COSMOLOGICAL CYCLES VIA WHITE HOLE EJECTION AND DYNAMICAL DARK ENERGY: AN AXIOMATIC MODEL OF THE THERMODYNAMIC ARROW OF TIME

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ABSTRACT

The Initial Entropy Problem asks why the early universe began in an exceptionally low gravitational entropy state despite matter and radiation being at thermal equilibrium. It remains one of the most fundamental unsolved paradoxes in modern physics. Standard cosmology accepts Penrose's Past Hypothesis ($S_{\text{initial}} \approx 0$) as a brute empirical fact, without a dynamical mechanism that enforces it. This paper presents a candidate **Center Origin White Hole Cyclic Cosmology**, built from thirteen explicit axioms. It is offered as an axiomatic framework, not a resolution of the problem it addresses.

The model proposes that the Big Bang is the time-reversed quantum-gravity bounce of a single, monolithic universal black hole reaching Planck density ($\rho_{\text{Planck}} \approx 5.16 \times 10^{96}$ kg/m^3). Three axioms carry the model's real explanatory weight, and each is flagged plainly rather than hidden in notation. Axiom 9 stipulates that gravitational entropy resets to zero at the transition. This is an explicit, stated exception to the Second Law of Thermodynamics, not a derived consequence of statistical mechanics, and it is the most radical assumption in the model. Axiom 11 stipulates that the transition is accompanied by repulsive anti-gravity. This cannot be derived from time-reversal of the Einstein field equations, a claim checked directly against the time symmetry of the Schwarzschild metric, so the axiom is grounded solely in its current untestability. Axiom 13 stipulates that dark energy is dynamical rather than a true cosmological constant, which would permit eventual recollapse. Current measurements ($\Omega_m \approx 0.315$, $\Omega_\Lambda \approx 0.685$) place the real universe decisively outside the recollapse regime under a constant Λ, so this axiom is an explicit, falsifiable bet on an open question in dark energy research, not an established result.

The remaining axioms cost less. They include a quantum geometry density ceiling in the spirit of Loop Quantum Cosmology's effective dynamics, a causal horizon distinction between black and white holes, and a closed hyperspherical (S^3) spatial topology whose regularity we verify directly. We derive the model's recollapse dynamics as an exact consequence of the Friedmann equation for a dust-dominated closed universe, and we show explicitly where and why this derivation fails to match a universe dominated by dark energy. This framework does not derive low initial entropy from more fundamental principles. It relocates the Past Hypothesis to a named, falsifiable transition, a reformulation of the open problem rather than its resolution.

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

1 Introduction: The Initial Entropy Paradox

The Second Law of Thermodynamics dictates that for any closed, isolated system, total microstate entropy increases monotonically over time:

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

Applying this to the observable universe implies that earlier cosmic epochs must have possessed lower entropy than later epochs. However, standard Big Bang cosmology posits that at $t \approx 380{,}000$ years (the Cosmic Microwave Background emission epoch), matter and radiation were in a state of near-perfect thermal equilibrium, corresponding to maximum matter entropy.

As Penrose demonstrated [1], the resolution requires distinguishing **matter entropy** (S_{matter}) from **gravitational entropy** (S_{grav}):

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

S_{matter} was high at the Big Bang, but S_{grav} (which measures spatial inhomogeneity and gravitational clumping through the Weyl curvature tensor $C_{\mu\nu\rho\sigma}$) was exceptionally 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 the phase-space volume ratio corresponding to this initial smooth state versus all possible gravitational configurations to be

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

Without a mathematical mechanism enforcing $S_{\text{grav}} \to 0$ at the initial singularity, standard General Relativity requires accepting the **Past Hypothesis** as an unexplained initial condition.

Here, we present a candidate cyclic framework built on thirteen explicit axioms, listed in full at the point each is used below. As Sections 3, 4, and 5 make explicit, three axioms (Axiom 9, Axiom 11, and Axiom 13) sustain the cycle, and none of them is a derivation. This paper does not claim to have removed the need for postulates. It claims only to have made them explicit and isolated them to specific, flagged assumptions, each checked against the physics it touches rather than presented as settled.

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 $\vec{x}_0 = (0, 0, 0)$.

2.1 Local Regularity and Spherically Symmetric Metric

The general line element of a spherically symmetric spacetime centered at $\vec{x}_0$ is

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

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

For general metric functions $a(t,r)$ and $R(t)$, smooth regularity at the origin $r \to 0$ without a conical deficit angle requires

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

As shown in Section 2.2 below, formulating the spatial geometry directly as a standard hyperspherical 3-sphere (S^3) automatically satisfies this condition and provides intrinsic smoothness everywhere: rewriting the S^3 metric in the areal-radius coordinate $r = R(t)\sin\chi$ gives $a(t,r) = R(t)/\sqrt{1-r^2}$, so $a(t,0) = R(t)$ exactly, as required.

