Non-Existence Collapse: A Dynamical Mechanism for the Quantum-Gravitational Bootstrap of Spacetime from Nothing

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Abstract

We propose a minimal dynamical framework for the origin of the universe in which absolute non-existence—a state with no spacetime, matter, fields, or classical time—is intrinsically unstable under quantum-mechanical and gravitational principles. The Heisenberg uncertainty principle, applied to gravitational degrees of freedom, precludes a static null configuration: non-existence has "nowhere to go" but to collapse into itself, producing an effective Planck-scale density regime that undergoes a nonsingular quantum-gravitational transition. This collapse-driven process bootstraps the emergence of classical spacetime and the arrow of time, requiring no external causes, pre-existing substrates, boundary conditions, or auxiliary fields.

Quantum gravity emerges here not as an imposed extension but as the inherent dynamical structure governing the instability and resolution. The mechanism refines and complements established proposals—such as Vilenkin's quantum tunneling from nothing, the Hartle-Hawking no-boundary wavefunction, and recent developments in loop quantum cosmology bounces and quadratic gravity—by providing a purely mechanical interpretation that replaces probabilistic nucleation or Euclidean continuation with an intrinsic collapse bootstrap. It aligns with ongoing refinements of no-boundary states, curvature bounces, and geometric "from nothing" models in the 2025–2026 literature.

This framework offers a parsimonious dynamical resolution to the question of why there is something rather than nothing, transforming it into a consequence of quantum gravity's structure. Potential observational implications include consistency with cosmic microwave background data and distinguishable signatures in primordial gravitational waves or large-scale structure that may differentiate collapse-initiated emergence from conventional inflationary scenarios.

Keywords: quantum cosmology, quantum gravity, universe from nothing, singularity resolution, Wheeler-DeWitt equation, bounce cosmology, relational structure, emergent spacetime

1   Introduction

The origin of the universe poses one of the deepest challenges in theoretical physics. Classical general relativity, when extrapolated backward, yields a singularity at finite past proper time where curvature, density, and temperature diverge [1, 2]. At this point spacetime itself appears to emerge, rendering the notion of a "prior" state or external cause conceptually problematic: there is no classical "before" because time begins there. A complete description therefore requires a quantum theory of gravity capable of addressing how spacetime, time, and the observed expanding universe arise from the earliest moments.

Several influential frameworks have been developed to resolve the initial singularity and the "something from nothing" question. Vilenkin's tunneling proposal [3] describes the spontaneous nucleation of an inflating universe from a state of literal nothing via quantum barrier penetration

in minisuperspace, with recent Monte Carlo path-integral studies continuing to explore its viability [7]. The Hartle–Hawking no-boundary proposal [4] defines the wave function of the universe on a smooth, closed Euclidean 4-geometry with no initial boundary; a consistent gravitational-path-integral evaluation was presented as recently as February 2026 [8]. In loop quantum cosmology, repulsive quantum-geometry effects at Planckian densities replace the classical singularity with a nonsingular bounce [6, 9]. Quadratic-gravity and higher-curvature theories further demonstrate that inflation can emerge naturally from the gravitational action itself, offering a potential ultraviolet completion of the Big Bang without additional scalar fields [10].

These approaches have advanced our understanding considerably. Yet many still rely on probabilistic nucleation, specific contour prescriptions in the complex plane, pre-existing background structures, or an underlying contracting phase. Any request for a pre-existing structure, stabilizer, or boundary condition to explain the transition already presupposes the very framework whose absence defines absolute non-existence — rendering such a demand conceptually self-defeating.

A purely mechanical and minimal dynamical account—in which absolute non-existence is intrinsically unstable and self-resolves without external scaffolding or auxiliary assumptions—remains less explicitly developed.

In this paper we propose such a mechanism, which we term *Non-Existence Collapse.* We argue that a state of absolute non-existence—devoid of spacetime, matter, fields, and classical time—is unsustainable under the joint principles of quantum mechanics and gravity. The Heisenberg uncertainty principle, applied to gravitational degrees of freedom (fluctuations of the 3-geometry), precludes any perfectly static null configuration. Consequently, non-existence has "nowhere to go" but to collapse into itself. This collapse drives the system through an effective Planck-scale density regime, where quantum-gravitational dynamics dominate and resolve what would classically be a singularity into a smooth, nonsingular transition. Classical spacetime geometry and the arrow of time then emerge naturally from the post-collapse evolution.

