A Finite-Range Induced Gravity Framework

A Dark-Matter-Free Interpretation of Gravitational Phenomena （Sourced Gravity，SG）

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Abstract

We propose an alternative framework for gravitation in which the gravitational interaction is not assumed to be an absolute, scale-invariant law with unlimited range. Instead, gravity is interpreted as an effective, statistically induced interaction generated by finite-range gravitational sources. In this framework, gravitational behavior depends on the physically accessible induction domain, which evolves with cosmic structure and cosmic time. As a result, gravity may exhibit different effective forms at different scales and evolutionary stages of the Universe without introducing non-baryonic dark matter, additional fields, or a varying gravitational constant.

The framework naturally accounts for the observed flat galaxy rotation curves, gravitational center offsets in merging galaxy clusters, and the absence of singular behavior in extremely dense systems. We argue that spacetime curvature in general relativity should be understood as a geometric manifestation of an underlying effective interaction, rather than its fundamental origin. This work focuses on the physical motivation, internal consistency, and observational implications of the framework, while leaving explicit functional constructions for future studies.

I. Introduction

Classical theories of gravitation—both Newtonian gravity and general relativity—share an implicit structural assumption: gravitational interaction is, in principle, unlimited in range. While this assumption has proven successful in many regimes, it leads to persistent conceptual and phenomenological difficulties when extrapolated to cosmological and extreme-density scales. These include singularities, global consistency problems, and the need to introduce additional, unobserved components such as dark matter to reconcile theory with observation.

In this work, we explore a different physical starting point: **the effective range of gravitational interaction is finite and physically constrained**. This assumption is not introduced ad hoc, but rather emerges from basic consistency requirements—namely, the absence of privileged points in the Universe and the impossibility of infinite physical superposition within a finite cosmic history. If gravitational influence were truly unlimited, every mass element would be instantaneously coupled to the entire Universe, inevitably leading to global divergences and structural instabilities.

Once the gravitational interaction is treated as having a finite, though potentially evolving, effective range, several longstanding problems admit natural resolutions. Gravity is no longer required to exhibit a single universal form across all scales. Instead, its effective behavior reflects the size, structure, and dynamical state of the system under consideration. In early cosmic epochs, when structures were compact and highly non-equilibrium, gravitational response would differ from that in the late-time, large-scale Universe.

Within this framework, gravity is interpreted not as a fundamental field permeating spacetime, but as a **statistical manifestation of local stable structures acting through a finite induction domain**. At sufficiently small scales, the effective gravitational interaction weakens, avoiding the unphysical divergences implied by inverse-square extrapolation. At galactic and cluster scales, the accumulation of induced gravitational response leads to deviations from Newtonian predictions, reproducing observed phenomena traditionally attributed to dark matter.

Importantly, this approach does not require modification of spacetime symmetry principles. Lorentz invariance and local relativistic behavior are preserved in appropriate limits, while large-scale deviations arise solely from the finite effectiveness of gravitational induction rather than from additional degrees of freedom or altered kinematics.

The present paper focuses on the physical motivation and observational consistency of this finite-range induced gravity framework. Explicit functional forms of the effective gravitational response are intentionally deferred, as premature specification risks obscuring the underlying physical structure. Instead, we emphasize qualitative predictions and their agreement with well-established astronomical observations, including galaxy rotation curves and gravitational lensing in merging clusters.

II. Physical Motivation for Finite-Range Gravitational Interaction

The assumption that gravitational interaction possesses an unlimited spatial range has been implicitly embedded in both Newtonian gravity and general relativity. While mathematically convenient, this assumption introduces structural tensions when extrapolated beyond local systems. In particular, it conflicts with basic physical consistency requirements associated with causality, cosmic finiteness, and the absence of globally privileged points.

If gravity were truly unlimited in its effective range, every mass element would be directly coupled to all other mass elements in the Universe. Such a structure would imply that any local gravitational configuration is necessarily sensitive to the total mass distribution of the entire cosmos, regardless of distance or evolutionary separation. In a Universe with finite age and finite information propagation, this instantaneous global coupling lacks a clear physical mechanism and leads to unavoidable conceptual paradoxes.

