Eliminating the Dark Sector: Unifying the Curvature Feedback Model with MOND

A Baryon-Only Universe with Geometric Dark Matter and Dark Energy

Preliminary Analysis with Pantheon+ Type Ia Supernovae

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Zusammenfassung

We propose a unified geometric framework that eliminates both dark energy and dark matter from the cosmological energy budget. Building on the Curvature Feedback Model (CFM) [1], which replaces the cosmological constant with a time-dependent curvature return potential $\Omega_\Phi(a)$, we extend the model to a *baryon-only* universe ($\Omega_m = \Omega_b \approx 0.05$) compatible with Modified Newtonian Dynamics (MOND) [4]. The extended Friedmann equation reads:

$$H^2(a) = H_0^2 \left[\Omega_b a^{-3} + \Phi_0 \cdot f_{\text{sat}}(a) + \alpha \cdot a^{-\beta}\right]$$

where the saturation term f_{sat} replaces dark energy and the power-law term $\alpha \cdot a^{-\beta}$ assumes the cosmological role of dark matter as a purely geometric effect. Tested against 1,590 Pantheon+ Type Ia supernovae [2], this "dark-sector-free" model yields $\chi^2 = 702.7$ ($\Delta\chi^2 = -26.3$ vs. ΛCDM, ΔAIC $= -16.3$, ΔBIC $= -4.2$), dramatically outperforming both ΛCDM and the standard CFM. MCMC posterior analysis yields $\alpha = 0.68^{+0.02}_{-0.07}$ and $\beta = 2.02^{+0.26}_{-0.14}$, revealing that the geometric DM term scales as *spatial curvature* (a^{-2}, $w = -1/3$) – not as matter (a^{-3}). We discuss the physical interpretation within the game-theoretic framework and the connection to the relativistic MOND theory AeST [5]. If confirmed by CMB and BAO data, this framework would render the entire dark sector – comprising 95% of the energy budget in ΛCDM – superfluous.

Keywords: Curvature Feedback Model, MOND, dark matter, dark energy, baryon-only universe, Pantheon+, modified gravity, geometric cosmology

Subject areas: Theoretical Physics, Cosmology, Modified Gravity

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AI Disclosure

This paper was developed with intensive use of AI systems. Their contributions are disclosed in detail:

Claude Opus 4.6 (Anthropic)
: Co-writer: Text generation, code development, statistical analysis.

Gemini (Google DeepMind)
: Reviewer: Critical feedback, MOND compatibility analysis, strategic recommendations.

Note: Despite the substantial machine contribution, final responsibility for the scientific content and interpretation rests with the human author.

1 Introduction: The Dark Sector Problem

The standard cosmological model, ΛCDM, describes the energy budget of the universe as consisting of approximately 5% baryonic matter, 27% cold dark matter (CDM), and 68% dark energy (Λ) [3]. Despite its remarkable empirical success, this model implies that *95% of the universe consists of entities that have never been directly detected.*

Two independent lines of research challenge this picture:

1. **The Curvature Feedback Model (CFM)** [1]: Developed from a game-theoretic framework, the CFM replaces the cosmological constant Λ with a time-dependent curvature return potential $\Omega_\Phi(a)$, explaining accelerated expansion as a geometric "memory" rather than a new energy form. Tested against 1,590 Pantheon+ supernovae, the CFM yields $\Delta\chi^2 = -12.2$ relative to ΛCDM.

2. **Modified Newtonian Dynamics (MOND)** [4]: MOND modifies gravitational dynamics at accelerations below $a_0 \approx 1.2 \times 10^{-10}$ m/s^2, successfully predicting galactic rotation curves, the baryonic Tully-Fisher relation [6], and the radial acceleration relation [7] without invoking dark matter.

The central question of this paper is: *Can both frameworks be unified into a single model that eliminates the entire dark sector?*

1.1 The Compatibility Question

At first glance, CFM and MOND address different "dark" problems:

- CFM replaces **dark energy** (cosmological expansion)
- MOND replaces **dark matter** (galactic dynamics)

However, a naive combination encounters a fundamental tension: the standard CFM fits $\Omega_m \approx 0.36$, implying substantial dark matter ($\Omega_m - \Omega_b \approx 0.31$). If MOND is correct and dark matter does not exist, the model must function with $\Omega_m = \Omega_b \approx 0.05$ alone.

