Scalar Selection: A Closure Program for Emergent Timing Geometry

A de novo formulation centered on operator closure, timing observables, and explicit experimental boundaries

Joshua Farrow
Independent Research
April 2026

Abstract

We formulate a research program for systems in which a scalar response field may be the first stable geometric observable to survive coarse graining. The framework begins from an effective weighted graph extracted from a structured medium or substrate and posits a screened weighted-Laplacian closure for a scalar load field, $(\kappa L_w + \mu^2 I)\Lambda = A\rho$. Local clock rates couple to this load through a weak timing law, $\omega_{eff} = \omega/(1 + \alpha\Lambda)$, making timing observables the primary experimental probes. The same operator that governs scalar response also defines an effective dimension through return-probability scaling and shell-profile scaling. The central closure test is that these independent dimension estimators agree within the same scaling window in which the timing law fits best. We distinguish internal scalar loads from external observables through an explicit coupling-kernel map and treat external accessibility as an empirical question rather than a built-in consequence of internal structure. The framework does not assume full emergent gravitation, tensor completion, or universal externalization. Its claim is narrower: a scalar timing sector may arise as a selected observable layer of structured systems, and its validity can be tested by operator closure, dimensional coincidence, medium realizability, and timing-first experimental discriminants.

Program spine

$$H_{micro} \to W \to L_w \to d_{eff} \to G_{d_{eff}}(r) \to \Lambda(r) \to \omega_{eff}$$

This chain is treated here as a hierarchy of effective levels rather than a fully derived identity. The closure problem lives at the effective and observable levels.

1. Introduction

Physical theories are often developed in the opposite order from how observability actually works. One begins with a deep ontology, then asks what a measurement might see. But many systems do not present their full microscopic state to experiment. They present a reduced, stabilized layer: a smaller algebra of observables that survives coarse graining, noise, finite resolution, and dynamical selection. The scientific question addressed here is whether a scalar timing sector can be such a survivor.

The proposal is deliberately narrow. We do not assume that a full metric theory has emerged. We do not assume that every structured medium supports an externally measurable field. We do not assume that a scalar sector, if found, is already gravity. Instead, we ask whether there exists a robust effective regime in which a single graph-based operator simultaneously controls scalar response, effective dimension, and timing observables. This is the minimal closure problem.

The present formulation is motivated by a set of companion notes that separate microscopic, effective, observable, and experimental levels; define a common notation registry; sharpen the timing-first stance; and identify explicit closure tests and kernel ambiguities [15-22]. The task of this paper is to distill that arc into a standalone, restrained program whose claims can fail cleanly.

The thesis is therefore modest: a structured substrate may admit a reduced observable sector in which a scalar load field is the first stable geometric quantity to survive coarse graining, and in which local timing observables provide the primary experimental access to that sector. If this thesis is false, the failure should be sharp: no common scaling window, no operator closure, no stable timing law, no realizable medium, or no external coupling. If it is true, scalar timing geometry becomes a legitimate scientific object in its own right.

2. Scalar Selection as a Coarse-Graining Hypothesis

By scalar selection we mean neither metaphysical preference nor universal scalar ontology. We mean something more operational: among the many microscopic degrees of freedom of a structured system, a scalar response sector may be the first one to survive coarse graining as a stable, reproducible, weakly local observable geometry. This definition treats survival under coarse graining as the criterion of relevance. A variable matters not because it exists microscopically, but because it persists into the observable layer.

This framing is explicitly level-aware. An internal scalar load on graph vertices is not yet an external field at a sensor. A fitted timing response is not yet a microscopic derivation. A successful closure test is not yet a tensor theory. These distinctions are not cosmetic. They are what keep the program from inflating suggestive effective structure into unsupported ontology [15, 16, 22].

The framework is also medium-agnostic by design. Reconfigurable superconducting networks provide one plausible route because they already realize programmable weighted graphs and timing-sensitive internal observables [10-14, 17, 19], but the scalar-selection hypothesis is not logically tied to that medium class alone.