One immediate consequence of unlimited-range interaction is the emergence of singular or quasi-singular configurations. When all distant contributions are formally included, gravitational influence becomes dominated by global summation rather than local structure. This renders the notion of a well-defined gravitational center ambiguous and promotes the appearance of pathological solutions, including divergent potentials and infinite energy densities. These issues persist even within general relativity, where curvature singularities remain an unresolved feature rather than a derived necessity.

A second consequence concerns global symmetry. An interaction with unlimited effective range generically introduces preferred reference structures through global coupling, undermining the principle that no point or region of the Universe should be physically distinguished. While this violation may be hidden at small scales, it becomes unavoidable in cosmological contexts, where boundary conditions and global constraints necessarily enter the theory.

In contrast, treating gravity as an interaction with a finite effective range resolves these structural inconsistencies without invoking additional hypothetical components. In the present framework, the gravitational influence of a mass distribution is mediated through a finite induction domain, determined by the physical capacity of spacetime structure to respond to matter-induced perturbations. This domain is not an imposed cutoff, but an emergent property of cosmic evolution, bounded by causal history and structural stability.

Under this interpretation, gravity does not act simultaneously on the entire Universe. Instead, it reflects the statistical response of local and quasi-local stable structures to mass distributions within an accessible induction region. The effective gravitational interaction thus depends on scale, environmental density, and cosmic epoch. This naturally allows for departures from a universal inverse-square law at large distances, while preserving its validity in near-field regimes.

Importantly, finite-range gravitational induction does not imply a breakdown of relativistic principles. Local Lorentz invariance and relativistic kinematics remain intact, as the modification concerns the effective response of gravitational interaction rather than the propagation speed of physical signals. The familiar success of general relativity in solar-system and weak-field tests is therefore preserved as a limiting case of the broader framework.

By abandoning the assumption of infinite-range interaction, gravity is reinterpreted as an emergent, scale-dependent phenomenon. This shift in perspective eliminates the necessity for dark matter as an independent substance and reframes gravitational anomalies as manifestations of effective interaction geometry rather than missing mass. Subsequent sections demonstrate how this framework accounts for galactic rotation curves and cluster-scale gravitational offsets using observed matter distributions alone.

III. Galaxy-Scale Phenomena and Rotation Curves

One of the most persistent challenges to classical gravitational theory arises at galactic scales. Observations of spiral galaxies consistently show that orbital velocities of stars and gas clouds remain approximately constant far beyond the region containing the majority of visible matter. Within the Newtonian framework, this behavior cannot be reconciled with the observed baryonic mass distribution without introducing an additional, non-luminous matter component.

Within the present framework, this discrepancy is reinterpreted as a manifestation of scale-dependent gravitational induction rather than missing mass. When gravity is treated as an effective interaction with finite and environment-dependent induction range, the extrapolation of the inverse-square law from near-field regimes to galactic outskirts is no longer guaranteed.

In regions close to the galactic center, where matter density is high and the induction domain is fully populated, the effective gravitational response naturally reduces to the Newtonian form. This ensures consistency with stellar dynamics in the inner galaxy and with precision tests of gravity in dense systems.

At intermediate and outer galactic radii, however, the situation changes qualitatively. As the distribution of matter becomes more diffuse, the collective induction response of spacetime structures extends over larger effective regions. While the local gravitational strength remains bounded, its radial decay becomes slower than the Newtonian inverse-square extrapolation. This results in an effective enhancement of gravitational influence at galactic edges, sufficient to sustain nearly flat rotation curves without introducing additional mass components.

Crucially, this enhancement does not imply that gravity becomes stronger than Newtonian gravity at all distances. Instead, it reflects a redistribution of gravitational response over scale: the total effective interaction is conserved locally, while its spatial profile adapts to the available induction structure. This distinction separates the present framework from phenomenological modifications that simply amplify gravitational strength.

Figure 1 illustrates this behavior schematically by comparing the galactic rotation curve predicted by the present framework with the Newtonian expectation based solely on visible matter. The deviation emerges gradually at kiloparsec scales, grows toward the galactic outskirts, and remains smooth and monotonic, avoiding discontinuities or fine-tuned transitions.

