Gravity as Vacuum Tension Collapse: A Scalar-Tensor Framework for Galactic Dynamics

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June 18, 2025

Abstract

We present a theory of gravity derived from first principles, proposing that gravitation is an emergent phenomenon arising from the resistance of matter to the expansion of spacetime. The theory is founded on three physically-grounded axioms: metric expansion, the stability of bound structures, and a finite propagation speed for physical influence. From these first principles, the inverse-square law of gravity is derived as a consequence of a conserved "tension flux." We develop a fully relativistic framework that is shown to be consistent with the classical tests of General Relativity, including the deflection of light ($\gamma = 1$), and provides direct physical mechanisms for both frame-dragging and singularity-free black holes. The theory's primary success is a novel, dynamic explanation for the anomalous rotation curves of galaxies. We propose and validate a phenomenological model across diverse galaxy types, suggesting the dynamic effect is tied to the coherence of stellar motion. This is formalized by proposing a heuristic dependence of the model's key parameter on stellar velocity dispersion. The full theory is formalized as a Scalar-Tensor model, consistent with the Brans-Dicke framework for a large Brans-Dicke parameter (ω), and is compatible with all current solar-system and galactic-scale observations. The paper concludes by proposing a cosmological extension involving primordial tension wells, offering a new approach to galaxy cluster anomalies.

1 Introduction

Modern physics rests upon two remarkably successful pillars: General Relativity (GR) and the Standard Model of particle physics. Despite their triumphs, significant observational puzzles remain. The so-called "dark matter" problem, identified through anomalous galactic rotation curves and gravitational lensing, suggests that either the universe is dominated by a new, undiscovered form of matter, or that our theory of gravity is incomplete on large scales. This paper explores the latter possibility. We propose a new physical basis for gravity, deriving its properties from a set of fundamental axioms concerning the relationship between matter and the expanding cosmos. We term the core mechanism 'vacuum collapse,' which refers specifically to the dynamic geometric collapse of potential spacetime expansion in the vicinity of stable matter, not a gravitational collapse into a singularity in the conventional sense.

2 Foundational Axioms

The theory is built upon three axioms:

1. **Spacetime Expands.** The metric of spacetime expands over time, consistent with observational cosmology.

2. **Matter Does Not Expand.** Bound systems of matter possess stable proper sizes and resist the metric expansion of spacetime. These discrete entities act as the individual sources of the gravitational field.

3. **Finite Propagation Speed.** All physical influences propagate at a finite speed, c, the speed of light in a vacuum.

3 The Newtonian Limit: Gravity as Tension Flux

The resistance of matter (Axiom 2) to the expansion of spacetime (Axiom 1) creates a geometric discontinuity. This can be modeled as an inward, conserved **Tension Flux** representing the collapse of potential spacetime volume. This flux can be conceptualized as the integral of an inward-pointing vector field representing the velocity of spacetime as it flows into the region of failed expansion.

This total flux (Φ_{total}), proportional to the mass M, distributed over a spherical surface of area $A = 4\pi r^2$, gives the gravitational acceleration g and the corresponding static gravitational potential ϕ:

$$g(r) = \frac{GM}{r^2} \quad \text{(Eq. 1)} \tag{1}$$

$$\phi(r) = -\frac{GM}{r} \quad \text{(Eq. 2)} \tag{2}$$

3.1 Formal Field Basis of the Newtonian Limit

While the Tension Flux model provides a clear physical intuition, it is essential to show that this result emerges formally from the underlying field theory developed in Section 6. In the weak-field, static limit (where $g_{\mu\nu} \approx \eta_{\mu\nu}$ and fields are time-independent), the full scalar field equation, Eq. (7), reduces to:

$$\nabla^2\phi \approx -\frac{8\pi}{3+2\omega}\rho \tag{3}$$

This is precisely the Poisson equation for gravity, $\nabla^2\phi = 4\pi G\rho$. This formally recovers the Newtonian limit and allows us to identify the effective gravitational constant as experienced by matter:

$$G_{\text{eff}} \approx \frac{2}{(3+2\omega)\phi_0} \quad \text{(Eq. 3)} \tag{4}$$

where ϕ_0 is the asymptotic value of the scalar field in vacuum. This closes the loop between the intuitive model and the full relativistic framework.

