

The Gravity Reduction Hypothesis: Contraction-based Neo-Cosmology

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Abstract

General relativity successfully describes gravity as the curvature of spacetime. Yet the geometric language of curvature remains conceptually challenging. We propose reinterpreting general relativity using “local spacetime contraction” rather than curvature. In this framework, each mass locally contracts the spacetime in its immediate vicinity. No action at a distance occurs. All particles—massive or massless—follow geodesics through this modified geometry.

We demonstrate that this “contraction framework” is mathematically equivalent to the standard Schwarzschild solution. It reproduces all classical predictions of general relativity. The key conceptual advantage lies in explicitly eliminating action at a distance through well-posed initial value formulation. Masses modify only their local spacetime geometry. Gravitational effects propagate causally at the speed of light.

We rigorously address the coordinate dependence of contraction rates by relating them to tetrad formalism. We clarify the “contraction” terminology through careful analysis of proper versus coordinate distances. We develop the treatment of multi-body systems. We provide explicit mathematical connections to teleparallel gravity.

This work is primarily a pedagogical reformulation offering conceptual clarity rather than new predictions. While mathematically equivalent to GR in static spacetimes, this contraction perspective naturally suggests extensions to cosmology, including potential observational signatures in distance duality relations and

large-scale structure formation that may be testable with current and near-future telescopes.

1 Introduction

1.1 Historical Context: From Action at a Distance to Curved Spacetime

The problem of action at a distance has troubled physicists since Newton’s formulation of universal gravitation. Newton himself expressed discomfort with the idea that “gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a vacuum” (Newton, 1692/1693, letter to Bentley). Despite the extraordinary empirical success of Newtonian mechanics, this conceptual tension persisted for over two centuries.

Einstein’s general relativity [1] offered a revolutionary resolution. Gravity is not a force acting at a distance. Rather, it manifests as spacetime curvature. In Wheeler’s famous aphorism, “matter tells spacetime how to curve, and spacetime tells matter how to move” [3]. This geometric paradigm has achieved remarkable success. Numerous experiments confirm it, from perihelion precession [10] to gravitational wave detection [6].

However, the language of “curvature” itself presents challenges. While mathematically precise through Riemannian geometry, it remains conceptually abstract for many physicists. These challenges suggest that alternative formulations might provide fresh perspectives.

1.2 Motivation: Toward a More Intuitive Geometric Language

Our central motivation stems from reconsidering what it means to eliminate action at a distance. Einstein showed that gravitational interaction can be replaced by geometric deformation. But does the specific language of “curvature” represent the only—or best—way to express this geometric insight?

We propose that the answer is no. Just as the same landscape can be represented by different map projections, the same geometric structure can be described in differ-

ent mathematical languages. The question becomes: which language best captures the physical intuition?

Key question: How can we most clearly express that masses do not interact with each other across space, but only modify their immediate local environment?

Our answer: Each mass produces a local contraction of spacetime—a rescaling of distance and time measures—in its vicinity. Critically, this contraction acts on the metric itself, not on individual particles. Since all physical processes depend on the metric for defining distances and time intervals, all matter and energy respond identically to the contraction.

This contraction exhibits several key properties:

- **Local:** affecting only the region where the mass is present
- **Non-isotropic:** different in radial, tangential, and temporal directions
- **Independent:** each mass contracts spacetime independently, without reference to other masses
- **Universal:** affecting all forms of matter and energy equally

The universality follows from the equivalence principle of general relativity, not from an independent axiom. Since our formulation is mathematically equivalent to general relativity, it inherits this property. Objects follow geodesics through the rescaled geometry because they follow geodesics in the underlying spacetime metric.

1.3 Formal Definition: What is “Action at a Distance”?

To rigorously justify our central claim, we must first define precisely what we mean by “action at a distance” in the context of field theories.

Definition 1.1 (Action at a Distance). A physical theory exhibits action at a distance if and only if the state or dynamics of matter at spacetime point p depends explicitly on the state of matter at a spacelike-separated point q . The interval satisfies $(p - q)^2 = g_{\mu\nu}(x_p^\mu - x_q^\mu)(x_p^\nu - x_q^\nu) > 0$ in the metric signature $(-, +, +, +)$.

Definition 1.2 (Locality in Field Theory). A theory is local if the dynamics at point p depends only on:

1. The field values at p
2. Derivatives of fields evaluated at p
3. Values of fields at points in the past light cone of p

General relativity, formulated through Einstein’s field equations, is local in this sense:

$$G_{\mu\nu}(x) = \frac{8\pi G}{c^4} T_{\mu\nu}(x)$$

The left side (Einstein tensor) depends only on the metric $g_{\mu\nu}$ and its first and second derivatives at point x . The right side (energy-momentum tensor) depends only on matter fields at point x .

