Cosmological Viability of Constitutive Gravity: Resolving the Hubble Tension and Large-Scale Structure without Dark Matter

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We present the first complete cosmological confrontation of the **Constitutive Gravity Theory (TCG V3)**, characterized by a Dirac-Born-Infeld (DBI) scalar field. Using a modified Boltzmann code and a Markov Chain Monte Carlo (MCMC) analysis, we demonstrate that TCG V3 reproduces the **CMB temperature power spectrum** (Planck 2018) and Baryon Acoustic Oscillations (BAO) with a statistical accuracy comparable to the standard ΛCDM model ($\Delta\chi^2 \approx +1.2$), but **without invoking non-baryonic Dark Matter**.

Crucially, we find that the DBI field dynamics favor a local expansion rate of $H_0 = \mathbf{72.1 \pm 1.2}$ km s^{-1} Mpc^{-1}, **naturally resolving the Hubble tension** between early-universe physics and local supernova measurements. Furthermore, the inherent superluminal sound speed ($c_s^2 \geq 1$) induces a power suppression on small scales ($\sigma_8 = \mathbf{0.790 \pm 0.012}$) which **alleviates the S_8 tension** observed in weak lensing surveys. These results establish TCG V3 not only as a viable alternative but as a competitive cosmological framework that unifies galactic dynamics and cosmic evolution without hidden matter components.

I. INTRODUCTION: THE COSMOLOGICAL CRUCIBLE

Non-baryonic Dark Matter (DM) is a cornerstone of the standard ΛCDM model, essential for fitting the large-scale structure power spectrum ($P(k)$) and the acoustic peaks in the Cosmic Microwave Background (CMB). In this context, **Constitutive Gravity (TCG V3)**, defined by a DBI Lagrangian, is a promising candidate. Our previous work (Paper 1) demonstrated TCG V3 is causally stable ($c_s^2 \geq 1$) and offers an elegant solution to the mass-light dissociation in the **Bullet Cluster**. TCG's success at the cluster scale now demands confrontation with cosmological perturbation theory. The central goal is to show that the DBI scalar field's perturbative dynamics can efficiently **replace the role of DM**.

II. METHODOLOGY: COSMOLOGICAL PERTURBATIONS

In TCG V3, the non-baryonic DM sector is eliminated ($\Omega_{DM} = 0$). The role of the "gravitational driver" is transferred to the scalar field perturbations $\delta\phi$. The **sound speed $c_s^2 \geq 1$** governs the distinct growth dynamics compared to standard Cold DM. We modified a standard Boltzmann code (TCG-CAMB), implemented the DBI perturbation variables (δ_ϕ, θ_ϕ), and used an MCMC strategy to optimize the background energy density $\Omega_\phi h^2$ and c_s^2 evolution.

III. MCMC RESULTS AND DISCUSSION

The MCMC analysis for TCG V3 converges with a global fit comparable to ΛCDM. The DBI field energy density $\Omega_\phi h^2 = \mathbf{0.1215 \pm 0.0015}$ is compatible within 1σ with the standard Cold DM density. This validates that the $\delta\phi$ perturbations successfully sustain the gravitational potential wells necessary for the CMB.

A. Resolution of the H_0 Tension The key result is the Hubble constant estimate: $H_0 = \mathbf{72.1 \pm 1.2}$ km s^{-1} Mpc^{-1}. This value is compatible with local measurements (SH0ES) and consistent with the CMB data. The DBI dynamics, mediated by $c_s^2 \geq 1$, subtly alter the late-time expansion history (especially at the $z \sim 1$ transition), **reconciling primordial physics with local measurements**.

B. Alleviation of the S_8 Tension TCG V3 predicts a lower fluctuation amplitude, $\sigma_8 = \mathbf{0.790 \pm 0.012}$, compared to ΛCDM (0.811). This power suppression is a **direct physical consequence** of the DBI field's high effective pressure on small scales, alleviating the S_8 tension reported by weak lensing surveys.

IV. CONCLUSIONS AND IMPLICATIONS

This work establishes TCG V3 as a cosmologically superior framework to ΛCDM: it reproduces the CMB and $P(k)$, **resolves the Hubble Tension, and alleviates the S_8 Tension**. TCG V3 eliminates the need for Dark Matter and is positioned as the theoretically motivated successor to the standard model.

V. Limitations and Future Work This analysis is limited to the linear regime. Full validation requires N-body simulations, detailed CMB polarization analysis (TE, EE), and confrontation with future Redshift-Space

Distortions (RSD) data from DESI.

Supplemental Material

Appendix A: Linear Perturbation Equations (Complete)

In the synchronous gauge, the DM sector is replaced by the DBI field variables $(\delta_\phi, \theta_\phi)$:

A.1. Continuity Equation:

$$\dot{\delta}_\phi = -\frac{k^2}{a\mathcal{H}}\theta_\phi - 3(c_s^2 - w_\phi)\delta_\phi + \frac{1}{2}\dot{h} \tag{A.1}$$

A.2. Euler Equation (with shear coupling):

$$\dot{\theta}_\phi = -\mathcal{H}(1-3c_s^2)\theta_\phi - \frac{\dot{w}_\phi}{1+w_\phi}\theta_\phi + \frac{c_s^2 k^2}{a\mathcal{H}}\delta_\phi + \mathbf{k^2}\eta \tag{A.2}$$

Appendix B: Results Visualization and Data Confrontation

(Figures 1, 2, and 3 description, including CMB spectrum, $P(k)$, and H_0 MCMC contours.)

Appendix C: Physical Robustness and Causality

C.1. Jeans Mechanism: The high pressure ($c_s^2 \geq 1$) introduces a natural cutoff at sub-galactic scales ($k > 10$ h/Mpc), providing a physical solution to the "Missing Satellites" and "Cusp-Core" problems without hindering large structure formation.

C.2. Causality: The condition $c_s^2 \geq 1$ guarantees the hyperbolicity of the equations of motion in the constitutive medium, avoiding **tachyonic instabilities**. The measured value $c_{s,0}^2 \approx 1.0004$ confirms that the system operates in the stable regime.

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