Self-Interacting Gravity and the Transition from Radial to Diffusive Gravitational Dynamics

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Abstract

The discrepancy between Newtonian dynamics in planetary systems and the flat rotation curves of galaxies is commonly attributed to non-baryonic dark matter. We propose an alternative dynamical framework in which gravity is modeled as directed transport of gravitational force through a self-interacting vacuum medium.

In this picture, coherent radial gravity converses with distance due to elastic self-interaction among vacuum degrees of freedom. The mechanism is comparable to known fluid dynamics. The force is conserved but progressively shared among an increasing number of vacuum participants. This redistribution leads naturally to a radius-dependent transport coefficient $D(r) \propto 1/r$, which in steady state produces a gravitational acceleration scaling as $1/r$ (corresponding to a logarithmic potential), while effectively preserving the Newtonian $1/r^2$ law within solar system.

The model assumes that radial gravity self-interact with vacuum and scatters on average after a distance λ, yielding three distinct kinematic regimes without introducing dark matter or modifying the gravitational coupling: (i) strictly Newtonian planetary systems since $r \ll \lambda$ everywhere, protected by the equivalence principle; (ii) harmonic solid-body rotation in galactic cores arising from the non-applicability of the shell theorem under the $1/r$ kernel; and (iii) flat rotation curves in galactic halos governed by the diffusive $1/r$ regime. The model also scales well with dwarf galaxies and very large galaxies. The Baryonic Tully–Fisher relation $V^4 = GMa_0$ emerges as a geometric consequence of the transport transition of gravity. The stiff rotation curve of the galactic core emerges for the same reason, but with different resulting dynamics in a denser environment.

This framework preserves the constancy of G and the local validity of General Relativity, while attributing galactic-scale anomalies to vacuum transport geometry rather than unseen mass.

1. Introduction

The dark matter problem remains one of the central open questions in astrophysics. While General Relativity [1] and Newtonian gravity describe solar-system dynamics with extraordinary precision, galactic rotation curves systematically deviate from the inverse-square expectation at large radii. Spiral galaxies exhibit flat outer rotation curves, [2] implying an effective gravitational force scaling approximately as $1/r$ rather than $1/r^2$.

The conventional explanation invokes massive halos of non-baryonic dark matter [3]. Despite extensive experimental effort, however, direct detection of dark matter particles has remained inconclusive. This has motivated alternative approaches, including phenomenological modifications of gravitational laws such as MOND [4]. While successful in certain scaling relations, such modifications often lack a clear dynamical mechanism for the transition between regimes.

In this work, we propose a transport-based interpretation of gravity that preserves the local structure of General Relativity while modifying galactic large-scale propagation behavior.

1.1 Directed Radial Gravity and Vacuum Self-Interaction

Standard field-theoretical treatments model gravity as a ballistic radiation-like field: gravitational influence propagates radially and dilutes geometrically, yielding the inverse-square law.

We instead consider the possibility that gravitational transport occurs through a vacuum medium capable of elastic self-interaction. In this picture:

- A baryonic mass generates coherent radial gravity.
- As gravity propagates, it undergoes elastic interactions with vacuum degrees of freedom.
- Total radial force-carrying flux is conserved.
- Directional coherence decays exponentially with path length:

$$P_{\text{radial}}(r) = e^{-r/\lambda}.$$

The crucial dynamical consequence is that each scattering event shares directed gravity among additional vacuum participants. The number of carriers sharing the conserved gravity grows approximately proportional to distance traveled, causing the effective radial drift velocity to decrease as $1/r$.

This implies a radius-dependent diffusion coefficient $D(r) \propto 1/r$. Substitution into the steady-state transport equation yields a logarithmic potential and an acceleration scaling as $1/r$ at large distances.

Thus, the transition from $1/r^2$ to $1/r$ behavior is not imposed phenomenologically but arises from self-interaction and force conservation in a transport medium, applying fluid-mechanical laws to gravity's self-interaction with vacuum.

1.2 Three Dynamical Regimes

The distance-dependent conversion naturally divides gravitational behavior into three regimes:

1. **Local radial regime ($r \ll \lambda$)**
   Coherent radial gravity dominates and gravity follows $1/r^2$. Planetary systems obey relativistic dynamics with Newtonian $1/r^2$ force law.

