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Not peer-reviewed version

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Posted Date: 11 March 2026

doi: 10.20944/preprints202603.0864.v1

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Article

Repulsive Self-Gravity and Emergent Attraction

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Abstract

We present a geometric model in which each particle is associated with its own private spacetime manifold—a world-block—constructed from Fermi–Walker coordinates. The intrinsic spatial metric on each proper-time slice is treated as a dynamical field with a universal stiffness constant. This single assumption leads to a consistent model where self-gravity is repulsive and mutual gravity is attractive and exactly Newtonian. Newton's constant emerges from the fundamental stiffness. The model provides a geometric derivation of the inverse-square law and suggests a connection to cosmology: the constant part of the strain field on large scales can be interpreted as a cosmological constant whose magnitude is set by the Hubble radius.

Keywords: repulsive self-gravity; attractive mutual-gravity; cosmological constant; dark energy

1. Introduction

The reconciliation of quantum mechanics with general relativity remains one of the most profound challenges in theoretical physics. While the search for a complete theory of quantum gravity continues—via approaches such as string theory, loop quantum gravity, and asymptotic safety—there is also value in exploring phenomenological bridges between the two pillars of modern physics. One such bridge is the Schrödinger–Newton equation, originally introduced by Diósi [1] and later advocated by Penrose [2,3] as a possible description of gravitational self-interaction in quantum systems.

The Schrödinger–Newton equation describes how a quantum wavefunction interacts with its own Newtonian gravitational potential. The mass density associated with the wavefunction sources the gravitational field, which in turn affects the evolution of the wavefunction itself. This coupled system gives rise to a nonlinear, nonlocal equation that has been extensively studied as a candidate for gravitational state reduction [2,4,5], as a possible test of quantized gravity [6], and for its mathematical structure and symmetries [7]. Critical analyses have examined the regime of validity and experimental prospects for detecting effects predicted by this equation [8,9].

In this paper we take a geometric route to the Schrödinger–Newton equation by using Fermi–Walker coordinates [10–12]. These coordinates adapt a local reference frame to an arbitrary timelike observer, whether inertial or accelerated. We elevate this coordinate system from a mere technical tool to a central physical concept. We propose that each quantum particle is associated with its own private Fermi–Walker spacetime—a four-dimensional manifold we call the **world-block**. On each proper-time slice of this world-block, the induced spatial metric is promoted to a dynamical field governed by an action principle.

This approach resonates with earlier geometric formulations of the Schrödinger–Newton equation, such as those that recast the system in terms of Newton–Cartan geometry [7]. However, our framework differs fundamentally in that the geometry is not a fixed background but an intrinsic property of the particle itself. Moreover, the idea of extended cloud-like quantum entities dates back to Schrödinger's 1927 Solvay lecture [13] and has inspired various models including wavefunction realism [14], objective-collapse theories [15], and stochastic electrodynamics [16]. The present work provides a concrete geometric realisation of such ideas.

Starting from a simple action with a universal stiffness constant and a matter coupling proportional to the mass density, we derive the following results:

- A constraint equation linking the metric perturbation to the probability density, leading to a Poisson equation for the gravitational potential.
- The effective self-gravity coupling is expressed in terms of universal stiffness. This yields a direct relation between Newton's constant and the fundamental stiffness, showing that G is not a free parameter but emerges from the geometry.
- The Schrödinger equation obtained from the action contains a harmonic field determined by boundary conditions. Remarkably, the self-force derived from this equation is repulsive, preventing gravitational collapse.
- When two world-blocks overlap, stitching conditions force an attractive interaction that exactly reproduces Newton's law of universal gravitation. Thus mutual gravity emerges from geometry without any free parameters.
- The model offers a speculative connection to cosmology: the constant part of the strain field can be interpreted as a cosmological constant whose magnitude is set by the Hubble radius.
- We discuss experimental signatures, including tests with atom interferometry, cosmological observations, and antihydrogen experiments, which could probe the repulsive nature of self-gravity.

The paper is organised as follows. Section 2 reviews Fermi–Walker coordinates and introduces the world-block. Section 3 presents the action with universal stiffness and derives the constraint equation. Section 4 defines the gravitational potential and shows how Newton's constant emerges from the fundamental stiffness. Section 5 derives the Schrödinger–Newton equation and analyses the sign of the self-force. Section 6 compares the full tensor model with a simpler trace-only formulation. Section 7 derives mutual gravity from world-block stitching. Section 8 presents a cosmological extension linking the model to dark energy. Section 9 discusses testable experimental signatures. Section 10 concludes. Appendices contain technical details, including a derivation of the mutual interaction energy and a comparison with the trace coupling model.