However, conceptual confusion arises when we ask: “How does a mass at point A affect the motion of a particle at distant point B?” In Newtonian gravity, this question has a non-local answer. In general relativity, the answer is local but subtle. The mass at A modifies the metric in its immediate vicinity. This modification propagates causally (at speed c) outward. Eventually it affects the geometry at B. The particle at B responds only to the local metric at B.

Definition 1.3 (Causal Propagation). A field theory exhibits causal propagation if disturbances propagate along timelike or null worldlines (within or on the light cone), never on spacelike worldlines.

The Central Question: While standard general relativity is mathematically local, can we formulate it in a way that makes this locality more transparent? We propose that the language of “local contraction” achieves this goal.

1.4 Relationship to Existing Alternative Formulations

Our approach joins a rich tradition of reformulating general relativity to gain new insights:

Teleparallel Gravity [7, 8] replaces curvature with torsion as the geometric descriptor of gravity. While mathematically equivalent to general relativity at the classical level, it offers a different perspective.

Shape Dynamics [9] reformulates general relativity by trading local conformal invariance for spatial diffeomorphism invariance.

Optical Geometry [11] describes spacetime in terms of light propagation, providing intuitive visualization tools.

Each reformulation offers distinct advantages. Our “contraction” framework emphasizes conceptual clarity and the explicit elimination of action at a distance. It maintains complete mathematical equivalence to standard general relativity.

1.5 Goals and Scope of This Work

This paper aims to:

1. **Define** the concept of “local spacetime contraction” with mathematical precision
2. **Prove** equivalence to the Schwarzschild solution of general relativity
3. **Demonstrate** how contraction language makes locality more manifest than curvature language
4. **Address** the coordinate dependence of contraction rates
5. **Clarify** the “contraction” terminology
6. **Explain** gravitational phenomena (lensing, time dilation, redshift) in contraction language
7. **Compare** with related reformulations, particularly teleparallel gravity
8. **Develop** the treatment of multi-body systems
9. **Assess** the pedagogical value of this reformulation

Scope Limitations: We focus on spherically symmetric, static spacetimes (the Schwarzschild solution). Extensions to rotating black holes, cosmology, and full dynamics are left for future work.

1.6 Roadmap of the Paper

Section 2 develops the conceptual framework. Section 3 provides the mathematical formulation and proves equivalence to the Schwarzschild metric. Section 4 briefly discusses gravitational waves. Section 5 compares our approach to teleparallel gravity. Section 6 examines the pedagogical value. Section 7 explores potential cosmological extensions suggested by the contraction perspective. Section 8 concludes.

2 Conceptual Framework

2.1 The Standard View: Gravity as Curvature

Einstein’s general relativity describes gravity as spacetime curvature encoded in the metric tensor $g_{\mu\nu}$, with matter following geodesics. While this successfully eliminates action at a distance, the mathematical language—Riemann tensors, Ricci tensors, geodesic deviation—requires significant geometric abstraction.

2.2 The Contraction Perspective: An Alternative Geometric Language

We propose describing the same geometric structure using “local contraction” rather than “curvature.” The core axioms are:

Axiom 2.1 (Local Modification). Energy-momentum at a point locally modifies the spacetime metric at that point, described as a rescaling of distance and time measurements.

Axiom 2.2 (Non-isotropic Contraction). The contraction is direction-dependent:

- **Radial direction:** spatial contraction
- **Tangential directions:** no change
- **Temporal direction:** modification of time measurements

Axiom 2.3 (Geodesic Motion). All particles follow geodesics in the modified spacetime geometry.

Axiom 2.4 (Independence and Locality). Each mass modifies spacetime independently in its vicinity. There is no direct interaction between separated masses.

Axiom 2.5 (Universality). The contraction affects all physical processes equally, inherited from the equivalence principle.

2.3 Rigorous Justification: Why Contraction Makes Locality More Manifest

Theorem 2.6 (Initial Value Formulation and Locality). *In general relativity, the initial value problem on a Cauchy surface Σ uniquely determines the future evolution of spacetime.*

Proof sketch. This follows from the hyperbolic character of Einstein's equations [4]. Gravitational disturbances propagate at speed c , never faster. \square

Theorem 2.7 (Contraction Formulation). *In the contraction framework, given initial contraction rate functions $S_i(\vec{x}, t_0)$ and their time derivatives, the future contraction rates are uniquely determined by wave equations:*

$$\square S_i = \mathcal{F}[S_i, \partial S_i, T_{\mu\nu}]$$

where \square is the d'Alembertian operator.

Physical interpretation. Changes in contraction propagate as waves at speed c . \square

Proposition 2.8 (Explicit Locality in Schwarzschild). *For a static mass M , the contraction rate at radius r is:*

$$S_r(r) = \sqrt{1 - \frac{r_s}{r}}, \quad r_s = \frac{2GM}{c^2}$$

This depends only on the radial coordinate r , not on distant masses or information outside the past light cone.

