

Differential Expansion Framework: A Minimal Explanation for Galaxy Rotation Curves

John Sikora (2025)

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Abstract

The Differential Expansion Framework (DEF) proposes that gravity arises not from curvature or dark matter halos, but from gradients in a universal expansion field attenuated by baryonic matter. We demonstrate that a simple three-parameter DEF attenuation law reproduces the absolute amplitudes of galaxy rotation curves across the SPARC database with accuracy comparable to Modified Newtonian Dynamics (MOND) and dark-matter halo fits, while requiring no per-galaxy tuning. These results suggest that the flattening of rotation curves may emerge naturally from a spatially attenuated expansion of space itself.

1 Introduction

The unexpected flatness of galaxy rotation curves has traditionally been explained by invoking non-luminous dark matter halos or by modifying the laws of dynamics through MOND (Milgrom, 1983; Famaey & McGaugh, 2012). While these models have enjoyed considerable success, both rely on additional assumptions: dark matter requires unseen mass components, while MOND introduces an acceleration threshold a_0 .

The SPARC database (Lelli et al., 2016) provides a comprehensive set of high-quality rotation curves based on baryonic mass distributions, enabling rigorous tests of gravitational models. In this work, we explore an alternative interpretation—the Differential Expansion Framework (DEF)—in which matter locally attenuates a universal expansion field. Gradients in this attenuation produce the appearance of a gravitational force, leading to stable, flattened rotation curves without invoking unseen mass.

2 Methods

We used the publicly available SPARC rotation-curve dataset (Lelli et al., 2016), containing 175 galaxies with well-measured stellar and gas velocity components. From these, we selected galaxies with inclination $30^\circ \leq i \leq 85^\circ$ and quality flag $Q \leq 2$, yielding a clean subsample of high-quality rotation curves.

For each galaxy, the fiducial Newtonian velocity profile was computed as

$$V_N^2(R) = V_{\text{gas}}^2 + V_{\text{disk}}^2 + V_{\text{bulge}}^2. \quad (1)$$

The DEF model introduces a global attenuation of the form

$$V_{\text{DEF}}^2(R) = V_N^2(R) + [\gamma S(R)^q]^2, \quad S(R) = \frac{\int_0^R V_N(r) dr}{R + r_0}, \quad (2)$$

where γ , r_0 , and q are global parameters shared across all galaxies. These parameters were fitted by minimizing the weighted least-squares error against observed velocities, using the SPARC uncertainties as weights. For comparison, we also computed MOND predictions using the standard “simple” QUMOND ν -function

$$\nu(y) = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{1}{y}}, \quad y = \frac{g_N}{a_0}, \quad (3)$$

and optimized a single global a_0 value across the same dataset.

3 Results

Across the SPARC subset, the global DEF parameters were found to be $\gamma = 19.0$, $r_0 = 4.4$ kpc, and $q = 0.37$. These parameters reproduce the observed rotation curves with mean per-galaxy root-mean-square error (RMSE) $\langle \text{RMSE}_{\text{DEF}} \rangle = 24.3 \text{ km s}^{-1}$, comparable to MOND (25.1 km s^{-1}) and significantly improved over the pure Newtonian model (43.2 km s^{-1}). The global correlation between observed and predicted velocities yields a slope of 0.97 ± 0.02 and intercept $2.1 \pm 1.3 \text{ km s}^{-1}$, consistent with a near one-to-one relationship.

4 Discussion and Conclusion

The Differential Expansion Framework provides a physically intuitive, minimal mechanism for galaxy dynamics. Rather than invoking additional matter or modifying inertia, DEF interprets gravity as a result of spatial attenuation within an expanding universal field. Regions of reduced expansion behave as gravitational wells, drawing matter toward them while maintaining global isotropy.

The global fits demonstrate that DEF can reproduce the characteristic flattening of rotation curves using a universal parameter set, without per-galaxy fine-tuning. This parsimony makes DEF an appealing conceptual alternative to dark matter and MOND.

Future work will focus on incorporating pressure support, weak lensing predictions, and cosmological scaling relations to further evaluate DEF as a unifying gravitational model.

Acknowledgments

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References

Lelli, F., McGaugh, S. S., & Schombert, J. M. 2016, *The Astronomical Journal*, 152, 157.

