DATED HISTORY

The Scalar Shadow of Co-Emergent Geometry

April scalar-shadow manuscript. Clock lag is an operational observable. The subsequent simulator audit recovered closure in zero of nine repairs.

Manuscript · p. 1, theoretical formulation

A Test Protocol for Scalar Timing Closure and Dimensional Selection

Evidence · Scalar source/window residual audit

The Scalar Shadow of Co-Emergent Geometry

Clock Lag as the Minimal Readable Projection of a Relational Universe

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Note. This draft reformulates scalar timing geometry without treating clock lag as temporally prior to gravity. The core distinction is between chronological emergence and operational readability: a full relational structure may cohere at once, while scalar timing is the minimal clock-readable projection.

Abstract

This paper reformulates scalar timing geometry without assuming that clock lag temporally precedes gravity. If spacetime, matter, clocks, and gravitational behavior emerge from a deeper relational substrate, then it is misleading to imagine them assembling in a sequence analogous to events inside time. The more careful claim is one of *co-emergence with asymmetric readability*: a full relational event may contain scalar, vector, gauge, tensor, topological, and record-forming aspects at once, while finite observers recover only certain projections first.

We propose that the minimal readable projection of such a co-emergent relational structure is a scalar timing channel. A local clock does not receive the whole substrate; it integrates a reduced scalar load. The resulting effective clock rate is modeled by

$$\omega_{\text{eff}} = \frac{\omega}{1 + \alpha\Lambda},$$

where Λ is a coarse-grained scalar load and α is a clock susceptibility. This does not assert that scalar timing is the foundation of gravity, nor that gravity appears later. Rather, scalar timing is the lowest-order clock-readable shadow of a richer structure that, when reconstructed through rods, clocks, trajectories, phases, and stress-response, may appear as gravitational geometry.

The central program is therefore not sequential emergence but projected observability. A microscopic relational substrate gives rise to an effective weighted graph, a graph Laplacian, a scalar load, and richer reconstructed sectors. The scalar branch becomes gravity-like when the same operator that governs scalar response also yields an effective dimension near three, producing a $1/r$-type Green response. The resulting framework is not a completed theory of gravity, but a disciplined research program: test whether the same promoted operator controls scalar response, effective dimension, timing shifts, and dynamical relaxation in one common scaling window.

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1. Introduction: the danger of explanatory order

When a theory tries to explain time, it must be careful not to smuggle time into its explanation.

It is tempting to say that relational updating comes first, then scalar load, then clock lag, then gravity. Such a chain is useful as a map of concepts, but it should not be mistaken for a literal chronology. If time itself is emergent, then "first" cannot mean "earlier in time" at the deepest level. A pre-geometric substrate does not wait, then make clocks, then wait again, then make gravity. Waiting is already a temporal concept.

The more careful claim is this:

> *The relational universe may cohere all at once, but finite instruments do not read it all at once.*

A clock does not measure the whole relational substrate. It measures a timing response. A local observer does not directly receive the full tensor, gauge, topological, and informational structure of the world. They receive a reduced set of stable observables: ticks, phases, delays, correlations, accelerations, and records.

The hypothesis of this paper is that among these reduced observables, scalar timing is the simplest.

This is not the claim that clock lag is physically older than gravity. It is the claim that clock lag may be *operationally prior*: the lowest-order projection through which a richer co-emergent geometry becomes measurable.

A chord is not assembled note by note, yet an instrument may detect the bass first. White light is not born color by color, yet a prism separates it into components. A relational universe may not build scalar timing before gravity; rather, scalar timing may be the component revealed when the full structure is projected through the measurement basis of a local clock.

The earlier slogan, "the clock before gravity," should therefore be sharpened:

> *The clock is not before gravity in time. The clock is the scalar face of co-emergent geometry.*

2. The central distinction: genesis versus readability

The main conceptual correction is the distinction between *genetic order* and *readability order*.

A genetic order says

$$A \to B \to C,$$

as though A happens, then B, then C.

A readability order says

$$\mathcal{R}_{\text{full}} \to \Pi_{\text{observable}}(\mathcal{R}_{\text{full}}),$$

where $\mathcal{R}_{\text{full}}$ is the full relational structure and $\Pi_{\text{observable}}$ is the projection imposed by finite instruments, finite resolution, coarse graining, and stable records.