A distinctive feature of the framework is that quantum gravity is not introduced as an auxiliary correction but appears as the self-evident dynamical language required to describe both the instability and its resolution. The mechanism thereby offers a parsimonious bridge between absolute non-existence and the observed universe, complementing rather than replacing existing proposals.

The paper is organized as follows. Section 2 formalizes the Non-Existence Collapse within the minisuperspace approximation and the Wheeler–DeWitt equation. Section 3 compares the proposal in detail with Vilenkin tunneling, the Hartle–Hawking no-boundary state, and recent bounce cosmologies. Section 4 discusses potential observational implications and falsifiability. We conclude in Section 5 with broader physical and philosophical consequences.

The central mechanical insight underlying the Non-Existence Collapse framework was first conceived by the author in late 1999, with the initial formulation documented in an envelope postmarked October 26, 2000, and has been refined in light of developments in quantum cosmology since that time.

2 Formalization of the Non-Existence Collapse in Minisuperspace and the Wheeler–DeWitt Equation

To give the proposed mechanism a concrete mathematical embodiment, we adopt the minisuperspace approximation, which reduces the infinite-dimensional superspace of all possible 3-geometries to a finite-dimensional configuration space parameterized by a small number of collective coordinates. For the simplest homogeneous and isotropic cosmology we consider the closed Friedmann–Lemaître–Robertson–Walker (FLRW) line element

$$ds^2 = -N^2(t)\,dt^2 + a^2(t)\,d\Omega_3^2, \tag{1}$$

where $a(t)$ is the scale factor and $N(t)$ is the lapse function. In this reduced model the only dynamical degree of freedom is the scale factor a, whose conjugate momentum is $p_a = -6\pi a\dot{a}/N$ (in units where $8\pi G = 1$). The spatial volume vanishes as $a \to 0$, so the limit $a \to 0$ provides a natural identification with the boundary of absolute non-existence: no classical geometry, no matter content, and no notion of classical time.

Canonical quantization of the Hamiltonian constraint $\mathcal{H} = 0$ of general relativity yields the timeless Wheeler–DeWitt equation [5]

$$\left[-\frac{\hbar^2}{2M}\frac{d^2}{da^2} + V(a) \right] \Psi(a) = 0, \tag{2}$$

where M is a constant proportional to the Planck mass squared (exact factor-ordering choices affect only sub-leading corrections near $a \to 0$) and $V(a)$ is the effective minisuperspace potential. For a closed universe without matter but with a small positive cosmological constant Λ (or equivalent vacuum energy), the leading form of the potential is

$$V(a) \propto -a + \frac{\Lambda}{3}a^3 + \text{higher-order curvature terms}. \tag{3}$$

Near $a \to 0$ the dominant term is linear and negative, so the potential behaves as an inverted harmonic oscillator: the wave function $\Psi(a)$ cannot remain confined to a stationary state at the origin. A perfectly static configuration with $\Psi(0) = 0$ and $\Psi'(0) = 0$ is forbidden by the Heisenberg uncertainty principle applied to the gravitational degrees of freedom (conjugate pair a and p_a). In other words, absolute non-existence possesses "nowhere to go" but to collapse into itself.

This dynamical instability is the mathematical realization of the Non-Existence Collapse. The wave function $\Psi(a)$ either tunnels through the barrier in the classically forbidden region (Vilenkin-type behavior) or evolves smoothly away from the null boundary (no-boundary-type behavior). At the Planck scale, $a \sim \ell_{\text{Pl}}$, full quantum-gravitational effects—whether arising from loop quantum cosmology (discrete area/volume operators), quadratic gravity, or any ultraviolet completion—replace the classical divergence with a finite maximum density $\rho_{\text{max}} \approx \rho_{\text{Pl}} \sim 5 \times 10^{94} \text{ g cm}^{-3}$. The repulsive character of the quantum-corrected potential prevents a true singularity and drives the system into a classically allowed regime where $a \gg \ell_{\text{Pl}}$.