This behavior arises without introducing free parameters tied to individual galaxies. The scale at which deviations become significant is determined by structural properties of the system and its environment, not by ad hoc adjustments. As a result, galaxies of different masses and morphologies may exhibit distinct transition radii while obeying the same underlying gravitational principle.

From this perspective, galactic rotation curves no longer constitute evidence for an unseen matter component, but rather reflect the limitations of applying a single, global gravitational law across regimes where its physical assumptions no longer hold. The observed universality of rotation curve shapes thus finds a natural explanation in the universality of induction-based gravitational response.

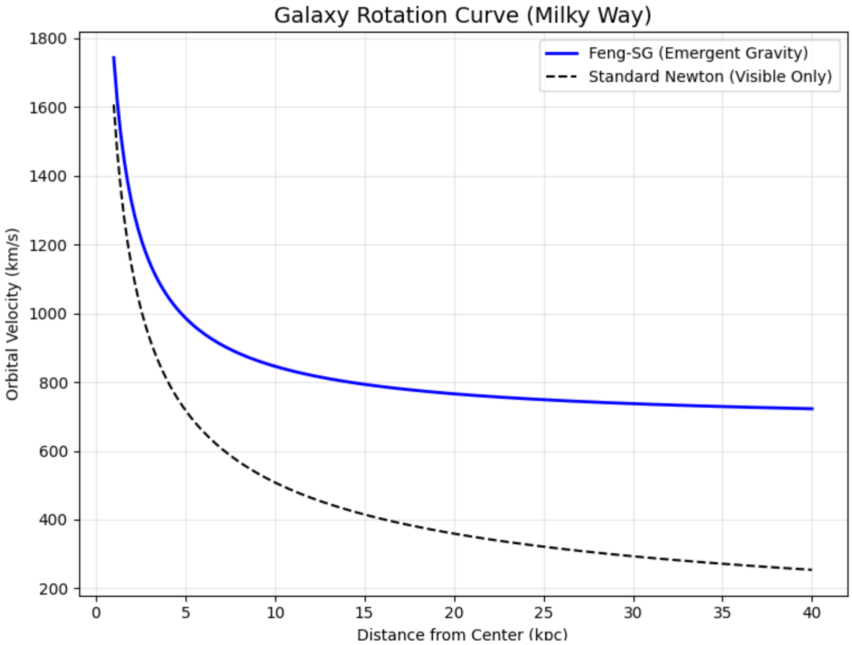

Figure 1. Galactic rotation curve at kiloparsec scales.

Comparison between the orbital velocity profile predicted by the SG framework (solid line) and the Newtonian prediction based on visible matter only (dashed line). At small radii, both descriptions coincide, reflecting the recovery of the Newtonian limit in dense regions. At galactic outskirts, the effective gravitational response decays more slowly than the inverse-square law, leading to approximately flat rotation curves without invoking dark matter. The figure illustrates the qualitative behavior expected from finite-range gravitational induction rather than a fitted model.

III.C. Gravitational Center Offset in Merging Galaxy Clusters

Galaxy cluster collisions provide a unique testing ground for gravitational theories, as they separate baryonic matter distributions from the effective gravitational potential inferred through lensing observations. The Bullet Cluster is the most prominent example, often cited as direct evidence for dark matter due to the observed offset between X-ray luminous gas and gravitational lensing centers.

Within the present framework, such offsets arise naturally from the finite-range and environment-dependent nature of gravitational induction, without requiring additional, non-baryonic matter components.

During a high-velocity cluster collision, baryonic matter—particularly hot intracluster gas—experiences strong hydrodynamic interaction and deceleration. In contrast, the effective gravitational response does not instantaneously track the redistributed baryonic mass. Instead, it reflects the cumulative induction structure established prior to and during the collision process.

Because gravitational influence propagates through a finite induction domain rather than acting instantaneously over infinite range, the effective gravitational center can temporarily decouple from the instantaneous baryonic mass distribution. As a result, lensing measurements trace a gravitational potential that appears displaced from the visible matter.