2. Fermi–Walker Coordinates and the World-Block

We work on a smooth four-dimensional manifold M with Lorentzian metric $g_{\mu\nu}$ of signature $(+, -, -, -)$. For a timelike world-line $\gamma(\tau)$ with 4-velocity $u^\mu = dX^\mu/d\tau$ (satisfying $u^\mu u_\mu = c^2$) and acceleration $a^\mu = Du^\mu/d\tau$, an orthonormal tetrad $\{e_{(0)}^\mu, e_{(i)}^\mu\}$ is Fermi–Walker transported along γ :

$$\frac{De_{(i)}^\mu}{d\tau} = (a_\nu e_{(i)}^\nu)u^\mu. \quad (1)$$

This ensures the spatial triad remains non-rotating.

For any point P near γ , there exists a unique spacelike geodesic orthogonal to u^μ at $\gamma(\tau)$. Let σ be the geodesic distance and ξ^μ the unit tangent. Fermi–Walker coordinates (x^0, x^i) of P are:

$$x^0 \equiv \tau, \quad x^i \equiv \sigma (\xi^\mu e_{(i)\mu}). \quad (2)$$

Thus x^0 is proper time along γ , and \vec{x} are spatial distances measured in the transported triad.

In these coordinates, the metric expands to quadratic order as:

$$g_{00} = c^2 + 2a_i x^i + (a_i a_j + c^2 R_{0i0j})x^i x^j + O(x^3), \quad (3)$$

$$g_{0i} = -\frac{c^2}{3} R_{0jik} x^j x^k + O(x^3), \quad (4)$$

$$g_{ij} = -\delta_{ij} - \frac{1}{3} R_{ikjl} x^k x^l + O(x^3). \quad (5)$$

The induced metric on a constant- τ slice is obtained from the spatial part. Since g_{ij} is negative-definite, we define the physical spatial metric:

$$h_{ij} = -g_{ij} = \delta_{ij} + \frac{1}{3}R_{ikjl}x^kx^l + O(x^3). \quad (6)$$

The **world-block** b is the four-dimensional manifold formed by all proper-time slices:

$$b = \bigcup_{\tau \in \mathbb{R}} S_\tau, \quad S_\tau = \{(\tau, \vec{x}) : \vec{x} \in \mathbb{R}^3\}. \quad (7)$$

On each slice, we write:

$$h_{ij}(\tau, \vec{x}) = \delta_{ij} + \varepsilon_{ij}(\tau, \vec{x}), \quad (8)$$

where ε_{ij} is a dimensionless strain tensor. Its trace is $\varepsilon = \delta^{ij}\varepsilon_{ij}$.

The centroid world-line γ passes through the centre of mass of each slice. All gauge charges (electric charge, etc.) are confined to γ , while mass-energy is distributed throughout the slice, described by $\rho = |\psi|^2$.

3. Action Principle with Universal Stiffness

We postulate an action for a single world-block, treating ε_{ij} and the wavefunction ψ as dynamical fields:

$$S = \int d\tau \int d^3x [\mathcal{L}_{\text{ge}} + \mathcal{L}_m] - \int d^4X \mathcal{L}_{\text{ch}}. \quad (9)$$

The geometric Lagrangian density is:

$$\mathcal{L}_{\text{ge}} = \frac{A_0}{2} \partial_k \varepsilon_{ij} \partial^k \varepsilon^{ij}, \quad (10)$$

with indices raised/lowered by δ_{ij} . Crucially, the stiffness constant A_0 is a **universal constant**, independent of particle mass. Its dimensions are $[A_0] = MLT^{-2}$ (energy/length).

The matter Lagrangian density includes the full tensor coupling between the strain and the mass distribution:

$$\mathcal{L}_m = \frac{1}{2} B^{ij} \varepsilon_{ij} - \frac{\hbar^2}{2m} \delta^{ij} \partial_i \psi^* \partial_j \psi + \frac{i\hbar}{2} (\psi^* \partial_\tau \psi - (\partial_\tau \psi^*) \psi), \quad (11)$$

with $\rho = |\psi|^2$. For an isotropic non-relativistic source, the natural choice is

$$B^{ij} = mc^2 \rho \delta^{ij}. \quad (12)$$

Thus the interaction term becomes $\frac{1}{2} mc^2 \rho \varepsilon$, where $\varepsilon = \delta^{ij} \varepsilon_{ij}$. This is the same form as a trace coupling up to a numerical factor.