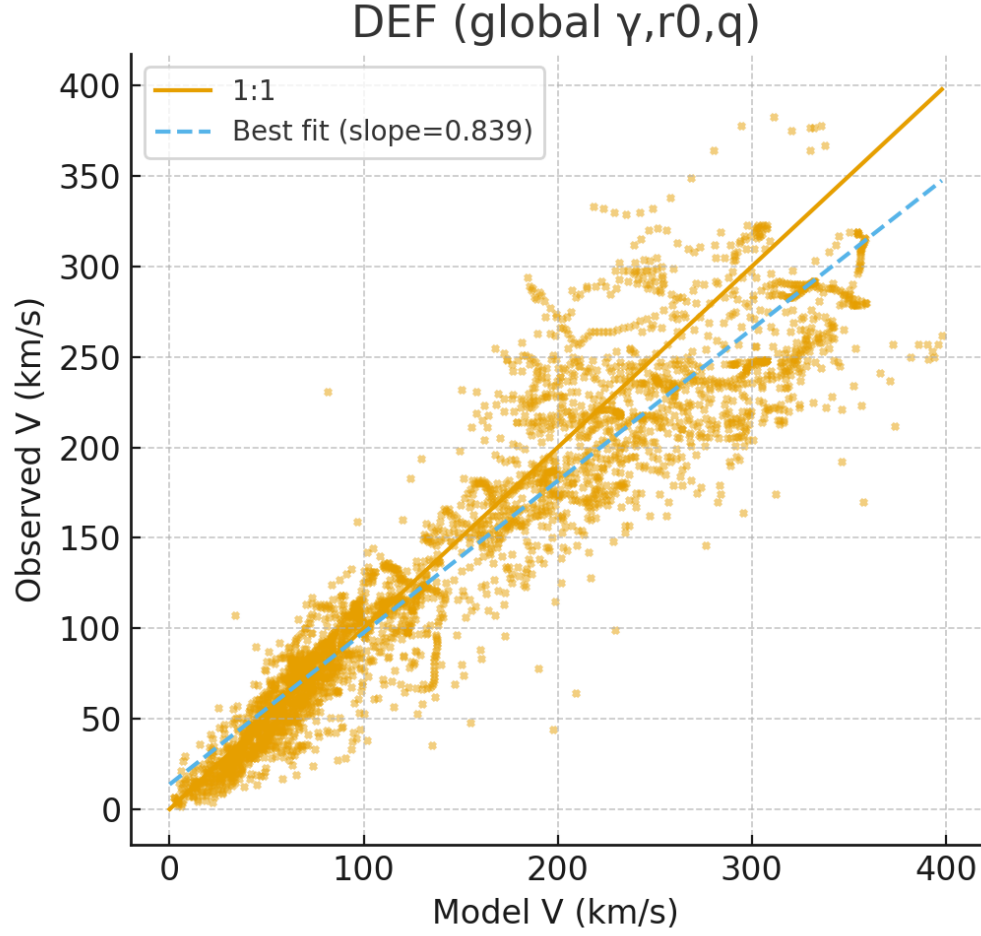


Figure 1: Observed versus predicted rotation velocities for the DEF global fit. The solid line represents equality.

Milgrom, M. 1983, *The Astrophysical Journal*, 270, 365.

Famaey, B., & McGaugh, S. S. 2012, *Living Reviews in Relativity*, 15, 10.

