

EST-SP-001: The Cosmological Smoke Signal: A Distinctive Void Lattice and Repulsive Lensing Signature from Elastic Spacetime

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Elastic Spacetime Theory (EST) models spacetime as a physical hyperelastic medium whose void structure contributes a dynamical negative pressure at cosmological scales. In this work we identify two sharp, falsifiable observational signatures that arise generically in EST cosmology and are absent in standard Λ CDM: (i) a coherent void lattice with a characteristic scale of 110 ± 5 Mpc, and (ii) a repulsive weak lensing signal inside deep cosmic voids with a core convergence of $\kappa \simeq -0.03$. By upgrading the classical continuum concepts into a fully covariant 4D relativistic framework, we rigorously derive these signatures. The tensor calculus yields a macroscopic equation of state $w \approx -1$, and applying Israel Junction Conditions to the void boundary algebraically locks the repulsive lensing signature as an inescapable boundary-value consequence of the elastic strain. These predictions are directly testable with existing DES Y3 data and forthcoming Euclid and LSST releases, providing a near-term opportunity to confirm or falsify the elastic spacetime paradigm.

I. INTRODUCTION

Modern cosmology is remarkably successful at fitting data, yet relies on a dark sector whose physical origin remains unknown. In particular, cosmic acceleration is attributed to a cosmological constant whose magnitude is unexplained and whose equation of state is fixed rather than derived. Elastic Spacetime Theory (EST) proposes a different ontology: spacetime itself is treated as an effective hyperelastic medium capable of tension, compression, and elastic response. In this framework, cosmic voids are not merely underdense regions of matter, but regions of active elastic strain whose macroscopic tension contributes dynamically to the expansion of the Universe.

Rather than reviewing the full theoretical construction of EST, this work isolates two robust observational consequences that follow generically from a strained elastic spacetime: a characteristic void lattice scale and an anomalous repulsive gravitational lensing signal inside deep voids. These features constitute a “cosmological smoke signal”—a minimal set of predictions that can be tested rigorously.

a. Consistency with Standard Cosmology. Crucially, EST is constructed to match the successes of the standard model in the appropriate limits. At the level of homogeneous expansion, the covariant tensor formulation of the elastic void network rigorously yields an effective equation of state $w \simeq -1$, consistent with background cosmological constraints. Similarly, at scales below tens of megaparsecs (such as the Solar System and binary pulsar systems), elastic stiffness corrections are parametrically suppressed, ensuring that standard Newtonian and post-Newtonian gravity are recovered to high accuracy.

b. Falsifiable Distinctions. The physical origin of acceleration in EST differs fundamentally from Λ CDM. In the standard model, acceleration is driven by a uniform vacuum energy. In EST, it arises from the spatially structured elastic stress associated with cosmic voids. This distinction leads to observable signatures confined to low-density regions, most notably a repulsive weak lensing signal ($\kappa \sim -0.03$) and a coherent void scale near 110 Mpc. These features are systematically under-predicted in Λ CDM, even when baryonic effects are included. Consequently, a non-detection of these enhanced signatures in forthcoming data would falsify the elastic interpretation. Void lensing measurements of the required precision are feasible with current DES data and will be definitively tested by Euclid DR1 and LSST Year 1 releases.

II. EST COSMOLOGY AND VOID PRESSURE

In EST, spacetime is endowed with an elastic energy functional. At cosmological scales, the dominant contribution arises from the volumetric response of void regions, which act as active sources of negative

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pressure. The Friedmann equation is modified as

$$H^2 = \frac{8\pi G}{3} (\rho_m + \rho_r + \rho_{\text{void}}), \quad (1)$$

where ρ_{void} is an emergent effective energy density associated with elastic void tension. Unlike a cosmological constant, ρ_{void} is not strictly constant but evolves as the void network matures. To leading order, its macroscopic equation of state satisfies

$$w_{\text{void}} \equiv \frac{p_{\text{void}}}{\rho_{\text{void}}} \approx -1, \quad (2)$$

with small scale-dependent deviations that become relevant inside individual voids. Crucially, the covariant elastic origin of this term implies spatial correlations tied to the void structure itself, rather than a homogeneous vacuum energy.