In that regime the WKB (semi-classical) approximation becomes valid,

$$\Psi(a) \approx \frac{1}{\sqrt{p(a)}} \exp\left(\pm\frac{i}{\hbar} \int^a p(a')\,da' \right), \tag{4}$$

and a classical spacetime trajectory $a(t)$ with a well-defined arrow of time emerges via decoherence or the Born–Oppenheimer separation of gravitational and matter degrees of freedom. Thus spacetime, time, and the expanding universe are bootstrapped directly from the quantum-gravitational dynamics of the collapse itself.

Within this framework quantum gravity is not an auxiliary patch applied after the fact; it is the minimal and self-evident structure required to describe both the instability of the null state and its resolution. The entire transition—from absolute non-existence to the observed cosmos—is therefore a single, law-governed quantum-gravitational process.

2.1 Relational Extension

To generalize beyond minisuperspace, introduce a relational coordinate R measuring differentiation ($R \to 0$ at the non-relational null state). The effective potential diverges as $R \to 0$, enforcing instability:

$$V(R) = \frac{\lambda}{R^2} + \frac{1}{2}kR^2 + \cdots \tag{5}$$

The relational Wheeler–DeWitt equation then reads

$$\left[-\frac{\hbar^2}{2M}\frac{d^2}{dR^2} + \frac{\lambda}{R^2} + V_{\text{coh}}(R) \right] \Psi(R) = 0. \tag{6}$$

This form ensures that the wave function cannot remain confined near $R = 0$, driving tunneling or smooth evolution toward finite relational structure and bootstrapping the emergence of classical spacetime.

3 Comparison with Established Frameworks

The Non-Existence Collapse mechanism is not intended to supplant existing proposals but to provide a minimal dynamical underpinning that unifies several of their central insights. By framing the transition from absolute non-existence as an intrinsic instability resolved by quantum-gravitational dynamics, it supplies a mechanical "why" that many approaches leave implicit. In this section we compare the proposal with four major lines of research.

3.1 Quantum Tunneling from Nothing (Vilenkin)

Vilenkin's tunneling proposal [3] describes the spontaneous nucleation of an inflating universe from a state of literal nothing via quantum barrier penetration in minisuperspace. The wave function is taken to be exponentially damped in the classically forbidden region, yielding a non-zero probability for the emergence of a closed de Sitter bubble. Recent work has continued to explore and refine this picture, including Monte Carlo path-integral studies of the tunneling amplitude [7] and detailed analyses of toroidal topologies [11], which conclude that semiclassical tunneling may require essential Planck-scale input in certain geometries.

The Non-Existence Collapse shares the same starting point—absolute non-existence—but reframes the transition as a dynamical self-resolution rather than a probabilistic event across a predefined barrier. The Wheeler–DeWitt dynamics near $a \to 0$ show that the null state is unstable; the "collapse into itself" is the tunneling process in mechanical form. This removes the need for an external contour prescription while preserving the successful prediction of immediate inflation.

3.2 Hartle–Hawking No-Boundary Proposal

The Hartle–Hawking wave function [4] assigns the quantum state of the universe to a smooth, compact Euclidean 4-geometry with no initial boundary or edge. Recent consistent evaluations of the gravitational path integral have strengthened the proposal, showing that the no-boundary state dominates probabilities for closed universes up to non-perturbative corrections [8].

Our mechanism is fully compatible with the no-boundary philosophy: the collapse smooths the null configuration into a rounded geometry without any sharp edge. The key addition is an explicit dynamical driver—the Heisenberg uncertainty applied to gravitational degrees of freedom—that explains why the wave function behaves this way. In the Non-Existence Collapse picture, the

Euclidean-to-Lorentzian transition arises naturally from the real-time evolution of the unstable null state rather than being imposed as a boundary condition.

3.3 Loop Quantum Cosmology and Bounce Scenarios

Loop quantum cosmology resolves the classical singularity through repulsive quantum-geometry effects at Planckian densities, replacing the big bang with a nonsingular bounce [6]. Recent extensions to inhomogeneous models demonstrate dynamical homogenization after the bounce [9], while modified LQC frameworks show rapid damping of shear and anisotropies in the deep quantum regime [15].

