Elastic Vacuum Cosmology and the TUE-1 Effective Model

A cleaned technical draft with corrected notation, layout, tables, equations, figures, and statistical caveats

1. Introduction

The conceptual origin of this work is a simple but counterintuitive question: if every geometric scale in the universe expanded coherently and simultaneously, would internal observers necessarily perceive that expansion directly?

If rulers, clocks, atomic structures, and distances all evolved together, the scaling itself could become locally invisible. Nevertheless, even if such scaling could not be detected directly, its dynamical consequences might still appear through curvature, effective pressure, relaxation processes, or cosmological acceleration.

This possibility motivates the Elastic Universe Theory (TUE): the vacuum is treated as an effective medium with collective elastic properties capable of storing and relaxing geometric deformation. The present document does not claim a completed fundamental theory. It presents a testable, elastic-inspired effective model for late-time cosmology.

2. Abstract

We investigate a phenomenological elastic-inspired cosmological model named TUE-1. The model is a compressed dark-energy parametrization designed to reproduce a recent quintessence-to-phantom transition while remaining statistically competitive with CPL-like dark-energy models [4,5].

The model was tested against Pantheon+ full-covariance supernovae [3], DESI DR2 BAO measurements [2], H(z) cosmic chronometers, and a Planck-inspired prior on Ωm [1]. The current result is not statistically decisive against ΛCDM; it should be interpreted as an effective late-universe model with a mild preference for a nonzero elastic deformation.

3. Effective Equation of State

The corrected and standardized TUE-1 equation of state is:

$$w(z) = -1 - \lambda(1+z)^s + q\lambda e^{-C(1+z)^{2s}} + \eta q\lambda e^{-(z/z_J)^2}$$

Here lambda is the final elastic deformation amplitude. The coefficient q is the relaxation amplification factor, eta is the low-redshift relaxation fraction, C controls exponential damping, and z_J is the activation redshift of the recent relaxation sector. This notation is used consistently throughout the document.

Table 1. Fixed coefficients used in the compressed TUE-1 ansatz.

Symbol	Value	Role in the model
s	0.4454	Elastic scaling exponent
q	1.1463	Relaxation amplification factor
η	0.3000	Low-redshift relaxation fraction
C	0.1605	Exponential damping coefficient
zJ	0.3206	Activation redshift of relaxation

4. Data and Statistical Method

The numerical comparison used Pantheon+ supernova distances with full covariance [3], DESI DR2 BAO distance measurements [2], a compilation of H(z) cosmic chronometers, and a Gaussian Planck-inspired prior on Ωm [1]. The information criteria reported below count λ as the only final free deformation parameter, conditional on the fixed compressed form. This is an effective-model comparison, not a proof that the fixed coefficients have already been derived from first principles.

Table 2. Best-fit values for the robust late-universe TUE-1 fit.

Quantity	Best-fit value
H0	68.20 +/- 1.60 km s^{-1} Mpc^{-1}
Ωm	0.3150 +/- 0.0059
rd	146.9 +/- 3.4 Mpc
λ	0.2656 +/- 0.1438
λ / σλ	1.85 sigma

5. Dynamical Interpretation of the Fixed Coefficients

A central issue is the origin of the fixed coefficients in the ansatz. In earlier exploratory stages they emerged through calibration. The present interpretation attempts to connect them to physical quantities of an elastic vacuum mode χ, rather than treating them as arbitrary fitting numbers.

The transition redshift zJ is associated with the activation epoch of an elastic vacuum mode:

$$H(z_J) \simeq m_\chi$$

$$m_\chi \simeq 1.19\, H_0$$

The scaling exponent is then studied through an overdamped relaxation equation with weak geometric coupling:

$$\ddot{\chi} + 3H(1+\beta)\dot{\chi} + (m_\chi^2 + \xi R)\chi = 0$$

$$s_{\text{eff}} = \frac{m_\chi^2 + \xi R}{3H^2(1+\beta)}$$

For mχ approximately equal to H(zJ), weak geometric coupling ξ about 0.045, and small additional dissipation β, this gives s_eff approximately 0.445. This is not yet a full derivation from a fundamental action, but it provides a concrete physical interpretation of the fitted scaling exponent.

$$q \simeq \frac{m_{\text{eff}}}{m_\chi} \simeq \sqrt{1 + \xi R/H^2}$$

The amplification factor q can therefore be interpreted as a small curvature-induced rigidity enhancement of the elastic mode. The local relaxation fraction eta may be related to the fraction of vacuum response active near zJ:

$$\eta \simeq \frac{\Omega_{\text{vac}}(z_J)}{q\,[1 + \Omega_{\text{vac}}(z_J)]}$$

