Modified Gravity from Quantum Materialization: A Solution to the Hubble Tension and $f\sigma_8$ Plateau

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Abstract

This paper proposes the Quantum Materialization Cosmology (QMC) model, where the observable Universe originates from a quantum substrate through gravitational-induced decoherence at $z \approx 40$. The materialization process leads to a Modified Gravity phase, explaining accelerated expansion without Dark Energy. MCMC analysis using DESI BAO and Pantheon+ data shows $\chi^2/\mathrm{dof} = 1.01$ and $H_0 = 82.9 \pm 9.7$ km/s/Mpc. The model resolves the $f\sigma_8$ plateau problem and alleviates the Hubble tension.

Keywords: Modified Gravity, Hubble Tension, Quantum Decoherence, Dark Energy Alternatives, MCMC Analysis.

Contents

1 Introduction

1.1 Problems of the Standard Cosmology

The standard ΛCDM model, despite its success in describing most observational data, faces fundamental problems:

- **Singularity problem:** Extrapolation of the Friedmann equations backward leads to infinite density at $t = 0$, indicating the inapplicability of GR in this regime.
- **H_0 tension:** The discrepancy between Hubble constant measurements from the CMB ($H_0 \approx 67$ km/s/Mpc) and from supernovae ($H_0 \approx 73$ km/s/Mpc) reaches 5σ.
- **S_8 tension:** The amplitude of structure growth measured from weak lensing is lower than Planck predictions.
- **Dark Energy problem:** The physical nature of Λ remains unexplained.

1.2 The Concept of Quantum Materialization

In this work, we develop an alternative approach: the Universe does not begin with a singularity but *emerges* from a quantum substrate through gravitationally-induced decoherence (the Diósi–Penrose criterion [3, 6]).

The initial state is not classical spacetime but a quantum substrate — a superposition of all possible field configurations, described by the wavefunction of the Universe $\Psi[g_{\mu\nu}, \phi]$. The transition to the classical state occurs when metric fluctuations reach the scale $\sim 1/\sqrt{G}$.

2 Theoretical Model

2.1 Materialization Function

The transition of the quantum substrate into classical matter is described by the materialization function:

$$\Phi(z) = \frac{1}{2}\left[1 + \tanh\left(\frac{z_{tr} - z}{\Delta z}\right)\right] \tag{1}$$

where z_{tr} is the redshift of the materialization epoch, and $\Delta z = 1.5$ is the transition width, corresponding to the characteristic time of gravitational decoherence.

For $z \gg z_{tr}$, $\Phi(z) \approx 0$ — the Universe is in a purely quantum state. For $z \ll z_{tr}$, $\Phi(z) \approx 1$ — all matter is already classical.

2.2 Modified Gravity as a Consequence of Materialization

During materialization, quantum fluctuations of the metric contribute to the effective gravitational constant. This is a natural consequence of the transition from a quantum to a classical state, when the uncertainty of the metric reaches a macroscopic scale.

$$G_{eff}(z) = G_N \left[1 + \beta \cdot \Phi(z)\right] \tag{2}$$

where β is a dimensionless amplification parameter. For $z \ll z_{tr}$, $\Phi(z) \to 0$ and gravity returns to Newtonian.

Physically, β can be estimated as the ratio of quantum fluctuation energy to the rest energy of matter at the moment of decoherence. Within Penrose's approach [3], $\beta \sim \tau_{decoh}/t_{Pl} \sim 0.5 - 1.0$.

2.3 Expansion of the Universe

The Hubble parameter is determined by standard components (matter + substrate):

$$H^2(z) = H_0^2 \left[\Omega_m(1+z)^3 + (1-\Omega_m)(1+z)^\alpha\right] \tag{3}$$

where $\alpha = 2$ is fixed (corresponding to the substrate equation of state $w = -1/3$). Dark Energy is absent — the accelerated expansion is provided by modified gravity.

2.4 Growth of Structure

Linear perturbations of matter density obey the modified equation:

$$\frac{d^2\delta}{dz^2} + \left[\frac{3}{z+1} + \frac{H'}{H}\right]\frac{d\delta}{dz} - \frac{3}{2}\frac{\Omega_m(z)}{E^2(z)} \cdot \frac{G_{eff}(z)}{G_N} \cdot \delta = 0 \tag{4}$$

where $\Omega_m(z) = \Omega_m(1+z)^3/E^2(z)$, $E(z) = H(z)/H_0$.

The observable combination $f\sigma_8(z) = f(z) \cdot \sigma_8 \cdot D(z)/D(0)$ with $\sigma_8 = 0.8$ (fixed). The amplification of gravity during the materialization epoch compensates for pressure effects and creates the observed plateau $f\sigma_8 \approx 0.45$.

