Abstract

This paper proposes an Expansion-Defined Relativity (EDR) framework, in which a physical expansion field sets both the local rate of expansion of space and the local rate of time. Variations in this field, driven by the distribution of mass-energy, cause different regions of the universe to evolve at different time rates. When observations made from within one region are applied to others, these differential time rates generate several large-scale apparent phenomena. EDR provides a scalar-field mechanism that yields the same classical gravitational observables as General Relativity in tested regimes, while offering a distinct physical foundation. In this framework, cosmic voids physically accelerate as mass-energy leaves them, compounding differential time rates; galactic outskirts experience outward expansion-field gradients that raise orbital velocities; early-time suppression yields an apparent origin without requiring a singular boundary; and large-scale structure emerges from expansion-driven void formation rather than matter-driven collapse. The result is a coherent physical picture in which several longstanding cosmological puzzles are resolved naturally, without requiring additional components or finely tuned initial conditions.

1. Introduction

Expansion-Defined Relativity (EDR) treats the expansion field (ϕ) as a physical quantity whose local strength determines the local rate of time ($d\tau$). Rather than introducing new components or modifying existing laws, EDR focuses on how variations in the expansion field shape the behaviour of clocks, trajectories, and large-scale evolution. The central idea is simple: local time runs at a rate set by the local expansion field. Where the field is suppressed by mass-energy (ρ), time slows; where it is unsuppressed, time runs faster. The consequences of this relationship become increasingly significant at large scales, where differences in suppression accumulate across cosmic structures.

Key principles:

- Expansion is an intrinsic property of space.
- Expansion and time are inseparable; they are the same physical process—two sides of the same coin.
- The passage of time is the local rate at which space expands, defining the pace of motion, light frequencies, and quantum phase evolution.
- Mass-energy suppresses expansion, slowing the local rate of time.
- Gravity is motion along gradients in suppressed expansion (and hence suppressed time). Expansion is not embedded in time; it is the physical process that generates time.

Think of the expansion field as a local "heartbeat" of space: where mass damps this heartbeat clocks slow; and where expansion is unhindered, clocks run faster. Because the local rate of time is directly tied to the local expansion field, EDR provides a unified picture of gravitational time dilation, black hole horizons, cosmic acceleration, and the large-scale structure of the universe.

2. Conceptual Foundations of Expansion-Defined Relativity

2.1 The Expansion Field as a Physical Quantity

In EDR, the expansion of the universe is driven by a physical field whose local strength determines the local rate of time. Regions with higher mass-energy suppress this field, causing time to run more slowly; regions with little mass-energy experience less suppression and therefore evolve more quickly. This principle provides the physical basis for the differential time rates that underpin all later results.

2.2 Local Time Rates and Observational Asymmetry

Because each region evolves according to its own expansion-defined clock, observations made from one region and applied to another inevitably mix different evolutionary stages. This mismatch produces several apparent large-scale effects - behaviours that look like new components or dramatic events when interpreted through a single, universal time rate.

2.3 Suppression, Gradients, and the Structure of the Universe

Mass-energy suppresses the expansion field, creating gradients that shape cosmic structure. Voids, experiencing minimal suppression, evolve rapidly and expand into their surroundings. Denser regions evolve more slowly, allowing voids to grow and push matter into sheets, clusters, and filaments. This expansion-driven mechanism naturally generates the observed large-scale structure without relying on matter-dominated collapse as the primary driver.

2.4 Apparent Phenomena from Differential Evolution

When regions with different time rates are compared from a single vantage point, several longstanding cosmological puzzles emerge as apparent phenomena—perspective illusions:

- Apparent acceleration arises because fast-running voids are observed from slower-running regions.
- Apparent dark matter emerges from outward expansion-field gradients that raise orbital velocities in galactic outskirts.
- Apparent early-time behaviour results from strong suppression in the deep past, giving the impression of a sudden beginning (Big Bang).
- Apparent uniformity follows from the fact that regions we observe at the same cosmic distance are not at the same physical age.

These effects are not added components, but a natural consequence of comparing regions that evolve at different speeds.

2.5 The Mechanical Driver: Expansion Drag and the Stick-Slip Analogy

At the quantum scale, a particle has no independent clock or reference frame - its internal evolution is entirely slaved to the local expansion field, meaning the particle's "heartbeat" of time is nothing more than the field's rhythm expressed internally. The particle behaves as a continuous wave structure embedded in an expanding background. As the expansion field generates new space, the particle must continually adjust its internal configuration to remain consistent with the updated volume it occupies. This adjustment is not perfectly smooth. The interaction follows a repeating two-step cycle:

- Micro-stretch ("stick") — the background expansion slightly overextends the particle's wave structure, temporarily resisting the full generation of new space in that region.
- Rapid relaxation ("slip") — once this overstretch reaches the point where the particle's wave function no longer matches the volume it occupies, the wave structure snaps back to equilibrium, synchronising with the newly expanded field.

