

Vacuum Coherence Gravity v15.0

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

Manuel Lazzaro

Independent Researcher, Italy

manuel.lazzaro@me.com

Code: github.com/manuzz88/gcv-theory

February 2026 — Version 15.1 (Preprint, not peer reviewed)

DOI: [10.5281/zenodo.17505641](https://doi.org/10.5281/zenodo.17505641)

Abstract

We present Vacuum Coherence Gravity v15.0 (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 $a_0 = 1.2 \times 10^{-10} \text{ m/s}^2$, 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 $\mu(a) = 1 + \mu_0 \Omega_{\text{DE}}(a)$. 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 ($r_s = 147.11 \text{ Mpc}$, 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.

New in v15.1: We apply GCV to CDG-2 ([Li et al., 2025](#)), a candidate dark galaxy in the Perseus cluster reported to be 99.94% dark matter. GCV predicts the extreme apparent dark matter fraction naturally (deep-MOND regime, $g_N/a_0 \sim 0.006$) and makes a testable prediction for the velocity dispersion: $\sigma \approx 21 \text{ km/s}$, measurable with follow-up spectroscopy.

GCV makes four 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, S_8 tension, CLASS Boltzmann solver, dark galaxies

Contents

1	Introduction	3
1.1	The Dark Matter and Dark Energy Problems	3
1.2	Core Idea	3
2	Theoretical Framework	3
2.1	Lagrangian Derivation	3
2.2	Galactic Scale: Modified Poisson Equation	3
2.3	Cosmological Scale: Modified Gravity	4
2.4	Note on the Galactic–Cosmological Connection	4
3	Galactic Scale Tests: SPARC 175 Galaxies	4
3.1	Method	4
3.2	Results	4
3.3	ISW Signal	4
4	Cosmological Scale: Modified CLASS Boltzmann Solver	5
4.1	CLASS Modification	5
4.2	Results	5
4.3	Statistical Interpretation	5
4.4	What is Preserved	5
5	Extreme Test Case: CDG-2 Dark Galaxy	6
5.1	Observed Properties	6
5.2	GCV Analysis	6
5.3	Testable Prediction	6
6	Falsifiable Predictions	7
7	Discussion	7
7.1	Summary of Tests	7
7.2	Honest Assessment of Limitations	7
7.3	Relation to Existing Frameworks	8
8	Conclusions	8
A	Version History	9
B	How to Reproduce	9

1 Introduction

1.1 The Dark Matter and Dark Energy Problems

The standard Λ CDM 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 ($3\text{--}4\sigma$ 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:

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

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

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

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:

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

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:

$$\mu(a) = 1 + \mu_0 \Omega_{\text{DE}}(a) \quad (4)$$

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

$$k^2 \Phi = -4\pi G a^2 \mu(a) \sum_i \rho_i \delta_i \quad (5)$$

Key property: $\mu(a) \rightarrow 1$ 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):

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

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: $\Delta T_{\text{ISW}}^{\text{GCV}} \approx 1.76 \times \Delta T_{\text{ISW}}^{\Lambda\text{CDM}}$. Observed: $-11.3 \mu\text{K}$ (Kovács et al., 2022); ΛCDM : $-9 \mu\text{K}$; GCV: $-16 \mu\text{K}$. 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 Λ CDM.

4.2 Results

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

Observable	Λ CDM	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+lensing). 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 Λ CDM
- Big Bang nucleosynthesis: $\mu(a) \rightarrow 1$ at $z > 10$
- Gravitational wave speed: tensor modes unaffected; consistent with GW170817 ($|c_{\text{gw}} - c|/c < 10^{-15}$)

5 Extreme Test Case: CDG-2 Dark Galaxy

CDG-2 (Candidate Dark Galaxy-2) is a recently discovered galaxy in the Perseus cluster (Li et al., 2025), consisting of four globular clusters (GCs) embedded in extremely faint diffuse emission. It represents one of the most dark-matter-dominated galaxies ever found and provides a stringent test for GCV.

5.1 Observed Properties

From Li et al. (2025) (arXiv:2506.15644):

- Distance: 75 Mpc (Perseus cluster)
- Total luminosity: $L_{V,\text{gal}} = 6.2 \pm 3.0 \times 10^6 L_\odot$
- Stellar mass: $M_* \approx 1.2 \times 10^7 M_\odot$ ($M/L_V \sim 2$)
- GC span diameter: ~ 1.2 kpc (4 GCs)
- Mean surface brightness: $\langle \mu \rangle_V \sim 27.5$ mag arcsec $^{-2}$
- DM halo mass (GC-to-halo relation): $2\text{--}5.7 \times 10^{10} M_\odot$
- Inferred DM fraction: 99.94%–99.98%

Critical note: The dark matter fraction is *not* measured dynamically. It is inferred from the empirical GC-to-halo mass relation (Harris et al., 2017; Burkert & Forbes, 2020). No velocity dispersion has been measured yet.