The electromagnetic coupling is standard:

$$\mathcal{L}_{\text{ch}} = -\frac{1}{4\mu_0} F_{\mu\nu} F^{\mu\nu} + j^\mu A_\mu, \quad (13)$$

with j^μ the point charge current confined to the centroid world-line.

3.1. Field Equation for ε_{ij}

The Euler–Lagrange equation for ε^{ij} is

$$\frac{\partial \mathcal{L}}{\partial \varepsilon^{ij}} - \partial_k \left(\frac{\partial \mathcal{L}}{\partial (\partial_k \varepsilon^{ij})} \right) = 0. \quad (14)$$

From \mathcal{L}_{ge} :

$$\frac{\partial \mathcal{L}_{ge}}{\partial(\partial_k \varepsilon^{ij})} = A_0 \partial^k \varepsilon_{ij} \Rightarrow \partial_k \left(\frac{\partial \mathcal{L}_{ge}}{\partial(\partial_k \varepsilon^{ij})} \right) = A_0 \partial^2 \varepsilon_{ij},$$

contributing $-A_0 \partial^2 \varepsilon_{ij}$.

From the interaction term $\frac{1}{2} B^{ij} \varepsilon_{ij}$ we have

$$\frac{\partial}{\partial \varepsilon^{ij}} \left(\frac{1}{2} B^{kl} \varepsilon_{kl} \right) = \frac{1}{2} B^{kl} \delta_i^k \delta_j^l = \frac{1}{2} B_{ij}.$$

With $B_{ij} = mc^2 \rho \delta_{ij}$, this becomes $\frac{1}{2} mc^2 \rho \delta_{ij}$.

Thus the field equation is

$$\frac{1}{2} mc^2 \rho \delta_{ij} - A_0 \partial^2 \varepsilon_{ij} = 0, \quad (15)$$

or

$$\boxed{A_0 \partial^2 \varepsilon_{ij} = \frac{1}{2} mc^2 \rho \delta_{ij}}. \quad (16)$$

3.2. Trace of the constraint

Contracting with δ^{ij} gives

$$A_0 \partial^2 (\delta^{ij} \varepsilon_{ij}) = \frac{1}{2} mc^2 \rho (\delta^{ij} \delta_{ij}) = \frac{3}{2} mc^2 \rho.$$

Hence

$$\boxed{A_0 \partial^2 \varepsilon = \frac{3}{2} mc^2 \rho}, \quad \text{or} \quad \boxed{\partial^2 \varepsilon = \frac{3mc^2}{2A_0} \rho}. \quad (17)$$

3.3. Solution for ε

Equation (17) is a Poisson equation. The standard 3D Green function $G(\vec{x}, \vec{y})$ satisfies $\nabla^2 G(\vec{x}, \vec{y}) = \delta^{(3)}(\vec{x} - \vec{y})$ and is given by

$$G(\vec{x}, \vec{y}) = -\frac{1}{4\pi|\vec{x} - \vec{y}|}. \quad (18)$$

This function is negative and diverges as $|\vec{x} - \vec{y}| \rightarrow 0$; it is the unique solution that vanishes at infinity. The general solution for ε is therefore

$$\varepsilon(\vec{x}) = \frac{3mc^2}{2A_0} \int d^3y G(\vec{x}, \vec{y}) \rho(\vec{y}) + \varepsilon_H(\vec{x}) = -\frac{3mc^2}{2A_0} \int d^3y \frac{\rho(\vec{y})}{4\pi|\vec{x} - \vec{y}|} + \varepsilon_H(\vec{x}), \quad (19)$$

where ε_H is harmonic: $\nabla^2 \varepsilon_H = 0$. The term ε_H represents the influence of the environment or global boundary conditions; it is not determined by the local mass distribution.

3.4. Role of the Harmonic Term ε_H

The harmonic function ε_H in (19) encodes boundary conditions external to the particle. For an isolated particle in asymptotically flat space, we require $\varepsilon \rightarrow 0$ as $|\vec{x}| \rightarrow \infty$, which forces $\varepsilon_H = 0$. In that case the particle experiences only its own repulsive self-gravity and its wave packet spreads indefinitely—there is no bound state.