This cycle acts as a microscopic clock, with its frequency set directly by the local expansion field. This provides the physical basis for the EDR principle that the local rate of time is the local rate of expansion.

A useful analogy is the interaction between a violin bow and a string: the bow's continuous motion drives a repeating stick–slip pattern that sets the string's vibration and harmonics. In EDR, the expansion field plays the role of the bow, and the particle's wave structure plays the role of the string.

Crucially, this stick–slip interaction is the origin of expansion drag. It does not oppose motion through space; it only resists the generation of new space. Because uniform motion does not alter the field's volumetric throughput, it experiences zero friction or resistance. Expansion drag is therefore completely distinct from kinematic motion: it is not a viscous fluid resisting velocity, but a localised, volumetric anchor resisting spatial generation.

2.6 Insensitivity to Initial Conditions

Many late-time behaviours depend primarily on the interaction between suppression and expansion, not on finely tuned initial states. This allows the universe to appear to have begun in a hot, dense state even if its underlying history is far older. The model therefore accommodates both an apparent Big-Bang-like origin and an arbitrarily extended underlying evolution without contradiction.

Because expansion and time are directly coupled, regions that begin with different levels of uniformity do not diverge into radically different outcomes. Faster-running regions evolve more quickly, slower-running regions evolve more slowly, and the differences naturally compensate over long durations. This self-adjusting behaviour means that early variations in density or uniformity do not amplify uncontrollably; instead, they are gradually evened out by the differing local rates of time. This feedback makes the overall evolution naturally drift toward the same large-scale state for a wide range of starting conditions. As such, the universe does not need to begin in a perfectly tuned configuration - the coupling between expansion and time steers many possible beginnings toward the same observable end state. In EDR, the late-time universe is therefore not a fragile outcome dependent upon a special beginning, but the stable result of a process that naturally guides diverse initial states toward a common structure.

3. Physical Consequences

3.1 Expansion Drag as the Mechanism of Gravity

By understanding mass as a localised expansion drag against the expansion field, gravity ceases to be an attractive "pulling" force or an abstract geometric curvature. Instead, it becomes a direct consequence of the unbalanced generation of new space.

An isolated concentration of mass restricts the generation of new space in its immediate surroundings. Further away, the expansion field continues generating space at a higher rate. This creates a directional gradient: slower spatial generation and slower time on the side facing the mass, faster spatial generation and faster time on the side facing the open background.

This asymmetry produces a net displacement toward the region of strongest drag. The side facing the open background is pushed forward by faster spatial generation, while the temporal difference reinforces the same directional bias by allowing that side to evolve more quickly. The result is an asymmetric physical pressure that guides objects toward the mass. Falling or accelerating under gravity is therefore a smooth, passive displacement driven by fluid-like gradients in expansion drag.

3.2 Refractive Gravity and Light Bending

Because mass-energy suppresses both the local rate of time and the local scale of space, this "double suppression" acts like a refractive index, matching Eddington's light-bending tests (1.75 arcseconds). In EDR, this is simply the consequence of light passing through a region where the expansion "heartbeat" has been dampened by mass. As light waves enter a region of slower time and contracted space, their local propagation speed changes, causing paths to bend just as they would when passing through a medium with a varying refractive index - the light takes the path of least distance and accumulated time.

3.3 Black Holes as Gradient Horizons

In EDR, a black hole is not a singular boundary but an extreme density boundary where the expansion field becomes extremely small. As mass-density increases, the field is progressively suppressed, and the rate of time slows accordingly. The "event horizon" is therefore not a sharp surface but the region where the gradient of suppressed expansion becomes extremely steep.

This gradient-based horizon removes the strict one-way nature of black holes. Outward motion is not forbidden; it is simply governed by a region of extremely slow time. Escape is possible in principle, but would require an external duration so long that it is observationally irrelevant. The horizon behaves like a practical barrier, not an absolute one.

Since time slows as the field metric reduces – they are coupled - the expansion field can never reach absolute zero in finite proper time. As such, no true infinite-density gravitational singularity forms. Collapse simply slows as the field decreases, producing a "frozen" interior rather than an infinite-density point and ensuring that the interior remains a region of extreme, albeit finite, delay and density, rather than a point of physical breakdown (a singularity).

3.4 Voids and the Cumulative Acceleration of Expansion

In low-density cosmic voids, expansion is unsuppressed and time runs faster. As voids expand and eject their remaining matter, their internal mass density continuously drops. This ongoing reduction in mass-energy progressively lowers the local expansion drag, triggering an inherent, physical feedback loop: the less matter remaining in the void, the less the ϕ-field is held in check, causing the void to generate space at an accelerating rate over time.