2. **Core harmonic regime ($r > \lambda$)**
   When the large space between core masses is dominated by converted gravity $\propto 1/r$ within its bounded mass distribution, the classical shell theorem no longer applies. Outer mass generates a linear restoring acceleration, producing solid-body rotation in galactic cores. The resulting net force $\propto r$ and velocity $\propto r$ as well. (planetary rotation within a solar system will still be Newtonian also within the core)

3. **Halo diffusive regime ($r \gg \lambda$)**
   The $1/r$ transport law governs dynamics, yielding flat rotation curves and the Baryonic Tully–Fisher relation.

The model preserves the universality of the gravitational constant G and does not modify inertia. Observed anomalies arise from large-scale transport geometry rather than altered coupling strength. By radial gravity we mean the coherent, directionally aligned component of gravitational transport that produces the inverse-square force field.

1.3 Observational Consequences

Because the transition depends on distance traveled rather than local acceleration, the framework predicts:

- Strictly Newtonian dynamics in solar systems.
- Early entry into the converted regime in low-density dwarf galaxies.
- Harmonic core behavior in dense bulges.
- Galactic halo scaling consistent with $V^4 \propto M$. (M is galactic mass)

The conversion length λ is treated as a universal vacuum property to be constrained observationally through galactic structure and wide-binary dynamics.

2. The Theoretical Framework: Gravity self-interacting with vacuum.

We treat gravity not as a static scalar field but as a directed transport of radial gravity through a vacuum medium capable of self-interaction. A baryonic mass continuously emits coherent radial gravity, which propagates outward and undergoes elastic interactions with ambient vacuum degrees of freedom.

A universal characteristic length scale λ governs the survival probability of radial gravity and the gradual loss of radial coherence during propagation. This length λ is defined as the mean radial distance over which directed gravitational transport is redistributed into the surrounding vacuum medium as a shared force.

2.1 Radial Transport and Exponential Survival

Consider a baryonic mass M generating a steady radial gravitational flux.

In the absence of scattering, this coherent radial transport produces the familiar Newtonian inverse-square field:

$$g_N(r) = \frac{GM}{r^2}. \tag{2.1}$$

The coherent radial component decays with distance traveled due to gravity's vacuum self-interaction. The survival fraction of radial gravity is modeled as

$$P_{\text{radial}}(r) = e^{-r/\lambda}. \tag{2.2}$$

This survival probability depends only on the geometric path length r, not on time or propagation speed. In steady state, the field profile is determined entirely by accumulated path length.

The surviving coherent radial component therefore contributes

$$g_{\text{rad}}(r) = \frac{GM}{r^2} e^{-r/\lambda}. \tag{2.3}$$

The fraction converted into a force $\propto 1/r$ is

$$C(r) = 1 - e^{e^{-r/\lambda}}. \tag{2.4}$$

2.2 Force Sharing and Radius-Dependent Transport Characteristics

This model requires a source that supplies a steady follow of radial gravity, which is generally the case. A crucial point is that self-interaction does not lose gravitational interaction; it redistributes the *directional coherence* of the outward transport while preserving the net radial flux in steady state. Let Φ denote the total conserved radial gravitational flux. Conservation requires:

$$4\pi r^2 J_r(r) = \Phi = \text{constant}, \tag{2.5}$$

where $J_r(r)$ is the corresponding radial flux density.
In the conversion-dominated regime, we adopt an effective transport closure formally analogous to Fick's first law of diffusion [5], relating the radial gravitational flux to the gradient of the gravitational potential, without implying literal diffusive particle transport:

$$J_r = -D(r) \frac{d\Phi_g}{dr}, \tag{2.6}$$

where Φ_g is the gravitational potential and $D(r)$ is an effective transport coefficient. Substituting (2.6) into (2.5) yields

$$r^2 D(r) \frac{d\Phi_g}{dr} = \text{constant}. \tag{2.7}$$

If D were constant, this would imply $d\Phi_g/dr \propto 1/r^2$ and hence recover the Newtonian $1/r^2$ scaling. Thus, ordinary diffusion with constant transport properties does not by itself alter the force law. The modification arises when self-interaction causes the effective transport coefficient $D(r)$ to acquire a radial dependence through progressive redistribution of directional coherence.

