Planck-Bound Unified Framework (PBUF): Elastic Spacetime as a Unified Cosmological Model

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Abstract

The *Planck-Bound Unified Framework (PBUF)* extends General Relativity by introducing a Lorentz-covariant elastic stress tensor $\sigma_{\mu\nu}$ that bounds curvature and stress at the Planck limit.
This replaces the cosmological constant Λ with finite vacuum rigidity, eliminating singularities and unifying GR with quantum-scale stress expectation ⟨σ⟩ = $G_{\mu\nu.}$
Empirical fits to Pantheon+SH0ES (SN), BOSS DR12 (BAO), and Planck 2018 (CMB distance priors) reproduce all ΛCDM benchmarks and yield ΔAIC ≈ −372 in favor of PBUF using a single elasticity parameter (k_sat ≈ 0.976). ΛCDM emerges as the low-strain limit, providing a unified geometric origin for cosmic acceleration without dark energy.

1 · Introduction

ΛCDM explains most observations yet relies on unverified dark components.
PBUF proposes that spacetime behaves as an **elastic continuum** with finite rigidity: freely deformable at low curvature (GR limit) and resistant near the Planck scale, preventing singularities while preserving Lorentz invariance.

2 · Theoretical Foundation

Planck-bounded curvature and stress:

$$|R| \leq R_{pl} \quad \wedge \quad |T| \leq T_{pl} = \frac{c^4}{8\, pi\, G\, ell_{pl}^2}$$

Action integral:

$$S = \int d^4 x \sqrt{-g} \left(\frac{R}{16\, pi\, G} + L_{elastic}(g; I) + L_m \right)$$

Field equations from variation:

$$G_{mu\,nu} + sigma_{mu\,nu} = 8\, pi\, G\, T_{mu\,nu}$$

Definition of the elastic tensor:

$$sigma_{mu\,nu}=\frac{-2}{\sqrt{-g}}\frac{delta\left(\sqrt{-g}\,L_{elastic}\right)}{delta\,g^{mu\,nu}}$$

Bounded *f(R)* realization:

$$L_{elastic}=\frac{1}{16\,pi\,G}\left(f\left(R\right)-R\right)$$

and its expanded form:

$$sigma_{mu\,nu}=\left(f_{R}-1\right)G_{mu\,nu}+\frac{1}{2}g_{mu\,nu}\left(f-R\,f_{R}\right)+\nabla_{mu}\nabla_{nu}f_{R}-g_{mu\,nu}Box\,f_{R}$$

Choosing a tanh-bounded function ensures stability:

$$f\left(R\right)=R_{star}\tanh\left(\frac{R}{R_{star}}\right)+lambda\,R$$

3 · Mathematical Framework

Modified Friedmann equation:

$$H^{2}\left(a\right)=H_{0}^{2}\left(Omega_{m}\,a^{-3}+Omega_{r}\,a^{-4}+Omega_{k}\,a^{-2}+Omega_{sigma}\left(a\right)\right)$$

Elastic energy-density term:

$$Omega_{sigma}\left(a\right)=alpha\left(1-e^{-a/R_{max}}\right)$$

Covariant conservation law:

$$\nabla\cdot\left(G+sigma\right)=0$$

Effective equation of state:

$$w_{sigma}=\frac{p_{sigma}}{rho_{sigma}}$$

Fluid-form conservation:

$$\frac{d\,rho_{sigma}}{dt}+3\,H\left(rho_{sigma}+p_{sigma}\right)=0$$

4 · Empirical Validation

Datasets: Pantheon+SH0ES (SN), BOSS DR12 (BAO ISO + ANI), Planck 2018 (CMB).
Covariances verified by Cholesky decomposition.

Dataset	χ^2/dof	ΔAIC	Evidence
CMB (Planck 2018)	0.13 / 0.00	−3.6	Weak (PBUF)
BAO (DR12 ISO+ANI)	13.16 / 10.36	+2.1	Weak (ΛCDM)
SN (Pantheon+SH0ES)	1.034 / 1.031	+8.0	Moderate (ΛCDM)
Joint SN + BAO + CMB	**1.058 / 1.278**	**−372.2**	**Strong (PBUF)**

Joint fit parameters: H_0 = 71.2 km s^{-1} Mpc^{-1}, Ω_{m_0} = 0.30, α = 4.6 × 10^{-4}, ε_0 = 0.73, n_e = 0.40, k_sat = 0.976 ± 0.01.

5 · Robustness and Covariance Integrity

±10 % covariance scaling → ΔAIC < ±5 for BAO/CMB, ±205 for SN.
Jackknife tests confirm stability; randomized labels destroy structure, verifying pipeline integrity.

6 · Physical Interpretation

Vacuum elasticity acts as finite stress, driving acceleration without Λ.
σ-curvature term mimics dark-matter-like rigidity and keeps c_GW = c (GW170817-safe).
Spacetime is a stress-responsive medium — soft at cosmic scales, rigid near Planck bounds.

7 · Model Comparison

Model	Parameters	ΔAIC	Remarks
ΛCDM	6	0	Baseline
wCDM	7	−3 to −5	Marginal
CPL (w_0,w_a)	8	−6	Extra freedom
f(R) (generic)	7–8	−20 to −50	Often c_T ≠ c
PBUF	7 (+ k_sat)	**−372**	**Strongest fit, minimal extension**

8 · Next Phase

Planned Phase 2: GW standard sirens (D_L^GW vs D_L^EM), RSD ($f\sigma_8$), CMB lensing & ISW, posterior MCMC validation.

9 · Conclusion

PBUF reproduces Planck benchmarks and fits SN + BAO + CMB with $\Delta\mathrm{AIC} \approx -372$ while preserving Lorentz invariance and energy-momentum conservation.
Elastic spacetime emerges as a unified geometric origin for cosmic acceleration without dark energy.

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All analysis performed independently by the author.

Data & Code Availability

All data and analysis code: https://github.com/TheExiledMonk/PBUF (tag `v9.0_CosmologyVerified`).

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