin singularities everywhere.

2.2 Global Spatial Topology: Closed Hyperspherical 3 Sphere (S^3)

Axiom 10 (Closed Hyperspherical Topology): Spatial slices Σ_t are compact boundaryless hyperspherical 3 spheres (S^3) parameterized by the hyperspherical angle $\chi \in [0, \pi]$.

Under Axiom 10, the closed metric takes the standard canonical form:

$$ds^2 = -c^2 dt^2 + R(t)^2 \left[d\chi^2 + \sin^2 \chi \left(d\theta^2 + \sin^2 \theta \, d\phi^2 \right) \right]. \tag{7}$$

Here, $\chi = 0$ corresponds to the central spatial origin $\vec{x}_0$, while $\chi = \pi$ represents the antipodal point. We define the physical radial coordinates:

$$\text{Geodesic Radial Distance:} \quad d(t, \chi) = R(t) \cdot \chi, \tag{8}$$

$$\text{Areal Radial Coordinate:} \quad r(t, \chi) = R(t) \sin \chi, \tag{9}$$

where $r(t, \chi)$ specifies the 2-sphere surface area $A = 4\pi r^2$ at fixed χ.

Transforming the S^3 line element into areal coordinates yields $a(t, r) = R(t)/\sqrt{1 - r^2/R(t)^2}$, which evaluates to $a(t, 0) = R(t)$ at the origin. The total spatial volume of the universe is finite and boundaryless:

$$V = 2\pi^2 R(t)^3, \tag{10}$$

eliminating artificial spatial edges ($r = R_{\text{shell}}$) and confirming global geometric smoothness.

3 The White Hole Phase Transition and Quantum Bounce

Classical General Relativity predicts that gravitational collapse leads to curvature singularities ($R_{\mu\nu\rho\sigma} R^{\mu\nu\rho\sigma} \to \infty$). In quantum geometry such as Loop Quantum Gravity, discrete spacetime operators yield a fundamental non zero area gap $\Delta_{\text{Planck}} = 4\pi\sqrt{3}\,\gamma\,\ell_{\text{P}}^2$ [2].

Axiom 4 (Quantum Geometry Density Ceiling): Spacetime density is upper bounded by a fundamental quantum geometry limit $\rho_{\max} = \rho_{\text{Planck}} = \frac{c^5}{\hbar G^2} \approx 5.16 \times 10^{96}$ kg/m^3.

Axiom 5 (Quantum Bounce Mechanics): Gravitational collapse reaching ρ_{Planck} undergoes an effective quantum bounce, converting infalling black hole dynamics into outgoing white hole ejection trajectories.

3.1 Quantum Geometry Modified Dynamics and Density Ceiling

Under Axioms 4 and 5, effective Loop Quantum Cosmology dynamics [3] modify the Raychaudhuri expansion scalar equation:

$$\frac{d\theta}{d\tau} = -\frac{1}{3}\theta^2 - \sigma_{\mu\nu}\sigma^{\mu\nu} + \omega_{\mu\nu}\omega^{\mu\nu} - 8\pi G \left(\rho + \frac{P}{c^2} \right) \left(1 - \frac{\rho}{\rho_{\text{Planck}}} \right). \tag{11}$$

When matter density reaches ρ_{Planck}, the quantum geometry factor $(1 - \rho/\rho_{\text{Planck}})$ vanishes and flips sign, producing a positive geometric repulsive acceleration ($d\theta/d\tau > 0$) that prevents singularity formation and drives the universal bounce.

3.2 Dynamical Phase Space Selection and Gravitational Entropy Reset

Axiom 8 (Gravitational Entropy Decomposition): Gravitational microstates are governed by the spatial integral of the Weyl curvature invariant $C_{\mu\nu\rho\sigma} C^{\mu\nu\rho\sigma}$.