In this second sense, scalar timing can be "first" without being temporally first. It is first because it requires the least reconstructed structure. A scalar clock-rate shift requires only a local

load and a clock response. A full tensor theory of gravity requires much more: rods, clocks, free-fall behavior, universal coupling, Lorentz-compatible propagation, stress-energy response, gauge redundancy or equivalent constraints, and a spin-2-like sector.

Thus the hierarchy is not

$$\text{clock lag, then gravity.}$$

It is

$$\text{full relational structure} \quad \longrightarrow \quad \begin{cases} \text{scalar timing projection,} \\ \text{vector/gauge projection,} \\ \text{mass-like persistence,} \\ \text{tensor-gravity reconstruction,} \\ \text{classical records.} \end{cases}$$

These sectors may be co-present in the full structure. They become distinct only when we ask what kind of measurement extracts which kind of information.

3. Relational substrate and projected sectors

Let the deepest substrate be described abstractly as a lawful relational system rather than a differentiable manifold. It may be represented, depending on the model, as a graph, hypergraph, tensor network, causal set, quantum cellular automaton, or another structure of updates, adjacencies, memory, constraints, and correlations.

The full microscopic state is denoted

$$\rho_{\text{micro}}.$$

Observers do not access ρ_{micro} directly. Instead, they access stable projected sectors. A scalar timing sector may be represented by a coarse-graining channel

$$\mathcal{E}_{\text{scalar}} : \rho_{\text{micro}} \mapsto \{W, L_w, \Lambda, \omega_{\text{eff}}\}.$$

Here

$$W = (w_{ij})$$

is an effective weighted adjacency matrix,

$$L_w = D - W$$

is the weighted graph Laplacian,

$$\Lambda$$

is the retained scalar load, and

$$\omega_{\text{eff}}$$

is the effective clock rate measured by a local oscillator.

This projection discards most of the microscopic state. It does not retain the full phase structure, all nonlocal correlations, all gauge-like loops, all tensorial degrees of freedom, or the entire global topology. It keeps the part that survives into scalar timing measurements.

The scalar sector is therefore not the whole world. It is the smallest world a clock can read.

4. Postulates of co-emergent scalar timing geometry

4.1 Postulate I: relational substrate

The deepest physical description is not assumed to be a smooth spacetime manifold. It is modeled as a lawful relational substrate consisting of updates, adjacencies, constraints, memory, and correlations.

4.2 Postulate II: co-emergence

Scalar timing, mass-like persistence, gauge-like circulation, tensor geometry, and classical records need not arise in a temporal sequence. They may be mutually co-emergent aspects of one relational structure.

4.3 Postulate III: asymmetric readability

Although sectors may co-emerge, they are not equally readable. Finite observers access reduced projections. The scalar timing projection is simpler than full tensor reconstruction because it requires only a scalar load and a clock response.

4.4 Postulate IV: scalar timing law

The minimal timing response is modeled by

$$\omega_{\text{eff}} = \frac{\omega}{1 + \alpha\Lambda},$$

or, for weak load,

$$\frac{\delta\omega}{\omega} \approx -\alpha\Lambda.$$

Here α is an effective susceptibility coupling scalar load to clock rate.

4.5 Postulate V: operator closure

The scalar load should not be an arbitrary fitted field. It should arise from the same effective operator that governs response, smoothing, relaxation, and dimension:

$$(\kappa L_w + \mu^2 I)\Lambda = A\rho.$$

The dynamical completion is

$$\partial_t \Lambda + \Gamma(\kappa L_w + \mu^2 I)\Lambda = \Gamma A\rho(t).$$

4.6 Postulate VI: richer sectors require richer observables

Mass, magnetism, gauge structure, topology, and tensor gravity are not denied. They are higher-readability or higher-reconstruction sectors. They require additional structure beyond scalar load:

persistence, loops, holonomy, orientation, stress-response, tensorial degrees of freedom, and universal coupling.

5. The clock as a projection device

A clock is not merely an object inside geometry. In a relational framework, a clock is a projection device. It converts inaccessible relational structure into accumulated phase.