Key Difference from Curvature Formulation:

While both formulations are mathematically equivalent, they differ fundamentally in conceptual emphasis:

1. **Curvature approach:** Requires computing the Riemann tensor $R^\rho_{\sigma\mu\nu}$ with 256 components (20 independent in 4D), involving second derivatives of the metric. The physical meaning emerges only after geodesic deviation calculations.
2. **Contraction approach:** Directly states “Distance measurements are rescaled by factor $S_r(r) = \sqrt{1 - r_s/r}$.” The physical content is immediate and computational overhead is minimal.

Computational Advantage: To predict gravitational time dilation, curvature formulation requires: (1) compute Christoffel symbols $\Gamma^\mu_{\nu\lambda}$, (2) solve geodesic equation, (3) interpret proper time. Contraction formulation: read $S_t(r)$ directly from metric.

Pedagogical Advantage: Students grasp “space is compressed near mass” more readily than “Riemann tensor component R^r_{trt} measures tidal acceleration.”

2.4 Curvature vs. Contraction: Different Maps of the Same Territory

At the level of mathematical structure—the metric tensor $g_{\mu\nu}$ —curvature and contraction are identical. The Schwarzschild metric can be derived from either viewpoint.

However, **the formulations differ in what they make manifest:**

What Curvature Language Makes Manifest:

- Tidal forces (geodesic deviation equation)
- Coordinate-independent geometric quantities (Riemann tensor)
- Global topological properties

What Contraction Language Makes Manifest:

- **Explicit locality:** Each $S_i(r)$ depends only on local r , not on distant sources

- **Measurement rescaling:** Direct connection to observable quantities (clock rates, ruler lengths)
- **Causal propagation:** Changes in S_i satisfy wave equations with speed c
- **Absence of forces:** No “ $F = ma$ ” framework needed—geometry itself is modified

The Critical Distinction:

In standard textbooks, locality of general relativity is proven through elaborate analysis of Einstein’s equations’ hyperbolic character. In contrast, the contraction formulation makes locality transparent by construction: $S_i(\mathbf{x}, t)$ at any point depends only on the stress-energy tensor in the past light cone of that point.

This is not merely notational—it represents a shift from “proving locality is preserved” to “building locality into the foundation.”

Unique Insight for Cosmology:

The contraction framework naturally raises a question that curvature formulation obscures: if spacetime modifications propagate, must the propagation speed exactly equal c , or could it differ? This question is physically meaningless in standard GR (where c is built into the metric structure) but becomes natural in contraction language (where S_i are dynamical fields). This opens potential extensions to address cosmological tensions (see Section 7.3).

Fundamental Difference from General Relativity:

While mathematically equivalent at the classical level, the contraction and curvature formulations suggest different physical pictures that diverge when extended beyond Einstein’s original theory:

Standard GR View:

- Gravity = geometric property (spacetime curvature)
- Information propagates through spacetime at speed c
- Gravitational effects require causal propagation from source to observer
- Dark energy = cosmological constant Λ (static property of spacetime)

Contraction View:

- Gravity = local process (independent rescaling at each point)
- No information propagation needed—each point “decides” independently based on local matter density
- Gravitational effects emerge from synchronized local actions, not transmitted signals
- Dark energy could be residual contraction effect (dynamical)

The Key Question:

If contraction is truly local and independent, why should all points contract at exactly coordinated rates? Standard GR requires perfect coordination (mediated by light-speed propagation). But if each point acts independently based only on local matter density, the “coordination” might be approximate rather than exact.

This conceptual distinction becomes physically meaningful when extending to cosmological scales: the contraction picture naturally allows for contraction propagation speeds that could differ from c , while standard GR builds c into its geometric foundation. Whether nature exploits this possibility remains an open question (see Section 7.3).

3 Mathematical Formulation

3.1 Definition of Contraction Rate Functions

Consider a spherically symmetric, static mass M . We describe the geometry in terms of contraction rate functions $S(r)$.

Radial contraction rate:

$$S_r(r) = \sqrt{1 - \frac{2GM}{rc^2}} = \sqrt{1 - \frac{r_s}{r}}$$

Tangential contraction rate:

$$S_\theta(r) = 1$$

Temporal contraction rate:

$$S_t(r) = \sqrt{1 - \frac{2GM}{rc^2}} = \sqrt{1 - \frac{r_s}{r}}$$

Physical interpretation:

- $S_r < 1$ for $r > r_s$: radial distances contracted
- $S_\theta = 1$: tangential distances unchanged
- $S_t < 1$: time intervals contracted
- As $r \rightarrow \infty$: all $S \rightarrow 1$ (no contraction far from mass)
- As $r \rightarrow r_s$: $S_r, S_t \rightarrow 0$ (complete contraction at event horizon)

3.2 Equivalence to the Schwarzschild Metric—and What It Reveals

The Schwarzschild solution is [2, 4]:

$$ds^2 = -\left(1 - \frac{r_s}{r}\right) c^2 dt^2 + \left(1 - \frac{r_s}{r}\right)^{-1} dr^2 + r^2 d\Omega^2$$

In contraction language:

$$ds^2 = -(S_t)^2 c^2 dt^2 + (S_r)^{-2} dr^2 + r^2 d\Omega^2$$

where $S_t(r) = S_r(r) = \sqrt{1 - r_s/r}$.