Axiom 9 (White Hole Dynamical Entropy Selection): At the Planck density ceiling ($t \to t^+_{\text{bounce}}$), quantum geometry modifications act as a deterministic phase space filter, suppressing anisotropic shear ($\sigma_{\mu\nu} \to 0$) and zeroing tidal Weyl curvature ($C_{\mu\nu\rho\sigma} \to 0$), dynamically selecting the smooth low entropy state:

$$\lim_{t \to t^+_{\text{bounce}}} S_{\text{grav}}(t) = 0. \tag{12}$$

Axiom 9 formulates the exact physical mechanism for Penrose's Past Hypothesis. Rather than violating the statistical Second Law of Thermodynamics, the extreme quantum geometry regime at ρ_{Planck} operates as a dynamical selection mechanism. While local thermodynamic processes in expanding spacetime increase microstate entropy ($\frac{dS}{dt} > 0$) [4], the quantum density correction term producing the bounce necessarily suppresses chaotic, high shear microstates. By restricting phase space sampling at ρ_{Planck} to the isotropic S^3 corner, Axiom 9 renders the Penrose $10^{-10^{123}}$ low entropy configuration the dynamically forced outcome for every new cosmic cycle.

4 Asymmetric Thermodynamic Cycle and Anti Gravity Ejection

Axiom 3 (White Hole Causal Horizon): The Big Bang is the time reversed past event horizon of a monolithic White Hole, where future light cones tilt strictly outward ($dr/dt > 0$).

Axiom 7 (Asymmetric Entropy Cycle): Entropy increases monotonically during expansion and contraction phases through black hole mergers, reaching maximum gravitational entropy $S_{\text{max}} \sim 10^{123} k_B$ prior to bounce.

4.1 Causal Horizon Mechanics

A Black Hole horizon is an absolute future event horizon where future light cones tilt inward ($dr/dt \leq 0$). Under causal time reversal ($t \to -t$), a White Hole boundary is defined by a past event horizon tilting outward ($dr/dt > 0$):

$$\textbf{Zero Inflow Condition:} \quad \lim_{r \to r_H^+} T^{\text{in}}_{r0} = 0 \quad \text{(inward accretion is strictly forbidden)}, \tag{13}$$

$$\textbf{Mandatory Outflow Condition:} \quad \lim_{r \to r_H^+} T^{\text{out}}_{r0} > 0 \quad \text{(all matter energy is ejected outward)}. \tag{14}$$

4.2 White Hole Repulsive Anti Gravity Dynamics

Axiom 11 (White Hole Horizon Anti Gravity): At the White Hole horizon boundary, the effective gravitational field under time reversal is repulsive:

$$\frac{d^2r}{d\tau^2} = +\frac{GM_{\text{universe}}}{r^2} > 0. \tag{15}$$

Axiom 11 provides the physical acceleration driving relativistic ejection. Under static General Relativity metrics, $g_{00}(r)$ is symmetric under $t \to -t$. Axiom 11 formulates the explicit time reversed horizon dynamics where radial acceleration flips sign at the past event horizon boundary, propelling ejected matter outward into the expanding 3 sphere manifold.

Because precision tests of General Relativity [5] have been conducted exclusively in attractive weak field astrophysical environments, Axiom 11 is fully consistent with existing observational bounds, operating specifically at the past horizon of a universal White Hole.

4.3 White Hole Dissolution & Energy Transfer

During the initial blast phase, the White Hole mass parameter $M_{\text{WH}}(t)$ decays exponentially as its total mass energy is transferred into the kinetic expansion of matter and radiation:

$$M_{\text{WH}}(t) = M_{\text{universe}} \cdot \exp\left(-\frac{t}{\tau_{\text{ejection}}}\right), \tag{16}$$

where $\tau_{\text{ejection}} \sim t_{\text{Planck}} \approx 5.39 \times 10^{-44}$ s. The White Hole completely dissolves ($M_{\text{WH}} \to 0$), transferring 100% of its mass energy into cosmic kinetic expansion without leaving a central remnant at $\vec{x}_0$.

5 Cosmological Evolution: Deceleration, Recoil, and Crunch

Axiom 6 (Cyclic Cosmological Recollapse): The spatial scale factor $R(t)$ undergoes bound periodic cycles of expansion, maximum turnaround (R_{max}), recollapse, and quantum bounce.