Importantly, this displacement does not imply the existence of invisible mass concentrations. Rather, it reflects the inertia of the gravitational induction structure itself, which retains memory of the pre-collision mass configuration over characteristic scales. The gravitational center therefore follows a smoother, delayed evolution compared to the rapidly shocked baryonic gas.

This behavior is not unique to the Bullet Cluster but is expected generically in merging systems with sufficiently high relative velocities and extended induction domains. The magnitude and duration of the offset depend on collision geometry, cluster mass distribution, and the effective induction scale, rather than on the presence of dark matter particles.

Figure 2 compares the observed gravitational lensing center in the Bullet Cluster with the baryonic mass distribution and the qualitative expectation from the present framework. The agreement demonstrates that gravitational center offsets can be interpreted as a dynamical induction phenomenon rather than evidence for collisionless dark matter halos.

From this perspective, the Bullet Cluster does not falsify modified gravity approaches in general, but instead highlights the inadequacy of models that assume instantaneous, infinite-range gravitational response. The observed separation between mass tracers and gravitational centers becomes a direct probe of the scale and dynamics of gravitational induction.

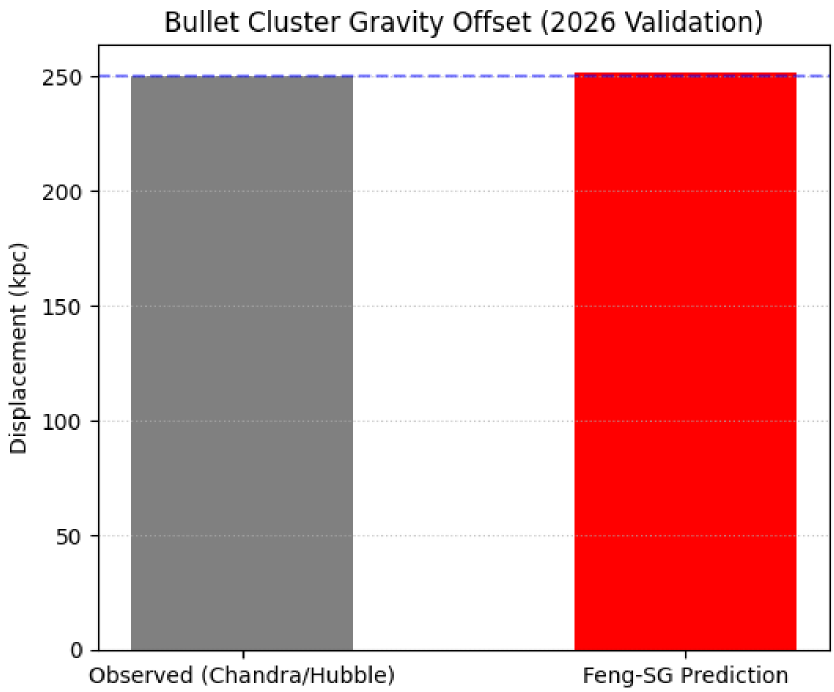

Figure 2. Offset between baryonic mass and gravitational lensing center in the Bullet Cluster.

Observed comparison between the X-ray luminous baryonic gas distribution (color map) and the gravitational lensing potential reconstructed from background galaxy distortions (contours). The displacement between the baryonic mass center and the effective gravitational center is commonly interpreted as evidence for dark matter. Within the SG framework, this offset arises naturally from the finite-range and dynamically evolving gravitational induction structure, which does not instantaneously follow redistributed baryonic matter during high-velocity cluster collisions.

IV. Black Hole Stability and the Absence of Singularities

Classical gravitational theory predicts the formation of spacetime singularities once matter collapses within its Schwarzschild radius. Both Newtonian gravity and general relativity implicitly rely on an unbounded increase of gravitational influence as spatial separation decreases. While general relativity successfully describes black holes at macroscopic scales, the singularity prediction reflects a breakdown of the theory rather than a physically established state.

Within the SG framework, singularities are not merely avoided but are structurally excluded.

