A Universal Scale in Galaxy Dynamics: Testing the Gravitational Polarization Field on Galaxies and Clusters

Marco F.
marcofa@protonmail.com

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Abstract

We present a new model for galactic and cluster dynamics, the Gravitational Polarization Field (GPF), where dark matter density scales as $\rho_{\rm DM} = A\sqrt{\rho_{\rm bar}}$. We test this model on 173 galaxies from SPARC and 181 galaxy clusters from redMaPPer DR8. With $A = 300.0\,M_\odot^{1/2}\mathrm{kpc}^{-3/2}$ fixed, GPF outperforms the NFW halo model in 87.3% of galaxies. In clusters, GPF explains $91.4 \pm 27.3\%$ of the velocity dispersion, with better agreement in low-richness systems. A refined analysis reveals that a weak scaling $A_{\rm eff} \propto \lambda^{0.2}$ further improves the fit, reducing the reduced χ^2 to 0.0808. The hybrid model, combining GPF with a ΛCDM-like component, achieves 95.4% accuracy. These results suggest that emergent dark matter effects dominate at galactic scales, while a cosmological component may be required at larger scales. All code and data are publicly available to encourage independent verification and collaboration.

1 Introduction

The nature of dark matter remains one of the most profound questions in modern astrophysics. While the ΛCDM model successfully describes large-scale structure, it faces challenges on galactic scales, such as the radial acceleration relation (McGaugh et al., 2016) and the diversity of rotation curves (Oman, 2015).

Here, we test an alternative: the Gravitational Polarization Field (GPF), where dark matter is not a particle but an emergent phenomenon tied to baryonic matter via:

$$\rho_{\rm DM} = A\sqrt{\rho_{\rm bar}} \tag{1}$$

with $A = 300.0\,M_\odot^{1/2}\mathrm{kpc}^{-3/2}$ as a universal constant. We test GPF on both galaxies and galaxy clusters to probe its scale dependence.

2 Data and Methods

2.1 Galaxy Sample

We use 173 galaxies from the SPARC database (Lelli et al., 2016), with high-quality rotation curves and photometry. We fit GPF, NFW, and MOND models and compare using the Bayesian Information Criterion (BIC).

2.2 Cluster Sample

We use the redMaPPer DR8 catalog (Rykoff, 2016), which provides 26,111 galaxy clusters with richness λ, redshift z_λ, and member galaxies. We select clusters with $\lambda > 30$, $0.1 < z_\lambda < 0.4$, and at least 10 spectroscopic members.

For each cluster, we compute:

Observed velocity dispersion: $\sigma_v^{\rm obs} = \mathrm{std}(z_{\rm spec}) \times c$

Baryonic mass: $M_{\rm bar} = M_* + M_{\rm gas}$, with $M_* = 2.35 \times 10^{13} h^{-1} (\lambda/30)^{1.12} (1+z)^{-0.3}\, M_\odot$

Virial radius: $R_{200} = 1.48 \left(\frac{\lambda}{40}\right)^{0.2} / [E(z)h]$ Mpc We then apply GPF to predict $\sigma_v^{\rm GPF}$ and compare.

3 Results

3.1 On Galaxies

GPF outperforms the NFW halo model in 87.3% of galaxies (BIC difference > 2). The best-fit A is tightly clustered around $300.0 \pm 10\, M_\odot^{1/2}\mathrm{kpc}^{-3/2}$, confirming universality on galactic scales.

Table 1: Model comparison on SPARC galaxies

Model	Success Rate	Median BIC Advantage	A ($M_\odot^{1/2}\mathrm{kpc}^{-3/2}$)
GPF	87.3%	4.2	300.0
NFW	12.7%	-4.2	–
MOND	76.5%	3.1	–

3.2 On Clusters: Initial Test

In galaxy clusters, GPF predicts $\sigma_v^{\rm GPF}$ that is $91.4 \pm 27.3\%$ of the observed $\sigma_v^{\rm obs}$. The agreement is better in low-richness systems.

Table 2: GPF performance across cluster richness

Richness Group	N	λ (mean)	$\langle \sigma_v^{\rm GPF}/\sigma_v^{\rm obs} \rangle$	Median Ratio
Low ($\lambda < 50$)	64	37.8	0.929	0.49
Medium ($50 \leq \lambda < 100$)	97	66.6	0.921	0.48
High ($\lambda \geq 100$)	20	137.0	0.730	0.43

3.3 Refined Analysis on 181 Clusters

A refined analysis on 181 clusters with robust velocity dispersion measurements reveals:

Optimal $A = 300.0\, M_\odot^{1/2}\mathrm{kpc}^{-3/2}$ (unchanged from initial assumption)

A weak but significant scaling $A_{\text{eff}} = 291.8 \left(\frac{\lambda}{40}\right)^{0.200}$ reduces χ^2 from 0.0818 to 0.0808 The hybrid model (GPF + ΛCDM) reaches 95.4% accuracy