In loop quantum cosmology, repulsive quantum-geometry effects at Planckian densities replace the classical singularity with a nonsingular bounce, often modeled as a symmetric rebound from a prior contracting phase. The Non-Existence Collapse framework offers a complementary dynamical origin: the high-density regime is reached through the mechanical collapse of absolute non-existence, driven by the intrinsic instability of the null state under quantum principles. This makes the nonsingular transition the source origination of expansion, rather than a recursive rebound from a prior cosmological phase.

The mechanism therefore provides a dynamical origin for the high-curvature state that LQC then resolves, tracing the entire chain—from absolute non-existence to classical expansion—within a single quantum-gravitational process.

3.4 Quadratic Gravity and Ultraviolet Completions

Quadratic gravity offers a renormalizable ultraviolet completion in which higher-curvature terms become dominant at high energies and can drive inflation without an external inflaton field. Recent work shows that such theories provide a smooth quantum completion of the Big Bang, with quadratic terms naturally generating the post-collapse expansion [10].

This dovetails especially cleanly with the Non-Existence Collapse. At the Planck-scale transition the quadratic (and higher) curvature corrections are no longer perturbative; they constitute the very dynamics that resolve the null-state instability and bootstrap classical spacetime. Quantum gravity thus emerges as self-evident: the same theory required to describe the collapse also supplies the ultraviolet completion of the subsequent cosmology.

3.5 Classical Geometric Creation from Nothing (Mannheim)

Recent work by Mannheim [14] proposes a classical geometric model in which a universe emerges from "nothing" via symmetry reduction in conformal gravity, with the Einstein tensor vanishing in a specific gauge to produce a closed de Sitter solution without matter fields. This approach provides an alternative to the cosmological principle by allowing creation from a vacuum state with negative energy modes.

While Mannheim's model achieves a mathematical creation from nothing in a classical framework, the present Non-Existence Collapse mechanism adds a quantum-dynamical dimension: the absolute null state is intrinsically unstable under quantum principles (Heisenberg uncertainty on gravitational degrees of freedom), forcing a mechanical collapse into a Planck-scale density regime that resolves nonsingularly via quantum gravity. This makes quantum gravity self-evident as the language of the transition, rather than an auxiliary correction to a classical solution. The two approaches are complementary: Mannheim's geometric "how" can be seen as an effective description within the quantum-dynamical "why" provided here.

In summary, the Non-Existence Collapse does not contradict these frameworks. Instead, it offers a unifying mechanical lens in which absolute non-existence is dynamically forced to resolve via quantum gravity. By making the necessity of a full quantum theory of gravity transparent at every step, the proposal may help guide the selection and refinement of specific quantization schemes and boundary conditions in future work.

4   Observational Implications and Falsifiability

While the Non-Existence Collapse is a theoretical framework operating at Planck scales far beyond direct access, it implies subtle but potentially distinguishable imprints on late-universe observables. These arise from the specific dynamics of the collapse-to-expansion transition, which differs in detail from purely classical inflationary scenarios or from other quantum-cosmological models.

The collapse resolves the null state into a finite-density, nonsingular regime where quantum-gravitational effects (repulsive geometry in LQC-like terms or higher-curvature dominance in quadratic gravity) dominate briefly before classical expansion takes over. This phase can generate a characteristic spectrum of primordial perturbations and gravitational waves (GWs) that deviates mildly from the standard slow-roll inflationary power spectrum.

Primordial tensor modes (primordial gravitational waves) are particularly promising. In conventional inflation, the tensor-to-scalar ratio r is set by the energy scale during slow-roll, and the spectrum is nearly scale-invariant with small running. The Non-Existence Collapse transition, however, introduces a brief high-curvature epoch where the effective equation of state and propagation of tensor modes may produce slight blue-tilted or suppressed features at small scales, or modified damping during propagation [12]. Current pulsar timing array (PTA) hints of a nanohertz stochastic GW background remain consistent with GR-like propagation but allow small deviations in damping parameters that future SKA observations could constrain to high precision, potentially ruling out or supporting collapse-specific modifications.

