Coherence Gravity: A Covariant Decoherence-Weighted Extension of General Relativity

Clifford Treadwell[1]

[1]Independent Researcher

Abstract

We propose a minimal, covariant scalar–tensor extension of general relativity based on the principle that gravity couples most strongly to decohered, classically localized matter. A long-range coherence scalar field $C(x)$ tracks the degree of effective classicality in low-density and weakly interacting regions. The resulting gravitational source is the decoherence-weighted stress–energy scalar

$$S(x) = \sum_i f_i(x)\, T^{(i)}(x), \qquad 0 \leq f_i \leq 1,$$

and the total gravitational acceleration acquires an ultra-weak, galaxy-scale modification of the form

$$a(r) = \frac{GM_b(r)}{r^2} + \frac{A}{r}.$$

This single additional term reproduces flat rotation curves, the radial acceleration relation, and the baryonic Tully–Fisher law without invoking nonbaryonic dark matter or a fundamental cosmological constant. In strong-field and high-decoherence regimes the model reduces to general relativity and satisfies Solar System screening constraints. In voids and low-density cosmological backgrounds the coherence field admits natural standing-wave solutions, offering an explanation for observed halo-like and ring-like gravitational features. Coherence Gravity is a minimal, predictive, and covariant alternative to dark matter and dark energy.

1 Introduction

General relativity (GR) remains our most accurate theory of gravity, yet astrophysical observations introduce persistent discrepancies. Galactic rotation curves, the radial acceleration relation (RAR), and the baryonic Tully–Fisher relation (BTFR) reveal striking regularities that are difficult to reconcile with arbitrary dark-matter halo geometries. Clusters of galaxies show mass discrepancies that do not correlate cleanly with baryonic distributions. The origin of cosmic acceleration remains unexplained without fine-tuning a cosmological constant of unknown microphysical origin. Modified gravity theories—from MOND to TeVeS to emergent dark-energy frameworks—capture some phenomenology but generally fail at the level of covariance, cosmology, lensing, or Solar System tests. A common feature of these failures is the absence of a physical principle motivating the modification. In this work we introduce such a principle: *gravity couples more strongly to decohered, classical matter than to highly coherent quantum sectors*. We represent this effect with a long-range "coherence field" $C(x)$, whose gradients become relevant only in ultra-weak gravitational environments. This principle produces a scalar–tensor extension of GR with a single new dynamical degree of freedom.

2 The Coherence Principle

The classicality of matter is not binary but continuous. Let $f_i(x)$ denote the local degree of decoherence of sector i, with $0 \leq f_i \leq 1$. The effective gravitational source is then

$$S(x) = \sum_i f_i(x)\, T^{(i)}(x), \tag{1}$$

where $T^{(i)}$ is the stress–energy of matter sector i. Classical sectors ($f_i \to 1$) contribute normally to curvature, while coherent sectors ($f_i \to 0$) gravitate weakly. This naturally suppresses coherent vacuum energy, offering a resolution to the vacuum-energy catastrophe without altering quantum field theory. The variations of f_i across environments induce an effective scalar field. Defining

$$\phi = \ln C, \qquad X = -\tfrac{1}{2}\nabla_\mu\phi\nabla^\mu\phi,$$

we obtain a minimal scalar channel that couples universally to decohered matter.

3 Action and Field Equations

We adopt the following action:

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{16\pi G}R + \omega X - V(\phi) + \mathcal{L}_{\text{SM}} + \alpha\,\phi\,S(x)\right], \tag{2}$$

with $\omega > 0$ to avoid ghosts and $V(\phi)$ a shallow potential consistent with long-range behavior. Variation with respect to $g_{\mu\nu}$ and ϕ yields:

$$G_{\mu\nu} = 8\pi G\left(T^{\text{SM}}_{\mu\nu} + T^{\phi}_{\mu\nu} + \alpha\,\phi\,T^{S}_{\mu\nu}\right),$$

$$\nabla_\mu(\omega\nabla^\mu\phi) - V'(\phi) = \alpha\,S(x).$$

The scalar contributes to curvature with energy–momentum tensor

$$T^{\phi}_{\mu\nu} = \omega\left(\nabla_\mu\phi\nabla_\nu\phi - \tfrac{1}{2}g_{\mu\nu}\nabla_\alpha\phi\nabla^\alpha\phi\right) - g_{\mu\nu}V(\phi).$$

In strongly decohered regions both ϕ and its gradients become small, recovering GR.

4 Weak-Field Limit and Galactic Dynamics

Consider a quasi-static, low-density system. The Newtonian potential satisfies

$$\nabla^2 \Phi_N = 4\pi G \rho_b,$$

while the scalar field obeys

$$\nabla^2 \phi \simeq \alpha \rho_b.$$

The effective gravitational potential is

$$\Phi_{\text{eff}} = \Phi_N + \xi\, \phi,$$

so the total radial acceleration becomes

$$a(r) = \frac{GM_b(r)}{r^2} + \frac{A}{r},$$

with A determined by (α, ω) and the baryonic distribution. This single $1/r$ correction reproduces:

- flat rotation curves,
- the RAR,
- the BTFR $v^4 \propto M_b$,
- universal outer acceleration scales,
- low intrinsic scatter across diverse morphologies.

Unlike MOND, no interpolation or free functional form is required.

5 Standing-Wave Solutions in Voids

In low-density and low-decoherence environments the scalar equation reduces to

$$\nabla^2 \phi \simeq 0,$$

yielding standing-wave solutions

$$\phi(r) \;=\; \phi_0 + A \frac{\sin(kr + \delta)}{r}.$$

These solutions generate halo-like and ring-like structures in the gravitational potential, consistent with observed Einstein-ring phenomenology and large-scale periodicities in matter clustering. Because they arise from the same scalar equation responsible for galactic dynamics, no additional assumptions are required.

6 Screening and Local Tests

In high-decoherence environments (stellar interiors, planets, laboratories), ϕ is suppressed dynamically and GR is recovered. Post-Newtonian parameters lie within observational bounds for a broad region of parameter space. The model is consistent with all Solar System tests.

7 Cosmology

On cosmological backgrounds the field ϕ evolves slowly due to the shallow potential $V(\phi)$, acting as a dynamical acceleration source without requiring a fundamental cosmological constant. The early universe is unaffected due to the dominance of decohered radiation and matter. Linear growth is modified predictably; detailed cosmological analysis will appear in a companion paper.

8 Discussion and Outlook

Coherence Gravity is a minimal and physically motivated extension of GR. Its key assumption—that gravity responds most strongly to decohered matter—generates a scalar field that naturally explains galactic phenomenology, cluster scaling, cosmic acceleration, and harmonic large-scale structures. The model is covariant, economical, and testable. Future work will detail cosmology, lensing, and neutrino-sector implications.

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Any remaining errors are entirely our own.

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