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

To avoid artificial spacetime boundaries (an "edge" at some $r = R_{\text{shell}}$), the global spatial slice Σ_t is formulated as a compact, boundaryless closed 3-sphere (S^3). Parameterized by the hyperspherical radial angle $\chi \in [0, \pi]$, the closed metric takes the standard form

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

Here $\chi = 0$ corresponds to the central origin $\vec{x}_0$, and $\chi = \pi$ is the antipodal point. We define two related radial quantities used throughout this paper:

$$\text{Geodesic radial distance:} \quad d(t,\chi) = R(t) \cdot \chi, \tag{8}$$
$$\text{Areal radial coordinate:} \quad r(t,\chi) = R(t)\sin\chi, \tag{9}$$

the latter determining the 2-sphere surface area $A = 4\pi r^2$ at fixed χ.

The total spatial volume is finite,

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

and requires no external boundary edge. This topology stays consistent across every section of this paper.

3 The White Hole Phase Transition

3.1 Quantum Gravity Density Ceiling

In classical General Relativity, gravitational collapse of a closed universe leads to a curvature singularity ($R_{\mu\nu\rho\sigma}R^{\mu\nu\rho\sigma} \to \infty$). In quantum geometry (e.g., Loop Quantum Gravity), the spectrum of the area and volume operators is discrete, possessing a minimal non-zero eigenvalue (the area gap $\Delta_{\text{Planck}} = 4\pi\sqrt{3}\,\gamma\,\ell_{\text{P}}^2$) [2].

This motivates a density-ratio correction to the Raychaudhuri equation. The correction follows the spirit of the effective-dynamics corrections found in Loop Quantum Cosmology [3], though we have not independently verified it to be equivalent to them:

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

When the density of the collapsing universal black hole reaches the critical Planck density limit,

$$\rho_{\max} = \rho_{\text{Planck}} = \frac{c^5}{\hbar G^2} \approx 5.16 \times 10^{96}\ \text{kg/m}^3, \tag{12}$$

the $(1 - \rho/\rho_{\text{Planck}})$ factor above is what drives $d\theta/d\tau > 0$. Positive matter pressure alone does *not* cause repulsion under standard sign conventions. It increases deceleration in the Raychaudhuri and Friedmann acceleration equations instead. The multiplicative $(1 - \rho/\rho_{\text{Planck}})$ correction term is what produces the bounce here, and the two mechanisms should not be conflated.

3.2 Axiom 9: An Explicit, Stipulated Local Violation of the Second Law

Axiom 9 states that gravitational entropy resets to zero at the White Hole transition:

$$\lim_{t \to t_{\text{bounce}}^+} S_{\text{grav}}(t) = 0 \qquad \text{(Axiom 9)}. \tag{13}$$

This model does not claim that Axiom 9 is consistent with, or derivable from, established thermodynamics. It is an explicit exception to the Second Law of Thermodynamics, confined to the instant of the White Hole transition. An earlier draft tried to motivate it through "free energy converting to stable matter, which occupies less phase space than radiation." We considered that mechanism and withdrew it, because it is not supported by known physics. The best-established comparable process, matter-antimatter pair annihilation into radiation, is measured and calculated to *increase* the entropy of the radiation bath. This is the same mechanism behind the cosmic photon background being warmer than the cosmic neutrino background [4]. No known process converting between matter and radiation has been shown to spontaneously decrease total entropy in an isolated system, in either direction.

Axiom 9 is therefore not a mechanism dressed in the language of statistical mechanics; it is a bare postulate that the Second Law does not hold at this one specific transition. This is the single most radical assumption in the model. The Second Law is among the most rigorously tested statements in physics, with no confirmed exception in over a century of experiment; Axiom 9 asserts one exists at the White Hole bounce, without independent justification beyond the requirement that the model needs it to reproduce the observed low-entropy Big Bang.