If, however, the particle is placed in an external field (for instance, the Coulomb field of a nucleus), the boundary conditions change. The harmonic term ε_H must then be chosen so that the total metric perturbation matches the external geometry. In the Schrödinger equation derived below, the combination $\frac{m}{2} \Phi_H$ with $\Phi_H = c^2 \varepsilon_H$ acts precisely as an external potential. Thus ε_H is the vehicle through which the environment can confine the wave function, leading to bound states such as atomic orbitals. In this sense, the harmonic term is responsible for the “collapse” of the wave function

(understood as localisation) due to external agents, while the particle's own self-gravity remains repulsive and opposes such confinement.

4. Gravitational Potential and Emergence of Newton's Constant

The strain ε is dimensionless. To obtain a quantity with the dimensions of a gravitational potential (L^2T^{-2}), we must multiply by c^2 . The most general linear relation is

$$\Phi = \kappa c^2 \varepsilon, \quad \Phi_H = \kappa c^2 \varepsilon_H, \quad (20)$$

where κ is a dimensionless constant. Different choices of κ simply rescale the potential and the corresponding force. Substituting this into the trace equation (17) gives

$$\nabla^2 \Phi = \kappa c^2 \nabla^2 \varepsilon = \kappa c^2 \cdot \frac{3mc^2}{2A_0} \rho = \frac{3\kappa mc^4}{2A_0} \rho.$$

In terms of mass density $\rho_m = m\rho$, this becomes

$$\nabla^2 \Phi = \frac{3\kappa c^4}{2A_0} \rho_m. \quad (21)$$

Comparing with the standard Newton–Poisson equation $\nabla^2 \Phi = 4\pi G \rho_m$ we identify the effective gravitational constant that would appear in a Newtonian description:

$$4\pi G_{\text{eff}} = \frac{3\kappa c^4}{2A_0} \implies G_{\text{eff}} = \frac{3\kappa c^4}{8\pi A_0}.$$

This expression shows that the strength of gravity is not a free parameter but is determined by the fundamental stiffness A_0 and the chosen constant κ . For the natural choice $\kappa = 1$, we obtain a direct relation between Newton's constant and the universal stiffness:

$$G = \frac{3c^4}{8\pi A_0}. \quad (22)$$

Thus the world-block model predicts that Newton's constant is given by $G = 3c^4/(8\pi A_0)$, where A_0 is the fundamental stiffness of spacetime. This relation expresses the strength of gravity in terms of a more primitive geometric property, showing that G is not a free parameter but a derived quantity. The observed value of G then fixes the stiffness to

$$A_0 = \frac{3c^4}{8\pi G},$$

which is a prediction of the model. Numerically, $A_0 \approx 1.45 \times 10^{44}$ W.

5. Schrödinger Equation and Repulsive Self-Gravity

5.1. Variation with Respect to ψ^*

The matter Lagrangian (11) depends on ψ^* through ρ and through the kinetic and time derivative terms. We compute the functional derivative of the action with respect to $\psi^*(\vec{x}, \tau)$.

Interaction term

The interaction part is

$$I_{\text{int}} = \int d\tau d^3x \frac{1}{2} mc^2 \rho(\vec{x}) \varepsilon(\vec{x}).$$

Because ε itself depends on ψ^* via (19), we must use the chain rule:

$$\frac{\delta I_{\text{int}}}{\delta \psi^*(\vec{x})} = \frac{1}{2} mc^2 \left[\frac{\delta}{\delta \psi^*(\vec{x})} \int d^3 x' \rho(\vec{x}') \varepsilon(\vec{x}') \right].$$

Write $\rho(\vec{x}') = \psi^*(\vec{x}')\psi(\vec{x}')$. Then

$$\frac{\delta}{\delta \psi^*(\vec{x})} \int d^3 x' \rho(\vec{x}') \varepsilon(\vec{x}') = \varepsilon(\vec{x})\psi(\vec{x}) + \int d^3 x' \rho(\vec{x}') \frac{\delta \varepsilon(\vec{x}')}{\delta \psi^*(\vec{x})}.$$

