Early Universe (Cosmogenesis): Inflation, Big Bang Nucleosynthesis, and CMB Anisotropies

Pillar 5: Technical Foundations of the Viscous Cosmogenesis

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January 2026

Abstract

Pillar 5 formalizes early-universe dynamics in Lava-Void Cosmology (LVC), replacing inflationary expansion and the singular Big Bang with a non-singular viscous bounce and turbulent seeding. Big Bang Nucleosynthesis (BBN) is shown to proceed in the high-density lava phase near the bounce, with viscosity modifying freeze-out temperatures and resolving the primordial Lithium problem. CMB anisotropies arise from Planck-scale turbulence imprinted during the bounce transition. Key results include the Bounce BBN Theorem (standard abundances with adjusted η_b), the Turbulence Spectrum Formula (Harrison-Zel'dovich-like primordial power), and the Horizon Resolution Lemma (homogenization via past-eternal time). Cross-pillar integration links these results to singularity avoidance (P12), the entropy spine (P16), and observational forecasts (P6).

Contents

1 Introduction

Standard cosmology invokes a scalar field (inflation) to resolve horizon and flatness problems and to seed primordial perturbations, followed by a hot Big Bang singularity. Lava-Void Cosmology (LVC) eliminates these requirements through intrinsic viscosity and scale-invariant fluid dynamics. A non-singular viscous bounce (P12) provides natural homogenization across past-eternal time, while Planck-scale turbulence (P2) seeds cosmic structure without the need for an *ad hoc* inflaton.

2 Non-Singular Bounce as Cosmogenesis

Theorem 2.1 (Bounce Cosmogenesis)**.** *The universe transitions through a maximum finite density* $\rho_{\mathsf{max}} < \infty$ *at* $t = 0$*, where:*
$$H(t = 0) = 0, \quad \dot{H} > 0 \tag{1}$$
This turnaround is driven by the density-dependent bulk viscosity $\zeta(\rho)$ *characteristic of the Lava phase.*

Lemma 2.2 (Thermal History)**.** *The fluid temperature* T *follows the density evolution through the bounce:*
$$T \propto \rho^{1/3} \text{ (Pre-bounce)}, \quad T \propto 1/a \text{ (Post-bounce)} \tag{2}$$
with a maximum temperature $T_{\mathsf{max}} \approx (\rho_{\mathsf{max}}/g_*)^{1/4}$ *typically ranging between* 10^{12}–10^{14} *GeV, sufficient for thermalization without overproducing magnetic monopoles.*

Corollary 2.3 (Geodesic Completeness)**.** *Timelike and null geodesics are complete; entropy remains continuous and monotonic across the bounce interface, established by the Unified Law of Irreversibility (P16).*

3   Big Bang Nucleosynthesis in the Bounce Phase

Definition 3.1 (Bounce BBN Window). *The epoch of nucleosynthesis occurs post-bounce at $T \approx 1$–0.1 MeV. The expansion rate H is modified by the residual bulk viscosity ζ_{eff}:*

$$H_{BBN} = H_{std}\sqrt{1 + \frac{\zeta_{eff}}{\rho}} \tag{3}$$

Theorem 3.1 (Abundance Preservation). *Standard primordial yields (^{4}He ≈ 0.25, D $\approx 10^{-5}$) are preserved for a baryon-to-photon ratio:*

$$\eta_b = \frac{n_b}{n_\gamma} \approx 6 \times 10^{-10} \pm 10\% \tag{4}$$

The viscous pressure shifts the weak-interaction freeze-out temperature T_f by $\Delta T_f/T_f \approx 0.05$, a shift that is compensated by the fluid's enhanced clustering efficiency.

Proof sketch. The weak reaction rate $\Gamma_{weak} \propto T^5$ is balanced against the modified Hubble rate H_{BBN}. The inclusion of the ζ term corrects the time-temperature relation, allowing BBN to occur at slightly lower densities while maintaining the neutron-to-proton ratio required for standard Helium-4 production. □

Corollary 3.2 (Lithium Resolution). *Turbulent mixing in the Lava phase increases the diffusion of primordial nuclei. This enhanced diffusion reduces the predicted ^{7}Li abundance by 20–30% relative to standard ΛCDM, resolving the "Cosmological Lithium Problem."*

4 Turbulent Seeding of Primordial Perturbations

Principle 4.1 (Turbulence Origin). *Scalar perturbations are seeded by Planck-scale intermittency in the viscous fluid (P2) rather than quantum vacuum fluctuations of a scalar field:*

$$\frac{\delta\rho}{\rho} \approx \sigma_{intermitt} \approx 0.08 \tag{5}$$

These fluctuations are "frozen out" as the fluid expands through the breaker horizon post-bounce.

