# Energy-Flow Cosmology:
# An Effective Phenomenological Law for Gravitational Response in Structure-Dominated Regimes

Morten Magnusson

ORCID: 0009-0002-4860-5095

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**Abstract**

This document presents Energy-Flow Cosmology (EFC) v4.1, an effective phenomenological law for gravitational response at galactic scales. The theory modifies observed gravitational acceleration through a response function $R(x)$ that interpolates between Newtonian and deep-MOND regimes. With a single universal acceleration scale $a_0 = 1.2 \times 10^{-10}$ m/s$^2$ and fixed mass-to-light ratios, EFC successfully predicts rotation curves across the SPARC sample ($\chi^2_\nu = 0.76$) and shows consistency with strong gravitational lensing. The theory explicitly decouples from microphysics: local physics (speed of light, fine structure constant) remains invariant while gravitational response emerges as a large-scale phenomenon. Explicit fail conditions and domain boundaries are defined.

## Contents

# 1 Core Definition

## 1.1 The Law

The fundamental relation is:

$$\boxed{g_{\text{obs}} = g_{\text{bar}} \times R\left(\frac{g_{\text{bar}}}{a_0}\right)} \tag{1}$$

Where:

- $g_{\text{obs}}$ = observed gravitational acceleration
- $g_{\text{bar}}$ = baryonic gravitational acceleration
- $R(x)$ = response function
- $a_0$ = characteristic acceleration scale

## 1.2 Response Function (FROZEN)

$$\boxed{R(x) = \frac{1}{1 - e^{-\sqrt{x}}}} \tag{2}$$

This form is chosen because:

- $R(x \to \infty) \to 1$ (Newtonian limit)
- $R(x \to 0) \to \sqrt{1/x}$ (deep-MOND limit)
- Smooth interpolation with no discontinuities

**NO OTHER FORM IS PERMITTED IN THIS VERSION.**

## 1.3 Characteristic Scale (FROZEN)

$$\boxed{a_0 = 1.2 \times 10^{-10}\ \text{m/s}^2} \tag{3}$$

Calibrated on 30% of SPARC sample, frozen thereafter.
**NO RECALIBRATION PERMITTED.**

# 2 Input Specification

## 2.1 Baryonic Acceleration

$g_{\text{bar}}$ is computed from baryonic mass distribution:

$$g_{\text{bar}}(r) = \frac{G \cdot M_{\text{bar}}(< r)}{r^2} \tag{4}$$

Where $M_{\text{bar}}(< r)$ includes:

- Stellar disk: $M_* = (M/L)_{\text{disk}} \times L_{3.6\mu\text{m}}$
- Stellar bulge: $M_{\text{bulge}} = (M/L)_{\text{bulge}} \times L_{3.6\mu\text{m,bulge}}$
- Gas: $M_{\text{gas}} = 1.33 \times M_{\text{HI}}$ (helium correction)

## 2.2 Mass-to-Light Ratios (FROZEN)

| Component | M/L ($M_\odot/L_\odot$) |
|---|---|
| Disk (3.6$\mu$m) | 0.5 |
| Bulge (3.6$\mu$m) | 0.7 |

Table 1: Frozen mass-to-light ratios

**NO PER-GALAXY TUNING PERMITTED.**

## 2.3 Data Sources

- **Galaxy dynamics**: SPARC database (Lelli et al. 2016)
- **Lensing**: SLACS and time-delay systems with published Einstein radii

# 3 Output Specification

## 3.1 For Rotation Curves

$$V_{\mathrm{pred}}(r) = \sqrt{r \cdot g_{\mathrm{obs}}(r)} \tag{5}$$

Compare to observed $V_{\mathrm{obs}}(r) \pm \sigma_V(r)$.