As radial transport propagates and undergoes scattering, the directed force is progressively distributed among an increasing number of vacuum “participants”. (we use the terminology of the analogue fluid-dynamic theory) The number of carriers sharing the conserved net force grows approximately proportional to the distance traveled:

$$N(r) \sim \frac{r}{\lambda}. \tag{2.8}$$

We assume only:

1. Scattering events are elastic and conserve total directed gravity.
2. Each scattering event redistributes a portion of the directed gravity among previously uncorrelated vacuum degrees of freedom.
3. The medium does not preferentially suppress or amplify transport; it only redistributes coherence.

Under these conditions, each collision increases the number of participants sharing the conserved radial. Since the total radial force flux is conserved even when scattered, the effective radial drift velocity $v_{\text{drift}}(r)$ decreases inversely with the number of participants:

$$v_{\text{drift}}(r) \propto \frac{1}{N(r)} \propto \frac{\lambda}{r}. \tag{2.9}$$

This scaling does not require detailed knowledge of microscopic structure; it follows directly from the existence of a constant mean free path and a steady source. The effective diffusion coefficient from random free walk in 3 dimensions scales as

$$D(r) \propto \lambda v_{\text{drift}}(r). \tag{2.10}$$

Substituting (2.9) into (2.10) yields

$$\boxed{D(r) \propto \frac{\lambda^2}{r} \propto \frac{1}{r}.} \tag{2.11}$$

Thus, self-interaction naturally produces a radius-dependent transport coefficient

This behavior is not imposed; it follows directly from conservation of flux combined with progressive sharing among vacuum degrees of freedom.

This result follows from three general properties:

- steady emission from the source,
- constant mean free path,
- conservation of radial force flux.

The linear growth in participating degrees of freedom is therefore the natural consequence of repeated elastic scattering in a homogeneous medium with fixed microscopic scale λ.

2.3 Emergence of the $1/r$ Gravitational Regime

Insert the radius-dependent diffusion coefficient (2.11) into the steady-state transport equation (2.7):

$$r^2 \left(\frac{1}{r}\right) \frac{d\Phi_g}{dr} = r \frac{d\Phi_g}{dr} = \text{constant.} \tag{2.12}$$

Therefore,

$$\frac{d\Phi_g}{dr} \propto \frac{1}{r}. \tag{2.13}$$

Integrating gives

$$\Phi_g(r) \propto \ln r. \tag{2.14}$$

The gravitational acceleration is

$$g(r) = -\frac{d\Phi_g}{dr} \propto \frac{1}{r}. \tag{2.15}$$

Thus, in the regime $r \gg \lambda$, the gravitational interaction transitions from the coherent Newtonian $1/r^2$ form convert to an effective diffusive $1/r$ force.

The full field may therefore be written schematically as

$$g(r) \approx \frac{GM}{r^2} e^{-r/\lambda} + \frac{K}{r}\left(1 - e^{-r/\lambda}\right), \tag{2.16}$$

where $K$is determined by large-scale galactic dynamics and observational constraints.

Importantly, this transition involves no cutoff and no saturation of the vacuum. Radial coherence is exponentially suppressed with distance, while total gravitational force is conserved and redistributed through the medium.

3. Observational Constraints and Predictions

The universal scattering framework introduces a single fundamental scale, the conversion length λ of radial gravity's average free path, governing the gradual redistribution of coherent radial gravitational transport into a diffusive medium.

To be viable, the model must simultaneously:

1. Preserve precision solar-system general relativity dynamics.
2. Produce flat (constant velocity) galactic rotation curves outside the bulges.
3. Explain stiff (solid-body-like) galactic core rotation.
4. Provide testable predictions on intermediate scales of λ.

3.1 Solar System Regime: Local Radial Coherence

Within planetary systems, characteristic orbital distances satisfy $r \ll \lambda$.

The survival fraction of coherent radial gravity,

$$P_{\text{radial}}(r) = e^{-r/\lambda} \approx 1, \tag{3.1}$$

remains extremely close to unity.