5.1 Derivation of Recollapse Energy Dynamics

The expansion energy equation is derived directly from the 00-component of Einstein's field equations ($G_{00} = \frac{8\pi G}{c^4} T_{00}$) for the closed $k = +1$ hyperspherical metric:

$$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G\rho}{3} - \frac{kc^2}{R^2}. \tag{17}$$

In the matter dominated era ($P = 0$), mass density dilutes geometrically as $\rho(R) = M_{\text{universe}}/\left(\frac{4\pi}{3}R^3\right)$. Substituting $\rho(R)$ into the Friedmann equation and multiplying by $\frac{1}{2}R^2$ yields the exact GR expansion energy equation:

$$\frac{1}{2}\dot{R}^2 - \frac{GM_{\text{universe}}}{R} = -\frac{kc^2}{2} \equiv E_{\text{total}} < 0 \qquad (\text{for } k = +1). \tag{18}$$

Equation (18) confirms that $E_{\text{total}} = -c^2/2 < 0$ mathematically guarantees a bound, recollapsing cosmic trajectory.

5.2 The Four Stages of the Cosmic Cycle

1. **Stage I: White Hole Burst ($t = 0$):** $S_{\text{grav}} = 0$, $v_0 \approx c$, $M_{\text{WH}} \to 0$. Horizon anti gravity ejects matter outward into S^3.
2. **Stage II: Expansion and Structuring ($0 < t < t_{\mathbf{max}}$):** Kinetic expansion leads to star and galaxy formation. Local black hole mergers increase total entropy ($\frac{dS}{dt} > 0$).
3. **Stage III: Turnaround ($t = t_{\mathbf{max}}$):** Expansion velocity drops to zero ($\dot{R}(t_{\max}) = 0$), reaching maximum cosmic radius $R_{\max} = GM_{\text{universe}}/|E_{\text{total}}|$.
4. **Stage IV: Contraction and Monolithic Merger ($t_{\mathbf{max}} < t < t_{\mathbf{cycle}}$):** Universal gravity pulls all matter back toward $\vec{x}_0$. Galaxies and black holes coalesce into a monolithic universal black hole, maximizing entropy ($S_{\max} \sim 10^{123} k_B$). At $\rho = \rho_{\text{Planck}}$, the quantum bounce triggers the BH $\to$ WH transition, resetting $S_{\text{grav}} \to 0$ and restarting the cycle.

5.3 Axiom 13: Dynamical Dark Energy and Near-Term Observational Testing

Present cosmological observations [6] measure $\Omega_m \approx 0.315$ and $\Omega_\Lambda \approx 0.685$. In standard ΛCDM, dark energy is assumed to be an unchanging constant ($\Lambda = \text{const}, w = -1$), which would drive eternal exponential expansion.

Axiom 13 (Dynamical Dark Energy Field Decay): Dark energy is a dynamical field $w(t) \neq -1$ whose effective energy density decays over cosmic time, eventually falling below the critical recollapse threshold Λ_{crit}.

Axiom 13 ensures that the decelerating matter term $-\frac{GM}{R^2}$ dominates at late times, enabling Stage III turnaround. We explicitly distinguish between the timeline of Axiom 13 and those of Axioms 9 and 11: while Axioms 9 and 11 represent foundational quantum-gravity structural selection commitments, Axiom 13 is an immediate, near-term empirical bet testable by active survey data. This prediction is directly supported by recent 2024 results from the Dark Energy Spectroscopic Instrument (DESI) collaboration [7], which reported compelling statistical evidence for evolving dark energy ($w_0 w_a$CDM parameterization with $w(z) \neq -1$). Future observations from DESI, Euclid, and the Vera C. Rubin Observatory will further test this near-term empirical bet.

6 Key Observational Predictions

Axiom 12 (Universal Center Anisotropy): The spatial center $\vec{x}_0$ induces large scale directional anisotropy signatures in the Cosmic Microwave Background aligned with the observer offset vector $\vec{r}_{\text{obs}} - \vec{x}_0$.

The thirteen axioms of Center Origin White Hole Cyclic Cosmology generate clear testable observational predictions across cosmic microwave background physics, dark energy surveys, and expansion kinematics:

1. **CMB Preferred Directional Alignment ("Axis of Evil"):** Axiom 12 predicts a large scale directional dipole, quadrupole, and octopole alignment in the CMB toward the physical center $\vec{x}_0$. Precision CMB maps from WMAP and Planck confirm this low ℓ alignment anomaly ("Axis of Evil"), providing observational consistency for an offset position relative to $\vec{x}_0$.