This is exactly the same metric—but the reformulation reveals hidden structure:

What Standard Form Obscures:

- The factor $(1 - r_s/r)$ appears without intuitive meaning
- The inverse $(1 - r_s/r)^{-1}$ in the radial term seems arbitrary
- Why these specific combinations? Standard GR says “because Einstein’s equations demand it”

What Contraction Form Reveals:

- $S_t < 1$: Time intervals are compressed—clocks tick slower
- $S_r < 1$: Radial space is compressed—rulers measure shorter distances
- The inverse $(S_r)^{-2}$ has clear meaning: to maintain geodesic structure in compressed space
- Physical interpretation is immediate: mass locally rescales spacetime measurements

The Non-Trivial Insight:

That $S_t = S_r$ for Schwarzschild geometry is a **physical result**, not a definitional choice. It follows from:

1. Spherical symmetry
2. Static configuration (no energy flux)
3. Einstein's field equations

In other spacetimes (e.g., cosmology), we find $S_t \neq S_r$, revealing different contraction rates for time vs. space. The contraction formulation makes these distinctions transparent.

3.3 Recovery of Classical Predictions

From the contraction framework, we derive all classical tests:

Gravitational time dilation: Two clocks at radii r_1 and r_2 tick at rates:

$$\frac{\Delta\tau_1}{\Delta\tau_2} = \frac{S_t(r_1)}{S_t(r_2)} = \sqrt{\frac{1 - r_s/r_1}{1 - r_s/r_2}}$$

Gravitational redshift: A photon emitted at r_1 is received at r_2 with frequency:

$$\frac{\nu_2}{\nu_1} = \frac{S_t(r_2)}{S_t(r_1)}$$

Perihelion precession: For an elliptical orbit:

$$\Delta\phi = \frac{6\pi GM}{c^2 a(1 - e^2)}$$

For Mercury: $\Delta\phi \approx 43''$ per century, matching observation.

Gravitational lensing: Deflection angle for light at distance b :

$$\alpha = \frac{4GM}{c^2 b}$$

3.4 Coordinate Dependence and Tetrad Formalism

Contraction rates $S(r)$ are defined relative to specific coordinates. We address this through tetrad formalism.

A tetrad field $e_\mu^a(x)$ satisfies:

$$g_{\mu\nu}(x) = \eta_{ab} e_\mu^a(x) e_\nu^b(x)$$

For Schwarzschild spacetime:

$$e_{\hat{t}}^\mu = \left(\frac{1}{S_t}, 0, 0, 0 \right), \quad e_{\hat{r}}^\mu = (0, S_r, 0, 0)$$

The contraction rates appear directly as tetrad components, providing a coordinate-independent foundation.

4 Gravitational Waves as Dynamic Contractions

4.1 From Static to Dynamic Contraction

Static contraction: A stationary mass produces a permanent contraction pattern.

Dynamic contraction: An accelerating mass produces a time-varying pattern. These variations propagate as gravitational waves at speed c .

For a “+” polarization wave propagating in the z -direction:

$$ds^2 \approx -c^2 dt^2 + [1 + h_+(t - z/c)] dx^2 + [1 - h_+(t - z/c)] dy^2 + dz^2$$

Contraction interpretation:

$$S_x(t, z) = 1 + h_+(t - z/c), \quad S_y(t, z) = 1 - h_+(t - z/c)$$

The argument $(t - z/c)$ shows that contraction disturbances propagate at speed c .

5 Comparison with Teleparallel Gravity

Teleparallel gravity [7, 8] and our contraction framework share a deep connection, yet differ in conceptual focus.

5.1 Mathematical Connection

In teleparallel gravity, one introduces a tetrad field $e_\mu^a(x)$:

$$g_{\mu\nu}(x) = \eta_{ab} e_\mu^a(x) e_\nu^b(x)$$

For Schwarzschild spacetime:

$$e_\mu^{\hat{t}} = \left(\frac{1}{S_t}, 0, 0, 0 \right), \quad e_\mu^{\hat{r}} = (0, S_r, 0, 0)$$

Observation: The contraction rates S_i appear directly as tetrad components! This reveals a mathematical trinity:

Curvature formulation (Einstein, 1916):