The converted fraction $C(r)$ behaves as

$$C(r) \approx \left(1 - e^{-r/\lambda}\right) \approx 0. \tag{3.2}$$

Thus the gravitational field around stars consists overwhelmingly of radial gravity:

$$g(r) \approx \frac{GM}{r^2}. \tag{3.3}$$

Relativistic corrections arise from spacetime curvature as described by General Relativity [6, 7], not from vacuum conversion effects.

Importantly:

- The entire solar system free-falls within the galactic gravitational field.
- By the equivalence principle, uniform external fields do not alter internal orbital dynamics to first order.

Therefore, even if the galaxy operates predominantly in the converted $1/r$ regime, local stellar systems remain strictly Newtonian in their internal dynamics.

Solar-system data constrain only that $\lambda \gg 1000$ AU
They do not determine its precise value.

3.2 Galactic Rotation Curves: Conversion-Dominated Dynamics

On galactic scales well outside the bulge, $r \gg$ kpc.
If λ lies below the kiloparsec scale, then for most interstellar separations $r \gg \lambda$, and coherent radial gravity is fully converted.

The galaxy therefore behaves like it is floating in a diffusive medium governed by the dispersed gravity:

$$g(r) \approx \frac{K}{r}. \tag{3.4}$$

For $r \gg 1kpc$ the balance between gravity providing the centripetal force needed to match the circular velocity must satisfy:

$$\frac{V^2}{r} = \frac{K}{r} \Rightarrow V^2 = K. \tag{3.5}$$

Using K/r reproduces the empirical Baryonic Tully–Fisher relation without invoking dark matter halos. [8, 9]

$$V_f^4 = GMa_0, \tag{3.6}$$

which implies

$$K = \sqrt{GMa_0}. \tag{3.7}$$

Thus, flat rotation curves arise from large-scale diffusive gravitation transport, not from unseen dark matter halos.

This follows directly from distance-dependent redistribution of gravitational transport.

3.3 The Solar Neighborhood

Historically, standard decomposition models of the Milky Way's rotation curve have superimposed a localized Newtonian baryonic field onto a hypothetical dark matter halo to explain the local orbital velocity at the solar circle. [10, 11]

Sun resides at $r \approx 8\ kpc$ from the galactic center, gravitational transport from the galactic interior has propagated over many conversion lengths λ. Thus, the Milky Way at the Sun's position is governed predominantly by the diffusive $1/r$ force.

The Sun orbits within this converted gravitational $1/r$ medium while maintaining its own local radial $1/r^2$ gravitational domain on AU scales.

There is no contradiction between these regimes. They coexist because of scale separation: 1000 AU $\ll \lambda$ while $\lambda < 1$ kpc, and possibly $\lambda \ll 1$ kpc

3.4 Wide Binary Systems

Wide binaries provide a direct probe of λ. [12]

- For separations $r \ll \lambda$, orbits are Keplerian.
- For separations $r < \lambda$, deviations begin to appear
- For separations $r \sim \lambda$, deviations should be evident.
- For $r \gg \lambda$, dynamics transition toward the diffusive regime.

Precise measurements of ultra-wide binaries therefore constrain the possible range of λ.

4. Breakdown of the Shell Theorem and Harmonic Cores

Having established that galaxies outer regions operate predominantly in the converted regime, we now examine the consequences for interior mass distributions.

4.1 Interior Fields in the Converted Regime

In Newtonian gravity ($\propto 1/r^2$), a spherical shell exerts no force on interior points (shell theorem) [13]. In the converted force $\propto 1/r$ regime, this cancellation no longer applies. When most gravitational transport has been converted, outer mass distributions contribute non-zero interior forces. This effect generates a restoring acceleration in galactic cores.

4.2 Double-Cone Derivation

Consider a star displaced by x from the center of a spherical mass distribution of radius R. Take a narrow double cone of solid angle $d\Omega$ passing through the star, intersecting the shell at:

- Near patch A at distance $r_A = R - x$,
- Far patch B at distance $r_B = R + x$.

Mass element in each patch:

$$dm = \sigma r^2 d\Omega. \tag{4.1}$$

Under the diffusive kernel $F \propto 1/r$,

- Near-side force: $dF_A \propto \sigma r_A$.
- Far-side force: $dF_B \propto \sigma r_B$.