4 Asymmetric Thermodynamic Cycle and Anti-Gravity Ejection

4.1 White Hole Causal Horizon Mechanics

A black hole horizon is defined by an absolute future event horizon where future light cones tilt strictly inward ($dr/dt \leq 0$): no particle can exit to $r > r_H$. A white hole is the exact causal time-reverse ($t \to -t$) of a black hole. Its boundary is a past event horizon where future light cones tilt strictly outward ($dr/dt > 0$). Consequently:

$$\textbf{Zero inflow:} \quad \lim_{r \to r_H^+} T_{r0}^{\text{in}} = 0 \quad \text{(nothing can fall into a white hole)}, \tag{14}$$

$$\textbf{Mandatory outflow:} \quad \lim_{r \to r_H^+} T_{r0}^{\text{out}} > 0 \quad \text{(everything inside must be ejected outward)}. \tag{15}$$

4.2 Axiom 11: An Explicit Postulate, Untestable by Current Observation

Axiom 11 states that the white hole horizon is accompanied by repulsive anti-gravity:

$$\frac{d^2 r}{d\tau^2} = +\frac{GM_{\text{universe}}}{r^2} > 0 \qquad \text{(Axiom 11, postulated)}. \tag{16}$$

This is *not* derived from time-reversal of the Einstein field equations. For a static, spherically symmetric metric, g_{00} is a function of r alone; since t enters the metric only through dt^2, the map $t \to -t$ leaves $g_{00}(r)$ unchanged at every radius. There is no "valley becoming a hill" under time-reversal for this class of metric. The potential's shape does not depend on which direction t is labeled to run. Attempts to derive Axiom 11 via the sign of dr/dt, via the sign of the Christoffel symbol Γ^r_{00}, and via the sign of g_{00} itself all fail for this same underlying reason.

Axiom 11 rests instead on a single, honest basis. It is currently untestable, and that is precisely why it does not conflict with existing General Relativity tests. Every precision test of GR, including planetary orbits, light bending, radar time delay, and binary pulsar timing [5], has been performed exclusively in ordinary attractive gravitational environments. None has ever probed a white hole horizon, because none is known to exist locally. This makes the axiom consistent with all existing data by construction, but for the same reason it is not yet supported by any observation either.

Astrophysical black holes are detected almost exclusively through their attractive influence on nearby matter: accretion disks heated by infalling gas, stars orbiting an unseen mass (e.g., the S-stars orbiting Sgr A*), or gravitational waves from infalling mergers. Under Axiom 11, a white hole would produce none of these signatures, since infalling matter would instead collide with the horizon's own outgoing matter and radiation. This is consistent with the total absence of confirmed white hole detections to date. We offer this as a consistency check, not as independent evidence for Axiom 11 specifically: the causal horizon structure alone (Section 4) already predicts the same non-detection outcome without requiring repulsive gravity, so absence of detection does not tell the two versions of the model apart.

4.3 Phenomenological Ejection Parameterization and White Hole Dissolution

During the initial blast phase, the white hole mass parameter $M_{\text{WH}}(t)$ is stipulated to decay as its energy is ejected into the expanding matter and radiation continuum. For modeling purposes, this rapid mass-loss phase can be parameterized phenomenologically as

$$M_{\text{WH}}(t) = M_{\text{universe}} \cdot \exp\left(-\frac{t}{\tau_{\text{ejection}}}\right). \tag{17}$$

The specific exponential form and the Planck-scale timescale ($\tau_{\text{ejection}} \sim t_{\text{Planck}} \approx 5.39 \times 10^{-44}$ s) are introduced as a simplified phenomenological ansatz rather than a derived result of the thirteen axioms. What the model strictly requires is the qualitative condition that the initial white hole completely dissolves ($M_{\text{WH}} \to 0$), transferring all mass-energy into the kinetic ejection of matter and radiation without leaving a central remnant at $\vec{x}_0$.

5 Cosmological Evolution: Deceleration, Recoil, and Crunch

5.1 Derivation from the General Relativity Friedmann Equation

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 ($k = +1$) metric of Section 2:

$$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G \rho}{3} - \frac{kc^2}{R^2}. \tag{18}$$

Dust-only assumption. This classical derivation assumes a pressureless matter/dust-dominated universe ($P = 0$) with zero cosmological constant ($\Lambda = 0$), where mass density dilutes purely geometrically as $\rho(R) = M_{\text{universe}}/\left(\frac{4\pi}{3}R^3\right) \propto R^{-3}$.

Substituting this matter density into the Friedmann equation and multiplying by $\frac{1}{2}R^2$ yields

$$\frac{1}{2}\dot{R}^2 - \frac{GM_{\text{universe}}}{R} = -\frac{kc^2}{2} \equiv E_{\text{total}} < 0 \qquad (\text{for } k = +1). \tag{19}$$

This confirms that Eq. (19) is a mathematically exact result of General Relativity for a spatially closed, dust-dominated universe, where $E_{\text{total}} = -c^2/2 < 0$ guarantees a bound, recollapsing trajectory.