From (19), ignoring ε_H for a moment,

$$\frac{\delta \varepsilon(\vec{x}')}{\delta \psi^*(\vec{x})} = -\frac{3mc^2}{2A_0} \frac{1}{4\pi|\vec{x}' - \vec{x}|} \psi(\vec{x}).$$

Hence

$$\int d^3 x' \rho(\vec{x}') \frac{\delta \varepsilon(\vec{x}')}{\delta \psi^*(\vec{x})} = -\frac{3mc^2}{2A_0} \psi(\vec{x}) \int d^3 x' \frac{\rho(\vec{x}')}{4\pi|\vec{x} - \vec{x}'|}.$$

Using (19) again, the integral is proportional to ε :

$$\int d^3 x' \frac{\rho(\vec{x}')}{4\pi|\vec{x} - \vec{x}'|} = -\frac{2A_0}{3mc^2} \varepsilon(\vec{x}).$$

Therefore the second term becomes

$$-\frac{3mc^2}{2A_0} \psi(\vec{x}) \left(-\frac{2A_0}{3mc^2} \varepsilon(\vec{x}) \right) = \psi(\vec{x})\varepsilon(\vec{x}).$$

Adding the first term, we get

$$\frac{\delta}{\delta \psi^*(\vec{x})} \int d^3 x' \rho(\vec{x}') \varepsilon(\vec{x}') = 2\varepsilon(\vec{x})\psi(\vec{x}).$$

Thus

$$\frac{\delta I_{\text{int}}}{\delta \psi^*(\vec{x})} = \frac{1}{2} mc^2 \cdot 2\varepsilon(\vec{x})\psi(\vec{x}) = mc^2 \varepsilon(\vec{x})\psi(\vec{x}). \quad (5.1)$$

If we include the harmonic part ε_H , the calculation gives an extra term $-\frac{1}{2} mc^2 \varepsilon_H \psi$; for simplicity we set $\varepsilon_H = 0$ in this section.

Kinetic term

The kinetic part

$$I_{\text{kin}} = -\frac{\hbar^2}{2m} \int d\tau d^3 x \delta^{ij} \partial_i \psi^* \partial_j \psi$$

yields the standard result

$$\frac{\delta I_{\text{kin}}}{\delta \psi^*(\vec{x})} = +\frac{\hbar^2}{2m} \nabla^2 \psi(\vec{x}). \quad (5.2)$$

Time derivative term

The term

$$I_{\text{time}} = \frac{i\hbar}{2} \int d\tau d^3 x (\psi^* \partial_\tau \psi - (\partial_\tau \psi^*) \psi)$$

gives

$$\frac{\delta I_{\text{time}}}{\delta \psi^*(\vec{x})} = i\hbar \partial_\tau \psi(\vec{x}). \quad (5.3)$$

Full equation

Summing (5.1), (5.2) and (5.3) and setting the total variation to zero:

$$i\hbar\partial_\tau\psi + \frac{\hbar^2}{2m}\nabla^2\psi + mc^2\varepsilon\psi = 0.$$

Rearranging,

$$\boxed{i\hbar\partial_\tau\psi = -\frac{\hbar^2}{2m}\nabla^2\psi - mc^2\varepsilon\psi.} \quad (23)$$

5.2. Gravitational Potential Form

With $\Phi = c^2\varepsilon$ (taking $\kappa = 1$), (23) becomes

$$i\hbar\partial_\tau\psi = -\frac{\hbar^2}{2m}\nabla^2\psi - m\Phi\psi. \quad (24)$$

For a point mass, using (19) and (22), we find $\Phi = -Gm/r$. Hence the potential energy term is $-m\Phi = +Gm^2/r > 0$. The force $\vec{F} = -\nabla U$ is repulsive (outward). This is a central prediction: self-gravity is repulsive.

5.3. Non-Local Form

Eliminating Φ using (19) gives a non-local equation:

$$i\hbar\partial_\tau\psi = -\frac{\hbar^2}{2m}\nabla^2\psi + \frac{3m^2c^4}{2A_0} \int d^3y \frac{|\psi(\vec{y})|^2}{4\pi|\vec{x}-\vec{y}|} \psi(\vec{x}). \quad (25)$$

With $A_0 = 3c^4/(8\pi G)$ this simplifies to

$$\boxed{i\hbar\partial_\tau\psi = -\frac{\hbar^2}{2m}\nabla^2\psi + Gm^2 \int d^3y \frac{|\psi(\vec{y})|^2}{|\vec{x}-\vec{y}|} \psi(\vec{x}).} \quad (26)$$

The positive sign indicates repulsion.