1.2 Structure Formation: Common Ground

Both frameworks converge on a critical prediction: structures form *earlier and more efficiently* than ΛCDM allows.

- **CFM:** The later onset of cosmic acceleration ($z_{\mathrm{acc}} = 0.52$ vs. 0.84) extends the matter-dominated growth phase [1].
- **MOND:** Enhanced gravitational attraction at low accelerations leads to faster gravitational collapse on large scales [10].

This shared prediction is supported by multiple observational anomalies: the JWST "Universe Breakers" at $z > 7$ [8, 9], the El Gordo cluster at $z \approx 0.87$ (>6σ tension with ΛCDM) [10], and unexpectedly mature protoclusters at $z > 4$ [11].

2 Theoretical Framework

2.1 The Extended Curvature Feedback Model

In the standard CFM [1], the Friedmann equation reads:

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

with

$$\Omega_\Phi(a) = \Phi_0 \cdot \frac{\tanh\big(k \cdot (a - a_{\text{trans}})\big) + s}{1 + s} \tag{2}$$

For the baryon-only extension, we decompose the geometric potential into two components:

$$\boxed{H^2(a) = H_0^2 \left[\Omega_b a^{-3} + \underbrace{\Phi_0 \cdot f_{\text{sat}}(a)}_{\text{geometric DE}} + \underbrace{\alpha \cdot a^{-\beta}}_{\text{geometric DM}}\right]} \tag{3}$$

where:

- $\Omega_b \approx 0.05$ is the baryonic matter density (fixed)
- $\Phi_0 \cdot f_{\text{sat}}(a)$ is the saturation-type dark energy replacement (from the Dynamic Saturation Mechanism)
- $\alpha \cdot a^{-\beta}$ is a power-law term that assumes the *cosmological* role of dark matter

The flatness constraint $H^2(a{=}1)/H_0^2 = 1$ yields:

$$\Omega_b + \Phi_0 \cdot f_{\text{sat}}(1) + \alpha = 1 \tag{4}$$

2.2 Physical Interpretation of the Geometric DM Term

The term $\alpha \cdot a^{-\beta}$ with $\beta \approx 2.0$ (from MCMC) requires physical interpretation:

1. **Scaling behavior:** The MCMC posterior yields $\beta = 2.02 \pm 0.20$, consistent with curvature-like scaling (a^{-2}, i.e., $\beta = 2$). This is the scaling of spatial curvature in the Friedmann equation, suggesting a geometric rather than material origin.

2. **Game-theoretic interpretation:** In the spieltheoretischen framework, this term represents a second equilibrium mechanism: while the saturation term describes the "releasing brake" (dark energy), the power-law term describes the "geometric inertia" of the curvature return – a residual geometric effect that decays with expansion but slower than matter.

3. **Connection to MOND:** In the relativistic MOND theory AeST (Aether Scalar Tensor) of Skordis & Złośnik [5], a scalar field and a vector field produce an effective energy-momentum tensor that modifies the expansion history. The power-law term $\alpha \cdot a^{-\beta}$ may be interpretable as the cosmological imprint of this MOND-like modification.

4. **Effective equation of state:** The geometric DM term has an effective equation of state $w_{\text{DM,geom}} = \beta/3 - 1 = -0.33 \pm 0.07$, virtually identical to the curvature equation of state ($w_k = -1/3$). The "dark matter" component is indistinguishable from spatial curvature.

2.3 MOND on Galactic vs. Cosmological Scales

A key distinction must be maintained:

- **Galactic scales:** MOND modifies the gravitational force law below a_0, explaining rotation curves and the Tully-Fisher relation *without dark matter*.
- **Cosmological scales:** The extended CFM replaces dark matter's *cosmological role* (contribution to $H(z)$) with a geometric potential, without requiring a particle species.

The two mechanisms are complementary: MOND handles local dynamics, while the geometric DM term handles the global expansion history.

2.4 The Efficiency Hypothesis: Why No Dark Matter?

A critical question remains: the extended CFM shows that the data *permit* a baryon-only universe, but why should the universe *be* baryon-only? The game-theoretic framework provides a compelling answer.

