A Cyclic 4D-Time Universe Model: Bounce, Expansion, and Turnaround Controlled by Closed Time Geometry

Jacob L. Powell

August 24, 2025

Abstract

We propose a conceptual cosmological framework in which the fourth dimension—time—is not infinite, but cyclic and bounded. This closed time geometry provides a natural mechanism for both the initiation of cosmic expansion (the bounce) and its termination (the turnaround), removing the need for external triggers. We sketch an effective Friedmann equation, inspired by Loop Quantum Cosmology (LQC) [1, 2], that incorporates quantum corrections to avoid singularities, and show how a large-a turnaround can arise through curvature or an effective negative cosmological term. The bounce is interpreted as a single-frame quantum state, linking emergent time concepts [5, 6] with cyclic and conformal cosmological models [3, 4].

1 Introduction

The classical theory of general relativity predicts singularities at the Big Bang and inside black holes, where the equations cease to be valid. Loop Quantum Cosmology (LQC) provides a resolution through quantum corrections that replace singularities with bounces [1, 2]. Other cyclic approaches, such as the ekpyrotic/cyclic scenario [3], posit a sequence of universes but often leave the termination of expansion unspecified. Penrose's Conformal Cyclic Cosmology (CCC) [4] offers an alternative by identifying the remote future of one aeon with the Big Bang of the next through conformal rescaling.

The proposal developed here differs in a key way: time itself is treated as a closed arc, with expansion and contraction bounded by its periodicity. This *cyclic 4D-time* ansatz eliminates the need for ad hoc triggers and provides a unified geometric controller for both the bounce and the turnaround.

2 Framework

2.1 Cyclic Time Ansatz

We posit periodic cosmic time $\tau \in [0, T)$ such that

$$a(\tau + T) = a(\tau).$$

The boundary conditions are

$$a(0) = a_{\min} > 0, \quad \dot{a}(0) = 0, \qquad a(T/2) = a_{\max}, \quad \dot{a}(T/2) = 0, \tag{1}$$

where $a_{\min}$ represents the bounce and $a_{\max}$ the turnaround.

2.2 Effective Friedmann Equation

Following the spirit of LQC [1], we consider the modified Friedmann equation

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\,\rho(a)\left(1 - \frac{\rho(a)}{\rho_c}\right) + \frac{\Lambda}{3} - \frac{k}{a^2}, \tag{2}$$

with $\rho(a) = \rho_{r0}a^{-4} + \rho_{m0}a^{-3} + \rho_\Lambda$ (toy form) and ρ_c the critical density. The factor $(1-\rho/\rho_c)$ generates a bounce at small a, while either $\Lambda < 0$ or $k > 0$ produces a large-a turnaround.

3 Results (Toy Examples)

3.1 Cyclic Scale Factor

Figure 1 shows an illustrative periodic $a(\tau)$ with bounce and turnaround.

