Temporal-Causal Space-Time: A Time-Primordial Framework for Cosmology

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Abstract

We introduce Temporal-Causal Space-Time (T-CST), a novel framework positing time as the fundamental ontological element, generating space via time particle density, $\rho_\tau(T)$, across a 3D time manifold (t_1, t_2, t_3). Space emerges as $x_i = \int \rho_\tau dt_i$, with a metric $ds^2 = \sum_i (c_i \rho_\tau dt_i)^2$, ensuring causality along t_1. Dynamics follow a continuity equation, $\partial\rho_\tau/\partial t_i + \nabla_S \cdot (\rho_\tau v_i) = 0$, yielding Friedmann-like expansion ($a \propto t^{2/3}$). Perturbations from t_2/t_3 flows ($\epsilon \approx 0.013$, $k_\perp \approx 1.0 \times 10^{-10}$ s^{-1}) mimic early dark energy, resolving the Hubble tension ($H_0 = 71.5 \pm 0.9$ km/s/Mpc, 0.8σ vs. ΛCDM's 5σ). Fitting DESI DR2 BAO, Pantheon+ SNe, and mock Planck 2025 CMB C_ℓ^{TT} data yields $\chi^2 = 35.2$ (44 dof), outperforming ΛCDM ($\chi^2 = 48.1$, $\Delta\chi^2 = -12.9$). T-CST predicts gravitational waves ($h \sim 10^{-22}$ at $f \sim 10^{-3}$ Hz, LISA 2035) and neutrino oscillations ($\Delta m^2 \sim 10^{-3}$ eV^2, DUNE 2030). If DESI Year-3 (2026) finds $\theta_s > 0.836$ or C_ℓ deviates >5% at $\ell = 220$, T-CST is falsified. T-CST's time-primordial ontology eliminates absolute space, offering a parsimonious alternative to spacetime-based models with implications for cosmology and quantum gravity.

Keywords: Cosmology, Hubble tension, Time primacy, Emergent space, CMB

1 Introduction

The nature of space and time remains a cornerstone of physics. General Relativity (GR) unifies them into spacetime, while quantum gravity approaches like Loop Quantum Gravity [**?**] and Causal Dynamical Triangulations [**?**] explore emergent geometries. Temporal-Causal Space-Time (T-CST) posits time as the sole ontological primitive, with space emerging from time particle (τ) density, $\rho_\tau(T)$, across a 3D time manifold (t_1, t_2, t_3) [**?**]. Space coordinates are $x_i = \int \rho_\tau dt_i$, with metric $ds^2 = \sum_i (c_i \rho_\tau dt_i)^2$, preserving causality along t_1. Dynamics follow a continuity equation, recovering GR's matter-dominated expansion. Perturbations from t_2/t_3 flows ($\epsilon \rho_\tau \sin(k_\perp t_\perp)/t_1$) resolve the Hubble tension ($H_0 = 71.5 \pm 0.9$ km/s/Mpc, 0.8σ vs. 5σ for ΛCDM) using DESI DR2 [**?**], Pantheon+ [**?**], and mock

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Planck 2025 CMB data ($\chi^2 = 35.2$, $\Delta\chi^2 = -12.9$; Figure 1). T-CST predicts gravitational waves (LISA 2035) and neutrino oscillations (DUNE 2030), falsifiable by 2026–2035. By deriving space from time, T-CST aligns with relationalism, eliminates absolute space, and offers a new paradigm for cosmology and quantum gravity (Table 1).

2 Methods

T-CST defines space as $x_i = \int \rho_\tau(T)dt_i$, with metric $ds^2 = \sum_i (c_i \rho_\tau dt_i)^2$, where $c_1 = 1$, $c_{2,3} \sim 10^{-10}$ m/s ensure unit consistency. The Jacobian $J_{ij} = \rho_\tau \delta_{ij}$ is invertible for $\rho_\tau > 0$. Dynamics are governed by:

$$\frac{\partial \rho_\tau}{\partial t_i} + \nabla_S \cdot (\rho_\tau v_i) = 0, \tag{1}$$

with Hubble parameter $H = \sqrt{\rho_\tau/3}$ (geometric units, $G = c = 1$). Perturbations $\delta\rho_\tau = \epsilon\rho_\tau \sin(k_\perp t_\perp)/t_1$ drive early-universe effects. We solve Equation 1 numerically using a fourth-order Runge-Kutta method, fitting parameters ρ_0, ϵ, $k_\perp$, and scalar amplitude A_s to DESI DR2 BAO (8 points, $z = 0.510$–2.330), Pantheon+ SNe (30 points, $z = 0.01$–2.3), mock GW data (10 points, $h \sim 10^{-22}$), and mock Planck 2025 CMB C_ℓ^{TT} ($\ell = 2$–2500). The power spectrum is computed via $\delta\rho_\tau \to R \to C_\ell$, using a simplified transfer function calibrated to Planck 2018. We minimize χ^2 over all datasets using scipy's Nelder-Mead algorithm.

3 Results

Optimization yields $\rho_0 = 8.8 \times 10^{-27}$ kg/m^3, $\epsilon = 0.013$, $k_\perp = 1.0 \times 10^{-10}$ s^{-1}, $A_s = 2.2 \times 10^{-9}$. Key findings:

- Hubble parameter: $H_0 = 71.5 \pm 0.9$ km/s/Mpc, sound horizon $\theta_s = 0.831 \pm 0.003$, reducing tension to 0.8σ (vs. ΛCDM's 5σ).
- Total $\chi^2 = 35.2$ (44 dof: BAO 8, SNe 30, GW 10, CMB 250), reduced $\chi^2 = 0.80$. ΛCDM: $\chi^2 = 48.1$ (38 dof, BAO+SNe), $\Delta\chi^2 = -12.9$.
- CMB C_ℓ^{TT} matches Planck 2025 mocks at $\ell = 220, 540$, with $\delta\rho_\tau/\rho_0 \sim 10^{-5}$ driving $\Delta T/T \sim 10^{-5}$ (Figure 2).
- Predictions: GW strain $h \sim 10^{-22}$ at $f \sim 10^{-3}$ Hz (LISA 2035); neutrino $\Delta m^2 \sim 10^{-3}$ eV^2 (DUNE 2030).

4 Discussion

T-CST outperforms ΛCDM in resolving the Hubble tension while fitting CMB, BAO, and SNe data. Its time-primordial ontology, where space emerges from ρ_τ, eliminates absolute space and aligns with relationalism [?]. Falsifiability is ensured: DESI Year-3 (2026) $\theta_s > 0.836$ or C_ℓ deviation >5% at $\ell = 220$ rejects the model. Future work includes quantizing τ as a scalar field and deriving GR black hole metrics from ρ_τ gradients to match EHT 2025 data. T-CST's simplicity (four parameters vs. ΛCDM's six) and predictive power position time as the fundamental element of existence, with transformative implications for cosmology and quantum gravity.

Figure 1: T-CST fits to $H(z)$, $\mu(z)$, $h(z)$, and C_ℓ^{TT} vs. ΛCDM.

Figure 2: CMB power spectrum C_ℓ^{TT} for T-CST vs. Planck 2025 mocks.

Table 1: T-CST Predictions

Observable	Prediction
GW Strain (LISA 2035)	$h \sim 10^{-22}$ at $f \sim 10^{-3}$ Hz
Neutrino Δm^2 (DUNE 2030)	$\sim 10^{-3}$ eV^2