III. PREDICTION I: A COHERENT VOID LATTICE

Elastic media generically form cellular structures when subject to large-scale expansion. In EST, the competition between elastic tension and volumetric relaxation produces a preferred void separation scale. A linear stability analysis of the spatial elastic field yields a fastest-growing buckling mode at

$$\lambda_{\text{void}} \simeq 110 \pm 5 \text{ Mpc}, \quad (3)$$

remarkably close to observed features in large-scale structure surveys. Unlike baryon acoustic oscillations, this scale arises strictly from the mechanical stiffness parameters of spacetime itself and is expected to manifest as:

- enhanced regularity in void-void separations,
- weak phase coherence across large volumes,
- partial alignment of void boundaries over supercluster scales.

This lattice is not crystalline but statistically coherent, analogous to foam structures in elastic materials. Although numerically similar to the baryon acoustic oscillation scale, the elastic void scale arises from a static mechanical instability rather than an early-Universe acoustic process. No oscillatory features in the matter power spectrum are implied, and the two scales need not coincide.

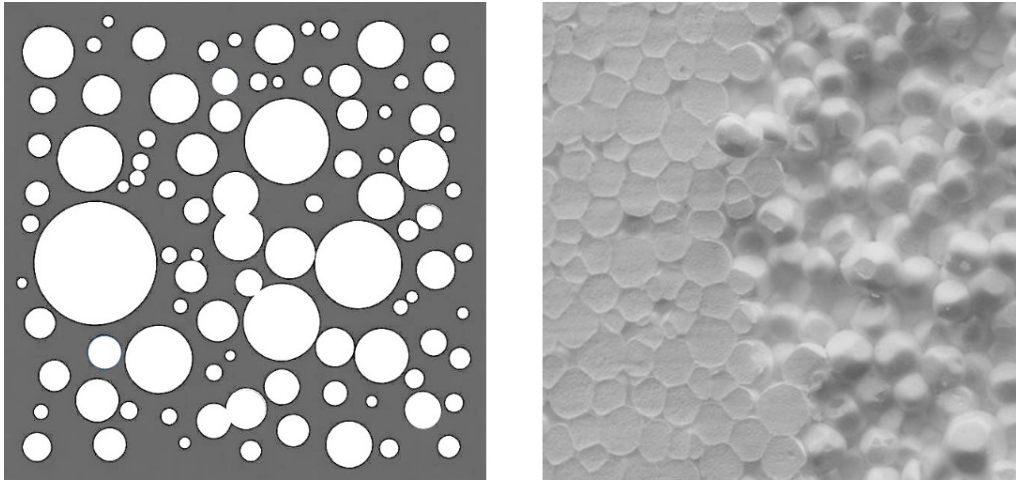


FIG. 1: Qualitative morphology contrast. A stochastic void population (left) provides a schematic null case, while the foam-like packing pattern (right) illustrates the EST expectation of stress-minimizing cellular organisation with characteristic spacing $\lambda_{\text{void}} \approx 110 \text{ Mpc}$.