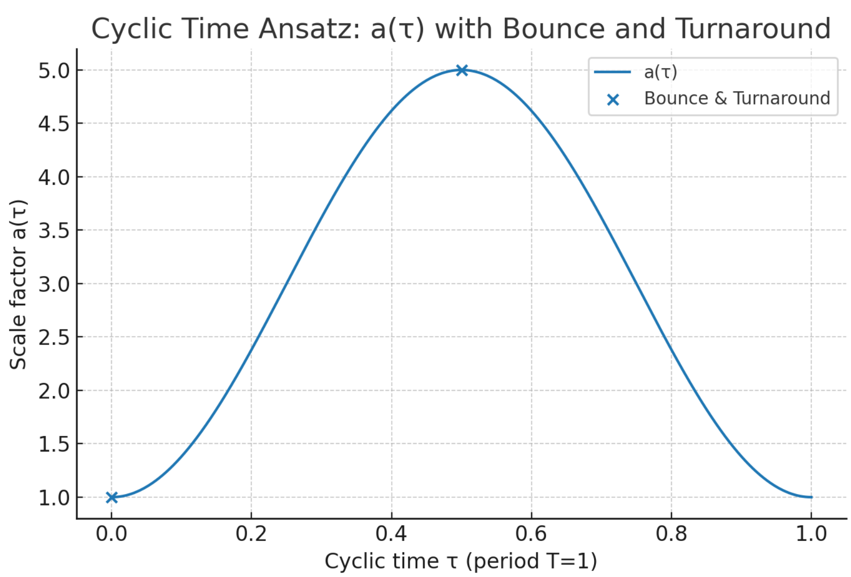

Figure 1: Cyclic time ansatz: $a(\tau)$ with bounce ($\tau = 0$) and turnaround ($\tau = T/2$).

3.2 Effective $H^2(a)$ with Two Turning Points

Figure 2 shows a toy $H^2(a)$ with both a small-a bounce and a large-a turnaround.

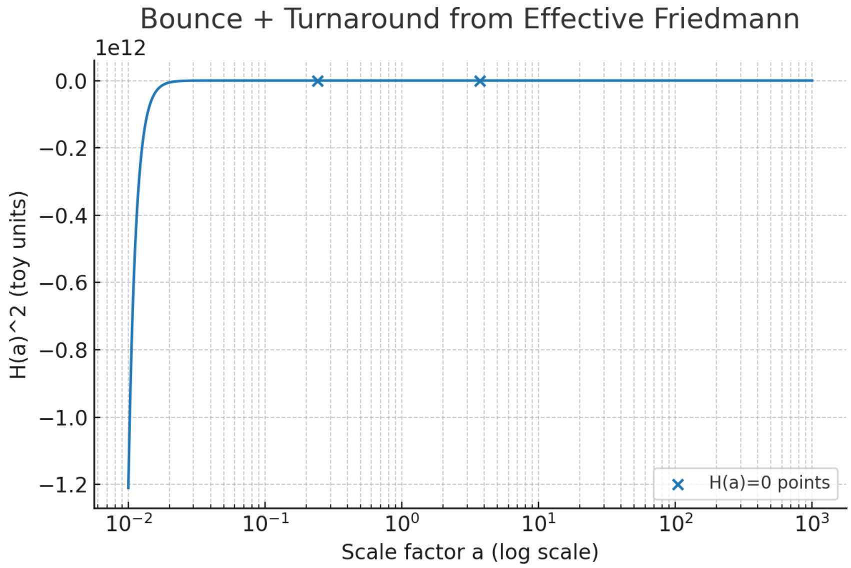

Figure 2: Toy $H^2(a)$ exhibiting a small-a bounce and a large-a turnaround.

4 Discussion

Compared to standard LQC [1], this model retains the quantum bounce but introduces a built-in turnaround through closed time geometry. Unlike CCC [4], which removes contraction via conformal mapping, this proposal preserves contraction and closes the cycle directly in time itself. The model also resonates with emergent-time perspectives such as the Hartle–Hawking wavefunction [5] and Rovelli's relational view of time [6].

By treating the bounce as a single-frame quantum state, the approach provides an intuitive resolution to the question of why classical time dilation does not apply at the origin of expansion.

5 Conclusions and Next Steps

We have presented a toy model embodying the idea of time as a closed controller loop. This framework unifies bounce and turnaround mechanisms in a geometric ansatz, offering a conceptual alternative to inflationary or purely conformal cyclic models.

Future work should focus on deriving the effective dynamics from a more fundamental quantum gravity theory, identifying potential observational discriminants (e.g. CMB non-Gaussianities, primordial gravitational waves, deviations from ΛCDM), and analyzing entropy flow across cycles.

Acknowledgments

The author thanks the open scientific community for providing freely accessible resources that make independent research possible. Foundational insights from Loop Quantum Cosmology, cyclic cosmology, and conformal cyclic cosmology by A. Ashtekar, M. Bojowald, P. Steinhardt, N. Turok, and R. Penrose have provided inspiration for the framing of this note.

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