5.2 The Four Stages of the Cycle

1. **Stage I: White Hole Burst** ($t = 0$). $S_{\text{grav}} = 0$, $v = v_0 \approx c$, $M_{\text{WH}} \to 0$. Anti-gravity ejects all matter outward.
2. **Stage II: Expansion and Structuring** ($0 < t < t_{\text{max}}$). Matter flies outward, stars and black holes form, and local black hole mergers increase entropy ($dS/dt > 0$).
3. **Stage III: Turnaround** ($t = t_{\text{max}}$). Kinetic energy drops to zero ($\dot{R}(t_{\text{max}}) = 0$) and expansion reaches its maximum radius, $R_{\text{max}} = GM_{\text{universe}}/|E_{\text{total}}|$.
4. **Stage IV: Contraction and Monolithic Merger** ($t_{\text{max}} < t < t_{\text{cycle}}$). Gravity pulls all galaxies and black holes back toward $\vec{x}_0$. Black holes coalesce into a single universal black hole, maximizing entropy ($S_{\text{max}} = k_B c^3 A/(4G\hbar) \sim 10^{123} k_B$). At $\rho = \rho_{\text{Planck}}$, the quantum bounce triggers the BH $\to$ WH transition and restarts the cycle.

5.3 Axiom 13: Dynamical Dark Energy Beneath the Recollapse Threshold

The derivation above proves that recollapse is exact for a closed $k = +1$ universe under a pure dust assumption ($\Lambda = 0$). This same result shows directly why the model conflicts with real cosmological observations. Type Ia supernova, CMB, and BAO data [6] establish that the real universe is not dust-only, but is currently dominated by dark energy, which adds a positive term to the Friedmann acceleration equation:

$$\frac{\ddot{R}}{R} = -\frac{4\pi G}{3}\left(\rho + \frac{3P}{c^2}\right) + \frac{\Lambda c^2}{3}. \tag{20}$$

Current measurements sit decisively in the eternal-expansion regime, not near the recollapse threshold: combined supernova, CMB, and BAO data give $\Omega_m \approx 0.315$ and $\Omega_\Lambda \approx 0.685$ [6]. Dark energy is more than double the matter density, and matter density alone is well below what a closed universe needs to recollapse unaided. Recollapse under a *constant* Λ at this measured value is ruled out, not merely disfavored.

Axiom 13 (new; not among the original twelve): Λ is not a fixed constant but a dynamical field whose effective value will decrease over cosmic time and eventually fall below the matter-density-dependent critical threshold Λ_{crit} required for recollapse, permitting the Stage III turnaround and Stage IV contraction described above.

Current data does not rule this out, but it does not establish it either. It remains a genuinely open, active research question. Dark energy's equation-of-state parameter w is measured to be close to -1 (the value for a true, unchanging constant), consistent with ΛCDM to good precision. The DESI collaboration's 2024 results reported mild statistical hints that w may evolve away from -1 [7], which is what this axiom would need to hold. That result is preliminary, though, and independent analysis or successor surveys have not yet confirmed it. Axiom 13 takes a definite, falsifiable position on an unresolved question. It is a bet on how that question resolves, not something this model establishes independently. Future DESI, Euclid, and Rubin/LSST data on the time evolution of w will test it directly.

Under the standard ΛCDM assumption that dark energy density is a true, unchanging constant, the $+\Lambda$ term eventually and permanently dominates over the decelerating dust term $-GM/R^2$, driving persistent accelerating expansion rather than turnaround. None of the original twelve axioms offer a way to prevent this. Axiom 13 supplies that mechanism by denying that Λ is constant in the first place. This connects the exact dust-only derivation directly to the observational conflict and its proposed resolution. The recollapse dynamics are mathematically exact for a dust-dominated universe. The real universe is presently dark energy dominated instead. Axiom 13 is the model's explicit, flagged bet that this will not remain permanently true.

6 Key Observational Predictions

Given the thirteen stated axioms, the model supports one qualitative, testable prediction from Axiom 12, plus Axiom 13's own falsifiable prediction (Section 5.3: measurable evolution in dark energy's equation-of-state parameter w). It cannot yet support quantitative predictions beyond these.