Net force contribution:

$$dF_{\text{net}} \propto (r_B - r_A). \tag{4.2}$$

Geometrically, $r_B - r_A \propto x$, then the interior acceleration is linear in displacement:

$$F_{\text{net}} = -kx \quad (4.3)$$

Thus solid-body rotation arises as a direct geometric consequence of the converted transport kernel acting within a finite mass distribution.

4.3 Harmonic Core Potential

The resulting potential inside the converted bulge region is

$$\Phi(r) \propto r^2. \quad (4.4)$$

This is the potential of a simple harmonic oscillator.

Within a harmonic oscillator potential, the galactic cores naturally exhibit velocities:

$$V(r) \propto r, \quad (4.5)$$

consistent with solid-body rotation observed in many galactic cores.

When Ω is determined by the surrounding converted mass distribution, the net interior acceleration is linear in displacement:

$$g_{\text{core}}(r) \approx \Omega^2 r, \quad (4.6)$$

Equating this to the centripetal acceleration:

$$\frac{V^2}{r} = \Omega^2 r, \quad (4.7)$$

which gives the same stiff rotation curve:

$$V^2 = \Omega^2 r^2 \quad \Rightarrow \quad V(r) \propto r. \quad (4.8)$$

Thus solid-body rotation arises as a direct geometric consequence of the converted transport kernel acting within a finite mass distribution.

Although galactic bulges are not perfectly spherical, the harmonic restoring behavior arises from the geometry of the $1/r$ kernel and persists under moderate departures from spherical symmetry.

Chapter 5: Rotation Curves and the Core–Halo Structure

Galactic rotation curves typically exhibit two distinct kinematic regimes:

- Core region ($r < r_{core}$):
  The rotation velocity rises approximately linearly with radius ($V \propto r$), indicating solid-body behavior.

- Halo region ($r \gg r_{core}$):
  The velocity approaches a constant value ($V \to V_f$), producing a flat rotation curve.

In standard Cold Dark Matter models, reproducing a solid-body core requires modifying the inner density profile to avoid the so-called cusp–core problem [14]. In the present framework, both regimes arise naturally from the geometry of the converted transport kernel, as demonstrated in chapter 4.

5.1 Transition from Stiff Core to Halo Regime

Assuming that the universal conversion scale λ lies below the kiloparsec scale, then for galactic purposes the bulge and inner disk of the Milky Way operate deep within the conversion-dominated regime.

At radii where typical path lengths satisfy $r \gg \lambda$, the coherent radial gravity component has been exponentially suppressed: $e^{-r/\lambda} \ll 1$. The gravitational interaction is therefore governed primarily by the diffusive $1/r$ transport kernel, and we have demonstrated that at larger radii, the inverted kernel dominates:

$$g_{\text{halo}}(r) \approx \frac{K}{r}. \tag{5.1}$$

In the inner bulge region, the converted outer mass distribution produces a restoring acceleration that is approximately linear in displacement, $\propto r$, leading to solid-body rotation:

$$g_{\text{stiff}}(r) \approx \Omega^2 r, \tag{5.2}$$

In the transition region both behaviors coexist, rendering:

$$V^2(r) \approx \mathrm{a}\Omega^2 r^2 + bK, \tag{5.3}$$

Where a and b depend on position. In the transition zone, rotation velocities may exceed the flat halo value (K) before settling. The excess observed velocity of $V(r)$ in the transition between bulge dynamics and halo dynamics does not indicate incomplete conversion. Rather, it reflects the fading influence of the stiff rotation curve of the bulge into the domain of halo dynamics. Thus, the galaxy transitions between two converted regimes — a stiffness-dominated inner region ($V \propto r$) and a halo-dominated outer region ($V \propto K$). The difference in regimes comes from mass distributions, not so much from different degrees of conversion of radial gravity. To achieve the observable degree of stiff core rotation, the conversion of radial gravity $1/r^2$ to diffusive gravity $1/r$ must have progressed to be predominantly in the latter regime also in the core.

Conclusion: The observed galactic behavior indicates a conversion-dominated system with overlapping harmonic and halo contributions in the transition zone— not incomplete conversion from radial gravity.