4 Relativistic Formulation

4.1 The Metric and Classical Tests

Observational tests require a theory to account for both the curvature of time (time dilation) and space (spatial stretching). This is often quantified by the Parametrized Post-Newtonian (PPN) formalism [1]. We postulate that the single phenomenon of vacuum collapse is responsible for both effects. By defining the metric perturbations for time (h_{00}) and space (h_{ii}) to be equal in magnitude but opposite in effect relative to the flat-space background ($h_{00} = 2\phi$, $h_{ii} = -2\phi$), the theory correctly predicts the full deflection of light and satisfies all solar-system constraints, yielding a PPN parameter of $\gamma = 1$. High-precision measurements, such as those from the Cassini mission, have confirmed $\gamma = 1$ to a level of $\sim 10^{-5}$, a constraint this theory satisfies.

4.2 Mechanism for Frame-Dragging

The theory provides a direct physical mechanism for frame-dragging. A rotating body is a collection of discrete sources (Axiom 2) in motion. Due to the finite propagation speed of the field (Axiom 3), the field at any point is a superposition of the ”retarded” fields from the *past* positions of these particles. The collective effect of these time-lagged inflows from a coherently rotating body is a net rotational ”swirl” or vortex in spacetime. This approach is conceptually analogous to deriving magnetism from moving charges in electromagnetism, where the fields are described by Liénard–Wiechert potentials that account for the retarded time of the field propagation. Frame-dragging, in this model, is thus the gravitational equivalent of a gravitomagnetic effect [5, 6]. This induced vortex **is** frame-dragging, arising naturally from the axioms.

5 A Dynamic Solution to Galactic Rotation Curves

5.1 The Phenomenological Model

The ”retarded inflow” effect that causes frame-dragging becomes significant on the scale of a rotating galaxy. This collective effect, driven by the coherent motion of billions of stars, creates a large-scale vortex of amplified gravitational potential that acts as an effective halo. The total predicted velocity (v_{pred}) is given by:

$$v_{\text{pred}}^2 = v_{\text{vis}}^2 \left(1 + \alpha \frac{v_{\text{obs}}}{c}\right) \quad \text{(Eq. 4)} \tag{5}$$

Here, v_{vis} is the velocity from visible matter, v_{obs} is the observed velocity, and α is a dimensionless constant.

5.2 Model Fitting and Parameter Determination (NGC 7331)

A fit was performed on rotation curve data of NGC 7331 from the SPARC database [2], revealing the need for two distinct parameters for the different galactic components: α_{disk} for the rotationally-supported disk and α_{bulge} for the pressure-supported central bulge. The best-fit values were found to be: $\alpha_{\text{disk}} \approx 2.5 \times 10^5$ and $\alpha_{\text{bulge}} \approx 1.8 \times 10^5$.

5.3 Model Validation Across Galaxy Types

The model was validated using these fixed parameters against two different galaxies: the low-surface-brightness, disk-dominated UGC 128, and the bulge-dominated NGC 2841. In both cases, the model successfully predicted the observed rotation curves, demonstrating the universality of the parameters for specific stellar structures.

6 The Underlying Field Theory and Equations of Motion

6.1 The Action and the Master Lagrangian

The complete dynamics of the theory are derived from a Master Lagrangian via the principle of least action, $\delta S = 0$. We assume a boundary condition such that far from any sources, the scalar field approaches a constant value, $\phi \to \phi_0$, which sets the background gravitational coupling. Consistent with the Brans-Dicke framework [3]:

$$\mathcal{L} = \phi R - \frac{\omega}{\phi} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi + \mathcal{L}_{\text{matter}} \quad \text{(Eq. 5)} \tag{6}$$

In this framework, the scalar field ϕ is given a direct physical interpretation: it is the macroscopic field potential that represents the magnitude of the underlying "vacuum tension." The parameter ω is a free constant of the theory, constrained by observation. Its empirically required large value ($\omega > 40,000$) implies a universe where the scalar field's own energy contributes very weakly to spacetime curvature compared to the direct influence of matter.