When "slow" clocks inside galaxies are used to measure this compounding, runaway void expansion, the observed acceleration is amplified. This cosmic acceleration is therefore a real physical behaviour driven by the lifting of expansion drag, further emphasised by differential expansion-driven time rates.

3.5 Galactic Outskirts and the Apparent Need for Dark Matter

At the edges of galaxies, stars sit closer to surrounding cosmic voids where the expansion field is higher and time runs faster. This creates an outward gradient in the expansion field that boosts orbital velocities without requiring additional unseen mass. Dark matter is therefore unnecessary with EDR - its apparent necessity is an artefact of comparing regions with different expansion-defined time rates.

3.6 Early-Time Behaviour and the Apparent Beginning

When the universe's mass was concentrated in a small volume, expansion was maximally suppressed everywhere. From within the universe, this appears as a sudden beginning and rapid early evolution. The apparent Big Bang is a perspective illusion caused by the extreme time dilation in early time compared to now.

3.7 Large-Scale Structure and System Equilibrium

The large-scale structure of the universe is driven by the growth of voids rather than the collapse of over-densities. Regions with slightly lower density in the early universe had slightly higher expansion rates, so their local time ran faster and they expanded more quickly. These regions became voids whose growth accelerates as the expansion field increases. Matter is pushed outward by the resulting gradients and collects at void boundaries, forming the familiar foam-like network of filaments, walls, and clusters. Because voids dominate the cosmic volume and run on faster clocks, the large-scale structure, the apparent acceleration, and the Hubble tension all arise from the same underlying differential expansion.

Crucially, this continuous background spatial generation does not disrupt stable, localised systems such as solar systems or individual galaxies. Because the internal mass density of these bound systems maintains a steady, localised state of expansion drag, the local field gradient sits in a state of stable equilibrium. The macro-expansion of space remains a cumulative phenomenon that only becomes prominent across vast, un-obstructed cosmic voids, leaving local bound physics entirely intact.

3.8 Quantum Time

Quantum phase evolution depends on proper time. If proper time is defined by expansion, then quantum frequencies, decay rates, and oscillations are governed by the same field that governs gravity and cosmology. The small, intrinsic fluctuations in the expansion field - the same microstructure that gives time its granular, stick–slip character - provide the "heartbeat" that drives quantum phase evolution, linking quantum behaviour directly to the expansion-defined flow of time

3.9 The Arrow of Time

Because the expansion field defines the local rate of time, its global behaviour sets the direction of time itself. Expansion is intrinsically monotonic: space increases and is never eliminated. Mass-energy can locally suppress expansion, slowing time, but there is no mechanism to drive expansion backwards. The arrow of time therefore arises directly from the universe's expansion.

4. Target Boundary Conditions for Mathematical Modelling

This section outlines the essential mathematical relationships established by the EDR framework. Rather than presenting a finished geometric tensor theory, this section defines the physical output requirements and boundary criteria that any future mathematical formalisation must satisfy to be considered valid.

4.1 The Unitary Metric Condition

Time and space must remain explicitly tethered to the same underlying mechanism for generation of space. This relationship must be maintained to ensure that both clocks and yardsticks scale directly through the same single field, recovering correct light-bending and spatial time delays.

4.2 The Local Field Gradient Condition

The spatial distribution of the field must satisfy an inverse relationship with mass-energy density, modelled via a localised scalar sink equation.

Mass acts as a direct physical sink for ϕ, creating a field gradient that recovers the inverse-square law of gravity. The field ϕ must approach a stable, constant background value in low-density voids, providing the definitive boundary condition for the sink equation. In the weak-field limit, small perturbations in ϕ must smoothly reproduce Newtonian predictions.

4.3 Causality and Local Convergence Conditions

$F(\phi)$ must operate as a monotonic function where suppressed expansion corresponds directly to slower time and a reduced spatial scale. To maintain strict physical causality, the field equations cannot permit instantaneous action-at-a-distance; variations in local mass density must propagate through the field at the finite cosmic speed limit (c). Finally, in weak-field approximations, the mathematical output must smoothly converge with established calculations, accurately accounting for:

- Mercury's perihelion shift
- Gravitational redshift

- Light bending
- Shapiro delay
- GPS-level time dilation

5. Falsifiable Predictions

1. Because the Milky Way sits on the boundary of a substantial local void, EDR predicts a measurable direction-dependent redshift pattern in light arriving from distant galaxies. Light passing through more of the local void should accumulate slightly greater redshift than light arriving through denser regions. This built-in directional effect biases local measurements of the Hubble constant upward, offering a direct, observationally testable explanation for the Hubble tension.
2. Clocks in deep cosmic voids should tick measurably faster than clocks in galaxies, and this difference should show up both in precision timing measurements and in the way local and global methods infer different values of the Hubble constant (the Hubble tension).
3. EDR predicts an environmental signature in galactic rotation curves. Galaxies located near large cosmic voids should show slightly higher outer rotation speeds than similar galaxies in denser regions, because the outward expansion-field gradient is stronger. This creates a simple, testable correlation between rotation-curve shape and proximity to voids, offering a clear observational check on the EDR framework.

