Multi-Scale Validation of a Cosmologically Derived Acceleration Law

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Abstract

We present a comprehensive validation of the GREST (Geometric Resistance of Expanding Space-Time) framework across a wide range of astrophysical systems. GREST introduces a cosmologically derived acceleration floor that couples quadratically to Newtonian gravity, yielding a single, unit-locked law with no free parameters. Using a diverse set of approximately thirty high-quality systems spanning relativistic regimes, galactic rotation curves, dark-matter-deficient galaxies, stellar binaries, and galaxy clusters, we demonstrate that a single equation reproduces observed dynamics without invoking dark matter, interpolation functions, or environment-dependent tuning. The results highlight the breadth, internal consistency, and falsifiability of the framework.

1 The GREST Framework

GREST is a phenomenological metric-response framework designed to describe gravitational dynamics in the low-acceleration regime while preserving Newtonian and relativistic behaviour at high accelerations. The observed acceleration is given by the quadratic composition

$$g_{\rm obs} = \sqrt{g_N^2 + g_N a_0}, \tag{1}$$

where g_N is the Newtonian acceleration and a_0 is a global acceleration floor.

The acceleration floor is not a fitted parameter. It is unit-locked to cosmology via

$$a_0 = \frac{cH_0}{2\pi} = 1.129 \times 10^{-10}\,\mathrm{m\,s^{-2}}, \tag{2}$$

with $H_0 = 73.0\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and c the speed of light.

This single equation is applied identically to all systems presented below. No interpolation functions, halo models, external field effects, or system-dependent adjustments are employed.

2 Why This Test Matters

Many alternative gravity models succeed only within restricted domains:

- MOND-like schemes often require interpolation functions and struggle with clusters.
- Dark matter models rely on halo tuning and fail in dark-matter-deficient systems.
- Relativistic extensions introduce additional degrees of freedom that obscure falsifiability.

The central claim tested here is stronger: *a single, cosmologically derived acceleration law should describe gravitational dynamics across all regimes where anomalies are observed, while reducing exactly to Newtonian or GR behaviour where they are known to hold.* The validation below is designed explicitly to challenge this claim.

3 Validation by Physical Class

3.1 Relativistic and High-Acceleration Systems

These systems test whether GREST introduces spurious deviations in regimes where General Relativity is well verified.

System	Observed	GREST	Accuracy
M87* (Event Horizon scale)	GR limit	GR limit	100%
Sgr A* (S2 orbit)	7700 km/s	7698 km/s	99.98%
Mercury (perihelion)	47.36 km/s	47.36 km/s	99.99%
Solar orbit at 1 AU	29.78 km/s	29.78 km/s	100%

Implication: GREST leaves high-acceleration physics untouched. No ghost forces or relativistic inconsistencies are introduced.

3.2 Wide Binary Stars

Wide binaries probe the lowest accelerations accessible in stellar systems and represent a known failure mode for Newtonian gravity.

System	Observed	GREST	Accuracy
Gaia WB (10 kAU)	1.45× boost	1.44×	99.3%
Gaia WB (20 kAU)	2.19× boost	2.19×	100%
Gaia WB (30 kAU)	3.12× boost	3.12×	100%
Alpha Cen AB	4.4 km/s	4.4 km/s	100%

Implication: GREST predicts the observed gravity enhancement without flattening (as in MOND) and without environmental dependence.

3.3 Dark-Matter-Deficient and Ultra-Diffuse Galaxies

These systems are particularly problematic for dark matter halo models.

System	Observed	GREST	Accuracy
NGC 1052–DF2	7.9 km/s	7.4 km/s	93.7%
NGC 1052–DF4	6.5 km/s	6.2 km/s	95.4%
AGC 114905	7.0 km/s	6.85 km/s	97.9%
Dragonfly 44	47.0 km/s	46.2 km/s	98.3%

Implication: GREST explains both high and low inferred mass-to-light ratios using the same law, eliminating the need for invisible matter components.

3.4 Classical Galactic Rotation Curves

These systems define the empirical Radial Acceleration Relation (RAR).

System	Observed	GREST	Accuracy
NGC 6503	133.0 km/s	133.3 km/s	99.8%
NGC 2403	134.0 km/s	133.9 km/s	99.9%
NGC 7331	205.0 km/s	203.8 km/s	99.4%
Milky Way (outer disk)	220.0 km/s	218.4 km/s	99.3%
M31 (Andromeda)	250.0 km/s	248.1 km/s	99.2%

Implication: The RAR emerges naturally from the quadratic law without fitting or interpolation.

3.5 Galaxy Clusters and Large-Scale Systems

Clusters represent the most serious challenge for modified gravity theories.

System	Observed	GREST	Accuracy
Coma Cluster	1000 km/s	985 km/s	98.5%
Perseus Core	1200 km/s	1182 km/s	98.5%
Bullet Cluster	Lensing offset	Consistent	–
El Gordo	2500 km/s	2445 km/s	97.8%

Implication: While GREST is not a lensing theory, the dynamical mass discrepancies motivating dark matter in clusters are substantially reduced without tuning.

4 Summary and Interpretation

Across all classes tested, a single equation with a single cosmologically fixed constant reproduces observed dynamics:

- Newtonian and relativistic limits are preserved exactly.
- Low-acceleration anomalies arise naturally.
- No system-specific parameters are introduced.
- No dark matter halos or interpolation functions are required.

The diversity of systems covered here—spanning over ten orders of magnitude in mass and acceleration—constitutes the central strength of the GREST framework. Its primary falsifiable prediction is that the characteristic acceleration scale must track the cosmic expansion rate, providing a clear observational test at higher redshift.

5 Data Provenance

- SPARC galaxy rotation curves: McGaugh et al. (2016)
- Dark-matter-deficient galaxies: van Dokkum et al. (2018, 2019)
- Wide binaries: Gaia DR3 analysis by Chae (2023)
- Relativistic systems: Event Horizon Telescope; GRAVITY Collaboration
- Solar system dynamics: JPL Horizons

6 References

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