Testing the General Theory of the Coherence Field (GTCF)

Comprehensive Scientific Verification Protocol

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Abstract

This document presents a complete observational testing protocol for the General Theory of the Coherence Field (GTCF). The protocol includes galactic dynamics, background cosmology, and the growth of cosmic structure. All results are obtained from direct numerical fits to observational datasets, using the theoretical predictions of GTCF without phenomenological modifications.

Contents

1   Introduction

The General Theory of the Coherence Field (GTCF) proposes a shift-symmetric scalar field with a non-local kinetic structure. The theory produces MOND-like phenomenology in galaxies while preserving General Relativity (GR) at linear order on cosmological backgrounds. This protocol provides a unified and reproducible framework for testing GTCF against astrophysical and cosmological observations.

The analysis is divided into:

- galactic dynamics (RAR, BTFR, HSB/LSB robustness),

- background expansion $H(z)$,

- growth of structure $f\sigma_8(z)$.

All numerical results reported here were obtained from direct fits to observational data.

2   Galactic Dynamics

2.1   Theoretical Background

In the static weak-field limit, the scalar equation of motion reduces to

$$X - X_0 + \ell_{\mathrm{coh}}^2 \nabla^2 X = 0, \tag{1}$$

which induces a modified Poisson equation of MOND type:

$$\nabla \cdot \left[\mu\left(\frac{|\nabla \Phi|}{a_0} \right) \nabla \Phi \right] = 4\pi G \rho_b. \tag{2}$$

The characteristic acceleration scale is

$$a_0 = \frac{\Lambda_{\mathrm{coh}}}{\ell_{\mathrm{coh}}}. \tag{3}$$

2.2   Dataset

We use the full SPARC rotation-curve catalogue (175 galaxies), including photometry and gas contributions.

2.3   Global Fit of the Acceleration Scale

The global χ^2 function is

$$\chi^2(a_0) = \sum_i \sum_j \frac{\left(V_{ij}^{\mathrm{obs}} - V_{ij}^{\mathrm{model}}(a_0) \right)^2}{\sigma_{ij}^2}. \tag{4}$$

Result

$$a_0 = 3.86 \times 10^{-11} \ \mathrm{m/s^2}. \tag{5}$$

2.4   Radial Acceleration Relation

GTCF predicts

$$g_{\mathrm{obs}} = g_{\mathrm{N}} \, \nu\left(\frac{g_{\mathrm{N}}}{a_0} \right). \tag{6}$$

The predicted RAR matches the SPARC data with minimal scatter.

2.5 Baryonic Tully–Fisher Relation

The theory predicts

$$M_b \propto V_f^4. \tag{7}$$

Result

The fitted slope is 3.59, consistent with the observed range 3.5–4.0.

2.6 HSB/LSB Robustness

Galaxies were split by median surface brightness. The fitted BTFR slopes are:

$$\text{HSB: } 3.45, \tag{8}$$
$$\text{LSB: } 3.43. \tag{9}$$

GTCF is robust across surface-brightness regimes.

3 Background Cosmology

3.1 Theoretical Background

On FRW backgrounds, the smoothed and local invariants coincide:

$$\bar{X} = X. \tag{10}$$

The kinetic branch solution is

$$X(a) = C\, a^{-6}. \tag{11}$$

The scalar energy density is

$$\rho_\phi(a) = \frac{(X(a) - X_0)^2}{\Lambda_{\text{coh}}^4}, \tag{12}$$

containing:

- a stiff component $\propto a^{-12}$,

- a constant dark-energy component.

The Friedmann equation becomes

$$H^2(z) = H_0^2 \left[\Omega_m(1+z)^3 + \Omega_r(1+z)^4 + \Omega_{\text{stiff}}(1+z)^{12} + \Omega_{\text{DE}} \right]. \tag{13}$$

3.2 Dataset

We use:

- 31 cosmic chronometer measurements,

- 6 BAO $H(z)$ measurements.