5.2 GCV Analysis

At the effective radius ($R_{\text{eff}} \sim 1.5$ kpc), the Newtonian acceleration from baryonic mass alone is:

$$\frac{g_N}{a_0} = \frac{GM_*}{a_0 R_{\text{eff}}^2} \approx 0.006 \quad (7)$$

This places CDG-2 deep in the MOND/GCV regime ($g_N \ll a_0$), where vacuum susceptibility provides an enhancement factor of $\sim 13\times$.

The apparent dynamical mass at R_{eff} is:

$$M_{\text{dyn}}^{\text{GCV}}(R_{\text{eff}}) \approx 1.6 \times 10^8 M_\odot \quad (8)$$

corresponding to an apparent dark matter fraction of $\sim 92\%$ at 1.5 kpc, rising to $> 96\%$ at 3 kpc and increasing further at larger radii.

5.3 Testable Prediction

In the deep-MOND regime, the velocity dispersion of a pressure-supported system depends only on baryonic mass and a_0 :

$$\sigma_{\text{GCV}} \sim (G M_* a_0)^{1/4} \approx 21 \text{ km/s} \quad (9)$$

For comparison, the Newtonian prediction (no dark matter) gives $\sigma_{\text{Newton}} \approx 6$ km/s at R_{eff} .

This prediction is made *before* any spectroscopic measurement of CDG-2, with no free parameters beyond $a_0 = 1.2 \times 10^{-10}$ m/s 2 . If follow-up spectroscopy measures $\sigma \approx 17\text{--}25$ km/s, it would strongly support GCV.

Table 3: GCV prediction for CDG-2 velocity dispersion

Baryonic mass assumption	σ_{GCV} (km/s)	Note
$M_b = 6 \times 10^6 M_\odot$ (low)	17.6	Lower L_V bound
$M_b = 1.2 \times 10^7 M_\odot$ (best)	20.9	Best estimate
$M_b = 1.8 \times 10^7 M_\odot$ (high)	23.1	Upper L_V bound
$M_b = 2.4 \times 10^7 M_\odot$ (+gas)	24.9	With 50% gas

6 Falsifiable Predictions

1. **Void expansion:** 5–15% faster than Λ CDM. 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 $w(z) = -1 + \epsilon \sigma^2(z) f_{\text{void}}(z)$, not linear CPL. Testable with DESI Year-3.
4. **CDG-2 velocity dispersion:** $\sigma \approx 21$ km/s (Eq. 9). Testable with spectroscopy of the GC system.

7 Discussion

7.1 Summary of Tests

Table 4: GCV vs Λ CDM: summary

Test	Λ CDM	GCV	Status
SPARC rotation curves (175)	Requires DM halo	0.06% deviation	Competitive
CDG-2 dark galaxy	Requires DM halo	Deep MOND, $\sigma \approx 21$ km/s	Prediction
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	<i>Not yet tested</i>	Unknown
Full MCMC	Mature	<i>Not yet done</i>	Unknown

7.2 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.

7.3 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).

8 Conclusions

We present GCV v15.0, 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:** Four predictions testable by 2028, including $\sigma \approx 21$ km/s for CDG-2.

GCV is not yet a proven replacement for Λ CDM. 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 119–139) and the modified CLASS C source are at <https://github.com/manuzz88/gcv-theory>. SPARC data: <http://astroweb.cwru.edu/SPARC/>.

References

- Bekenstein, J. D. 2004, Phys. Rev. D, 70, 083509
- Bellini, E., & Sawicki, I. 2015, JCAP, 07, 050

Blas, D., Lesgourgues, J., & Tram, T. 2011, JCAP, 07, 034

DES Collaboration 2022, Phys. Rev. D, 105, 023520

Heymans, C., et al. 2021, A&A, 646, A140

Kovács, A., et al. 2022, MNRAS, 515, 4417

Lelli, F., McGaugh, S. S., & Schombert, J. M. 2016, AJ, 152, 157

Akerib, D. S., et al. 2017, Phys. Rev. Lett., 118, 021303

McGaugh, S. S., Lelli, F., & Schombert, J. M. 2016, Phys. Rev. Lett., 117, 201101

Milgrom, M. 1983, ApJ, 270, 365

Planck Collaboration 2020, A&A, 641, A6

Riess, A. G., et al. 2022, ApJ, 934, L7

Verlinde, E. 2017, SciPost Phys., 2, 016

Li, D., et al. 2025, ApJ Lett., arXiv:2506.15644

Harris, W. E., Harris, G. L., & Hudson, M. J. 2017, ApJ, 836, 67

Burkert, A., & Forbes, D. A. 2020, AJ, 159, 56

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.
- v15.0 (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 $3.9\sigma \rightarrow 2.6\sigma$.
- v15.1 (2026-02-21): Added CDG-2 dark galaxy test case (Section 5). Testable prediction: $\sigma \approx 21$ km/s.

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

# Run the CDG-2 dark galaxy test (Script 139)
```

```
python3 gcv_gpu_tests/theory/139_CDG2_Dark_Galaxy_GCV_Test.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.