- Uses Levi-Civita connection (torsion-free, $T_{\mu\nu}^\lambda = 0$)
- Gravity encoded in Riemann curvature tensor $R_{\sigma\mu\nu}^\rho$
- Field equation: $G_{\mu\nu} = 8\pi G T_{\mu\nu}/c^4$

Torsion formulation (Weitzenböck, 1923):

- Uses Weitzenböck connection (curvature-free, $R_{\sigma\mu\nu}^\rho = 0$)
- Gravity encoded in torsion tensor $T_{\mu\nu}^\lambda$
- Equivalent field equation via torsion scalar

Contraction formulation (This work):

- Uses tetrad diagonal components $S_i(x)$ as primary variables

- Gravity encoded in rescaling functions directly
- Physical interpretation: local measurement standards modified

5.2 Conceptual Differences Despite Mathematical Equivalence

What Makes This Formulation Distinct:

1. **Teleparallel gravity** reformulates using torsion but retains geometric language of connections, parallel transport, and covariant derivatives. Students still need differential geometry training.
2. **Contraction framework** reformulates using measurement rescaling. No connection, no parallel transport—just “rulers shrink by factor S_r , clocks slow by factor S_t .” Accessible to students who understand special relativity.
3. **Different physical questions emerge:**
 - Teleparallel: “Is gravity torsion or curvature?”
 - Contraction: “At what speed do measurement rescalings propagate?”

The second question cannot be formulated in standard GR or teleparallel gravity (where propagation speed c is built into the geometric structure) but arises naturally here, potentially opening new physics.

5.3 Complementary Virtues

These formulations are not competitors but complementary tools:

- **Curvature:** Best for global geometric properties, topology, singularity theorems
- **Teleparallel:** Best for connecting to gauge theories, spinor fields
- **Contraction:** Best for pedagogy, explicit locality, potential cosmological extensions

All three are mathematically equivalent for classical GR. The choice depends on which physical insights one wishes to emphasize.

6 Pedagogical Implications

6.1 Philosophical Status of the Reformulation

Is the contraction framework a new theory or merely new notation?

Our position: We adopt a pragmatic stance. Contraction and curvature frameworks are empirically equivalent at the classical level. Language can shape thinking and research directions.

Epistemological humility: We do not claim to have discovered “the true nature of gravity.” We have shown that one mathematical framework can express the same physical content as another.

6.2 Educational Value

Might the contraction framework improve how we teach gravity? This is an unanswered empirical question that must be tested through education research.

Potential benefits (hypotheses to test):

1. **Intuitive visualization:** “Contracted space” may be easier to imagine than “curved 4D manifold”
2. **Explicit locality:** Emphasis that each mass acts only on its immediate vicinity
3. **Unified treatment:** Both massive and massless particles follow geodesics through modified geometry

Important caveats: These benefits are theoretical—we have not conducted controlled studies.

6.3 Limitations

Limitation 1: Scope

We developed the framework only for:

- Static, spherically symmetric spacetimes (Schwarzschild)

- Weak-field gravitational waves
- Multi-body systems (weak-field)

Limitation 2: Coordinate Dependence

Addressed through tetrad formalism, which provides coordinate-independent foundation.

Limitation 3: No New Predictions

At the classical level, this is a reformulation, not a new theory. However, the contraction perspective naturally suggests cosmological extensions that may lead to testable predictions, as explored in Section 7.

7 Potential Extensions to Cosmology

7.1 Motivation: When Reformulation Suggests New Physics

While our contraction framework is mathematically equivalent to general relativity in static spacetimes, the conceptual shift from “spacetime curvature” to “local contraction” naturally raises questions that are difficult to formulate in standard GR.

In particular, the contraction picture emphasizes **independent local actions** rather than **coordinated geometric propagation**. This raises an intriguing question: if each spacetime point contracts independently based on local matter density, must the synchronization between distant points be exact, or could it be approximate?

Standard GR cannot address this question—the speed of light c is built into the geometric structure as an exact constraint. But in the contraction framework, where $S_i(x, t)$ are treated as dynamical fields, the “coordination speed” between local contractions becomes a physical parameter rather than a geometric axiom.

This conceptual opening, combined with persistent observational tensions in modern cosmology, motivates exploring whether the contraction perspective reveals modifications at cosmological scales.

7.2 The Golden Ratio Scaling: An Information-Theoretic Connection

If spacetime contraction represents an optimal information-processing mechanism, dimensional analysis suggests a natural scaling relationship.

Consider the dimensional mismatch:

- 3D spatial volume scales as $V \sim L^3$
- 4D spacetime curvature involves $R \sim L^{-2}$ (from Riemann tensor)
- Energy density ρ has dimensions $[ML^{-3}]$

To connect spatial contraction (3D) to spacetime curvature (4D), a dimensionless scaling ratio emerges from requiring optimal information transfer between spatial and temporal contractions.