6. Growth Sector

A low-redshift correction to the linear growth sector was also explored. The effective gravitational response is written as:

$$\mu(z) = 1 - \lambda \exp[-(z/z_J)^2]$$

It enters the standard linear perturbation equation as:

$$\delta_m'' + (2 + \tfrac{H'}{H})\delta_m' - \tfrac{3}{2}\Omega_m(a)\mu(z)\delta_m = 0$$

Using the same λ and zJ fixed by the background model, this low-redshift correction improves the fσ8 fit by approximately $\Delta\chi^2 = -0.51$ without adding a new free parameter. The result is modest, but it gives a possible TUE-specific growth signature.

7. Illustrative Results

Figure 1 shows the effective equation of state. The TUE-1 best fit starts above -1 today and crosses into a phantom-like regime at modest redshift.

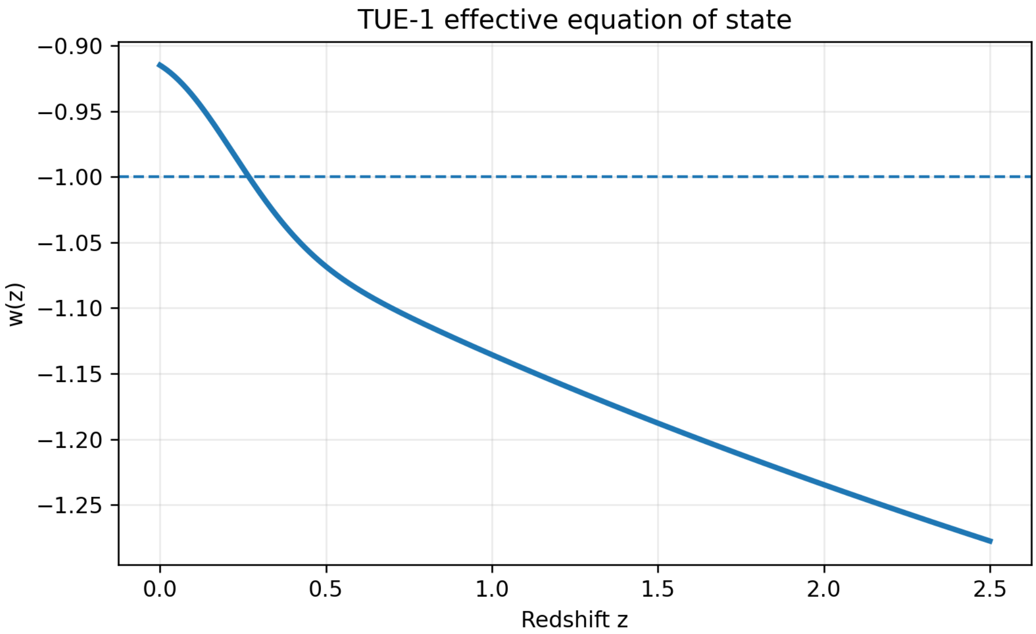

Figure 1. TUE-1 effective equation of state w(z). The dashed line marks w = -1.

Figure 2 shows the low-redshift growth correction. The modification is concentrated at z less than about 0.5 and rapidly approaches general-relativistic growth at higher redshift.