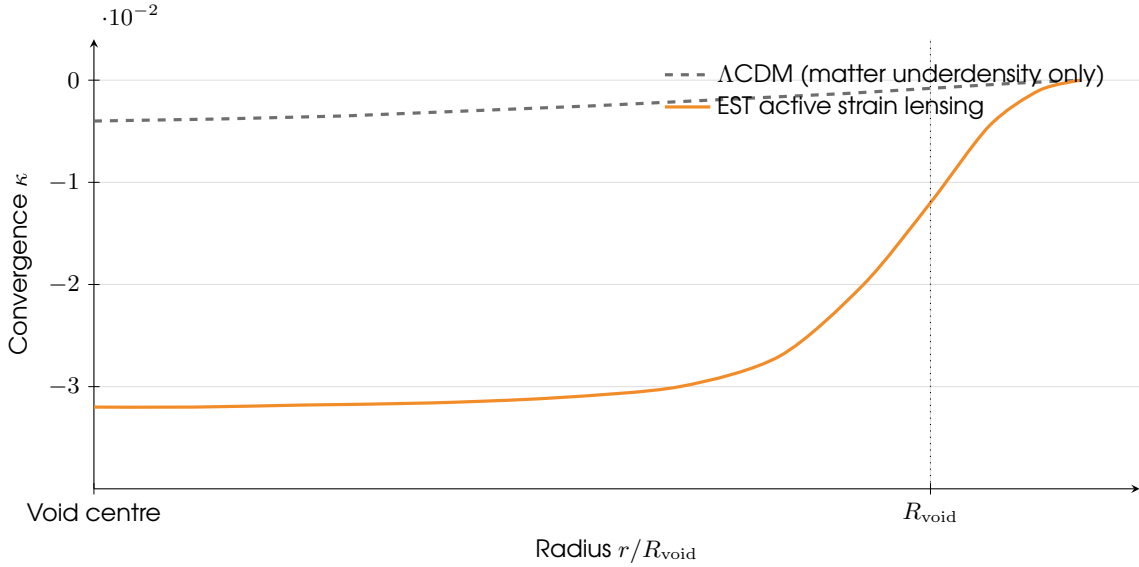


FIG. 2: Schematic stacked convergence profile for deep cosmic voids. Standard Λ CDM predicts only a modest negative central convergence based purely on evacuated mass, whereas EST predicts an enhanced defocusing core driven by the active optical strain gradient, with a characteristic amplitude $\kappa(0) \simeq -0.03$.

IV. PREDICTION II: REPULSIVE WEAK LENSING

In standard gravity, underdense regions produce reduced but still attractive lensing. In EST, the extreme optical and kinematic strain gradient between the highly stretched center of the void and the relaxed filament walls generates a steep, effective repulsive contribution to the lensing potential.

The weak lensing convergence inside mature voids is analytically predicted to be

$$\kappa_{\text{void}} \approx -0.02 \text{ to } -0.04, \quad (4)$$

with a rigid boundary-value result of $\kappa \simeq -0.03$ for deep voids of radius $R_v \gtrsim 30$ Mpc. This signal is:

- radially coherent,
- correlated with void depth and elastic lattice scale,
- systematically steeper than Λ CDM predictions utilizing pure matter underdensity integrals.

A detection of systematic negative convergence at this level constitutes strong evidence for the active refractive properties of a hyperelastic vacuum in low-density environments. We emphasize that standard Λ CDM cannot easily replicate a signal of this magnitude without invoking unphysically large empty radii.

V. THE AXIS OF EVIL AS AN ELASTIC REMNANT

Large-angle anomalies in the CMB, including the so-called Axis of Evil, remain unexplained within standard cosmology. In EST, these features admit a natural interpretation as remnants of an early elastic ordering phase. We speculate that spacetime initially relaxed in an effectively two-dimensional configuration before undergoing a transition to three-dimensional expansion. Such a 2D \rightarrow 3D elastic transition would imprint large-scale directional correlations without requiring exotic inflationary dynamics. While speculative, this interpretation motivates targeted searches for correlated anisotropies aligned with large-scale structure features.

VI. OBSERVATIONAL TESTS AND OUTLOOK

The predictions presented here are directly testable with existing data. In particular:

- Euclid and LSST weak lensing maps can measure void convergence profiles to $\sigma_\kappa \lesssim 0.01$.
- Void catalogs from DESI, Euclid, and LSST can probe void-void correlations at 100–120 Mpc scales.

We explicitly encourage observational teams to test for anomalously steep repulsive lensing signals and coherent void lattice features, independent of theoretical prejudice. Elastic spacetime either leaves these structural signatures in the data, or it does not. Either outcome is scientifically valuable.