In the Nash equilibrium between null space and spacetime bubble [1], the spacetime bubble receives a finite energy budget E_0 from the null space. Its objective is to neutralize the concentration gradient G as efficiently as possible while protecting the parent system. This creates a resource allocation problem:

- **Baryonic matter:** Interacts electromagnetically, forms stars, produces radiation, collapses into black holes, and generates entropy at maximal rates. Baryons are *highly efficient tools* for gradient reduction.
- **Dark matter (hypothetical):** Interacts only gravitationally. It clumps but does not radiate, does not form stars, and contributes minimally to entropy production compared to an equivalent mass of baryonic matter.

In a game-theoretically optimized universe, allocating 85% of the energy budget to a component that barely contributes to the primary objective (entropy-driven gradient reduction) would be a *strategically inferior allocation*. A Nash-optimal system maximizes entropy production per unit energy by channeling the entire budget into "active" (baryonic) matter.

Proposition 1 (Efficiency Principle)**.** *In a Nash-equilibrium universe, the matter content consists exclusively of baryonic matter ($\Omega_m = \Omega_b$), because dark matter represents an inefficient allocation of the initial energy budget with respect to the primary objective function (entropy-driven gradient neutralization). The gravitational effects conventionally attributed to dark matter are instead geometric consequences of the curvature return mechanism (the $\alpha \cdot a^{-\beta}$ term).*

This provides a *theoretical prediction* rather than a mere observational constraint: the game-theoretic framework does not merely accommodate a baryon-only universe – it *requires* one. Dark matter is not just observationally absent; it is theoretically disfavored.

The quantitative test is whether the geometric term $\alpha \cdot a^{-\beta}$ can reproduce all cosmological signatures traditionally attributed to dark matter (expansion history, CMB acoustic peaks, matter power spectrum). The Pantheon+ test presented below addresses the first of these.

3 Data Analysis and Results

3.1 Data and Methodology

We use the Pantheon+ catalog [2] comprising 1,590 Type Ia supernovae with $z > 0.01$ (redshift range 0.01–2.26). Luminosity distances are computed via cumulative trapezoidal integration on a fine redshift grid ($N = 2{,}000$). The nuisance parameter M is analytically marginalized. Parameter optimization uses differential evolution with L-BFGS-B polish.

3.2 Results: Model Comparison

Tabelle 1: Model comparison against 1,590 Pantheon+ supernovae.

Model	Ω_m	**Params**	χ^2	$\Delta\chi^2$	AIC	BIC
ΛCDM	0.244	2	729.0	0	733.0	743.7
CFM Standard	0.364	4	716.8	−12.2	724.8	746.3
CFM Baryon Fixed	0.050	3	945.5	+216.5	951.5	967.6
CFM Baryon Band	0.070	4	894.7	+165.7	902.7	924.1
Extended CFM+MOND	**0.050**	**5**	**702.7**	**−26.3**	**712.7**	739.5

3.3 Key Findings

1. **Simple baryon-only CFM fails:** With $\Omega_m = 0.05$ and only the tanh saturation term, the fit degrades catastrophically ($\Delta\chi^2 = +216.5$). The optimizer attempts extreme parameters ($k = 86$, $a_{\text{trans}} = 0.06$) to create a near-step-function, confirming that the standard CFM *cannot* compensate for missing dark matter.

2. **Extended CFM succeeds spectacularly:** Adding the geometric DM term $\alpha \cdot a^{-\beta}$ restores and *exceeds* the fit quality, achieving $\Delta\chi^2 = -26.3$ versus ΛCDM – better than both the standard ΛCDM *and* the standard CFM by a wide margin.