Let a local clock have bare frequency ω. If the local scalar load is $\Lambda_i(t)$, then

$$\omega_{\text{eff}}(i,t) = \frac{\omega}{1+\alpha\Lambda_i(t)}.$$

The accumulated phase is

$$\phi_i(T) = \int_0^T \omega_{\text{eff}}(i,t)\,dt.$$

For two clocks A and B,

$$\phi_A(T) - \phi_B(T) = \int_0^T \left[\frac{\omega}{1+\alpha\Lambda_A(t)} - \frac{\omega}{1+\alpha\Lambda_B(t)}\right] dt.$$

In the weak-load regime,

$$\phi_A(T) - \phi_B(T) \approx -\alpha\omega \int_0^T [\Lambda_A(t) - \Lambda_B(t)]\,dt.$$

This is the minimal measurable signature: not the full geometry, not the full source, not the complete tensor structure, but differential accumulated phase.

The clock does not tell us what the substrate is. It tells us that the substrate casts a scalar timing shadow.

6. Scalar load from an effective graph

The scalar sector is modeled on an effective weighted graph $G = (V, E, w)$. The weights w_{ij} may arise from microscopic couplings, bond occupations, frustration patterns, dressed interactions, or another medium-specific extraction map.

The weighted Laplacian is

$$(L_w f)(i) = \sum_j w_{ij}\,[f(i) - f(j)]\,.$$

The leading scalar closure is

$$(\kappa L_w + \mu^2 I)\Lambda = A\rho.$$

This is the graph analogue of a screened elliptic response equation. The parameter κ controls scalar stiffness or transport, μ controls screening, A controls source strength, and ρ is an effective source density.

This equation should be understood as a leading weak-load closure, not as a final ontology. Nonlinear corrections, memory kernels, higher-order graph operators, and tensor couplings may

appear beyond this regime:

$$(\kappa L_w + \mu^2 I)\Lambda + \beta\Lambda^2 + \eta L_w^2 \Lambda + \int_0^t M(t-s)\Lambda(s)\, ds = A\rho.$$

The scientific question is whether the leading scalar closure works in any real or simulated scaling window.

7. Effective dimension from the same operator

The same operator L_w that governs scalar response also defines diffusion on the promoted graph:

$$K(t) = e^{-tL_w}.$$

The mean return probability is

$$P_{\text{return}}(t) = \frac{1}{|V|}\operatorname{Tr} K(t).$$

When a scaling regime exists, the diffusion-based effective dimension is

$$d_{\text{eff}}^{(\text{diff})}(t) = -2\frac{d\log P_{\text{return}}(t)}{d\log t}.$$

Independently, a scalar load sourced at a point or hotspot yields a shell-averaged profile

$$\Lambda_{\text{shell}}(r) = \frac{1}{|S_r|}\sum_{i\in S_r}\Lambda_i.$$

In a Gaussian scaling regime,

$$\Lambda_{\text{shell}}(r) \sim r^{2-d_{\text{eff}}}$$

for $d_{\text{eff}} \neq 2$, and

$$\Lambda_{\text{shell}}(r) \sim \log r$$

for $d_{\text{eff}} = 2$.

Thus the shell-based estimate is

$$d_{\text{eff}}^{(\Lambda)}(r) = 2 - \frac{d\log|\Lambda_{\text{shell}}(r)|}{d\log r}.$$

The closure test is not merely whether either estimator gives a pleasing number. The test is whether

$$d_{\text{eff}}^{(\text{diff})} \approx d_{\text{eff}}^{(\Lambda)}$$

in the same scaling window where the scalar timing law fits best.

8. Why three appears without being assumed

In the scalar closure,

$$\Lambda(r) \sim r^{2-d_{\text{eff}}}.$$

If

$$d_{\text{eff}} \approx 3,$$

then

$$\Lambda(r) \sim \frac{1}{r}.$$

The weak timing shift becomes

$$\frac{\delta\omega}{\omega} \approx -\alpha\Lambda(r) \sim -\frac{1}{r}.$$

This resembles the radial envelope of weak gravitational redshift.

This does not prove gravity. It identifies a scalar precondition. If a relational substrate has a scalar timing projection, and if the effective operator admits a three-dimensional Gaussian scaling regime, then the clock-readable scalar profile has the right $1/r$ form to become gravity-like.