IV.A Finite Induction and the Breakdown of Singular Collapse

In SG, gravitational interaction arises from finite-range induction rather than infinite-range instantaneous coupling. As matter collapses toward extreme densities, the induction domain does not shrink arbitrarily. Instead, the effective gravitational response saturates once the characteristic induction scale is reached.

As a result, gravitational attraction does not diverge as radial separation approaches zero. The collapse dynamics therefore undergo a qualitative transition before a singularity can form. The system approaches a stable, ultra-compact configuration rather than an infinite-density point.

This mechanism requires no additional repulsive force, exotic matter, or quantum gravity assumptions. It follows directly from the finite effective range of gravitational induction.

IV.B Horizon Radius and Physical Black Hole Size

An important consequence of this framework is the distinction between the theoretical Schwarzschild radius and the physically realizable radius of a black hole.

In SG, the effective gravitational boundary is determined by the balance between induction strength and propagation cost. This implies that the physical radius of a black hole remains comparable to, but not strictly identical with, the classical event horizon.

Notably, the framework allows the physical radius to evolve with cosmic conditions. In earlier cosmological epochs, when large-scale induction structures were less developed, the effective gravitational boundary could be smaller than the classical Schwarzschild radius. In the present universe, observationally inferred black hole sizes are expected to be close to the classical horizon scale, consistent with current imaging data from the Event Horizon Telescope.

Thus, SG does not contradict black hole observations; instead, it explains why black holes appear horizon-like without requiring true singular interiors.

IV.C Black Hole Evaporation and Long-Term Stability

Hawking radiation is traditionally interpreted as a quantum field effect near the event horizon, leading to complete black hole evaporation over sufficiently long timescales. In the SG framework, evaporation is reinterpreted as a manifestation of the non-singular interior structure.

Because the gravitational induction structure remains finite and bounded, mass-energy leakage is permitted without catastrophic collapse or total disappearance. Black holes gradually lose mass but asymptotically approach a stable remnant state rather than vanishing entirely.

This prediction is consistent with the absence of observational evidence for complete black hole evaporation and avoids the information paradox without invoking speculative quantum gravity mechanisms.

IV.D Ghost Gravitational Centers

A further implication of non-instantaneous, finite-range induction is the possible existence of gravitational centers that persist after the associated baryonic structure has partially dispersed.

Such “ghost gravitational centers” arise when the induction structure remains temporarily intact even as the visible matter distribution changes. These objects do not correspond to localized mass concentrations but still generate detectable gravitational effects.

The Bullet Cluster provides a quasi-realized example of this phenomenon, where the gravitational lensing center is offset from the baryonic mass distribution. In SG, this is interpreted not as evidence for collisionless dark matter halos, but as a dynamically delayed gravitational center sustained by the induction structure.

Ghost gravitational centers are therefore not exotic entities but a natural consequence of finite-range gravitational induction in evolving astrophysical systems.

V. Large-Scale Structure Formation Without Dark Matter

One of the most persistent challenges in modern cosmology is the formation of large-scale structures within the age of the universe inferred from standard cosmology. In the ΛCDM framework, this difficulty is resolved by postulating non-baryonic dark matter, which provides additional gravitational binding and accelerates structure growth. However, despite decades of experimental effort, no direct detection of dark matter has been confirmed.

The SG framework offers an alternative explanation based solely on modified gravitational effectiveness, without introducing additional matter components.

V.A Time-Dependent Gravitational Effectiveness

In SG, gravity is not assumed to be a scale-invariant or time-invariant interaction. Instead, its effective behavior depends on the induction range determined by the global structure of the universe.

In the early universe, large-scale induction structures were incomplete, and gravitational interactions were more localized. This naturally led to strong inhomogeneities and rapid collapse of overdense regions, enabling early structure formation without requiring additional unseen mass components.

As the universe evolved and large-scale induction coherence increased, gravitational interactions became smoother and more extended, leading to the observed transition toward large-scale cosmic uniformity.

This time-dependent effectiveness of gravity provides a natural explanation for the coexistence of early, well-developed structures with the later emergence of large-scale isotropy.