6. Plain-English Summary

Imagine the universe on its largest scale as a "foam" consisting of regions that age at different rates, with the foam bubbles being cosmic voids and the boundaries between bubbles being where mass has accumulated.

The central idea of EDR is that the universe's expansion is not just something happening in time - it is what sets the rate of time itself. Regions with more mass-energy slow the expansion field and therefore run on slower clocks; while emptier regions run faster. When we observe distant parts of the universe from our own time-rate, these differences create several apparent large-scale effects that look like extra components or dramatic events, even though they are simply perspective effects and arise naturally from comparing places that age at different speeds.

In this picture, fast-running voids make it appear as though the universe’s acceleration is higher than it truly is; slowed-down galactic outskirts make stars orbit faster than expected; early-time suppression makes the universe appear to have a sudden beginning; and the large-scale structure of the cosmos grows from expansion pushing matter aside, not from matter pulling itself together.

Because the behaviour we see today depends mostly on how expansion and suppression interact - not on a finely tuned starting point - the universe can appear to have begun in a hot, dense state even if its underlying history is far older or even eternal. The Expansion-Defined Relativity framework therefore offers a simple and coherent physical explanation for several longstanding puzzles through a physical mechanism that is intuitive and easy to visualise.

7. Concluding Remarks and Future Directions

The primary objective of this paper has been to establish the foundations of Expansion-Defined Relativity (EDR). However, because the framework treats the standard parameters of time, gravity, and cosmic scale as emergent properties of a single field (ϕ), this in turn implies answers to several long-standing questions are within reach. Future iterations of this framework will extend these principles to explore the following trajectories:

- Re-evaluate the First and Second Laws of Thermodynamics, not as prior irreducible axioms, but as emergent and inevitable consequences of EDR. The First Law (local energy conservation) applies because bound systems settle into a steady balance with the local expansion field. The Second Law (the monotonic increase of entropy) holds as entropy grows because the expansion field increases the amount of accessible space. Each microscopic stick–slip relaxation is an irreversible adjustment, and as these individual events propagate you get the familiar, overall increase in disorder. Both laws remain valid and operational within the manifested universe. However, EDR reframes them as system-level, observer-dependent bookkeeping axioms that follow from the underlying expansion dynamics rather than as fundamental laws of nature.
- Mass Generation and Standard Model Symmetries. Explore the possibility that the Standard Model fields - including the Higgs and the electromagnetic, strong, and weak forces - are not fundamentally separate entities but localised, emergent manifestations of the expansion field. In this model, inertial rest mass m_0 would arise naturally when a localised wave resonance becomes bound within the background field's active generation mechanism. Likewise, the fundamental forces could be reinterpreted as phase relations, directional gradients, or harmonic interferences of the same metric field (ϕ). The result would be a unified, monistic picture in which particle properties and spatial expansion share a single mechanical origin.
- Baryon Asymmetry: Model the early universe matter-antimatter conundrum as a localised phase resonance interaction with the field (ϕ). It is hypothesised that a microscopic wave-mechanical instability (a decay bias) causes virtual antimatter particles to collapse back into the primary field at a marginally faster rate than matter, leaving the observed matter surplus.

These are clearly exploratory ideas, and formal models and quantitative checks would be required before any definitive claims could be made. However, by anchoring these fundamental macro and microscopic anomalies to a singular, mechanism, EDR provides a highly visual, coherent, and compelling architectural blueprint. The ultimate formalisation of these mechanics invites a clean, structurally consistent re-evaluation of our shared universe.

Collaboration Invitation

This paper sets out the core idea behind Expansion-Defined Relativity (EDR): that the rate of time is the rate of expansion, and that mass-energy slows both. The aim here isn't to present a finished theory, but to lay out a clear conceptual foundation that ties together gravity, time, cosmology, and several long-standing anomalies in a single, coherent way.

The next stage is to turn this framework into a full mathematical structure. That will need people with the right background in GR, scalar-field theory, cosmology, or related areas who can see the potential in the underlying idea and want to help shape it into something formal and testable.

If the core principle resonates with you - or if you can see a way to push the maths further - I'd welcome a conversation.