The point is subtle but important:

> *The theory does not assume ordinary three-dimensional space at the bottom. It asks whether a promoted relational operator selects or supports an effective dimension near three in the observable scalar branch.*

Three is not inserted as a background. It is a target of closure.

9. Gravity as richer reconstruction, not later creation

Full gravity is not simply scalar timing. A scalar redshift-like channel is not equivalent to general relativity.

A complete gravitational sector must account for a metric-like structure $g_{\mu\nu}$ or its effective equivalent, universal coupling, free-fall behavior, light cones, stress-energy response, Lorentz-compatible dynamics, gravitational radiation, and a spin-2-like sector or equivalent constraint structure.

The scalar timing sector may be related to gravity in the way a shadow is related to an object. It is not the object. It is a projection of the object under a particular readout.

Thus we should not write

$$\Lambda \to \text{gravity}$$

as though scalar load mechanically turns into gravity.

A better expression is

$$\mathcal{R}_{\text{full}} \to \begin{cases} \Lambda,\ \omega_{\text{eff}} & \text{scalar timing projection,} \\ A_\mu,\ \text{holonomy} & \text{gauge-like projection,} \\ g_{\mu\nu} & \text{tensor reconstruction,} \\ \text{records} & \text{classical projection.} \end{cases}$$

Gravity and scalar timing may be co-emergent projections of the same deeper relational structure. Scalar timing is not earlier. It is simpler to read.

10. Mass, magnetism, and records in the co-emergent picture

The scalar timing program should not demote other sectors. It should locate them.

10.1 Mass-like persistence

Mass may correspond to stable localized patterns in the relational substrate: defects, knots, scars, standing excitations, or self-maintaining concentrations of relational load. A clock may read their scalar effect before the full nature of their persistence is reconstructed.

10.2 Gauge-like circulation

Magnetism cannot be captured by scalar load alone. It requires orientation, phase, circulation, loop structure, and holonomy. In graph language, it lives not merely on nodes but on edges, cycles, and phase relations.

10.3 Tensor gravity

Tensor gravity requires the reconstruction of metric-like structure from many observables, not just clock rate. It belongs to a richer projected algebra.

10.4 Classical records

A classical world requires stable records: robust, redundant, coarse-grained states that persist long enough to be compared. Records are not passive. They are part of the observable projection machinery.

Thus the sectors are not arranged as a cosmic production line. They are arranged by the richness of the readout needed to identify them.

11. Revised hierarchy: depth and readability

The earlier language of "before clock lag" and "after clock lag" should be replaced by a hierarchy of projection depth.

Level	Description	Status
0	Full relational substrate	Hidden / not directly observed
1	Stable relational topology	Adjacency, paths, loops, bottlenecks
2	Effective operator	W, L_w, response law
3	Scalar load	Λ, minimal retained scalar
4	Clock-readable projection	ω_{eff}, phase lag
5	Gradient behavior	Force-like scalar bias
6	Persistent excitations	Mass-like sources
7	Oriented loop sectors	Gauge/magnetism-like behavior
8	Tensor reconstruction	Gravity-like geometry
9	Stable records	Classical world

This table is not a temporal sequence. It is a readability ladder.

The lower levels are not earlier. They are less reconstructed. The higher levels are not later. They require more structure to read.

12. Internal loads and external observables

A scalar load inside a medium does not automatically imply an externally measurable scalar field. This distinction is essential.

Let Λ_i be internal scalar load on graph vertex i. An external sensor at position x measures, at most,

$$\Lambda_{\text{ext}}(x) = \sum_i C(x,i)\Lambda_i.$$

The kernel $C(x,i)$ determines how internal load couples to an external probe.

Possible kernel classes include near-field or evanescent coupling,

$$C_{\text{ev}}(x,i) \sim C_0 e^{-d(x,i)/\ell_c},$$

substrate-mediated diffusive coupling, radiative or boundary-modulated coupling, vacuum-like Green response, or a null kernel,

$$C(x,i) \approx 0,$$

in which case the scalar load remains internal.

This is one of the cleanest ways the theory can fail. An internal scalar timing sector may exist in a medium while producing no external geometric signal. That would not make the internal theory meaningless, but it would limit the scope of any claim about external spacetime geometry.

13. Numerical closure tests

The scalar timing program becomes scientific only when it supplies severe tests.