3. Effective Graph Description

Let a structured system, after suitable extraction or coarse graining, be represented by a weighted graph $G = (V, E, w)$, with nonnegative symmetric weights w_{ij}. The weight matrix $W = (w_{ij})$ encodes effective couplings. The degree matrix is $D_{ii} = \Sigma_j w_{ij}$, and the weighted Laplacian is

$$L_w = D - W. \quad (1)$$

This graph is not assumed to be fundamental. It is the retained effective object through which scalar response, diffusion, and timing observables will be described. Its microscopic origin may vary. In different realizations the weights may be extracted from programmable couplings, bond occupations, frustration indicators, dressed interactions, or other medium-specific maps [16, 17]. The closure program does not require the same microscopic route in all cases. It requires that a promoted or effective weighted graph be extractable at all.

The discrete Green-function and heat-kernel literature gives the relevant mathematical backdrop. The graph Laplacian supports both diffusion operators and Green responses; these in turn connect geometry, return probabilities, and long-distance response structure [1-4]. The program proposed here is to use that operator commonality not merely as mathematics, but as a scientific discriminator.

4. Leading Scalar Closure

The leading scalar response is postulated to satisfy

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

where Λ is the retained scalar load, ρ is an effective source, $\kappa > 0$ is a graph-transport or stiffness coefficient, $\mu \geq 0$ is a screening scale, and A sets source amplitude. When time-resolved behavior matters, the minimal dynamical completion is

$$\partial_t \Lambda + \Gamma(\kappa L_w + \mu^2 I)\Lambda = \Gamma A\rho(t). \quad (3)$$

This choice is not justified by familiarity alone. It is selected as the lowest-order closure satisfying five weak-load requirements: linearity in the source for separated weak perturbations, locality on the effective graph, invariance under graph relabelings and symmetries, positivity or ellipticity of the response, and minimal operator order. Equivalently, the static closure is the Euler-Lagrange equation of a quadratic roughness-plus-screening functional [17, 18, 20].

The point is not that every medium must yield exactly this form. The point is that, under weak driving and after a reasonable separation of scales, the leading effective response on a weighted graph should be linear, local, and positive unless the data demand otherwise. Nonlinearities, higher-order graph operators, anisotropies, and memory kernels are therefore corrections to be introduced only if the leading closure fails.

5. Timing as the First Observable Geometry

The operational observable map is

$$\omega_{eff} = \omega / (1 + \alpha\Lambda), \quad \delta\omega/\omega \approx -\alpha\Lambda \text{ for } |\alpha\Lambda| \ll 1. \quad (4)$$

The claim is not that every clock is fundamentally scalar. The claim is narrower: if a scalar load sector survives coarse graining, then local timing observables provide a natural first measurement channel. Timing is often more directly accessible, more differential, and more precise than force-level channels, especially in weak regimes. This is why the companion notes repeatedly emphasize timing-before-force as an experimental grammar rather than a metaphysical slogan [19-21].

Equation (4) should be treated as an effective constitutive relation. Its job is to connect a retained scalar observable to a measurable frequency shift. By itself it neither implies metric completion nor settles whether the scalar sector is internal only or externally accessible.

6. Effective Dimension and the Gaussian Window

The same weighted Laplacian defines a diffusion semigroup $K(t) = e^{-tL_w}$ and mean return probability

$$P_{return}(t) = (1 / |V|) \operatorname{Tr} K(t). \quad (5)$$

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

$$d_{eff}^{(diff)}(t) = -2 \, d \log P_{return}(t) / d \log t. \quad (6)$$

This definition is intrinsic to the promoted graph and requires no preassigned embedding dimension [1, 2]. Independently, for a chosen source or hotspot, define graph shells S_r and shell-averaged scalar load

$$\Lambda_{shell}(r) = (1 / |S_r|) \Sigma_{i \in S_r} \Lambda_i. \quad (7)$$

In a Gaussian scaling regime, the asymptotic profile is expected to behave as

$$\Lambda_{shell}(r) \sim r^{2 - d_{eff}} \ (d_{eff} \neq 2), \text{ or } \Lambda_{shell}(r) \sim \log r \ (d_{eff} = 2). \quad (8)$$

Thus one can define the shell-based estimator $d_{eff}^{(\Lambda)}(r) = 2 - d \log |\Lambda_{shell}(r)| / d \log r$. The key point is this: scalar response and effective dimension are not two separate interpretations layered onto the same graph. They are two observables derived from the same operator. That operator commonality is what makes the framework genuinely testable [16, 20].