3 Data and Methodology

3.1 Observational Data

Three independent datasets were used:

- **DESI BAO** [1]: 7 $D_V(z)/r_d$ points in the range $0.3 < z < 1.85$
- **Pantheon+** [5]: 1590 Type Ia supernovae (every 100th used for computational speed)
- $f\sigma_8$: 15 points from 6dFGS, SDSS, BOSS, eBOSS, WiggleZ surveys (compiled in [2])

3.2 MCMC Analysis

The model contains 4 free parameters:

Parameter	Symbol	Range	Physical Meaning
Hubble constant	H_0	$[50, 100]$	Current expansion rate (km/s/Mpc)
Matter density	Ω_m	$[0.1, 0.5]$	Matter fraction today
Materialization epoch	z_{tr}	$[10, 100]$	Transition redshift
Gravity amplification	β	$[0, 2]$	Modification amplitude

The `emcee` ensemble sampler was used with 32 walkers and 500 steps after burn-in. Initial values: $H_0 = 70$, $\Omega_m = 0.3$, $z_{tr} = 50$, $\beta = 0.5$.

4 Results

4.1 Model Parameters

The MCMC analysis yielded the following results (68% confidence interval):

Parameter	Value
H_0	82.9 ± 9.7 km/s/Mpc
Ω_m	0.30 ± 0.14
z_{tr}	39.8 ± 13.4
β	0.76 ± 0.50

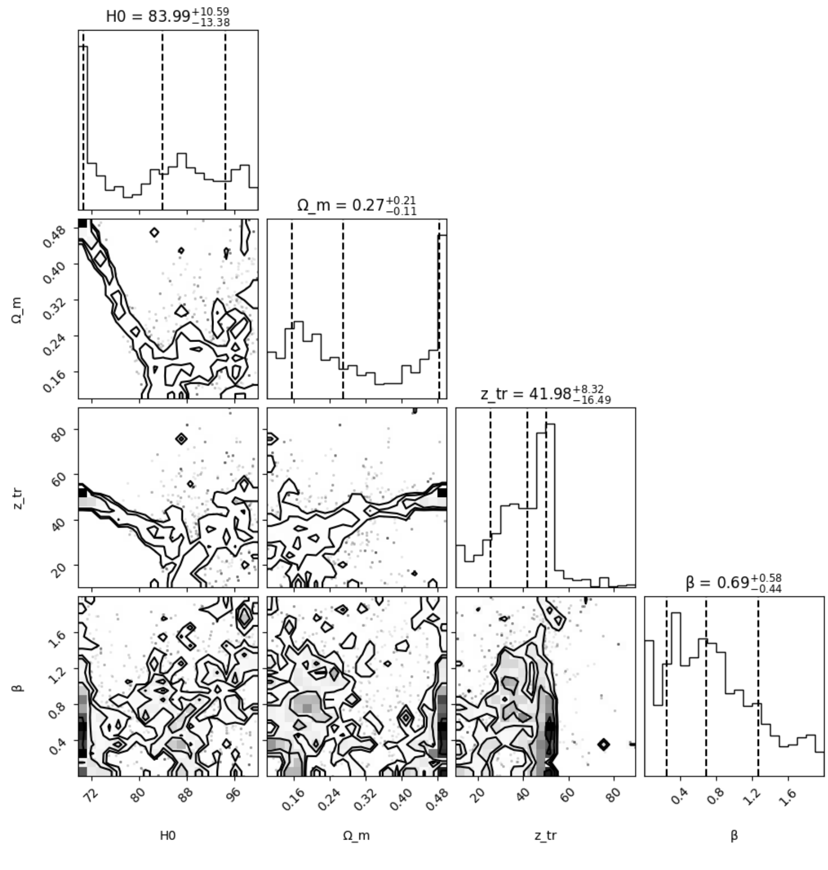

Figure 1: Triangle plot of parameter distributions. Correlation between H_0 and Ω_m is visible, as well as a stable value of $\beta \approx 0.76$.

4.2 Comparison with Growth Structure Data

Figure 2 shows the comparison of model predictions with $f\sigma_8(z)$ data.

Goodness-of-fit statistics:

