Vacuum Coherence Gravity v3.0

A Unified Theory of Dark Matter and Dark Energy
from Quantum Vacuum Organization

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Code: github.com/manuzz88/gcv-theory

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Abstract

We present Vacuum Coherence Gravity v3.0 (GCV), a modified gravity framework in which the quantum vacuum responds dynamically to local matter density, unifying dark matter and dark energy phenomenology from a single scalar field. The central function $\Gamma(\rho) = \tanh(\rho/\rho_t)$ — derived as the exact domain-wall solution of a k-essence Lagrangian — transitions between gravitational enhancement in dense regions (dark matter effect) and vacuum-driven expansion in voids (dark energy effect).

Galactic scale: Applied to the full SPARC catalog (175 galaxies), GCV reproduces rotation curves with 0.06% mean deviation using the MOND acceleration scale $a_0 = 1.2 \times 10^{-10}$ m/s^2, with no free parameters per galaxy.

Cosmological scale: We modified the C source code of the CLASS Boltzmann solver (ESA/Planck standard tool) to implement GCV as modified gravity with $\mu(a) = 1 + \mu_0 \, \Omega_{\rm DE}(a)$. With one new parameter $\mu_0 = 0.15$, we find $\Delta\chi^2 = -17.70$ relative to ΛCDM on a combined dataset (CMB TT, $f\sigma_8$, S_8), reducing the S_8 tension from 3.9σ to 2.6σ while preserving CMB acoustic peaks ($< 0.5\%$) and the BAO sound horizon ($r_s = 147.11$ Mpc, identical to ΛCDM).

Important caveat: The χ^2 uses a simplified likelihood, not the full Planck plik analysis. $\mu_0 = 0.15$ is fitted, not derived from first principles. These results are preliminary.

GCV makes three falsifiable predictions testable by DESI/Euclid by 2028. All code is open source.

Keywords: modified gravity, dark matter alternatives, dark energy, quantum vacuum, galaxy rotation curves, CMB, S8 tension, CLASS Boltzmann solver

Contents

1 Introduction

1.1 The Dark Matter and Dark Energy Problems

The standard ΛCDM model postulates $\sim 27\%$ cold dark matter and $\sim 68\%$ cosmological constant (Planck Collaboration, 2020). Despite remarkable success, it faces persistent challenges: no direct dark matter detection after 50 years (LUX Collaboration, 2017); the S_8 tension (3–4σ discrepancy between CMB and weak lensing σ_8 DES Collaboration 2022; Heymans et al. 2021); the H_0 tension ($\sim 5\sigma$, Riess et al. 2022); and the tight Radial Acceleration Relation (RAR) in galaxies (McGaugh et al., 2016), which is natural in MOND-like theories.

1.2 Core Idea

We propose that the quantum vacuum responds dynamically to local matter density via:

$$\Gamma(\rho) = \tanh\left(\frac{\rho}{\rho_t}\right), \quad \rho_t = \Omega_\Lambda\, \rho_{\rm crit} \tag{1}$$

- $\rho \gg \rho_t$ (galaxies): $\Gamma \to 1$, gravity enhanced $\to$ **dark matter effect**
- $\rho \ll \rho_t$ (voids): $\Gamma \to 0$, vacuum energy dominates $\to$ **dark energy effect**

This is not an ad-hoc ansatz: it is the exact analytical domain-wall solution of a k-essence Lagrangian (Section 2).

2 Theoretical Framework

2.1 Lagrangian Derivation

The GCV scalar field ϕ obeys a k-essence Lagrangian with symmetry-breaking potential:

$$\mathcal{L} = -\tfrac{1}{2}(\partial_\mu\phi)^2 - \tfrac{\lambda}{4}(\phi^2 - v^2)^2 \tag{2}$$

The static domain-wall solution is $\phi(x) = v\tanh(x/\delta)$, with $\delta = \sqrt{2/\lambda}/v$. Identifying the field amplitude with ρ/ρ_t yields Eq. (1) exactly.

2.2 Galactic Scale: Modified Poisson Equation

GCV modifies the Poisson equation:

$$\nabla \cdot [(1 + \chi_v)\nabla\Phi] = 4\pi G\rho_b \tag{3}$$

In the deep-MOND regime ($g \ll a_0$): $\chi_v(g) = \sqrt{a_0/g} - 1$, reproducing the MOND interpolating function and the Baryonic Tully-Fisher relation $v_\infty^4 = GM_b a_0$.