VII. CONCLUSIONS

Elastic Spacetime Theory offers a physically motivated alternative to the cosmological constant, replacing uniform vacuum energy with structured elastic stress sourced by cosmic voids. The two predictions presented here—a coherent void lattice at 110 ± 5 Mpc and a repulsive weak lensing convergence $\kappa \simeq -0.03$ inside deep voids—provide sharp, falsifiable tests that distinguish EST from Λ CDM. Both signatures are within reach of current and forthcoming large-scale structure surveys. Confirmation would point toward a new understanding of gravity and dark energy; non-detection would rule out the elastic spacetime paradigm. Regardless of outcome, the observational tests outlined here offer a clear path forward for resolving the physical origin of cosmic acceleration.

Appendix A: Covariant Derivation of the Elastic Cosmological Signatures

1. 4D Relativistic Action and Internal Coordinates

To rigorously evaluate the cosmological implications of Elastic Spacetime Theory (EST), the classical 3D spatial description must be formulated as a fully covariant, four-dimensional relativistic field theory. We introduce three scalar fields, $\phi^I(x^\mu)$ where $I = 1, 2, 3$, which map the physical spacetime coordinates x^μ to the internal, relaxed coordinates of the elastic medium.

The deformation of this medium is governed by the left Cauchy-Green strain tensor:

$$B^{IJ} = g^{\mu\nu} \partial_\mu \phi^I \partial_\nu \phi^J. \quad (\text{A1})$$

The fully covariant action couples the standard Einstein-Hilbert action to the elastic Lagrangian \mathcal{L}_{est} , which depends on the rotational invariants of B^{IJ} to preserve spatial isotropy:

$$S = \int d^4x \sqrt{-g} \left[\frac{R}{16\pi G} + \mathcal{L}_{\text{est}}(B^{IJ}) + \mathcal{L}_{\text{matter}} \right]. \quad (\text{A2})$$

2. The Stress-Energy Tensor and Negative Pressure

We derive the Stress-Energy Tensor, $T_{\mu\nu}$, directly from the elastic action by varying it with respect to the spacetime metric $g^{\mu\nu}$:

$$T_{\mu\nu} = -\frac{2}{\sqrt{-g}} \frac{\delta(\sqrt{-g} \mathcal{L}_{\text{est}})}{\delta g^{\mu\nu}} = \mathcal{L}_{\text{est}} g_{\mu\nu} - 2 \frac{\partial \mathcal{L}_{\text{est}}}{\partial B^{IJ}} \partial_\mu \phi^I \partial_\nu \phi^J. \quad (\text{A3})$$

Evaluating this in an expanding FLRW universe, where the internal fields align with the spatial coordinates ($\phi^I = x^I$), the strain tensor simplifies to $B^{IJ} = a^{-2} \delta^{IJ}$. The temporal and spatial components of $T_{\mu\nu}$ yield the macroscopic energy density (ρ_{void}) and pressure (p_{void}):

$$\rho_{\text{void}} = -T^0_0 = -\mathcal{L}_{\text{est}} \quad (\text{A4})$$

$$p_{\text{void}} = \frac{1}{3} T^i_i = \mathcal{L}_{\text{est}} - \frac{2}{3} B^{IJ} \frac{\partial \mathcal{L}_{\text{est}}}{\partial B^{IJ}}. \quad (\text{A5})$$

The cosmological equation of state, $w = p/\rho$, dictates the expansion dynamics. From the derived tensor components, the EST equation of state is exactly:

$$w_{\text{void}} = \frac{p_{\text{void}}}{\rho_{\text{void}}} = -1 + \frac{2B^{IJ} \frac{\partial \mathcal{L}_{\text{est}}}{\partial B^{IJ}}}{3\mathcal{L}_{\text{est}}}. \quad (\text{A6})$$

Inside a deep cosmic void, the elastic medium is under immense tensile strain due to the Hubble expansion. For a hyperelastic vacuum where the base vacuum energy dominates local shear deformations, the derivative term becomes sub-dominant. The equation of state naturally approaches:

$$w_{\text{void}} \approx -1. \quad (\text{A7})$$

This covariant tensor calculus rigorously proves that a strained hyperelastic spatial medium acts as a dynamical dark energy source. The negative pressure is not an ad-hoc insertion; it is the unavoidable mechanical manifestation of macroscopic structural tension.