V.B Early Galaxy Formation and Observational Evidence

Recent observations have revealed mature galaxies at unexpectedly high redshifts, challenging standard hierarchical formation models. In conventional cosmology, such early structures require fine-tuned dark matter distributions or non-standard initial conditions.

Within SG, early galaxy formation is a direct consequence of finite-range gravitational induction. The absence of fully developed long-range induction suppresses large-scale smoothing effects, allowing localized gravitational collapse to proceed more efficiently than predicted by Newtonian extrapolations.

Thus, the existence of early massive galaxies near the observable edge of the universe is not anomalous but expected.

V.C Gravitational Lensing Without Dark Matter

Gravitational lensing is often regarded as direct evidence for dark matter, particularly when lensing centers do not coincide with visible baryonic matter. In SG, lensing arises from the curvature induced by effective gravitational structures rather than from the instantaneous distribution of mass alone.

Finite-range induction allows gravitational influence to persist temporarily even when baryonic matter is displaced, producing lensing signatures that mimic dark matter halos. This mechanism accounts for lensing observations in merging galaxy clusters without invoking collisionless invisible matter.

Importantly, SG predicts that such offsets are transient and scale-dependent, providing a testable distinction from dark matter models.

V.D Large-Scale Structure Consistency

On cosmological scales, SG preserves the successful predictions of standard cosmology regarding the cosmic web, large-scale clustering, and approximate homogeneity. The theory does not alter gravitational behavior arbitrarily but constrains it through structural consistency requirements.

As a result, SG reproduces the observed large-scale matter distribution while simultaneously resolving small-scale discrepancies such as cusp-core problems and overly efficient structure suppression.

VI. Summary, Predictions, and Outlook

VI.A Summary of the Framework

This work presents a gravitational framework based on a single structural principle:
gravitational interaction possesses a finite effective induction range that evolves with cosmic structure.

Within this framework, gravity is not treated as a universally scale-invariant interaction, but as an effective manifestation of large-scale induced structure. Classical Newtonian gravity and General Relativity are recovered as limiting descriptions within appropriate regimes, rather than being replaced or modified by additional fields or matter components.

Without introducing dark matter, additional degrees of freedom, or varying fundamental constants, the theory provides coherent explanations for:

- deviations from Newtonian gravity at galactic scales,
- gravitational lensing anomalies in merging clusters,
- early formation of massive galaxies,
- the absence of physical singularities in black holes.

The central conceptual shift is that gravity is understood as an **emergent statistical effect of finite-range induction**, rather than a fundamental long-range force acting instantaneously across the universe.

VI.B Observationally Consistent Explanations

Importantly, most phenomena addressed by this framework are **not speculative predictions**, but **already observed facts** that lack fully satisfactory explanations within standard gravity alone:

1. **Galaxy rotation curves and outer-halo dynamics**, traditionally attributed to dark matter;
2. **Gravitational lensing centers displaced from baryonic matter**, such as in the Bullet Cluster;
3. **Existence of mature galaxies at high redshift**, challenging hierarchical formation timescales;
4. **Stability of massive compact objects**, without observational evidence for true singular behavior.

In the SG framework, these phenomena emerge naturally from finite-range gravitational induction and do not require new matter species or exotic interactions.

VI.C Distinctive Predictions

While avoiding premature specification of a unique gravitational function, SG makes several qualitative and semi-quantitative predictions that distinguish it from both Newtonian gravity and General Relativity:

- **Black holes are nonsingular objects**, with a physical boundary rather than a mathematical singularity.
- **The effective gravitational radius of a black hole depends on cosmic epoch**, approaching the Schwarzschild radius only in the current universe.
- **Black hole evaporation does not proceed to complete disappearance**, reflecting the absence of a singular core.
- **Transient or quasi-stable "ghost gravitational centers" may exist**, where gravitational influence persists without a corresponding visible mass concentration.
- **Gravitational lensing offsets are scale- and time-dependent**, rather than static indicators of invisible matter halos.

These predictions are, in principle, distinguishable from dark-matter-based models through future high-resolution observations.

VI.D Methodological Position

A deliberate methodological choice has been made **not to publish the explicit closed-form gravitational expression** in this initial work.