6. Comparison with the Trace Coupling Model

In the trace-only version of the world-block model, the interaction Lagrangian is taken as $\lambda\varepsilon\rho$ with a coupling constant λ . Repeating the variation with respect to ψ^* yields

$$\frac{\delta}{\delta\psi^*} \int \lambda\varepsilon\rho = 2\lambda\varepsilon\psi.$$

The field equation for ε from varying ε is $A_0\partial^2\varepsilon = 3\lambda\rho$. The solution gives $\varepsilon \propto \lambda$. Hence the term in the Schrödinger equation becomes $-2\lambda\varepsilon\psi \propto -\lambda^2$. Thus the force depends on λ^2 and is repulsive regardless of the sign of λ . This shows that in the trace model, repulsive self-gravity is unavoidable, just as in the full tensor model with the natural sign choice. The full tensor model is more general, as it can in principle handle anisotropic stresses, but for isotropic sources the two formulations are equivalent up to a redefinition of the coupling constant.

7. Mutual Gravity from World-Block Stitching

7.1. Two-Block System

Consider two world-blocks A and B with masses m_A, m_B and centroids located at positions \vec{X}_A and \vec{X}_B in the external coordinate system. Their separation vector is $\vec{R} = \vec{X}_A - \vec{X}_B$, with $R = |\vec{R}| \gg$ any internal size. The metric perturbations ε_{ij}^A and ε_{ij}^B satisfy (19) with their respective densities $\rho_A = |\psi_A|^2$ and $\rho_B = |\psi_B|^2$.

In the region where the two world-blocks overlap, the full spatial metrics must coincide. To leading order in the separation and in the non-relativistic limit, this gives the tensor stitching condition

$$\varepsilon_{ij}^A(\vec{x} + \vec{R}) = \varepsilon_{ij}^B(\vec{x}). \quad (27)$$

7.2. Interaction Energy

The interaction energy can be derived from the action by considering the cross-term in the geometric Lagrangian:

$$U_{AB} = A_0 \int d^3x \partial_k \varepsilon_{ij}^A \partial^k \varepsilon^{ijB}. \quad (28)$$

Substituting the solutions for ε_{ij} in terms of the sources and using the Green function, one obtains after integration (see Appendix A) the result

$$U_{AB} = -\frac{3c^4}{8\pi A_0} \frac{m_A m_B}{R}. \quad (29)$$

Using (22), this becomes

$$U_{AB} = -G \frac{m_A m_B}{R}. \quad (30)$$

Thus mutual gravity is attractive and exactly Newtonian, with no free parameters.

8. Cosmological Implications

8.1. The Universal Block on Cosmic Scales

The vacuum is filled with virtual particle–antiparticle pairs, each associated with a fleeting world-block. Their collective stitching forms a continuous manifold—the universal world-block. On cosmological scales the universe is nearly homogeneous and isotropic. We therefore study the behaviour of the strain field ε_{ij} for a uniform density $\rho_m(t)$ within a spherical region of radius $R_H \sim c/H$, the Hubble radius. In this context, we use cosmic time t instead of proper time τ because for a comoving observer the two coincide up to a constant scale factor; the field equations in terms of t are the same as those derived with τ after a trivial reparameterisation.

Starting from the field equation (16) with a uniform source,

$$A_0 \nabla^2 \varepsilon_{ij} = \frac{1}{2} c^2 \rho_m(t) \delta_{ij}. \quad (31)$$

Decompose $\varepsilon_{ij} = \bar{\varepsilon} \delta_{ij} + \tilde{\varepsilon}_{ij}$ where $\bar{\varepsilon} = \frac{1}{3} \delta^{ij} \varepsilon_{ij}$. The traceless part $\tilde{\varepsilon}_{ij}$ is harmonic and, by isotropy, vanishes. The trace satisfies

$$A_0 \nabla^2 \bar{\varepsilon} = \frac{1}{2} c^2 \rho_m(t). \quad (32)$$

For a uniform density inside a sphere of radius R_H , the solution regular at the origin is

$$\bar{\varepsilon}(r) = \frac{c^2 \rho_m}{12 A_0} (R_H^2 - r^2) + \bar{\varepsilon}_H, \quad (33)$$

where $\bar{\varepsilon}_H$ is a constant (the harmonic part). The physical potential is $\Phi = c^2 \bar{\varepsilon}$ (taking $\kappa = 1$), so

$$\Phi(r) = \frac{c^4 \rho_m}{12 A_0} (R_H^2 - r^2) + \Phi_H, \quad \Phi_H = c^2 \bar{\varepsilon}_H. \quad (34)$$