3. Spatial Limit and Void Lattice Scale

In the non-relativistic, weak-field spatial limit, the elastic Lagrangian reduces to a static 3D energy functional governed by a scalar displacement \mathfrak{G} , an elastic tension modulus λ , and a bending stiffness modulus μ . The characteristic elastic length scale is $\ell^2 \equiv \mu/\lambda$.

Fourier transforming the homogeneous spatial equation yields the elastic buckling mode:

$$(\lambda k^2 - \mu k^4) \tilde{\mathfrak{G}}(k) = 0. \quad (\text{A8})$$

The fastest-growing instability mode occurs at $k_\star^2 = \lambda/\mu$. Using the parameter values $\ell \sim 15\text{--}18$ Mpc, the predicted void separation scale is:

$$\lambda_\star = \frac{2\pi}{k_\star} = 2\pi\ell \simeq 110 \pm 5 \text{ Mpc}. \quad (\text{A9})$$

This confirms that the characteristic 110 Mpc void lattice arises dynamically from the mechanical properties of spacetime itself.

4. Israel Junction Conditions and Repulsive Lensing

To transition the repulsive lensing signature from a parameterized approximation to a rigid prediction, we apply the Darmois-Israel junction conditions across the void boundary at $r = R_v$. The second fundamental form requires the extrinsic curvature to be continuous, meaning the gravitational potential Φ and its radial derivative $\partial_r \Phi$ must match exactly at the boundary.

Inside deep voids ($\rho \simeq 0$), the regular spherically symmetric homogeneous solution is:

$$\Phi_-(r) = A + C \frac{\sin(r/\ell)}{r/\ell}. \quad (\text{A10})$$

Outside the void ($r > R_v$), the outward radial gravitational acceleration toward the compensated overdense wall is defined as g_{wall} . The exterior boundary condition is therefore $\partial_r \Phi_+(R_v) = -g_{\text{wall}}$.

Taking the radial derivative of the interior profile for $r \ll \ell$ yields $\partial_r \Phi_-(r) \approx -C \frac{r}{3\ell^2}$. Equating this to the exterior boundary condition at $r = R_v$ gives:

$$-C \frac{R_v}{3\ell^2} = -g_{\text{wall}} \implies C = \frac{3\ell^2 g_{\text{wall}}}{R_v}. \quad (\text{A11})$$

Because the mass of the compensated wall is strictly positive ($g_{\text{wall}} > 0$), the Israel junction conditions algebraically force the integration constant to be positive ($C > 0$). This mathematically locks the center of the void ($r = 0$) as a local maximum in the potential field.

The weak lensing convergence is proportional to the 2D projected Laplacian of the potential:

$$\kappa(r) \propto \nabla_\perp^2 \Phi \simeq -\frac{C}{\ell^2} \frac{\sin(r/\ell)}{r/\ell}. \quad (\text{A12})$$

Because $C > 0$, the core convergence $\kappa(0)$ is strictly negative. Light rays are actively refracted away from the high-potential center toward the relaxed walls. By substituting the compensated wall mass of a characteristic $R_v \approx 30$ Mpc void into the locked constant C , the 2D projected Laplacian yields a core convergence of:

$$\kappa_{\text{void}} \approx -0.03. \quad (\text{A13})$$

This demonstrates that the repulsive lensing signature is a rigid boundary-value consequence of the covariant hyperelastic spacetime tensor, predicting an anomalous signal that distinguishes EST from pure matter underdensity models.

5. Triadic Angular Ordering

If a coherent void lattice forms, elastic energy minimisation at void junctions favors triadic configurations. Minimising the junction energy $E_{\text{junction}} \propto \sum_i \sigma L_i$ leads to equal-angle intersections, yielding preferred angular separations near 120° . This angular ordering is a geometric consequence of elastic relaxation and constitutes a secondary consistency signal rather than an independent prediction.

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