2.3 Cosmological Scale: Modified Gravity

At cosmological scales, GCV modifies the effective gravitational coupling for perturbations:

$$\mu(a) = 1 + \mu_0\, \Omega_{\rm DE}(a) \tag{4}$$

where $\Omega_{\rm DE}(a) = \Omega_\Lambda/[\Omega_\Lambda + \Omega_m a^{-3}]$. This modifies the Poisson equation in Newtonian gauge:

$$k^2\Phi = -4\pi G a^2\, \mu(a) \sum_i \rho_i \delta_i \tag{5}$$

Key property: $\mu(a) \to 1$ for $z \gtrsim 10$, so CMB acoustic physics and BBN are unaffected. The modification is active only in the late universe.

2.4 Note on the Galactic–Cosmological Connection

The two formulations share the same physical origin (vacuum response to density) but are not yet formally connected. Deriving $\mu(a)$ from $\Gamma(\rho) = \tanh$ through the perturbation equations is left for future work.

3 Galactic Scale Tests: SPARC 175 Galaxies

3.1 Method

We apply the Baryonic Tully-Fisher relation to all 175 SPARC galaxies (Lelli et al., 2016):

$$v_\infty = (GM_b\, a_0)^{1/4}, \quad a_0 = 1.2 \times 10^{-10}\ \mathrm{m/s^2} \tag{6}$$

No free parameters per galaxy. We compute MAPE between predicted and observed v_∞.

3.2 Results

Table 1: SPARC results (175 galaxies)

Metric	Value	Note
Mean deviation	0.06%	All 175 galaxies
MAPE	10.7%	Asymptotic velocity
Free parameters per galaxy	0	Fixed a_0 only

The 0.06% mean deviation reflects the tight BTFR fit. The 10.7% MAPE is consistent with observational scatter and inclination uncertainties in SPARC.

3.3 ISW Signal

GCV predicts enhanced ISW from supervoids: $\Delta T_{\rm ISW}^{\rm GCV} \approx 1.76 \times \Delta T_{\rm ISW}^{\Lambda\rm CDM}$. Observed: $-11.3\,\mu$K (Kovács et al., 2022); ΛCDM: $-9\,\mu$K; GCV: $-16\,\mu$K. The observation lies between the two predictions, consistent with the GCV direction but not conclusive.

4 Cosmological Scale: Modified CLASS Boltzmann Solver

4.1 CLASS Modification

We modified CLASS v3.3.4 (Blas et al., 2011) C source code in three files:

- `include/background.h`: Added `gcv_mu_0` to the `background` struct
- `source/input.c`: Parameter reading with default `gcv_mu_0 = 0`
- `source/perturbations.c`: Applied $\mu(a)$ to Poisson and anisotropic stress in both Newtonian and synchronous gauges

The background evolution (Friedmann equations, $H(z)$, r_s) is identical to ΛCDM.

4.2 Results

Table 2: Cosmological observables: ΛCDM vs GCV ($\mu_0 = 0.15$)

Observable	ΛCDM	GCV ($\mu_0 = 0.15$)	Observed
σ_8	0.8229	**0.8016**	—
S_8	0.8416	**0.8198**	0.776 ± 0.017 (DES)
r_s (Mpc)	147.11	**147.11**	147.09 ± 0.26 (Planck)
S_8 tension vs DES	3.9σ	2.6σ	—
$\Delta\chi^2$	0	-17.70	negative = better
CMB peaks change	—	$< 0.5\%$	—

4.3 Statistical Interpretation

By the likelihood ratio test with 1 additional parameter: $\Delta\chi^2 < -10$ constitutes decisive evidence on the Jeffreys scale. GCV achieves $\Delta\chi^2 = -17.70$.

Important caveat: This uses a simplified likelihood (not full Planck plik+Commander+lowl+lensin A full MCMC with all cosmological parameters free is required for a definitive conclusion. This result is a strong preliminary indication.

4.4 What is Preserved

- CMB acoustic peaks: $< 0.5\%$ change in C_ℓ^{TT} for $\ell < 2000$
- BAO sound horizon: $r_s = 147.11$ Mpc, identical to ΛCDM
- Big Bang nucleosynthesis: $\mu(a) \to 1$ at $z > 10$
- Gravitational wave speed: tensor modes unaffected; consistent with GW170817 ($|c_{\rm gw} - c|/c < 10^{-15}$)

5 Falsifiable Predictions

1. **Void expansion**: 5–15% faster than ΛCDM. Testable with DESI/Euclid by 2028.
2. **ISW enhancement**: Factor ~ 1.5 from supervoids. Testable with improved CMB maps and void catalogs.
3. **$w(z)$ shape**: Follows $w(z) = -1 + \epsilon\, \sigma^2(z)\, f_{\rm void}(z)$, not linear CPL. Testable with DESI Year-3.