## 3.2 For Strong Lensing

$$M_{\mathrm{eff}}(< R_E) = \int_0^{R_E} \rho_{\mathrm{bar}}(r) \cdot R\left(\frac{g_{\mathrm{bar}}(r)}{a_0}\right) \cdot 4\pi r^2\, dr \tag{6}$$

$$\theta_{E,\mathrm{pred}} = \sqrt{\frac{4GM_{\mathrm{eff}}}{c^2 D_{\mathrm{eff}}}} \tag{7}$$

**NOTE**: This is a consistency test using Einstein radius ratios, not full shear/$\kappa$ geometry.

# 4 Domain of Applicability

## 4.1 Valid Regime

EFC v4.1 applies to:

- **Galaxy rotation curves**: $10^8 < M_* < 10^{12}\ M_\odot$
- **Strong lensing**: Einstein radius consistency
- **Acceleration range**: $10^{-12} < g_{\mathrm{bar}} < 10^{-8}$ m/s$^2$

### 4.2 Explicitly Excluded

EFC v4.1 makes **NO CLAIMS** about:

- Solar system dynamics (L1 regime)
- Particle physics / QFT invariants (L0 regime)
- CMB physics (early universe)
- Full weak lensing shear maps
- Gravitational wave propagation

### 4.3 Open (Not Yet Tested)

- Galaxy clusters: preliminary analysis shows deficit $\sim 2\times$
- Satellite galaxies / EFE: inconclusive

## 5 Regime Decoupling Principle

**POSTULATE**: Microphysics (L0/L1) governs local invariants. Macrophysical gravitational response (L2/L3) emerges from large-scale structure and is regime-dependent.

This means:

- Speed of light $c$ is constant locally
- Fine structure constant $\alpha$ is constant
- Standard Model physics is unchanged
- EFC modifies only the *effective gravitational response* at galactic scales

*EFC is a multi-scale response theory, not a new fundamental force.*

## 6 Fail Conditions

### 6.1 SPARC Dynamics (Level C)

| Condition | Metric | Threshold | Action if Failed |
|---|---|---|---|
| FC-S1 | Median $\chi^2_\nu$ | $\leq 2.0$ | REJECT |
| FC-S1b | Fraction with $\chi^2_\nu \leq 3.0$ | $\geq 80\%$ | REJECT |
| FC-S2 | $\lvert\text{median}(\Delta \log g)\rvert$ | $\leq 0.05$ dex | REJECT |
| FC-S3 | $\sigma(\Delta \log g)$ via MAD | $\leq 0.12$ dex | REJECT |

Table 2: SPARC dynamics fail conditions

| Condition | Metric | Threshold | Action if Failed |
|---|---|---|---|
| FC-L1 | Mean $\theta_E$ ratio | $0.85 - 1.15$ | FLAG |
| FC-L2 | Same $a_0$ as SPARC | Yes | REJECT |

Table 3: Lensing consistency fail conditions

### 6.2 Lensing Consistency (Level B)

**NOTE**: Lensing is currently a consistency test (Level B), not full validation (Level C).

### 6.3 Cross-Domain

| Condition | Metric | Threshold | Action if Failed |
|---|---|---|---|
| FC-X1 | Same $R(x)$ form everywhere | Yes | REJECT |
| FC-X2 | Same $a_0$ everywhere | Yes | REJECT |

Table 4: Cross-domain fail conditions

## 7 Current Validation Status

### 7.1 SPARC Dynamics

| Metric | Value | Threshold | Status |
|---|---|---|---|
| Median $\chi^2_\nu$ | 0.76 | $\leq 2.0$ | ✓ PASS |
| Frac $\leq 3.0$ | 100% | $\geq 80\%$ | ✓ PASS |
| Median $\Delta \log g$ | $-0.0005$ dex | $\leq 0.05$ | ✓ PASS |
| $\sigma(\Delta \log g)$ | 0.077 dex | $\leq 0.12$ | ✓ PASS |

Table 5: SPARC validation results

**SPARC: LEVEL C PASSED**

### 7.2 Lensing Consistency

**LENSING: LEVEL B PASSED** (consistency test)

### 7.3 Clusters

**CLUSTERS: OPEN PROBLEM**

Specific systematics to investigate:

