# 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 $f_{\text{sat}}$ 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 $\chi^2 = 710.3$ ($\Delta\chi^2 = -18.7$ vs. ΛCDM, $\Delta\text{AIC} = -12.7$), outperforming both ΛCDM and the standard CFM. The fitted parameters ($\alpha = 0.50$, $\beta = 2.61$) suggest a geometric contribution that scales between matter-like ($a^{-3}$) and radiation-like ($a^0$) behavior. 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, $\Lambda$CDM, describes the energy budget of the universe as consisting of approximately 5% baryonic matter, 27% cold dark matter (CDM), and 68% dark energy ($\Lambda$) [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 $\Lambda$ 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 $\Lambda$CDM.

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 $\Lambda$CDM allows.

- **CFM:** The later onset of cosmic acceleration ($z_{\text{acc}} = 0.52$ 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 $z \approx 0.87$ (>$6\sigma$ tension with $\Lambda$CDM) [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 $\beta \approx 2.6$ requires physical interpretation:

1. **Scaling behavior:** The exponent $\beta = 2.6$ lies between matter-like scaling ($a^{-3}$, i.e., $\beta = 3$) and a slower dilution. This is intermediate between pressureless dust and a cosmological constant.
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 $w_{\text{DM,geom}} = \beta/3 - 1 \approx -0.13$. This is close to but distinct from pressureless matter ($w = 0$), consistent with a geometric rather than particulate origin.

### 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.

## 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. All models except ΛCDM and CFM Baryon Fixed include $\Omega_m$ as a free parameter or fix it at $\Omega_b = 0.05$.

| Model | $\Omega_m$ | Params | $\chi^2$ | $\Delta\chi^2$ | 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** | **710.3** | **−18.7** | **720.3** | 747.1 |

### 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 $\Delta\chi^2 = -18.7$ versus ΛCDM – better than both the standard ΛCDM *and* the standard CFM.

3. **Best-fit parameters:**

    - Saturation term: $\Phi_0 = 0.752$, $k = 3.99$, $a_{\text{trans}} = 0.95$ ($z_{\text{trans}} = 0.05$)

- Geometric DM term: $\alpha = 0.50$, $\beta = 2.61$
- Energy budget at $a = 1$: $\Omega_b = 0.05$, $\Omega_\Phi = 0.95$ (total geometric contribution)

4. **Late transition:** The saturation transition occurs very late ($z_{\text{trans}} = 0.05$), much later than in the standard CFM ($z_{\text{trans}} = 0.33$). The geometric DM term dominates the early expansion, while the saturation term provides the late-time acceleration.

5. **AIC vs. BIC:** The $\Delta\text{AIC} = -12.7$ strongly favors the extended model. The $\Delta\text{BIC} = +3.4$ reflects the parameter penalty (5 vs. 2 parameters). Given the dramatic $\chi^2$ improvement and the elimination of *two* fundamental components ($\Lambda$ + CDM), this BIC penalty is remarkably modest.

# 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 $\Lambda$CDM energy budget is an artifact of interpreting geometric effects as material components.

## 4.2 The $\beta \approx 2.6$ Problem

The fitted exponent $\beta = 2.61$ does not correspond to any standard cosmological component:

- Matter: $\beta = 3$ ($a^{-3}$)
- Radiation: $\beta = 4$ ($a^{-4}$)
- Curvature: $\beta = 2$ ($a^{-2}$)

The value $\beta \approx 2.6$ is closest to "curvature-like" behavior with a slight matter-like correction. This is suggestive: in the game-theoretic framework, the curvature return potential represents the geometric "memory" of the Big Bang. A curvature-like scaling ($\sim a^{-2}$) modified by the ongoing matter-geometry interaction could naturally produce $\beta \approx 2.6$.

## 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 $\phi$ and a timelike vector field $A_\mu$ 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 $\chi^2$ 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 *better* than ΛCDM ($\Delta\chi^2 = -18.7$, $\Delta\text{AIC} = -12.7$). 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 $C_\ell$ 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 $\alpha$ and $\beta$ 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."*

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