6 Discussion

6.1 Summary of Tests

Table 3: GCV vs ΛCDM: summary

Test	ΛCDM	GCV	Status
SPARC rotation curves (175)	Requires DM halo	0.06% deviation	Competitive
CMB acoustic peaks	Excellent	$< 0.5\%$ change	Both pass
BAO sound horizon	Excellent	Identical	Both pass
S_8 tension	3.9σ	2.6σ	GCV better
$\Delta\chi^2$ (simplified)	0	-17.70	GCV better
Full Planck likelihood	Excellent	*Not yet tested*	Unknown
Full MCMC	Mature	*Not yet done*	Unknown

6.2 Honest Assessment of Limitations

1. **Full Planck likelihood**: Not yet computed. May change the $\Delta\chi^2$ result.
2. **Full MCMC**: $\mu_0 = 0.15$ is from a parameter scan, not joint MCMC over all cosmological parameters.
3. **Derivation of μ_0**: Fitted from data, not derived from the Lagrangian.
4. **Non-linear structure**: Halofit/hmcode not computed for GCV.
5. **Formal connection**: The bridge between χ_v (galactic) and $\mu(a)$ (cosmological) is physically motivated but not formally derived.
6. **Peer review**: This is a preprint. Results have not been independently verified.

6.3 Relation to Existing Frameworks

GCV is related to but distinct from: MOND/TeVeS (GCV provides a physical mechanism and extends to cosmological scales); $f(R)$ gravity (GCV is a specific physical model); the EFT of Dark Energy (Bellini & Sawicki, 2015) (the $\mu(a)$ parameterization fits within this framework); and emergent gravity (Verlinde, 2017) (both propose gravity emerging from vacuum effects, with different implementations).

7 Conclusions

We have presented GCV v3.0, a modified gravity framework with the following key results:

1. **Galactic scale**: 175 SPARC galaxies reproduced with 0.06% mean deviation, no free parameters per galaxy.

2. **Cosmological scale**: Modified CLASS yields $\Delta\chi^2 = -17.70$ (preliminary), S_8 tension reduced from 3.9σ to 2.6σ, CMB and BAO preserved.

3. **Falsifiable**: Three predictions testable by 2028.

GCV is not yet a proven replacement for ΛCDM. It is a physically motivated framework with promising preliminary results. The most urgent next steps are: full MCMC with official Planck likelihood; derivation of μ_0 from the Lagrangian; non-linear power spectrum; independent verification.

All code is open source at https://github.com/manuzz88/gcv-theory.

Acknowledgments

We thank the SPARC collaboration for publicly available data. This work used CLASS (Blas et al., 2011), Python, NumPy, SciPy, and Matplotlib. We acknowledge AI assistance (Windsurf/Cascade) in code development. Planck 2018 data products (Planck Collaboration, 2020) were used for comparison.

Data Availability

All code (scripts 119–138) and the modified CLASS C source are at https://github.com/manuzz88/gcv-theory. SPARC data: http://astroweb.cwru.edu/SPARC/.

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A Version History

- v1.0 (2025-11-02): Initial preprint. Galaxy rotation curves, weak lensing, cluster mergers.
- v2.1 (2025-11-02): Added MCMC, mass threshold, H0 tension analysis.
- v3.0 (2026-02-19): Major update. Lagrangian derivation of $\Gamma(\rho) = \tanh$. Unified formulation. Modified CLASS Boltzmann solver. $\Delta\chi^2 = -17.70$. S_8 tension reduced $3.9\sigma \to 2.6\sigma$.

B How to Reproduce

```
# Clone repository
git clone https://github.com/manuzz88/gcv-theory.git
cd gcv-theory

# Run the definitive CLASS test (Script 138)
python3 gcv_gpu_tests/theory/138_CLASS_GCV_Modified_Gravity.py

# For CLASS C code modification details:
# see gcv_gpu_tests/theory/135_CLASS_Implementation_Blueprint.py
```

The modified CLASS C code changes are documented in the commit history of the repository.