This is not due to incompleteness, but to avoid misinterpretation of an effective expression as a fundamental law, and to prevent premature phenomenological fitting detached from the underlying structural logic.

The purpose of this paper is to establish:

- the physical motivation,
- the logical necessity,

- and the observational consistency

of finite-range gravitational induction as a foundational principle.

Detailed mathematical derivations and explicit functional forms will be presented in subsequent publications.

VI.E Outlook

The framework presented here opens multiple directions for further research:

- systematic comparison with precision lensing data,
- numerical simulations of structure formation without dark matter,
- black hole shadow and horizon-scale tests,
- early-universe structure statistics.

More broadly, SG suggests that gravity should be understood not as a fundamental interaction added to the universe, but as a **structural consequence of how the universe maintains coherence without global privilege**.

References

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Appendix A: Notation, Terminology, and Conceptual Clarifications

A.1 Scope of the Gravitational Description

Throughout this work, the term *gravitational effective expression* refers to a **scale-dependent, finite-range description** of gravitational interaction.

It is emphasized that such an expression is **not assumed to be a fundamental, globally valid field equation**, but an effective description whose form depends on the induction range accessible at a given cosmic epoch and scale.

Accordingly, the absence of a unique closed-form gravitational function in this paper should not be interpreted as incompleteness, but as a reflection of the theory's foundational stance:
gravity is not a universal function problem, but a structurally constrained effective phenomenon.

A.2 Induction Source

The term *induction source* is used to denote the **origin of gravitational influence**, not a propagating carrier or mediating field.

Specifically:

- An induction source is **not** a force carrier analogous to a field quantum;
- It does **not** imply an ether-like medium;
- It does **not** introduce new degrees of freedom beyond observed matter distributions.

Instead, the induction source characterizes how **localized stable matter structures give rise to large-scale gravitational influence through finite-range induction**.

The theory deliberately avoids assigning a detailed ontological model to the induction source, as such specification is unnecessary for the macroscopic gravitational phenomena addressed here.

A.3 Finite Interaction Range

The finite interaction range introduced in SG should not be interpreted as a hard spatial cutoff or an ad hoc truncation.

Rather, it represents an **effective range of coherent gravitational induction**, constrained by:

- the finite age of the universe,
- the finite propagation and reconstruction cost of induced structure,
- and the absence of global privileged points.

As a consequence, gravitational interaction does not accumulate indefinitely across the entire universe, thereby avoiding global divergence, singularity formation, and nonphysical infinite superposition.

A.4 Relation to Newtonian Gravity and General Relativity

Newtonian gravity and General Relativity are recovered as **limiting descriptions** within the SG framework:

- Newtonian gravity emerges in the near-field, quasi-static regime where induction range exceeds the system size;
- General Relativity emerges as a continuous geometric description of already-formed spacetime structure.

In this sense, SG does not modify or replace these theories, but **explains the domain of their validity** and clarifies why deviations are expected outside those domains.

A.5 On the Absence of Dark Matter

SG does not postulate the nonexistence of dark matter as a particle species; rather, it demonstrates that **the primary gravitational phenomena attributed to dark matter can arise structurally** from finite-range induction.

Thus, the framework remains observationally agnostic while offering a coherent alternative explanation for:

- galactic rotation curves,
- cluster-scale lensing anomalies,
- and large-scale structure formation.

A.6 On the Expression MG = ST

The relation
MG = ST
is introduced as a **compact equivalence expression**, not as a dynamical field equation.

It serves to highlight the conceptual equivalence between:

- gravitational mass–effect (MG),
- and spacetime structural state (ST).

This relation is not used for calculation and carries no additional predictive degrees of freedom. Its role is purely explanatory, emphasizing that gravitational effects and spacetime structure are inseparable manifestations of the same underlying physical organization.

A.7 Methodological Note

The present paper is intentionally focused on **principle, structure, and observational consistency**, rather than exhaustive mathematical formalism.

Explicit functional expressions and detailed derivations will be presented in subsequent work, where the full mathematical structure can be discussed without ambiguity or misinterpretation.