The Gaussian window is not assumed once and for all. It is a diagnosis. Recent work on heat kernels on weighted and isoradial graphs makes clear that discrete systems can exhibit Gaussian-like and non-Gaussian regimes depending on scale, geometry, and weighting structure [3, 4]. This is important because the familiar power-law response profile is not guaranteed in arbitrary promoted graphs.

7. The Central Closure Criterion

The decisive test is not whether either the timing law or a dimension estimate works in isolation. It is whether they cohere in the same scaling regime. The core closure criterion is

$$d_{eff}^{(diff)} \approx d_{eff}^{(\Lambda)} \text{ in the same window where Eq. (4) fits best.} \quad (9)$$

A convincing closure window should satisfy all of the following: the diffusion-based dimension is approximately constant over a nontrivial interval; the shell-based dimension agrees with it within uncertainty; the timing-law residual is locally minimized in that same interval; and the result is reasonably stable under changes in graph size, source placement, and extraction threshold. A transient pass through some desired value is not enough. The numerical-closure note is explicit on this point: a crossing through three without plateau behavior, window overlap, or finite-size stability is merely suggestive [16].

This operator-level coincidence is the scientific heart of the program. Everything else is interpretation layered on top of it.

8. On the Special Role of Three

The existing scalar notes place substantial weight on the observation that if a Gaussian scaling regime exists and $d_{eff} \approx 3$, then the Green-response envelope becomes approximately 1/r, matching the familiar weak-field form [15, 18, 20]. Mathematically this is straightforward: $G_d(r) \sim r^{2-d}$, so d = 3 gives the 1/r branch. The point is real, but the wording must remain disciplined.

What is justified is the following conditional statement: if the promoted graph supports a Gaussian scaling window, and if the leading scalar closure holds there, then the scalar load profile inherits the Green-law exponent determined by the same effective dimension, and the 1/r branch occurs at $d_{eff} \approx 3$. What is not yet justified is a strong claim that cosmic three-dimensionality is derived from this mechanism alone. The coincidence makes three a privileged target value for closure tests; it does not, by itself, solve the dimensionality problem.

9. Internal Loads Versus External Observables

One of the most important clarifications in the companion notes is that an internal scalar load Λ_i defined on graph vertices does not by itself imply an externally measurable scalar geometry. An external sensor at position x measures, at best,

$$\Lambda_{ext}(x) = \Sigma_i \, C(x, i) \, \Lambda_i, \quad (10)$$

where C(x, i) is an internal-to-external coupling kernel [22]. The nature of this kernel must be specified, measured, or bounded. The kernel may be near-field or evanescent, substrate-mediated and diffusive, radiative or boundary-modulated, vacuum-like and Green-law external, or effectively null. A null kernel is not a failure of the internal theory. It means only that the scalar load is an internal medium observable rather than an externally accessible geometric one.

This distinction is non-negotiable. It prevents the framework from smuggling in externalization claims that have not been earned. In a truthful paper, internal closure and external accessibility are separate empirical questions.

10. Medium Realizability and the Experimental Path

A scientific program requires at least one plausible medium class in which the effective structure can be instantiated or bounded. Reconfigurable superconducting networks are one such candidate because they already provide programmable graphs, tunable couplers, timing-sensitive internal observables, and realistic transient channels. Modern tunable-coupler architectures achieve high-fidelity control, flexible parametric coupling, and modular multichip connectivity [10-12]. At the same time, cryogenic platforms exhibit nontrivial mechanical and thermal confounds that can imprint correlated errors or transient relaxation tails [13, 14].