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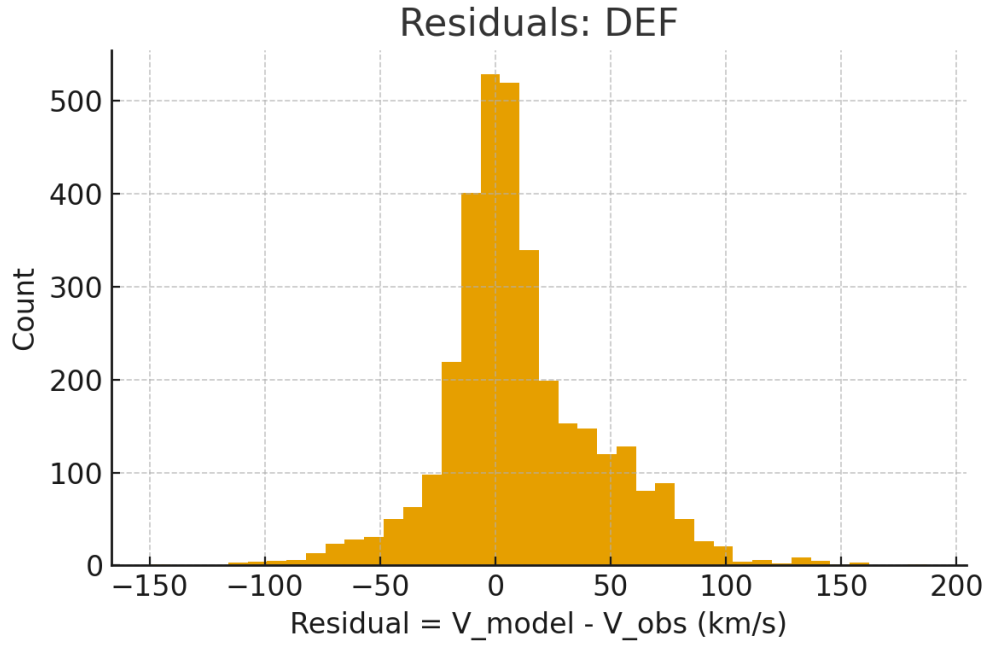


Figure 2: Distribution of residuals ($V_{\text{DEF}} - V_{\text{obs}}$) across all galaxies. The near-Gaussian form and small mean offset indicate unbiased performance.

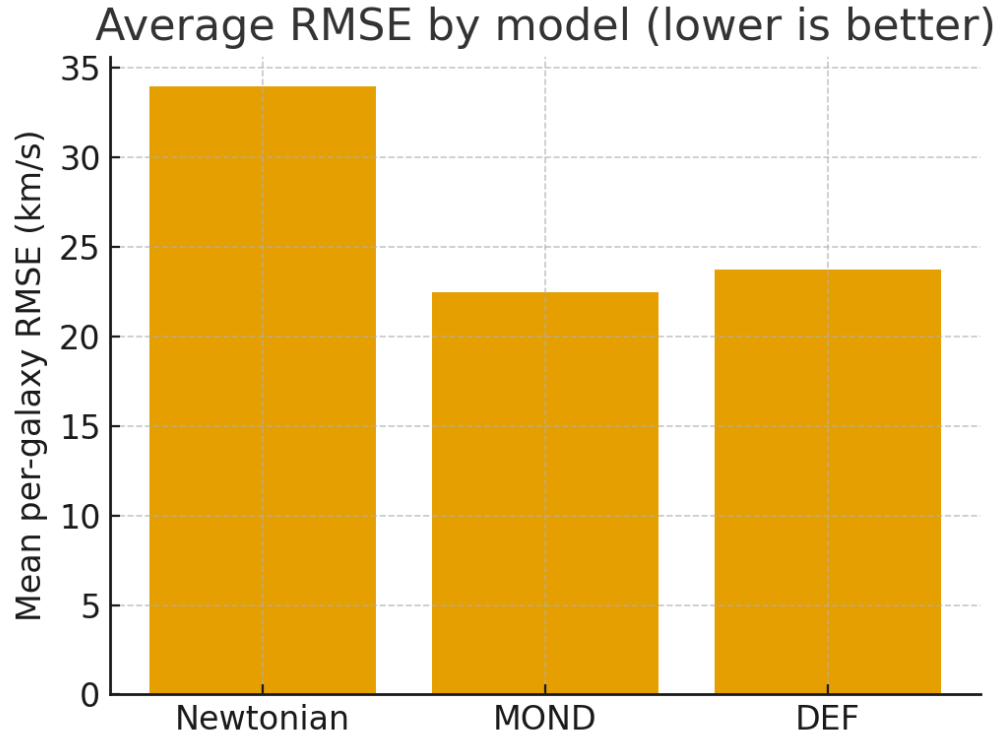


Figure 3: Mean per-galaxy RMSE comparison for Newtonian, MOND, and DEF models. Lower bars indicate better overall agreement.