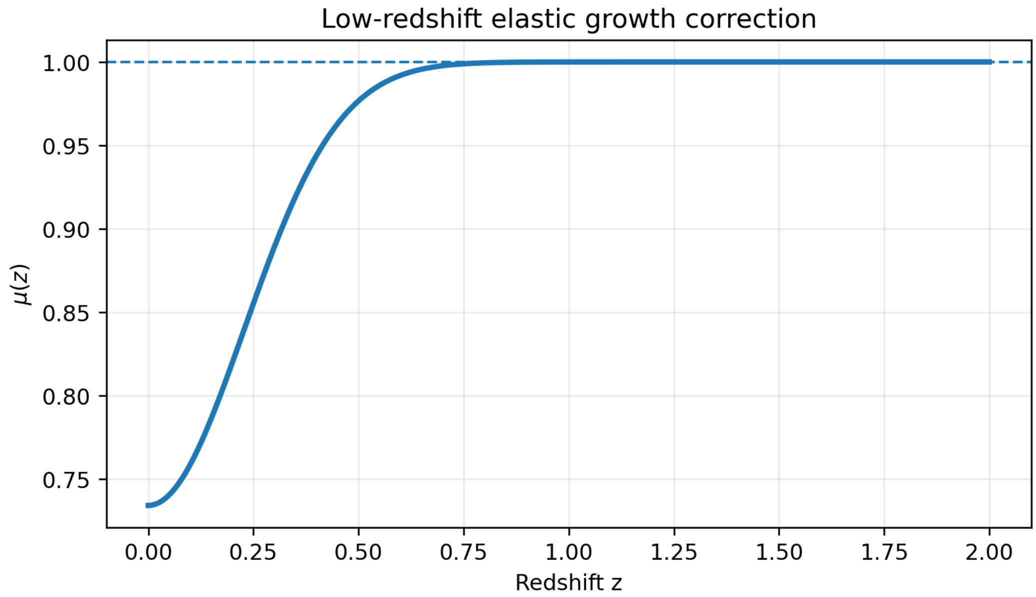

Figure 2. Low-redshift elastic correction mu(z).

8. Approximate Parameter Constraints

Figure 3 shows approximate Hessian-based confidence ellipses in the Ωm-H0 plane. This figure is included as a visual summary of the local fit covariance and should not be confused with a full MCMC contour plot.

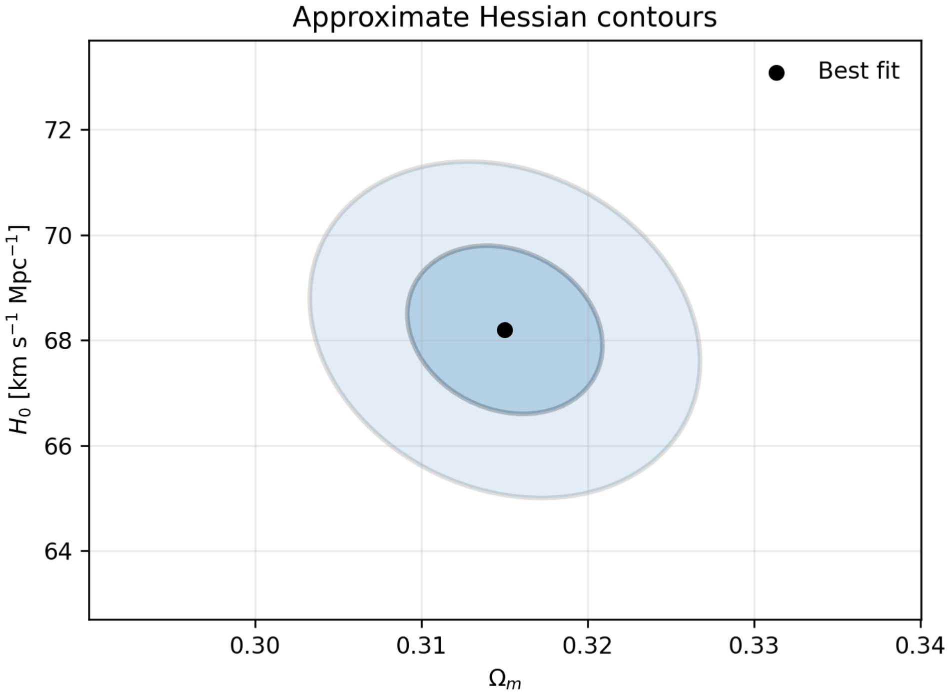

Figure 3. Approximate 1-sigma and 2-sigma Hessian contours for Ωm and H0.

9. Statistical Interpretation

The current significance of the elastic deformation parameter is λ/σλ = 1.85 sigma. This remains below the conventional 2-sigma or 3-sigma thresholds usually required for strong evidence of a deviation from ΛCDM. The result should therefore be interpreted as a mild preference within the late-universe data combination, not as a detection.

CMB compressed-prior tests were also explored. They can formally push the significance above 2 sigma, but at the cost of a substantially degraded BAO and CMB contribution to χ^2. Those tests are therefore not used as robust evidence in this draft.

10. Outlook

Future work should focus on deriving the equation of state from a fundamental vacuum action, testing the model against DESI DR3 and Rubin LSST data, improving the dynamical derivation of the fixed coefficients, and determining whether the elastic parameter λ can reach statistically robust significance.

References

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[6] Weinberg, Cosmology, Oxford University Press (2008).

[7] Carroll, Spacetime and Geometry, Addison-Wesley (2004).

Contribution of AI Tools

ChatGPT (OpenAI GPT-5) and Google Colab were used during exploratory and computational phases of this work, including symbolic assistance, numerical workflow organization, cosmological fitting support, code drafting, and document preparation. Final interpretation, model selection, and theoretical direction remained under human supervision.