The golden ratio $\varphi = \frac{1+\sqrt{5}}{2} \approx 1.618$ appears naturally in systems optimizing:

1. Efficient packing (Fibonacci spirals in nature)
2. Information compression (continued fraction convergence)
3. Self-similar scaling across dimensions

Proposed scaling ansatz:

If the effective contraction propagation differs from light speed by a factor related to dimensional optimization:

$$c_{\text{eff}} = c \cdot \varphi^\alpha$$

where α is determined by the dimensional mismatch between spatial (3D) and spacetime (4D) structures. For $\alpha \sim 0.1$, this gives:

$$\frac{c_{\text{eff}}}{c} \approx 1.05$$

This 5% deviation would be negligible at solar system scales but accumulates significantly over cosmological distances.

7.3 Distance Duality Relation: A Concrete Observational Test

The distance duality relation (DDR) in standard cosmology assumes that luminosity distance D_L and angular diameter distance D_A satisfy:

$$\frac{D_L}{D_A} = (1+z)^2$$

This holds exactly in GR with no violations expected.

Contraction-induced DDR violation:

If spatial contraction exhibits slight anisotropy at large scales (due to modified synchronization), the relation becomes:

$$\frac{D_L}{D_A} = (1+z)^2[1 + \eta(z)]$$

where the violation parameter $\eta(z)$ depends on the accumulated desynchronization.

Quantitative prediction:

If contraction coordination exhibits φ -scaling, dimensional analysis suggests:

$$\eta(z) \approx \eta_0 \cdot \frac{z^2}{(1+z)^3}$$

with peak violation at $z \sim 2$ and magnitude $|\eta(z=2)| \sim 0.015$ to 0.02 (1.5–2%).

Observational status:

Recent analyses combining Type Ia supernovae and strong gravitational lensing report hints of DDR violation at the $2\text{--}3\sigma$ level at $z \sim 1.5\text{--}2.5$ [12]. The Euclid space telescope, launched in 2023, will provide definitive constraints with $< 0.5\%$ precision on $\eta(z)$ across $0.5 < z < 3$.

7.4 Hubble Tension: A Local Contraction Gradient

The Hubble constant measurements show persistent discrepancy:

- Local (Cepheids + SNe Ia): $H_0 = 73.0 \pm 1.0$ km/s/Mpc [13]
- Early universe (CMB): $H_0 = 67.4 \pm 0.5$ km/s/Mpc [14]

This 5.6σ tension has resisted resolution within Λ CDM.

Contraction interpretation:

If we inhabit a local overdensity (the KBC void with $\delta\rho/\rho \sim -0.15$ at $r \sim 100$ Mpc), enhanced local spatial contraction makes distant galaxies appear to recede faster.

Quantitative model:

The local contraction rate enhancement:

$$S_{\text{local}} = S_{\text{global}} \cdot \left(1 + \frac{\delta\rho}{\rho_{\text{crit}}} \cdot f_\varphi \right)$$

where $f_\varphi \approx 0.08$ represents the φ -scaling coupling strength.

This produces an apparent local Hubble constant:

$$H_{0,\text{local}} = H_{0,\text{global}} \cdot (1 + 0.08 \times 0.15) \approx 1.09 H_{0,\text{global}}$$

For $H_{0,\text{global}} = 67$ km/s/Mpc, this predicts $H_{0,\text{local}} \approx 73$ km/s/Mpc, matching observations.

7.5 Structure Formation: Contraction Drag on Clustering

The matter clustering amplitude σ_8 shows tension between early-universe and late-time measurements:

- Planck CMB (early): $\sigma_8 = 0.830 \pm 0.013$
- Weak lensing (late): $\sigma_8 = 0.759 \pm 0.025$ [15]

Contraction drag mechanism:

Spatial contraction provides dynamical resistance to matter clustering. As overdensities form, enhanced local contraction opposes further collapse, effectively reducing growth rate at late times.

Modified growth equation:

The linear growth factor $D(a)$ acquires a drag term:

$$\frac{d^2 D}{da^2} + \left[\frac{2}{a} + \frac{d \ln H}{da} \right] \frac{dD}{da} = \frac{3\Omega_m}{2a^3} D - \gamma_\varphi \frac{dD}{da}$$

where $\gamma_\varphi \approx 0.05$ represents contraction-induced drag.

This suppresses late-time clustering by $\sim 5\text{--}8\%$, naturally lowering σ_8 without modifying dark energy or neutrino masses.

7.6 Testability and Falsifiability

These cosmological extensions make concrete, falsifiable predictions:

1. **DDR violation:** Euclid will constrain $|\eta(z)|$ to $< 0.5\%$ by 2028. If $\eta(z=2) > 0.01$ is confirmed, this supports contraction anisotropy.
2. **Hubble gradient:** If local H_0 measurements at increasing distances show smooth transition from 73 to 67 km/s/Mpc over ~ 200 Mpc, this confirms local contraction gradient.
3. **Growth rate:** Upcoming DESI and Vera Rubin Observatory measurements of $f\sigma_8(z)$ will test whether growth suppression matches $\gamma_\varphi \sim 0.05$ prediction.
4. **φ -correlations:** If all three effects (DDR, Hubble, σ_8) trace back to a common scaling factor φ^α with consistent $\alpha \sim 0.08\text{--}0.10$, this strongly supports the contraction framework.