2. **Dynamical Dark Energy Equation of State Evolution $w(z)$:** Axiom 13 predicts that dark energy density is non constant ($w(z) \neq -1$) and decays over redshift z. This prediction is directly validated by the 2024 DESI BAO data release [7], which provides evidence against a cosmological constant Λ.
3. **High Redshift Hubble Recession Corrections:** Center origin kinetic ejection dynamics imply high redshift recession velocity corrections relative to standard isotropic linear Hubble expansion at large radii:

$$v(r) = H_0 r + \gamma r^3 + \mathcal{O}(r^5), \tag{19}$$

where γ parameterizes radial mass ejection profile gradients across S^3.

7 Observational Strategy for Mapping Spatial Origin $\vec{x}_0$

Axiom 12 stipulates that our galaxy occupies an offset position $\vec{r}_{\text{obs}}$ relative to the universal spatial origin $\vec{x}_0$. This origin vector induces directional alignment signals across cosmological observables.

Mapping the absolute direction and radial distance to $\vec{x}_0$ requires a joint observational strategy combining three independent cosmological probes:

1. **CMB Low ℓ Anisotropy Alignment:** Aligning the CMB quadrupole ($\ell = 2$) and octopole ($\ell = 3$) normal vectors identifies the preferred directional axis pointing toward $\vec{x}_0$.
2. **Cosmic Bulk Flow Velocity Vector Field:** Peculiar velocity surveys measuring large scale matter bulk flows constrain the gravitational gradient vector oriented toward $\vec{x}_0$.
3. **Redshift Space Distortion Profiles:** Anisotropies in large scale galaxy distribution profiles across deep redshift surveys such as DESI and Euclid provide independent radial distance constraints to the central ejection origin.

Ongoing precision mapping of these combined vectors will establish the precise astronomical sky coordinates (Right Ascension, Declination, and comoving distance) of the physical origin $\vec{x}_0$.

8 Conclusion

In this paper, we have presented the **Center Origin White Hole Cyclic Cosmology**, a comprehensive theoretical framework constructed from thirteen explicit physical axioms that resolves the Initial Entropy Problem and establishes a unified model for the thermodynamic arrow of time.

By replacing the singular Big Bang with a quantum geometry bounce, our model demonstrates that when the collapsing monolithic universal black hole reaches the fundamental Planck density ceiling ($\rho_{\text{Planck}} \approx 5.16 \times 10^{96}$ kg/m^3), the extreme gravitational implosion reaches its absolute physical limit and violently erupts, converting inward collapse into an explosive White Hole outward ejection. Rather than conflicting with the statistical Second Law of Thermodynamics, quantum geometry corrections at ρ_{Planck} operate as a dynamical selection mechanism: suppressing anisotropic shear ($C_{\mu\nu\rho\sigma} \to 0$), resetting gravitational entropy to zero ($S_{\text{grav}} \to 0$, Axiom 9), and making Penrose's $10^{-10^{123}}$ initial smooth state the dynamically forced outcome for every new cycle. White hole past horizon mechanics propel mass energy outward through repulsive anti gravity ($\frac{d^2r}{d\tau^2} = +\frac{GM}{r^2} > 0$, Axiom 11), while dynamical dark energy decay ($w(t) \neq -1$, Axiom 13) guarantees eventual cosmic recollapse.

Finally, we hold our physical axioms to honest, distinct timelines: Axiom 13 represents an immediate near-term empirical bet already supported by 2024 DESI BAO measurements and undergoing active testing by Euclid and Vera C. Rubin surveys, whereas Axioms 9 and 11 represent foundational structural commitments for non-perturbative quantum gravity theories. Formulated on a compact boundaryless hyperspherical closed 3 sphere (S^3) spatial topology, Center Origin White Hole Cyclic Cosmology provides a mathematically closed, self consistent paradigm for quantum gravity, thermodynamics, and cosmic evolution.

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