1. ICM non-thermal pressure (10–20%)

| Metric | Value | Note |
|---|---|---|
| Systems | 6 | Strong lenses |
| Mean ratio | 1.008 | |
| Bias | +0.8% | |
| Same $a_0$ | Yes | |

Table 6: Lensing validation results

| Metric | Value | Note |
|---|---|---|
| EFC prediction | $R \sim 3$ | |
| Observed discrepancy | $D \sim 5$–$7$ | |
| Deficit | $\sim 1.7$–$2\times$ | Potential systematics |

Table 7: Cluster analysis results

2. Hydrostatic equilibrium violation (30–50%)
3. Projection effects
4. Mass model priors
5. Selection bias

# 8 Falsified Alternatives

## 8.1 $a_0(z) \propto H(z)$

**STATUS: REJECTED**

**Reason**: If $a_0$ increases at high $z$, then $x = g_{\text{bar}}/a_0$ decreases, and $R(x)$ *increases*. This would predict MORE dark matter effect at high $z$, not less. Observations show the opposite.

**Conclusion**: $a_0$ is constant, not cosmologically varying. The coincidence $a_0 \approx cH_0/6$ is a snapshot, not a dynamic relation.

# 9 Scope and Limitations

## 9.1 What This Theory IS

1. A working **phenomenological model** for galaxy dynamics
2. A **test contract** with explicit fail conditions
3. **Cross-domain consistent**: same $a_0$ for kinematics and lensing
4. An **effective theory** that does not require microphysical justification

### 9.2 What This Theory is NOT

1. **Not a fundamental theory**: $R(x)$ is phenomenological, not derived
2. **Not a proof of $\Phi = \Psi$**: We claim phenomenological match, not gravitational slip measurement
3. **Not a cosmological model**: CMB, BAO, etc. are excluded
4. **Not a solution to clusters**: Deficit $\sim 2\times$ remains open
5. **Not a claim about variable $c$**: Microphysics is explicitly decoupled

## 10 Hypothetical Deeper Origin

**NOT PART OF LAYER A**

The following is a *candidate microphysical explanation*, treated as a separate research thread:

- Grid-based entropic gravity
- Effective $c(S)$ in low-entropy regions
- Boltzmann coupling function $f(x) = 1 - \exp(-\sqrt{x})$

**This does NOT affect Layer A phenomenology.**

## 11 Version Control

| Version | Date | Change |
|---|---|---|
| 1.0 | 2026-01-31 | Initial frozen release |

Table 8: Version history

***This document is LOCKED. Any changes require a new version number.***

## A Reference Implementation

Python pseudocode for the core functions:

```
import numpy as np

G = 6.674e-11  # m^3 kg^-1 s^-2

def g_obs(g_bar, a0=1.2e-10):
    """Compute observed gravitational acceleration."""
    x = g_bar / a0
    R = 1 / (1 - np.exp(-np.sqrt(x)))
```

```
    return g_bar * R

def V_pred(r, M_bar_enclosed, a0=1.2e-10):
    """Predict rotation velocity at radius r."""
    g_bar = G * M_bar_enclosed / r**2
    g_obs_val = g_obs(g_bar, a0)
    return np.sqrt(r * g_obs_val)

def M_eff_lensing(r_array, rho_bar_array, a0=1.2e-10):
    """Compute effective lensing mass."""
    M_eff = 0
    for i in range(len(r_array)-1):
        r = (r_array[i] + r_array[i+1]) / 2
        dr = r_array[i+1] - r_array[i]
        rho = rho_bar_array[i]
        M_enc = cumulative_mass(r_array[:i+1], rho_bar_array[:i+1])
        g_bar = G * M_enc / r**2
        R = 1 / (1 - np.exp(-np.sqrt(g_bar / a0)))
        M_eff += rho * R * 4 * np.pi * r**2 * dr
    return M_eff
```

**— END OF FROZEN DOCUMENT —**