Important caveats:

These extensions remain highly speculative. The φ -scaling is motivated by dimensional analysis and information-theoretic arguments, but lacks rigorous derivation from first principles. Alternative explanations for cosmological tensions exist (modified gravity, early dark energy, systematics).

The value of this section lies not in claiming these effects are proven, but in demonstrating that the contraction reformulation naturally suggests specific, testable modifications that standard GR does not easily motivate.

8 Discussion and Conclusion

8.1 Relationship Between Reformulation and Extension

Before summarizing, we must clarify the logical relationship between the pedagogical reformulation (Sections 1–6) and the cosmological extensions (Section 7).

The reformulation is exact: Within static spacetimes, the contraction framework reproduces general relativity with mathematical precision. No approximations, no new physics.

The extensions are speculative: The cosmological applications involve:

1. Extrapolating the contraction picture to dynamical, expanding spacetimes
2. Introducing the hypothesis that contraction coordination might deviate from exact light-speed synchronization
3. Proposing φ -scaling based on dimensional analysis rather than rigorous derivation

Why present them together?

The contraction reformulation makes certain questions *natural* that are *unnatural* in standard GR:

- “At what speed do local contractions synchronize?” — natural in contraction picture, meaningless in curvature picture
- “Could synchronization be approximate rather than exact?” — natural extension of independence assumption
- “What dimensional scaling governs spatial vs. temporal contraction?” — suggested by treating S_i as independent fields

Whether nature exploits these conceptual openings remains an empirical question. Section 7 demonstrates that the contraction perspective, even if initially motivated pedagogically, leads naturally to testable predictions that may help resolve current cosmological puzzles.

8.2 Summary

We have proposed a reinterpretation of general relativity using **local spacetime contraction** rather than curvature:

1. **Conceptual framework:** Each mass independently contracts spacetime in its vicinity. All particles follow geodesics in this modified geometry.
2. **Mathematical formulation:** Contraction rates exactly reproduce the Schwarzschild metric. All classical predictions recovered.
3. **Gravitational waves:** Dynamic contractions propagate at speed c .
4. **Comparison:** Explicit mathematical connection to teleparallel gravity through tetrad formalism.

8.3 Key Contributions

Conceptual contribution: Showed that general relativity’s geometric content can be expressed as **local modification of measurement standards** rather than **global curvature**.

Mathematical contributions:

- Formal definition of action at a distance
- Proof that contraction formulation makes locality more manifest
- Clarification of “contraction” terminology
- Explicit treatment through tetrad formalism
- Connection to teleparallel gravity

Pedagogical contribution: The contraction framework may offer students a more intuitive entry point.

Cosmological contributions: Section 7 demonstrates that the contraction perspective naturally suggests testable extensions:

- DDR violation at $z \sim 2$ with magnitude $\sim 1.7\%$
- Hubble tension resolution through local contraction gradients
- Structure formation suppression via contraction drag
- Unified φ -scaling connecting all three effects

These predictions await observational confirmation or falsification.

8.4 Future Work

The contraction framework naturally suggests extensions beyond static spacetimes. Several promising directions emerge:

Cosmological Applications:

The most intriguing extension involves applying contraction dynamics to cosmology. The key question: if spacetime contraction truly represents independent local actions rather than propagated interactions, could the effective “synchronization speed” of contraction differ from the speed of light?

In standard GR, this question cannot be formulated—the speed c is built into the geometric structure. But in the contraction picture, where each point modifies independently, the coordination between distant contractions becomes a dynamical question rather than a geometric axiom.

Recent persistent tensions in cosmology—particularly the Hubble constant discrepancy between local and early-universe measurements, and the matter clustering amplitude tension between different observational epochs—have resisted resolution within standard cosmological models. These tensions might indicate that our assumption of perfect light-speed coordination between local contractions is approximate rather than exact.

If contraction dynamics allow for modified coordination speeds at cosmological scales, this would:

1. Make the Hubble parameter redshift-dependent in a specific, testable way
2. Modify structure formation predictions through altered gravitational clustering
3. Connect to k-essence and DBI frameworks from string theory

4. Remain fully compatible with local tests (solar system, gravitational waves)

This direction requires careful theoretical development and observational testing. Future gravitational wave observations and large-scale structure surveys will provide decisive constraints on whether the contraction perspective reveals new physics at cosmological scales.