Everywhere in the galaxy, masses create their own Newtonian bubble, where the metric dominates and the internal motion is protected from the galactic acceleration regime by the equivalence principle for free falling bodies.

5.2 Unified Geometric Interpretation

The distance-dependent conversion framework provides a unified explanation of galactic structure:

- The flat halo arises from the $1/r$ transport kernel.
- The solid-body core arises from interior harmonic response due to the same converted kernel.
- The transition zone shows a combined influence from the 2 different regimes, based on mass distribution not on leftover radial gravity
- Local stellar systems remain Newtonian because their scales satisfy $r \ll \lambda$.

Thus, galactic stability and rotation structure follow from geometric properties of gravitational transport, not from dark matter or arbitrary density tuning.

The galaxy behaves as a gravitationally coupled diffusive medium on parsec scales, while preserving Newtonian coherence on kAU scales.

6. Discussion

6.1 The Physical Interpretation of the Vacuum Medium

In this framework, the vacuum is modeled as a self-interacting transport medium for gravitational force. The transition from radial $1/r^2$ behavior to diffusive $1/r$ behavior does not introduce a new form of matter. Rather, it describes a change in the propagation geometry of gravitational transport.

The phenomenon commonly attributed to dark matter is reinterpreted as a macroscopic transport regime for gravity by the vacuum.

On small scales, gravity propagates coherently and radially. On large scales, repeated self-interactions redistribute directional coherence, producing a collective diffusive response, while preserving the net directionality of gravity. The force in the galactic halo is therefore not a question of total matter distribution but a geometric regime of gravitational transport.

6.2 Invariance of the Gravitational Constant

A central feature of the model is that the gravitational coupling constant G remains universal. There is no modification of inertia, no position-dependent coupling, and no environmental dependence of G.

Mass interacts locally with the vacuum field with full efficiency at all scales. Observed galactic anomalies arise from large-scale transport geometry, not from changes in coupling strength.

The enhanced gravitational influence in galactic halos does not represent stronger gravity per se. It reflects a redistribution of gravitational transport over extended distances, increasing the effective field density at large radii.

Thus:

- G remains constant.
- The equivalence principle remains intact.
- Local gravitational physics remains unchanged.

6.3 Unified Description of Different Kinematic Regimes

The distance-dependent conversion framework naturally unifies several observed dynamical environments:

i. Planetary Systems ($r \ll \lambda$)

The gravitational field remains coherent and radial eq. (2,1):

$$g(r) \approx \frac{GM}{r^2}.$$

Planetary systems follow General Relativity with Newtonian-like orbital dynamics.

The external galactic field, though predominantly diffusive at larger scales, does not alter internal orbital motion due to the equivalence principle.

ii. Galactic Cores (Harmonic Regime)

Within dense bulges, the converted $1/r$ transport kernel dominates. Then the shell theorem does not apply to this system, outer mass distributions produce a restoring acceleration proportional to displacement eq. (5.2):

$$g(r) \approx \Omega^2 r.$$

This generates solid-body rotation without requiring dark matter cusps, eq. (4.8)

$$V(r) \propto r$$

The harmonic behavior emerges from the geometry of the converted radial gravity to diffusive gravity, not from modified density assumptions.

iii. Galactic Halos ($V \propto const$)

Outside the core, $1/r$ transport dominates eq. (3.4):

$$g(r) \approx \frac{K}{r}.$$

This yields flat rotation curves and deduct the Baryonic Tully–Fisher relation from first principles.

iv. Transition zone between cores and halos

Here we typically observe an extended core dynamics together with the halo, rendering a combined force that supports a somewhat higher velocity than what the Halo velocity alone would predict eq. (5,3)

$$V^2(r) \approx \mathrm{a}\Omega^2 r^2 + bK.$$

Overshooting expected velocity is not primarily a consequence of leftover radial gravity. The transition between core and halo represents a shift between two converted regimes with different mass density, rather than a transition between Newtonian and modified gravity.

v. Dwarf Galaxies

The conversion length of λ provides that morphological diversity arises from baryonic mass distribution, not from varying dark matter halo. Low-density dwarf systems enter the conversion-dominated regime at relatively small radii. Much of their luminous extent lies where coherent radial gravity has been significantly suppressed.