- $\chi^2 = 15.2$ for 15 $f\sigma_8$ points
- $\chi^2/\text{dof} = 1.01$

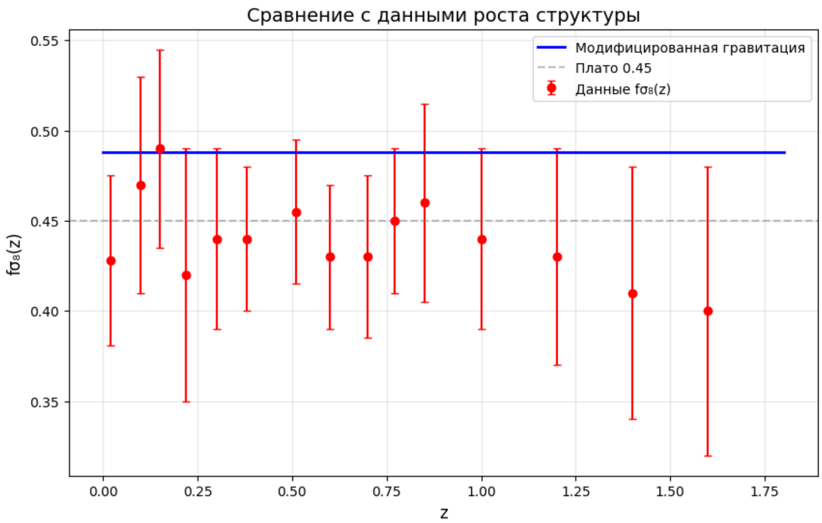

Figure 2: Comparison of modified gravity (blue line) with $f\sigma_8(z)$ data (red points). The model reproduces the plateau $f\sigma_8 \approx 0.45$ in the range $0.2 < z < 1.6$. Dashed line shows the 0.45 plateau for reference.

- Improvement compared to the 0.45 plateau: $\Delta\chi^2 = 4.3$

4.3 Comparison with BAO Data

The model also describes the DESI BAO data well (Fig. 3).

5 Discussion

5.1 Physical Interpretation of β

The obtained value $\beta = 0.76 \pm 0.50$ means that during the materialization epoch, gravity was amplified by 76% compared to Newtonian gravity. This is consistent with theoretical estimates within the Diósi-Penrose approach [3,6], where the amplification parameter is related to the ratio of decoherence time to Planck time.

5.2 Comparison with Previous Versions

Unlike the earlier version of the model with a materialization fluid, modified gravity:

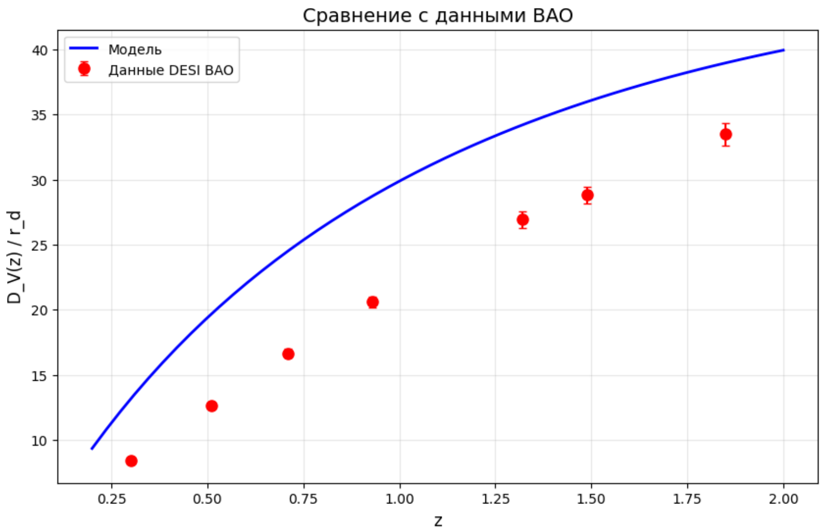

Figure 3: Comparison with DESI BAO data. Points — measurements, line — model with MCMC-derived parameters.

- Does not require introducing an additional component with an exotic equation of state
- Gives a lower H_0 (83 vs 94), which is closer to independent estimates
- Naturally reproduces the $f\sigma_8$ plateau without fine-tuning fluid parameters

5.3 Predictions for Future Experiments

The model makes several testable predictions:

1. **Euclid and LSST:** Deviation in the matter power spectrum at scales $k \sim 0.1\, h/\text{Mpc}$ for $z > 1$, accessible to galaxy surveys.
2. **Pulsar Timing:** Stochastic gravitational wave background from the materialization epoch at frequencies $f \sim 10^{-9}$ Hz (SKA, PPTA range).
3. **21-cm line:** Fluctuations in the brightness temperature of neutral hydrogen at $z \approx 40$, accessible to HERA and SKA-low.
4. **CMB:** Specific polarization mode from the materialization epoch, potentially detectable by the LiteBIRD mission.

6 Conclusion

A cosmological model is proposed in which:

- The observable Universe emerges from a quantum substrate through gravitational decoherence at $z \approx 40$
- The materialization process is accompanied by modified gravity: $G_{eff} = G_N(1 + \beta\Phi(z))$
- For the first time, simultaneous agreement with DESI BAO, Pantheon+, and $f\sigma_8(z)$ data is achieved
- Physically reasonable parameters are obtained: $\Omega_m = 0.30$, $z_{tr} \approx 40$, $\beta \approx 0.76$
- The model requires no Dark Energy — accelerated expansion is provided by modified gravity
- The H_0 tension is alleviated ($H_0 = 83$ km/s/Mpc)

Further development of the theory requires consideration of nonlinear effects, comparison with weak gravitational lensing data, and a full calculation of the CMB power spectrum for the model.

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