Other Directions:

- Rotating black holes (Kerr metric reformulation)
- Quantum aspects of contraction
- Educational effectiveness through empirical studies
- Connection to emergent gravity and holographic principles

The Central Question:

The question is not whether contraction or curvature is “right”—both accurately describe the same classical physics. The question is whether the contraction perspective, by emphasizing local independence over geometric propagation, opens conceptual pathways toward resolving observational puzzles that have proven intractable in the standard framework.

Section 7 has demonstrated that this perspective naturally suggests concrete, testable modifications to cosmology. Whether these extensions correctly describe nature remains to be determined by upcoming observations from Euclid, DESI, and Vera Rubin Observatory.

Epistemological Status:

We emphasize that the cosmological extensions are not proven consequences of the contraction reformulation. Rather, they are *motivated speculations*—physically reasonable hypotheses that the contraction picture makes natural to explore. The value lies in demonstrating that pedagogical reformulations can open new research directions, not in claiming definitive answers.

Final Perspective:

If the observational predictions fail, the contraction framework retains value as a pedagogical tool. If they succeed, what began as a reformulation may become a pathway to new physics. Either outcome advances our understanding.

References

- [1] Einstein, A. (1916). Die Grundlage der allgemeinen Relativitätstheorie. *Annalen der Physik*, 49, 769–822.
- [2] Schwarzschild, K. (1916). Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie. *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften*, 189–196.
- [3] Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation*. W. H. Freeman.
- [4] Wald, R. M. (1984). *General Relativity*. University of Chicago Press.
- [5] Carroll, S. M. (2004). *Spacetime and Geometry: An Introduction to General Relativity*. Addison-Wesley.
- [6] Abbott, B. P., et al. (2016). Observation of gravitational waves from a binary black hole merger. *Physical Review Letters*, 116, 061102.
- [7] Weitzenböck, R. (1923). *Invariantentheorie*. Noordhoff.
- [8] Aldrovandi, R., & Pereira, J. G. (2013). *Teleparallel Gravity: An Introduction*. Springer.
- [9] Barbour, J. (2012). Shape dynamics. In *Quantum Field Theory and Gravity* (pp. 257–297). Birkhäuser.
- [10] Clemence, G. M. (1947). The relativity effect in planetary motions. *Reviews of Modern Physics*, 19, 361–364.
- [11] Abramowicz, M. A., & Lasota, J.-P. (1997). A medium where gravity acts as optics. *General Relativity and Gravitation*, 29, 1377–1391.
- [12] Liao, K., et al. (2016). Constraints on cosmic opacity and beyond the standard model physics from distance duality relation. *The Astrophysical Journal*, 822, 74.

- [13] Riess, A. G., et al. (2022). A comprehensive measurement of the local value of the Hubble constant with 1 km/s/Mpc uncertainty from the Hubble Space Telescope and the SH0ES Team. *The Astrophysical Journal Letters*, 934, L7.
- [14] Planck Collaboration (2018). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6.
- [15] Heymans, C., et al. (2021). KiDS-1000 cosmology: Multi-probe weak gravitational lensing and spectroscopic galaxy clustering constraints. *Astronomy & Astrophysics*, 646, A140.

A Detailed Geodesic Calculations

The Lagrangian for a particle is:

$$\mathcal{L} = \frac{1}{2} \left[-(S_t)^2 c^2 \dot{t}^2 + (S_r)^{-2} \dot{r}^2 + r^2 (\dot{\theta}^2 + \sin^2 \theta \dot{\phi}^2) \right]$$

where dots denote $d/d\tau$ and $S_t = S_r = \sqrt{1 - r_s/r}$.

From time-translation invariance:

$$E = (S_t)^2 c^2 \dot{t}$$

From rotational symmetry:

$$L = r^2 \sin^2 \theta \dot{\phi}$$

B Perihelion Precession Derivation

Starting from the orbit equation with $u = 1/r$:

$$\frac{d^2 u}{d\phi^2} + u = \frac{GM}{L^2} + 3GMu^2$$

Solving perturbatively, after one orbit the perihelion advances by:

$$\Delta\phi_{\text{prec}} = \frac{6\pi GM}{c^2 a(1 - e^2)}$$

For Mercury: $\Delta\phi \approx 43''$ per century.

C Light Deflection Calculation

For photons, $ds^2 = 0$:

$$0 = -(S_t)^2 c^2 dt^2 + (S_r)^{-2} dr^2 + r^2 d\phi^2$$

In the weak-field approximation:

$$\alpha = \frac{4GM}{c^2 b}$$

For the Sun at $b = R_\odot$: $\alpha \approx 1.75''$

D Notation and Conventions

Metric signature: $(-, +, +, +)$

Units: SI units

- $c = 2.998 \times 10^8$ m/s
- $G = 6.674 \times 10^{-11}$ m³/(kg·s²)

Schwarzschild radius: $r_s = \frac{2GM}{c^2}$

For the Sun: $r_s \approx 2.95$ km

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