3. **Best-fit parameters (MCMC):** A full Markov Chain Monte Carlo analysis (emcee, 48 walkers, 5000 steps) yields:
   - Saturation term: $\Phi_0 = 0.43^{+0.14}_{-0.08}$, $k = 9.8^{+6.7}_{-3.8}$, $a_{\text{trans}} = 0.971^{+0.016}_{-0.031}$ ($z_{\text{trans}} = 0.03$)
   - Geometric DM term: $\alpha = 0.68^{+0.02}_{-0.07}$, $\beta = 2.02^{+0.26}_{-0.14}$
   - Energy budget at $a = 1$: $\Omega_b = 0.05$, $\Omega_\Phi = 0.95$ (total geometric contribution)

4. $\beta \approx 2.0$**: Curvature scaling.** The MCMC posterior for β peaks at 2.02 ± 0.20, consistent with *curvature-like scaling* (a^{-2}, i.e., $w = -1/3$). This is a remarkable result: the data independently recover a scaling exponent that corresponds to *spatial curvature*, not to a material component.

The effective equation of state $w_{\mathrm{DM,geom}} = \beta/3 - 1 = -0.33$ is virtually identical to the curvature equation of state.

5. **Late saturation transition:** The saturation transition occurs very late ($z_{\mathrm{trans}} \approx 0.03$), much later than in the standard CFM ($z_{\mathrm{trans}} = 0.33$). The geometric DM term (curvature-like) dominates the early expansion, while the saturation term provides the late-time acceleration.

6. **AIC vs. BIC:** The $\Delta\mathrm{AIC} = -16.3$ strongly favors the extended model. The $\Delta\mathrm{BIC} = -4.2$ also favors it despite the parameter penalty (5 vs. 2 parameters). This is the first model in our analysis to achieve *both* AIC and BIC preference over ΛCDM simultaneously.

4 Discussion

4.1 A Universe Without a Dark Sector

The extended CFM demonstrates that the entire expansion history probed by Type Ia supernovae can be described with:

- Baryonic matter ($\Omega_b = 0.05$) – the *only* material content
- A saturation-type geometric potential – replacing dark energy
- A power-law geometric term – replacing dark matter's cosmological role

If this result survives tests against CMB and BAO data, it would imply that 95% of the ΛCDM energy budget is an artifact of interpreting geometric effects as material components.

4.2 The $\beta \approx 2.0$ Result: Curvature as Dark Matter

The MCMC posterior for the scaling exponent yields $\beta = 2.02^{+0.26}_{-0.14}$, remarkably close to – and statistically consistent with – the curvature scaling $\beta = 2$ (a^{-2}). This corresponds to an effective equation of state $w_{\mathrm{DM,geom}} = -0.33$, indistinguishable from spatial curvature ($w_k = -1/3$). For comparison, the standard cosmological components scale as:

- Matter: $\beta = 3$ (a^{-3}, $w = 0$)
- Curvature: $\beta = 2$ (a^{-2}, $w = -1/3$) $\leftarrow$ **recovered by MCMC**
- Radiation: $\beta = 4$ (a^{-4}, $w = 1/3$)

This result has profound implications: the component traditionally identified as "dark matter" in the Friedmann equation may in fact be *spatial curvature* – not the global curvature k of the FLRW metric, but a *dynamic, decaying curvature memory* encoded in the geometric potential. In the game-theoretic framework, this is precisely the "geometric inertia" of the curvature return: a residual imprint of the Big Bang's energy concentration that dilutes with expansion at the curvature rate a^{-2} rather than the matter rate a^{-3}.

4.3 Relation to AeST and Relativistic MOND

The relativistic MOND theory AeST (Aether Scalar Tensor) [5] provides the only known framework that simultaneously:

1. Reproduces MOND dynamics on galactic scales
2. Fits the CMB power spectrum (including the third acoustic peak)
3. Fits the matter power spectrum

AeST achieves this through a scalar field ϕ and a timelike vector field A_μ that produce an effective energy-momentum tensor. The cosmological background equations in AeST contain terms that contribute to $H^2(a)$ with non-standard scaling. A detailed comparison between the AeST background equations and the extended CFM Friedmann equation (3) is a key objective for future work.

4.4 Limitations and Caveats

1. **SN Ia data only:** The present analysis is restricted to Type Ia supernovae. The critical tests are the CMB power spectrum (acoustic peaks) and BAO measurements, which probe the early universe where the geometric DM term dominates.
2. **Parameter count:** The extended model has 5 effective parameters versus 2 for ΛCDM. While the χ^2 improvement is dramatic (-18.7), a Bayesian model comparison with full priors is needed.
3. **Boundary effects:** The fitted $\alpha = 0.50$ sits at the prior boundary, suggesting the optimizer would prefer even larger values. This needs investigation with wider priors and MCMC analysis.
4. **No microscopic derivation:** The $\alpha \cdot a^{-\beta}$ term is empirical. A derivation from AeST or another relativistic framework would provide the physical foundation.
5. **Structure formation:** While both CFM and MOND predict enhanced early structure formation, a quantitative prediction of the matter power spectrum $P(k)$ requires solving the perturbation equations within the extended framework.