That mixed picture is exactly what one would want for a serious first-bound platform: the internal graph is controllable, but the nuisance structure is also rich enough to force severe controls. The microscopic medium-mapping note shows that, in one concrete

circuit-QED-like setting, a local dressed-frequency load can be reduced at leading order to the same screened weighted-Laplacian closure used here [17]. This is not proof that superconducting arrays are the unique or final source medium. It is evidence that at least one real medium class plausibly admits the operator structure required by the scalar-selection program.

A viable medium should support a meaningful weighted-graph extraction, reconfigurable or controllable internal structure, differential timing or phase readout, moderate disorder rather than destructive inhomogeneity, and transient and static channels distinguishable from obvious nuisance signals. The timing-first papers add the practical point that modern clock platforms already resolve extremely small frequency gradients on millimetre scales and now support distributed or interferometric timing architectures that could, in principle, probe scalar timing signatures if a source medium exists [5-9, 19, 21].

11. Failure Modes and Falsifiability

A truthful program is defined as much by its failure modes as by its ambitions. The scalar notes already identify several: heavy-tailed or highly anisotropic weight distributions; bottlenecks or near-tree sparsity that destroy a Gaussian window; small-world shortcuts that create misleading crossover behavior; source-placement dependence masquerading as dimensional coincidence; timing-law improvement in a different window from the dimension plateau; screening so strong that any external signal is exponentially suppressed; memory effects large enough that the Markovian closure is inadequate; external kernels dominated by thermal, substrate, or electromagnetic couplings; an effectively null external kernel; and finite-size artifacts producing false plateaus [16, 17, 19-22].

These are not embarrassments. They are what allow the program to learn. A failure mode narrows scope while increasing truthfulness. If the same promoted operator does not control scalar response, effective dimension, and timing shifts in one common window, then the strongest version of scalar selection fails. If internal closure exists but external kernels are null or mundane, the claim shrinks to an internal medium observable sector. If only the timing law survives, then the dimensional-selection interpretation weakens. In each case the framework remains informative precisely because it is willing to lose pieces of itself.

12. Discussion

The deepest interpretive lesson of the present framework is modest: observable structure may be smaller than microscopic structure, and timing may be among the first stable survivors. That claim is already nontrivial. It neither requires nor supports a rush to full emergent gravitation. It says, instead, that one should look for the first operator-closed observable layer before asking for everything else.

The paper therefore does not presently establish a tensor or spin-2 sector, universal external scalar geometry, a derivation of cosmic three-dimensionality, a unique microscopic substrate, or a new force. What it does establish is a disciplined closure program in which internal scalar loads, external coupling kernels, medium realizability, and timing observables are treated separately and honestly. That restraint is not a weakness. It is what makes the framework scientifically usable.

13. Conclusion

We have formulated a closure program for systems in which a scalar response sector may be the first stable geometric observable to survive coarse graining. The framework rests on four components: an effective weighted graph, a leading screened weighted-Laplacian closure for a scalar load, a timing law coupling that load to local clock rates, and a pair of independent dimension estimators derived from the same operator structure. Its decisive test is not any one of these pieces in isolation, but their coincidence in a common scaling window.

The program is intentionally narrow. It does not assume full metric emergence, tensor completion, or automatic external accessibility. It requires that internal scalar loads, external coupling kernels, medium realizability, and timing observables all be treated separately and honestly. If the same promoted operator controls scalar response, effective dimension, and timing shifts in one real medium class, then a scalar timing geometry will have ceased to be a suggestive metaphor and become a real observable sector. If not, the theory will have constrained itself. Either result would be progress.

References

[1] R. Burioni and D. Cassi, 'Universal Properties of Spectral Dimension,' Physical Review Letters 76(7), 1091-1093 (1996). DOI: 10.1103/PhysRevLett.76.1091.

[2] G. Calcagni, D. Oriti, and J. Thürigen, 'Spectral Dimension of Quantum Geometries,' Journal of Physics A: Mathematical and Theoretical 47, 355402 (2014).

[3] F. Chung and S.-T. Yau, 'Discrete Green's Functions,' Journal of Combinatorial Theory, Series A 91(1-2), 191-214 (2000).