On CMB scales, the mechanism predicts consistency with Planck data but possible subtle deviations in the low-multipole power suppression or non-Gaussianity statistics if the collapse homogenizes inhomogeneities asymmetrically [9]. Future high-resolution CMB polarization experiments (e.g., Simons Observatory, CMB-S4) targeting B-modes from primordial GWs could detect or bound the tensor spectrum shape, distinguishing collapse-initiated emergence from standard inflation if the transition imprints a characteristic cutoff or tilt [13].

Large-scale structure observables (galaxy power spectrum, BAO, redshift-space distortions) provide complementary tests. The post-collapse inflationary phase should reproduce the observed amplitude and near-scale-invariance, but any residual inhomogeneity suppression from the bounce could manifest as mild deviations in the matter power spectrum at intermediate scales, testable with upcoming DESI/Euclid data.

In summary, the Non-Existence Collapse is falsifiable: a decisive detection of scale-invariant primordial B-modes with $r \gtrsim 0.01$ and no anomalous tilt/damping would favor conventional inflation over collapse-specific dynamics. Conversely, future non-detection of expected inflationary GWs, combined with PTA/SKA bounds favoring modified tensor propagation, would strengthen the case for a quantum-gravitational bootstrap origin. While direct Planck-scale signatures remain elusive, these indirect probes offer meaningful avenues for empirical discrimination.

5 Conclusions

We have presented the Non-Existence Collapse as a minimal dynamical mechanism for the origin of the universe. Absolute non-existence—a configuration with no spacetime, matter, fields, or classical time—is shown to be intrinsically unstable under the joint action of quantum mechanics and gravity. The Heisenberg uncertainty principle applied to gravitational degrees of freedom forbids any static null state. The framework is deliberately ruthless in its parsimony: it subtracts the unwarranted assumption of stability at absolute non-existence and lets the joint structure of quantum mechanics and gravity do the rest.

This self-resolution drives the configuration through a nonsingular, Planck-scale density regime where quantum-gravitational dynamics dominate, bootstrapping classical spacetime geometry and the arrow of time without external causes, pre-existing substrates, or auxiliary fields.

A central result is that quantum gravity emerges as self-evident: it is the necessary and minimal descriptive language for both the instability of the null state and its dynamical resolution. The mechanism therefore transforms the longstanding philosophical question "why something rather than nothing?" into a physical inevitability governed by the structure of quantum gravity itself.

The proposal aligns naturally with and refines several established frameworks. It provides a mechanical interpretation of Vilenkin tunneling, complements the Hartle–Hawking no-boundary state by supplying an explicit dynamical driver, incorporates the repulsive resolution of singularities in loop quantum cosmology, and dovetails with the ultraviolet completion offered by quadratic gravity and higher-curvature theories. By unifying these insights under a single collapse-driven bootstrap, the framework offers conceptual economy without introducing new ad-hoc elements.

Several directions remain open for future investigation. A more detailed treatment in full superspace (beyond minisuperspace) could reveal how inhomogeneities and anisotropies are suppressed during the collapse phase. Explicit calculations in loop quantum cosmology or quadratic gravity would allow quantitative predictions for the post-collapse power spectrum and tensor modes. Observational constraints from upcoming CMB polarization experiments, pulsar timing arrays, and large-scale structure surveys may ultimately distinguish collapse-initiated emergence from conventional inflationary scenarios, providing empirical tests of the proposed mechanism.

If the Non-Existence Collapse withstands such scrutiny, it would represent a parsimonious step toward a complete quantum-cosmological description of the universe's origin—one in which the transition from nothing is not merely possible, but dynamically required.

In the post-collapse regime the unitary wavefunction, seeded by the same gravitational uncertainty that destabilized the null state, naturally branches via decoherence into a hierarchical tree of classical realizations — offering a clean bridge to Everettian many-worlds interpretations and the observed fractal-like hierarchy of cosmic structure.

While the present framework focuses on the quantum-gravitational origin of spacetime, the underlying instability and self-resolution principle may naturally extend to the emergence and organization of structure at astrophysical and cosmological scales—a direction for future investigation.

Acknowledgments

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