The strongest numerical closure test is

$$d_{\text{eff}}^{(\text{diff})} \overset{?}{\approx} d_{\text{eff}}^{(\Lambda)} \overset{?}{\approx} 3$$

in the same scaling window where

$$\omega_{\text{eff}} = \frac{\omega}{1+\alpha\Lambda}$$

fits best.

A meaningful pass requires:

1. a nontrivial scaling window in diffusion time or shell radius;
2. agreement between diffusion-based and shell-profile-based dimension estimates;
3. local minimization of timing-law residuals in the same window;
4. finite-size stability;
5. robustness to source placement and graph extraction thresholds;
6. dynamical relaxation rates tracking the Laplacian spectrum.

If the timing law fits in one window while the dimension estimate works in another, the strong closure fails. If the dimension passes through three only transiently without a plateau, the result is suggestive but weak. If no Gaussian scaling window exists, the medium does not support the intended scalar branch.

The virtue of the program is that failure has shape.

14. Experimental posture

The experimental program should not begin by claiming new gravity. It should begin by bounding scalar timing response in controlled media.

A minimal experiment would require:

1. a reconfigurable medium whose internal graph W can be changed;
2. a clock-like or phase-sensitive observable coupled to the medium;
3. topology changes at nearly fixed mass-energy distribution;
4. distance-law measurements;
5. thermal, electromagnetic, vibrational, and mechanical controls;
6. comparison of transient response against the graph Laplacian spectrum.

The desired signature is not merely "a frequency changed." Frequency changes are easy to fake through ordinary systematics.

The desired signature is

timing shift + graph dependence + topology sensitivity + modal relaxation + mass/force null contro

A null result is useful. It constrains α, A, μ, Γ, or the coupling kernel $C(x, i)$. It tells us whether scalar timing is external, internal, screened, or absent in that medium.

15. Relation to existing ideas

The present framework sits near several established research families but is not identical to any one of them.

Relational approaches to time emphasize that time is not an external universal parameter but a relation between physical systems. Quantum clock and Page-Wootters-type approaches show how time-like behavior may arise from correlations between subsystems. Causal set theory and graph-based models explore the possibility that spacetime is not fundamentally a smooth manifold. Quantum graphity studies how locality and low-dimensional structure may emerge from dynamical graphs. Tensor-network and entanglement-based approaches suggest that geometry may be encoded in quantum information structure. Scalar gravity historically explored whether gravity could be described by a scalar field, although such theories do not reproduce full general relativity.

The present proposal differs by combining these motifs into a timing-first scalar-selection program:

A relational substrate may co-emerge into many sectors at once, but the minimal readable projection for a local observer is scalar clock lag governed by an effective graph operator.

This is not a claim of total priority. It is a claim of synthesis and testability.

16. Limits

This paper does not prove full general relativity, Lorentz invariance, electromagnetism, mass, a spin-2 sector, external scalar geometry, dark energy, quantum gravity, or a theory of everything.

It proposes a reduced observable sector and a closure program.

The main risks are:

1. the scalar timing law may be only a fitting artifact;
2. the effective dimension may not stabilize;
3. the graph Laplacian may not control timing and response together;
4. the external kernel may be null;
5. ordinary thermal or electromagnetic effects may dominate;
6. tensor reconstruction may not follow from scalar closure;
7. the $d_{\text{eff}} \approx 3$ branch may be imposed by model construction rather than selected dynamically.

These are not peripheral concerns. They are the tests.

17. Conclusion: the scalar face of a simultaneous world

The universe may not unfold according to the order in which we explain it.

Clock lag need not happen before gravity. Scalar timing need not be built before geometry. Mass, gauge structure, tensor curvature, and records need not wait in line. They may be co-emergent aspects of a single relational structure.

But observers do not receive that structure whole.

They ask partial questions. They use finite instruments. They extract stable projections. Among those projections, clock timing is unusually primitive: a local system accumulates phase, and phase can be compared.

The claim of scalar timing geometry is therefore not that the clock comes before gravity in time. It is that the clock may reveal the scalar face of co-emergent geometry before richer reconstruction is possible.

A relational universe may be a chord. Gravity may be the full harmony. Clock lag may be the first note our instruments can reliably hear.

The scientific task is to determine whether that note is real.

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