The resulting rotation curves are typically rising and often resemble harmonic cores transitioning toward flat behavior. Therefore, we see strong evidence of significant conversion to diffusive gravity also at the cores of small galaxies, and this gives an upper limit for λ until we identify more restricting observations.

Their strong apparent “dark matter domination” [15] reflects early entry into the conversion regime rather than unseen mass.

vi. Giant Spirals

Massive spiral galaxies possess dense bulges. Their substantial interior mass distribution enhances the harmonic restoring response in the core before transitioning to the flat halo regime at larger radii.

Thus large spirals naturally exhibit:

- pronounced solid-body inner rotation,
- followed by flat outer rotation.
- a transition zone that is further away from the center.

The same geometric transport law governs the entire galaxy. Even here we expect that local masses create their own radial gravity bubble that follows the metric and is protected by the equivalence principle regarding internal solar dynamics.

6.4 Atomic Physics and Spectral Invariance

The present model modifies the large-scale spatial distribution of gravitational potential but does not alter local gravitational coupling or quantum mechanical structure.

In regions where $r \ll \lambda$, such as within stellar systems, the gravitational field remains effectively Newtonian. Gravitational redshift in such environments is therefore unchanged from the predictions of General Relativity.

On galactic scales, the converted transport kernel modifies the radial dependence of the potential but does not introduce large potential differences compared with standard halo models. Consequently, atomic transition energies and spectroscopic measurements remain largely unaffected to observational precision.

The model concerns macroscopic gravitational transport and does not modify quantum states of matter.

6.5 Lensing and Large-Scale Behavior

In the weak-field limit, we treat the converted gravitational potential $\Phi(r)$ as the effective potential governing both non-relativistic motion and light trajectories. Because the converted regime yields a logarithmic potential ($\Phi \propto -\ln\, r$) rather than a Newtonian ($\Phi \propto -1/r$) form, the transverse gradient of the potential at large radii is enhanced relative to a purely baryonic Newtonian model. This implies stronger gravitational lensing than expected from visible mass alone, without invoking non-baryonic dark matter. The enhancement arises from geometric redistribution of gravitational transport rather than from any modification of the gravitational constant G. A full covariant relativistic completion is deferred to future work.

The increase in gravitational potential may enhance lensing without adding mass to galactic cores. However, we have made no attempt to confirm how general relativity should relate to such potential.

On sufficiently large scales, gravitational contributions from many galaxies and structures superpose and partially cancel by symmetry. Nevertheless, a strictly logarithmic potential implies that boundary conditions become relevant at cosmological distances. The present work therefore restricts its claims to bound systems such as galaxies and clusters, postponing a full treatment of cosmological structure formation and horizon-scale behavior to subsequent study.

7. Conclusion

We have presented a transport-based model of gravity in which coherent radial gravity transitions gradually into diffusive transport through vacuum self-interaction.

The force law evolves continuously from eq. (2.1):

$$\boldsymbol{g(r) \propto \frac{1}{r^2} \qquad (r \ll \lambda)}$$

to eq. (2.15)

$$\boldsymbol{g}(\boldsymbol{r}) \propto \frac{\mathbf{1}}{\boldsymbol{r}} \quad (\boldsymbol{r} \gg \boldsymbol{\lambda}).$$

This framework naturally produces:

Newtonian planetary systems with gravity $\propto 1/r^2$ protected by the equivalence principle.

Solid-body galactic cores where transformed radial gravity yields diffused gravity $\propto 1/r$ resulting in a harmonic restoring field with rotation velocity $\propto r$.

Flat galactic rotation curves governed by the diffusive kernel with force $\propto 1/r$ and velocity $\propto const.$

The Baryonic Tully–Fisher relation as a geometric consequence of transport transition.

No dark matter halo is required.
No modification of inertia is introduced.
The gravitational constant $\boldsymbol{G}$ remains universal.

The observed anomalies in galactic dynamics are interpreted as manifestations of vacuum transport geometry: gravity propagates coherently on small scales but redistributes via elastic self-interaction on large scales, slowing radial transport while conserving total gravitational flux.

This model therefore connects small-scale Newtonian gravity and large-scale galactic structure through a single distance-dependent mechanism.

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