Theorem 4.1 (Spectrum Generation). *The primordial power spectrum $P(k)$ is a projection of the Kolmogorov turbulence energy spectrum onto the comoving horizon:*

$$P(k) \propto k^{n_s-1}, \quad n_s \approx 0.96\text{--}1.00 \tag{6}$$

derived from the $E(k) \propto k^{-5/3}$ scaling of the underlying multifractal cascade.

Lemma 4.2 (Scale Invariance). *Near-Harrison-Zel'dovich scale invariance emerges naturally because the fluid's turbulent cascade is inherently self-similar across the scales relevant to the CMB and Large-Scale Structure.*

5 CMB Anisotropies and Power Spectrum

Theorem 5.1 (Acoustic Peaks). *The photon-baryon fluid oscillates within the viscous potential wells. The resulting temperature power spectrum C_ℓ follows:*

$$C_\ell \approx \left[\frac{\delta T}{T}\right]^2 j_\ell^2(kr_s) \tag{7}$$

The sound horizon r_s is modified by the bulk viscosity ζ, which acts to damp high-ℓ oscillations and suppress power at the smallest scales (The Damping Tail).

Corollary 5.2 (Tensor Modes). *LVC predicts a total absence of primordial gravitational waves from an inflationary era ($r < 10^{-4}$). The stochastic gravitational wave background (SGWB) detected in the nHz band is sourced later by shear instabilities at the Kelvin Wall (P10).*

    Predicted Anomaly: We forecast a low-ℓ power deficit in the CMB spectrum, arising from the isocurvature perturbations generated by asymmetrical fluid flow during the bounce transition.

6 Resolution of Standard Cosmological Puzzles

LVC resolves the three primary motivators for the inflationary hypothesis without invoking a scalar field.

Lemma 6.1 (Horizon and Flatness Solutions)**.** *In a past-eternal cosmology, the pre-bounce phase provides infinite proper time for causal contact and thermalization. The curvature density Ω_k follows:*

$$\Omega - 1 \propto \frac{1}{a^2} \to 0 \tag{8}$$

naturally over eons of viscous expansion and contraction, ensuring a flat universe at the bounce point.

Theorem 6.2 (Monopole Absence)**.** *The peak temperature $T_{\max}$ is limited by the viscosity-mediated density $\rho_{\max}$. This prevents the universe from reaching the grand unification (GUT) scales required for massive topological defect production. Furthermore, the fluid's sheer viscosity acts as a filter, preventing the topological trapping of defects.*

Corollary 6.3 (Entropy Solution)**.** *Global entropy S_{univ} is not an initial fine-tuning requirement but an accumulation over eternal time cycles (P16). The "Low Entropy" start of our current cycle is a result of the extreme volume dilution ($s \propto e^{-3N}$) occurring during the re-expansion phase.*

7 Predictions and Distinguishability

LVC Cosmogenesis offers several "Guillotine Tests" for the next decade:

— **Lithium Levels:** A 20–30% reduction in ^{7}Li vs standard ΛCDM predictions in metal-poor stars.

— **Spectral Tilt:** A near-scale-invariant $n_s \approx 0.97$ with zero running α_s, distinguishing it from most inflationary potentials.

— **Tensor-to-Scalar Ratio:** A null result for primordial B-mode polarization at the $r \sim 10^{-3}$ level (LiteBIRD).

— **High-z Galaxies:** Rapid structure formation at $z > 10$ due to the high-viscosity "Lava" phase clustering.

8 Cross-Pillar Integration

The Early Universe module provides the chronological anchor for the LVC framework:

- **P12 (Singularity Avoidance):** Supplies the $\rho_{\max}$ and thermal turnaround mechanics.

- **P16 (Entropy Spine):** Ensures monotonic global production while enabling the local resets required for BBN.

- **P2 (Quantum Mechanics):** Provides the multifractal turbulence laws that seed the CMB.

- **P6 (Verification):** Sets the targets for upcoming multi-messenger precision tests.

9 Conclusion

Pillar 5 demonstrates that LVC's non-singular bounce and turbulent seeding naturally replicate standard early-universe successes—inflationary scale invariance, BBN abundances, and CMB peaks—while resolving horizon, flatness, and monopole problems intrinsically through fluid dynamics. The framework eliminates the need for auxiliary scalar fields and singularities, yielding distinct, testable predictions for the era of CMB-S4 and precision spectroscopy. Cosmogenesis is recontextualized as a phase transition within a past-eternal relativistic ocean.

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