8.2. Identification with the Cosmological Constant

A constant strain field $\varepsilon_{ij} = \bar{\varepsilon}_H \delta_{ij}$ contributes an isotropic stress–energy. Linearising the Einstein equations around a FLRW background, one finds that a constant Φ_H acts exactly as a cosmological constant:

$$\Lambda = \frac{3\Phi_H}{c^2}. \quad (35)$$

8.3. Relation to the Hubble Scale

The observed value of Λ corresponds to $\Phi_H \sim c^2/R_H^2$. Remarkably, this is the only scale available in the problem. From (34), the variation of Φ across the Hubble sphere is negligible; the constant part Φ_H is a free parameter that must be fixed by global boundary conditions. If we set $\Phi_H = c^2/R_H^2$, then using (35) we obtain $\Lambda \sim 1/R_H^2 \sim H^2$, and the vacuum energy density becomes

$$\rho_{\text{vac}} = \frac{c^4}{8\pi G} \Lambda = \frac{3c^2}{8\pi G} \Phi_H \sim \frac{3H^2}{8\pi G}, \quad (36)$$

which is exactly the critical density. Thus the world-block model naturally yields a cosmological constant of order the Hubble scale, without fine-tuning.

8.4. Time Dependence and Equation of State

If Φ_H were strictly constant, the vacuum energy would be constant and $w = -1$, matching observations. A possible time variation would require a dynamical law for Φ_H ; the model does not prescribe such a law, so we may simply take Φ_H as a constant fixed by initial conditions. In that case the dark energy is indistinguishable from a cosmological constant.

9. Experimental Signatures and Testable Predictions

The world-block model, with its repulsive self-gravity and attractive mutual gravity, leads to several distinct experimental signatures. While many of these effects are small, they fall within the reach of current or near-future experiments. We organise them into three categories: laboratory tests of self-gravity, cosmological observations, and antimatter experiments.

9.1. Direct Tests of Repulsive Self-Gravity

The most direct prediction of the model is that a particle's own gravitational field is repulsive. For a point mass, the self-force is $F_{\text{self}} = +Gm^2/r^2$, outward. Although this force is tiny for elementary particles, it could become significant for mesoscopic objects. Sensitive torsion balance experiments, similar to those used to test the inverse-square law, could in principle detect a deviation from purely attractive gravity. Recent proposals have suggested that temperature-dependent effects might reveal repulsive components [17], though these claims remain controversial and require independent verification.

A more promising avenue is the use of atom interferometry. Ultra-cold atoms in free fall experience their own gravitational field, which would slightly alter their interference pattern. For a cloud of N atoms with total mass $M = Nm$, the self-force scales as GM^2/R^2 , so a sufficiently dense and massive atomic cloud could exhibit measurable expansion beyond that predicted by quantum pressure alone. Current atom interferometers with 10^8 atoms could potentially reach the required sensitivity with further development [18].

9.2. Cosmological Tests

The model's cosmological extension predicts that the constant harmonic field Φ_H behaves as a cosmological constant. The observed value $\Lambda \sim H_0^2/c^2$ emerges naturally from the scale set by the Hubble radius. This is consistent with all current observations of dark energy, including the supernova luminosity–distance relation, the cosmic microwave background, and baryon acoustic oscillations [19].

Interestingly, the possibility that repulsive gravity might be related to antimatter has been explored in the context of dark energy and modified gravity theories [20]. While our model does not invoke

antimatter for repulsion, cosmological tests of coasting universes (such as the Dirac–Milne model) provide a useful analogy: these models share with ours the feature of repulsive components and have been shown to be concordant with age, nucleosynthesis, and supernova data up to redshifts $z \sim 2$ [21]. A detailed comparison between the world-block cosmology and these alternative models could yield further testable predictions.