1. **CMB preferred direction (point-of-origin alignment), qualitative and testable.** Axiom 12 stipulates a true physical center $\vec{x}_0$. If our position is offset from $\vec{x}_0$, the CMB should show a large-scale anisotropy aligned toward it. The observed "Axis of Evil" (quadrupole-octopole alignment in WMAP/Planck data) is a real, measured anomaly consistent in kind with this prediction. It is of marginal statistical significance on its own, though, since it is a low-ℓ effect with large cosmic variance, and it remains disputed as to whether it reflects new physics, foreground residuals, or statistical chance. It does not by itself confirm a preferred center. This should be treated as "not yet ruled out," not as supporting evidence.
2. **Radial expansion correction, qualitative only.** Axiom 12 (center origin geometry, driven by ejection rather than by the metric) implies recession velocities should deviate from the standard linear Hubble law at some order. The original twelve axioms do not specify the functional form or magnitude of this deviation. Asserting a specific term such as $v(r) = H_0 r + \gamma r^3$ with no derived value for γ is not a prediction, but an unconstrained placeholder. A genuine prediction here requires additional modeling not licensed by the given axioms.
3. **Primordial black hole mass scale, not supported.** A specific figure ($m_{\text{PBH}} \approx 10^{15}$ g) is a real number from unrelated standard black hole physics: the mass at which Hawking evaporation lifetime equals the current age of the universe. It is not derived from this model's contraction dynamics, and presenting it without that derivation would misrepresent it as a prediction of this theory. No PBH mass prediction is currently supported by the thirteen axioms.

7 Locating $\vec{x}_0$: An Open Empirical Question, Not a Derived Result

An earlier draft of this work attempted to report specific sky coordinates for $\vec{x}_0$: a galactic longitude and latitude, equatorial right ascension and declination, a named constellation, and a distance in light-years, obtained by combining the CMB quadrupole-octopole alignment vector with the CMB bulk-flow vector. We withhold that calculation from this paper. On review, it rested on two problems. First, the vector-combination procedure has no basis in the thirteen stated axioms or in any established cosmological method; there is no standard technique for combining these two independently measured directions to locate a universal center. Second, it contained an internal arithmetic inconsistency, in which the three vector components were not combined by the same operation. A specific astronomical claim of this kind should not be presented without a real, checkable, non-arbitrary method behind it, and we found none.

What Axiom 12 actually licenses is qualitative, not quantitative. If a true center $\vec{x}_0$ exists and we are offset from it, some large-scale directional signature in the CMB or bulk flow is expected in principle (Section 6, Prediction 1). Deriving an actual sky position from that, a real right ascension and declination, would require a specific, justified observational method relating measured anisotropy amplitude and alignment to physical distance and direction. The thirteen axioms do not supply that method, and we do not propose one here. Locating $\vec{x}_0$, if it exists, remains open for future work.

8 Conclusion, and What This Model Does Not Establish

This paper presents the Center Origin White Hole Cyclic Cosmology as a self-consistent narrative built on thirteen stated axioms. These include a quantum-geometry density ceiling (Axiom 4, in the spirit of Loop Quantum Cosmology's effective dynamics), a postulated causal-structure horizon distinction (Axiom 3), and three axioms that carry the model's real explanatory weight: Axiom 9 (the White Hole transition resets gravitational entropy to zero, an explicit stipulated exception to the Second Law), Axiom 11 (the transition is accompanied by repulsive anti-gravity, untestable by construction), and Axiom 13 (dark energy is dynamical and will fall below the recollapse threshold, a live but unconfirmed research question). None of these three is derived from established physics in this paper. All three are stipulated, and each is flagged at the point it is introduced.

This means the model does *not* provide a dynamical derivation of low initial entropy from more fundamental principles. It relocates the Past Hypothesis from "the universe began smooth, unexplained" to "the White Hole transition resets entropy, unexplained," a reformulation of the open problem, not a resolution of it. The model's accommodation of the observed accelerating expansion (Section 5.3) rests on Axiom 13, a genuinely open empirical question rather than an established result. Current data on dark energy's equation of state is consistent with the evolution this axiom requires, but does not confirm it. The model also does not support a specific, checkable location for $\vec{x}_0$ (Section 7).

What it does offer is an internally consistent cyclic framework in which the Second Law, black hole thermodynamics, and a postulated bounce mechanism fit together without contradicting each other, with its heaviest assumptions named plainly rather than hidden in notation. We present it as a candidate structure for further work, not a solved problem, and not a claimed resolution of the Initial Entropy Problem. Any future development of this model should treat Axioms 9, 11, and 13 as the load-bearing, falsifiable commitments they are. It should prioritize either deriving them from a more fundamental theory or subjecting them to observational test, rather than treating their current stipulated status as settled.

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