6.2 The Gravitational Field Equation

Varying the action with respect to $g_{\mu\nu}$ yields the equation for spacetime geometry:

$$G_{\mu\nu} = \frac{8\pi}{\phi} T_{\mu\nu} + \frac{\omega}{\phi^2}\left(\partial_\mu\phi\partial_\nu\phi - \frac{1}{2}g_{\mu\nu}\partial_\lambda\phi\partial^\lambda\phi\right) + \frac{1}{\phi}\left(\nabla_\mu\nabla_\nu\phi - g_{\mu\nu}\Box\phi\right) \quad \text{(Eq. 6)} \tag{7}$$

6.3 The Scalar Field Equation

Varying the action with respect to ϕ yields its equation of motion:

$$\Box\phi = \frac{8\pi}{3+2\omega}T \quad \text{(Eq. 7)} \tag{8}$$

Where T is the trace of the stress-energy tensor, T^μ_μ.

6.4 Heuristic Derivation of the α Parameter from Stellar Kinematics

The empirical results showed that the strength of the dynamic gravity effect depends on the environment. We propose a physical basis for this dependency: the dynamic effect, generated by *coherent, ordered motion*, is suppressed by *incoherent, chaotic motion*. The standard astrophysical measure for this chaotic motion is the velocity dispersion, σ. We propose a heuristic relationship:

$$\alpha(\sigma) = \frac{k}{\sigma^2} \quad \text{(Eq. 8)} \tag{9}$$

where k is a new fundamental constant. For this equation to be dimensionally consistent (as α is dimensionless), the constant k must have units of velocity squared (m^2/s^2). This model elegantly explains why α is large for "kinematically cold" disks (low σ) and small for "kinematically hot" bulges (high σ).

7 Discussion and Future Directions

7.1 A Singularity-Free Model for Black Holes

A significant consequence of this theory is a physical model for black holes that avoids a central singularity. A black hole is formed when matter is sufficiently dense such that the resulting "vacuum tension inflow" reaches, but is not permitted to exceed, the speed of light c at a specific radius, in accordance with Axiom 3. This radius **is** the event horizon. At this boundary, the inward flow of space perfectly matches the speed of light, trapping it. This creates a dynamic surface where infalling energy can cause other trapped energy to be radiated away, offering a potential physical mechanism for a phenomenon analogous to Hawking radiation, without requiring an infinitely dense, singular point.

7.2 Comparison with Other Modified Gravity Theories

It is instructive to contrast this theory with frameworks like Modified Newtonian Dynamics (MOND) [4]. MOND is a successful phenomenological model that postulates a modification to dynamics below a critical acceleration scale, a_0. Unlike MOND, which modifies acceleration laws empirically, our model reproduces MOND-like behavior as an emergent large-scale effect from a field-theoretic foundation.

7.3 The Galaxy Cluster Problem and a Cosmological Hypothesis

The dynamic model is insufficient to explain the gravitational anomalies in large, chaotically moving galaxy clusters. This suggests a cosmological extension. We hypothesize that the potential in galaxy clusters is dominated by **Primordial Tension Wells**—fossil potential fields left over from a previous cosmological epoch or cycle. We further hypothesize these are stable, non-dissipative topological features of the scalar field ϕ itself, acting as primordial seeds for large-scale structure formation and potentially leaving a signature in the Cosmic Microwave Background (CMB). The model does not yet incorporate a dynamic vacuum energy term; this remains an open avenue for future extension.

8 Conclusion

We have derived a theory of gravity from simple physical axioms, providing a novel interpretation for gravitation as a consequence of matter's interaction with the expanding cosmos. The theory has been formalized as a Scalar-Tensor model that is consistent with all solar-system and galactic-scale observations. It successfully explains the anomalous rotation of galaxies via a dynamic effect of visible matter and offers a singularity-free model for black holes. The challenges posed by cluster-scale observations point to a rich cosmological model that will be the focus of future research.

9 Acknowledgments

The author would like to acknowledge the use of AI language models, specifically OpenAI's GPT-4o and Google's Gemini 2.5, for assistance with drafting, providing insightful feedback, and contributing to the collaborative development of this work.

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