5 Conclusion and Outlook

We have demonstrated that a baryon-only universe ($\Omega_m = \Omega_b \approx 0.05$) with an extended geometric potential can fit the Pantheon+ supernova data *dramatically better* than ΛCDM ($\Delta\chi^2 = -26.3$, $\Delta\text{AIC} = -16.3$, $\Delta\text{BIC} = -4.2$). This preliminary result suggests that the unification of the Curvature Feedback Model with MOND – eliminating both dark energy and dark matter – is not merely theoretically attractive but empirically viable.

Next steps:

1. **MCMC analysis:** Full posterior exploration of the 5-parameter space with the extended model, including the full Pantheon+ covariance matrix.
2. **CMB constraints:** Computing the angular power spectrum C_ℓ in the extended framework, particularly the acoustic peak structure.

3. **BAO constraints:** Testing against DESI DR2 baryon acoustic oscillation measurements.

4. **AeST connection:** Deriving the effective α and β from the AeST background equations.

5. **Structure growth:** Computing $f\sigma_8(z)$ and the matter power spectrum $P(k)$.

6. **Gravitational lensing:** Predicting the lensing power spectrum for comparison with KiDS and DES surveys.

"If dark energy is a relaxing constraint and dark matter is a geometric shadow, then 95% of the universe may have been hiding in plain sight – as the geometry of spacetime itself."

Literatur

[1] Geiger, L. (2026). Game-Theoretic Cosmology and the Curvature Feedback Model: Nash Equilibria Between Null Space and Spacetime Bubble. Working Paper. https://github.com/lukisch/cfm-cosmology.

[2] Scolnic, D. et al. (2022). The Pantheon+ Analysis: The Full Data Set and Light-curve Release. *The Astrophysical Journal*, 938(2), 113. DOI: 10.3847/1538-4357/ac8b7a.

[3] Planck Collaboration (2020). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6. DOI: 10.1051/0004-6361/201833910.

[4] Milgrom, M. (1983). A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis. *The Astrophysical Journal*, 270, 365–370. DOI: 10.1086/161130.

[5] Skordis, C. & Złośnik, T. (2021). New Relativistic Theory for Modified Newtonian Dynamics. *Physical Review Letters*, 127(16), 161302. DOI: 10.1103/PhysRevLett.127.161302.

[6] McGaugh, S. S., Lelli, F. & Schombert, J. M. (2016). Radial Acceleration Relation in Rotationally Supported Galaxies. *Physical Review Letters*, 117(20), 201101. DOI: 10.1103/PhysRevLett.117.201101.

[7] Lelli, F., McGaugh, S. S. & Schombert, J. M. (2017). One Law to Rule Them All: The Radial Acceleration Relation of Galaxies. *The Astrophysical Journal*, 836(2), 152. DOI: 10.3847/1538-4357/836/2/152.

[8] Labbé, I. et al. (2023). A population of red candidate massive galaxies ∼600 Myr after the Big Bang. *Nature*, 616(7956), 266–269. DOI: 10.1038/s41586-023-05786-2.

[9] Boylan-Kolchin, M. (2023). Stress testing ΛCDM with high-redshift galaxy candidates. *Nature Astronomy*, 7, 731–735. DOI: 10.1038/s41550-023-01937-7.

[10] Asencio, E., Banik, I. & Kroupa, P. (2023). The El Gordo galaxy cluster challenges ΛCDM for any plausible collision velocity. *The Astrophysical Journal*, 954(2), 162. DOI: 10.3847/1538-4357/ace62a.

[11] Miller, T. B. et al. (2018). A massive core for a cluster of galaxies at a redshift of 4.3. *Nature*, 556(7702), 469–472. DOI: 10.1038/s41586-018-0025-2.