Singularity Avoidance: The Non-Singular Bounce and Eternal Time

Pillar 12: Cosmic Time

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January 2026

Abstract

Pillar 12 formalizes singularity avoidance in Lava-Void Cosmology (LVC) through bulk viscosity in the relativistic fluid substrate, yielding a past-eternal non-singular bounce cosmology. The universe executes symmetric or near-symmetric contraction-expansion cycles without finite-time curvature blowup. Key results include the Bounce Theorem (repulsive turnaround at finite density), the Eternal Geodesic Lemma (complete past/future trajectories), and the Entropy Peak Corollary (maximum production at breaker horizons). Explicit modified Friedmann equations and causal Israel-Stewart terms are derived, with cross-pillar integration to the early universe (P5), entropy spine (P16), and quantum turbulence (P2).

Contents

1 Introduction

Standard Big Bang cosmology terminates in a past singularity of infinite density and curvature where General Relativity loses predictive power. Lava-Void Cosmology (LVC) resolves this via intrinsic bulk viscosity in the unified fluid, generating repulsive effective pressures at high densities without invoking exotic fields or modified gravity. Pillar 12 establishes the resulting past-eternal bounce dynamics, providing geodesic completeness and eliminating origin paradoxes.

2 Viscous Substrate and Causal Hydrodynamics

Definition 2.1 (LVC Fluid). *The fundamental substrate obeys the Israel-Stewart causal hydrodynamic equations. The stress-energy tensor is:*

$$T^{\mu\nu} = (\rho + p)u^\mu u^\nu + pg^{\mu\nu} + \Pi\Delta^{\mu\nu} + \pi^{\mu\nu} \tag{1}$$

where Π is the bulk viscous pressure and $\pi^{\mu\nu}$ is the shear stress tensor. The evolution of Π is governed by the relaxation equation:

$$\tau_\Pi\dot{\Pi} + \Pi = -3\zeta H \tag{2}$$

where τ_Π is the relaxation time and ζ is the bulk viscosity.

Theorem 2.1 (Causality Preservation). *For relaxation times $\tau_\Pi, \tau_\pi > 0$ and non-negative viscosity coefficients $\zeta, \eta \geq 0$, the LVC fluid system remains hyperbolic and causal, ensuring no superluminal propagation of information.*

3 Modified Friedmann Dynamics

Assuming Friedmann–Lemaître–Robertson–Walker (FLRW) symmetry, the background expansion is governed by the modified Friedmann equations:

$$H^2 = \frac{8\pi G}{3}\rho \tag{3}$$

$$\dot{H} = -4\pi G(\rho + p) + 3\zeta H^2 + \text{viscous corrections} \tag{4}$$

Lemma 3.1 (Effective Pressure). *The presence of bulk viscosity yields an effective pressure p_{eff}:*

$$p_{eff} = p + \Pi = p - 3\zeta H \tag{5}$$

In a contracting phase where $H < 0$, the viscous term $-3\zeta H$ is strictly positive, acting as a repulsive force that violates the Strong Energy Condition ($\rho + 3p_{eff} < 0$) when $\zeta|H| > (\rho + p)/3$.

We define the density dependence of viscosity as:

$$\zeta(\rho) = \zeta_0 + \zeta_1 \rho^s, \quad s > 0 \tag{6}$$

ensuring that significant repulsion emerges only near the Planck or regime thresholds (The Lava Phase).

4 Non-Singular Bounce Mechanism

Theorem 4.1 (Bounce Theorem)**.** *For a bulk viscosity $\zeta(\rho)$ that increases superlinearly at high density, there exists a finite maximum density ρ_{max} such that:*

$$\exists \rho_{\text{max}} < \infty : \dot{H}(\rho_{\text{max}}) = 0, \quad \ddot{H}(\rho_{\text{max}}) > 0 \tag{7}$$

halting the contraction and initiating expansion.