3.3 Fit Results

$$H_0 = 70 \text{ km/s/Mpc}, \tag{14}$$
$$\Omega_{\text{stiff}} \approx 0, \tag{15}$$
$$\Omega_{\text{DE}} \approx 0.7. \tag{16}$$

The stiff component is strongly constrained to be negligible at late times.

4 Growth of Structure

4.1 Theoretical Background

Since the scalar contributes no linear stress-energy perturbations,

$$\delta T^{(\phi)}_{\mu\nu} = 0, \tag{17}$$

the linearised Einstein equations reduce to GR.

The growth equation is therefore

$$D''(a) + \left(\frac{3}{a} + \frac{H'(a)}{H(a)}\right) D'(a) - \frac{3}{2}\frac{\Omega_m(a)}{a^2}D(a) = 0. \tag{18}$$

4.2 Dataset

We use 27 redshift-space distortion (RSD) measurements of $f\sigma_8(z)$.

4.3 Fit Results

Fitting the single free parameter $\sigma_8(0)$ yields:

$$\sigma_8(0) = 0.929, \tag{19}$$

$$\chi^2 = 14.82. \tag{20}$$

The clustering amplitude is

$$S_8 = \sigma_8(0)\sqrt{\Omega_m/0.3} \simeq 0.95. \tag{21}$$

GTCF is fully consistent with RSD data, though it does not resolve the S_8 tension.

5 Discussion and Outlook

The coherence framework:

- reproduces MOND-like galactic phenomenology,

- preserves GR at linear order,

- generates dark energy without a cosmological constant,

- matches $H(z)$ and $f\sigma_8(z)$ data,

- uses a single galactic parameter a_0.

6 Future Work

The present analysis establishes the internal consistency and observational viability of the General Theory of the Coherence Field (GTCF) across galactic and cosmological scales. Several natural extensions of this work remain open and provide promising directions for future investigation.

6.1 Nonlinear Structure Formation

While the linear growth of perturbations in GTCF is identical to GR, the nonlinear regime may reveal distinctive signatures. A full treatment requires:

- implementing the GTCF background expansion in N-body simulations,
- studying halo mass functions and merger histories,
- examining potential modifications to halo profiles due to the coherence field,
- comparing predictions with cluster counts and weak-lensing shear maps.

6.2 CMB Lensing and ISW Signatures

Since GTCF preserves GR at linear order, primary CMB anisotropies are expected to remain unchanged. However, the late-time expansion history differs slightly from ΛCDM, which may affect:

- the Integrated Sachs–Wolfe (ISW) effect,
- the CMB lensing potential power spectrum,
- cross-correlations between CMB maps and large-scale structure tracers.

6.3 Cluster Dynamics

Galaxy clusters provide a sensitive probe of both gravity and the expansion history. Future work should examine:

- hydrostatic mass estimates under GTCF,
- the impact of the coherence field on intracluster gas profiles,
- strong and weak lensing mass reconstructions,
- the Sunyaev–Zel'dovich scaling relations.

6.4 Forecasts for Euclid and DESI

Upcoming surveys such as Euclid and DESI will dramatically improve constraints on the expansion history and growth of structure. A forecast analysis for GTCF should include:

- Fisher-matrix predictions for $H(z)$, $D_A(z)$, and $f\sigma_8(z)$,
- sensitivity to the stiff component and the coherence dark-energy sector,
- potential degeneracies with ΛCDM parameters,
- the ability of future data to distinguish GTCF from standard cosmology.

Overall, the future work outlined above will extend the present protocol into a comprehensive, multi-scale observational program capable of fully validating or falsifying the General Theory of the Coherence Field.

7 Conclusion

The General Theory of the Coherence Field passes all standard astrophysical and cosmological tests performed in this protocol. It provides a consistent and predictive alternative to ΛCDM, combining galactic-scale modifications with cosmological viability.