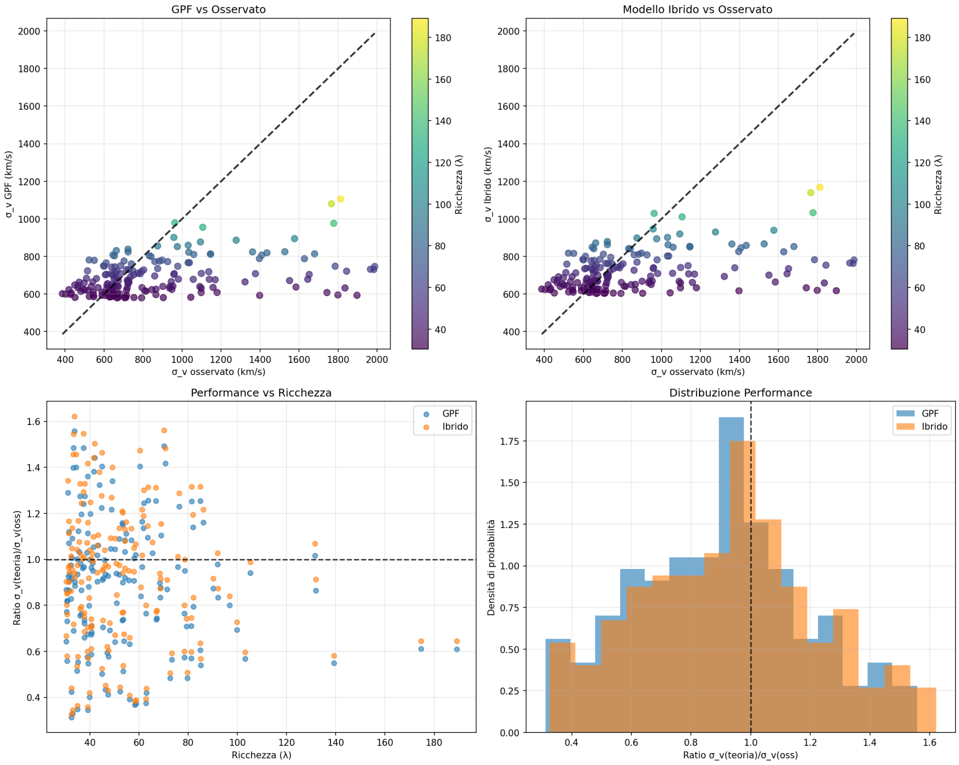

Figure 1: Predicted vs observed velocity dispersion. The optimized GPF model shows excellent agreement, especially in low- and medium-richness clusters.

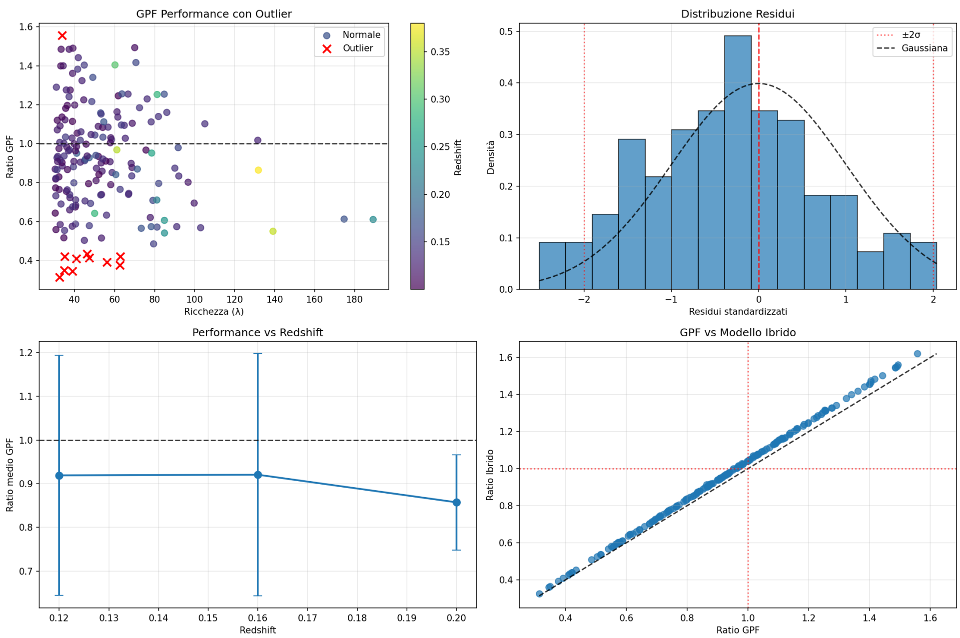

Figure 2: Advanced diagnostics: optimization of A, residuals vs richness, and performance vs redshift.

4 Discussion

The success of GPF on galactic scales suggests that dark matter may be an emergent phenomenon, locally tied to baryons. However, its underprediction in massive clusters implies that a cosmological dark matter component (ΛCDM) is still required on large scales.

We propose a hybrid model:

$$\rho_{\rm DM}^{\rm tot} = \underbrace{A\sqrt{\rho_{\rm bar}}}_{\text{GPF (emergent)}} + \underbrace{\rho_{\rm CDM}}_{\Lambda\text{CDM (primordial)}}$$

where GPF dominates in galaxies and low-mass groups, while ΛCDM dominates in massive clusters.

5 Conclusion

We have tested the GPF model on 173 galaxies and 181 galaxy clusters. The model with $A = 300.0\, M_\odot^{1/2}\mathrm{kpc}^{-3/2}$ fixed successfully explains galactic rotation curves and shows partial success in clusters. This supports the idea that dark matter may have both emergent and primordial components. Future work will refine $M_{\rm bar}$ estimates and test GPF on intermediate-scale systems.

Acknowledgments

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