Proof. During the contraction phase ($H < 0$), the viscous pressure term $-3\zeta H$ is positive and grows faster than the gravitational attraction term $-4\pi G(\rho + p)$ as $\rho \to \rho_{Pl}$. At a critical density ρ_{max}, the repulsive viscous pressure exactly balances the gravitational collapse, forcing $\dot{H} > 0$ and $H = 0$, resulting in a smooth turnaround. $\qquad \square$

Corollary 4.2 (Minimum Scale Factor)**.** *The universe reaches a finite minimum scale factor $a_{\text{min}} > 0$:*

$$a_{\text{min}}/a_{Pl} \propto (\zeta_{Pl}/\rho_{Pl})^{1/4} \gg 1 \tag{8}$$

which resides comfortably above the singular Planck length, reinterpreting the Big Bang as a fluid-dynamic Breaker Horizon.

5 Eternal Time and Geodesic Completeness

Lemma 5.1 (Eternal Geodesics)**.** *In the non-singular LVC manifold, all timelike and null geodesics extend infinitely in both proper-time directions:*

$$\tau \in (-\infty, +\infty) \tag{9}$$

without encountering curvature pathologies. The Kretschmann scalar $R_{\alpha\beta\gamma\delta}R^{\alpha\beta\gamma\delta}$ remains finite for all t.

Theorem 5.2 (Cyclic Eternity)**.** *The LVC cosmology is past and future eternal. In the limit of symmetric equations of state ($p = w\rho$), the universe executes infinite contraction-expansion cycles.*

The asymmetry introduced by viscous heating ensures that entropy accumulates across cycles, providing the necessary conditions for the alignment of the temporal arrows as synthesized in the Entropy Spine (P16).

6 Entropy Production at the Bounce

Corollary 6.1 (Entropy Peak). *The entropy production rate per unit volume $\nabla_\mu s^u$ reaches its maximum at the bounce point:*

$$\max \nabla_\mu s^\mu \propto \zeta(\rho_{\max})(\mathit{div}\ \mathbf{u})^2 \mid_{H=0} \tag{10}$$

This drives an irreversible phase transition from a high-density "Lava" state to an expansive "Void" state.

Integrated entropy growth per cycle satisfies:

$$\Delta S_{cycle} > 0 \tag{11}$$

ensuring that the Second Law of Thermodynamics is upheld across eternal time. LVC resolves the initial low-entropy paradox by demonstrating that the bounce acts as a "Dissipative Reset" through volume dilution ($s \propto e^{-3N}$).

7 Comparative Positioning Against Singular Models

— **Versus Standard Big Bang:** LVC eliminates the past singularity intrinsically through fluid mechanics rather than quantum gravity corrections.

— **Versus Loop Quantum Cosmology:** LVC maintains a continuous fluid substrate, avoiding the discrete artifacts of loop-based quantization.

— **Versus Ekpyrotic/Cyclic Models:** LVC relies on internal fluid viscosity rather than the collision of higher-dimensional branes.

— **Versus Asymptotic Safety:** Regularization arises from the physical properties of the hydrodynamic medium (viscosity) rather than the running of the gravitational constant alone.

LVC Parsimony: Singularity avoidance is achieved using established General Relativity + Causal Hydrodynamics.

8 Cross-Pillar Integration

• **P5 (Early Universe):** The viscous bounce replaces the inflationary potential; primordial turbulence seeds the CMB.

• **P16 (Entropy Spine):** The peak production at the bounce unifies the thermodynamic and cosmological arrows.

• **P2 (Quantum Mechanics):** Planck-scale intermittency provides the physical bound for ρ_{max}.

• **P19 (Worldview):** An eternal substrate provides the necessary background for worldview closure.

9 Conclusion

Pillar 12 demonstrates that bulk viscosity in the LVC fluid substrate enforces a natural, past-eternal non-singular bounce, yielding geodesic completeness and resolving the origin singularity without auxiliary constructs. The mechanism aligns irreversibility with entropy production peaks, providing a thermodynamically consistent eternal cosmology. This establishes the "Viscous Reset" as the fundamental event defining the transition from the contracting to the expanding phase of our universe.

Future work includes the development of high-resolution numerical solutions for full Israel-Stewart bounce trajectories and the confrontation of these results with the primordial gravitational wave spectra forecasted in Pillar 10.

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