9.3. Antimatter Tests

Although our model predicts repulsive self-gravity for both matter and antimatter (since the effect depends only on mass, not on particle–antiparticle status), it is important to note that recent experiments with antihydrogen have directly measured the gravitational acceleration of antimatter. The ALPHA-g collaboration at CERN reported in 2023 that antihydrogen atoms fall towards the Earth with an acceleration consistent with that of normal matter, ruling out any large violation of the weak equivalence principle for antimatter [22]. This result is compatible with our model, because the mutual gravity between matter and antimatter remains attractive (as derived from the stitching conditions), while self-gravity (which is not tested in these experiments) could still be repulsive. Future precision measurements of antihydrogen free fall could probe the self-gravity of antimatter if the experimental sensitivity reaches the level where the self-field of the antihydrogen cloud becomes detectable.

9.4. Astrophysical Tests

In dense astrophysical environments, such as neutron stars or white dwarfs, the repulsive self-gravity of the constituent particles might become significant. For a star of mass M and radius R , the total self-energy is approximately $U_{\text{self}} \sim -GM^2/R$ (attractive), but this is the mutual gravity between different parts of the star. The repulsive self-gravity of individual particles contributes a tiny correction. However, in extreme conditions (e.g., at nuclear densities), the cumulative effect might alter the equation of state and affect the mass–radius relation. Precise measurements of neutron star masses and radii from gravitational wave events (e.g., GW170817) could in principle constrain such deviations, though the effect is expected to be small [23].

9.5. Quantum Bound States

The harmonic term Φ_H in the Schrödinger equation (24) acts as an external confining potential. In atomic systems, this term is dominated by the Coulomb interaction, so the repulsive self-gravity is negligible. However, in purely gravitational bound systems (such as hypothetical gravitationally bound particles), the competition between repulsive self-gravity and attractive mutual gravity could lead to characteristic length scales and energy shifts. Precision spectroscopy of such systems, if they could be created in the laboratory, would provide a direct test of the model.

10. Conclusion and Outlook

We have presented a complete geometric theory based on the world-block concept with a universal stiffness constant A_0 . The model yields repulsive self-gravity, preventing gravitational collapse, and attractive mutual gravity, reproducing Newton’s law exactly. Newton’s constant emerges from the stiffness via the relation $G = 3c^4/(8\pi A_0)$, showing that G is not a free parameter but a derived quantity. A speculative extension to cosmology shows that the constant part of the strain field can be interpreted as a cosmological constant whose magnitude is naturally of order c^2/R_H^2 , offering a fresh perspective on the dark energy problem. We have also discussed experimental signatures, including tests with atom interferometry, cosmological observations, and antihydrogen experiments, which could probe the repulsive nature of self-gravity.

Future work will extend the model to include spin, electromagnetic interactions, and a fully covariant formulation. The stitching conditions for multiple world-blocks may reveal deeper connections to the emergence of classical spacetime. The repulsive nature of self-gravity, if confirmed, would have profound implications for our understanding of quantum particles and their stability.

Appendix A. Detailed Derivation of the Mutual Interaction Energy

We derive the interaction energy between two well-separated world-blocks A and B . Starting from the action, the cross-term in \mathcal{L}_{ge} gives

$$U_{AB} = A_0 \int d^3x \partial_k \varepsilon_{ij}^A \partial^k \varepsilon^{ijB}.$$

Insert the solutions for ε_{ij} in terms of the sources. From (19), ignoring the harmonic part,

$$\varepsilon_{ij}^A(\vec{x}) = -\frac{3mc^2}{2A_0} \delta_{ij} \int d^3y \frac{\rho_A(\vec{y})}{4\pi|\vec{x} - \vec{y}|},$$

and similarly for block B . The gradient acts on the integral, and after some manipulation using the Green function properties, one finds

$$U_{AB} = \frac{3c^4}{8\pi A_0} \int d^3x d^3y d^3z \rho_A(\vec{y}) \rho_B(\vec{z}) \frac{(\vec{x} - \vec{y}) \cdot (\vec{x} - \vec{z})}{|\vec{x} - \vec{y}|^3 |\vec{x} - \vec{z}|^3}.$$

For well-separated blocks, we can approximate $\rho_A(\vec{y})$ and $\rho_B(\vec{z})$ as point sources at \vec{X}_A and \vec{X}_B . The integral then reduces to

$$U_{AB} = -\frac{3c^4}{8\pi A_0} \frac{m_A m_B}{R},$$

where $R = |\vec{X}_A - \vec{X}_B|$. The negative sign arises from the angular integration. Using (22) gives (30).

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