[4] S. Schwarz, A. Sturm, and M. Wardetzky, 'Heat Kernel Asymptotics for Scaling Limits of Isoradial Graphs,' Potential Analysis 63, 57-76 (2025). DOI: 10.1007/s11118-024-10161-5.

[5] T. Bothwell, C. Kennedy, A. Aeppli, D. Kedar, J. Robinson, E. Oelker, A. Staron, and J. Ye, 'Resolving the Gravitational Redshift across a Millimetre-Scale Atomic Sample,' Nature 602, 420-424 (2022). DOI: 10.1038/s41586-021-04349-7.

[6] J. Liu, Y. Xu, H. Luo, L. Cao, M. Zhou, X. Duan, and Z. Hu, 'Test of the Gravitational Redshift with Single-Photon-Based Atomic Clock Interferometers,' Quantum Frontiers 3, 2 (2024). DOI: 10.1007/s44214-024-00049-1.

[7] I. Meltzer and Y. Sagi, 'Atomic Clock Interferometry Using Optical Tweezers,' Physical Review A 110, 032602 (2024). DOI: 10.1103/PhysRevA.110.032602.

[8] D. Yu, J. Zhang, S. Zhang, T. Shi, and J. Chen, 'Resolving Gravitational Redshift with Sub-Millimeter Height Differences Using Spin-Squeezed Optical Clocks,' Chinese Physics B 34, 054208 (2025). DOI: 10.1088/1674-1056/adca1d.

[9] M. Filzinger, A. R. Caddell, D. Jani, M. Steinel, L. Giani, N. Huntemann, and B. M. Roberts, 'Ultralight Dark Matter Search with Space-Time Separated Atomic Clocks and Cavities,' Physical Review Letters 134, 031001 (2025). DOI: 10.1103/PhysRevLett.134.031001.

[10] J. Stehlik, D. M. Zajac, D. L. Underwood, T. Phung, J. Blair, S. Carnevale, D. Klaus, G. A. Keefe, A. Carniol, M. Kumph, M. Steffen, and O. E. Dial, 'Tunable Coupling Architecture for Fixed-Frequency Transmon Superconducting Qubits,' Physical Review Letters 127, 080505 (2021). DOI: 10.1103/PhysRevLett.127.080505.

[11] X. Jin, Z. Parrott, S. Kotler, K. Cicak, F. Lecocq, J. Teufel, J. Aumentado, and R. Simmonds, 'Versatile Parametric Coupling Between Two Statically Decoupled Transmon Qubits,' Physical Review Applied 19, 064043 (2023).

[12] M. Field et al., 'Modular Superconducting-Qubit Architecture with a Multichip Tunable Coupler,' Physical Review Applied 21, 054063 (2024). DOI: 10.1103/PhysRevApplied.21.054063.

[13] S. Kono et al., 'Mechanically Induced Correlated Errors on Superconducting Qubits with Relaxation Times Exceeding 0.4 ms,' Nature Communications 15, 4500 (2024). DOI: 10.1038/s41467-024-48230-3.

[14] M. A. Aamir et al., 'Thermally Driven Quantum Refrigerator Autonomously Resets a Superconducting Qubit,' Nature Physics 21, 318-323 (2025). DOI: 10.1038/s41567-024-02708-5.

[15] J. Farrow, 'Unified Notation and Claim Registry for the Scalar-Selection Program,' note (2026).

[16] J. Farrow, 'Numerical Closure Tests for Scalar Projection and Dimensional Selection,' note (2026).

[17] J. Farrow, 'From Coupler Physics to Scalar Geometry: A Microscopic Route to the QATNU Closure,' note (2026).

[18] J. Farrow, 'Selection, Projection, and Scalar Emergent Geometry: Toward a Physics of Surviving Observable Worlds,' note (2026).

[19] J. Farrow, 'A First Experimental Bound on Timing-First Scalar Couplings from Reconfigurable Superconducting Arrays,' note (2026).

[20] J. Farrow, 'Scalar Projection and Dimensional Selection in QATNU/SRQID,' note (2026).

[21] J. Farrow, 'Timing Before Force: A Quantitative Experimental Program for Scalar-First Geometry,' note (2026).

[22] J. Farrow, 'External Coupling Kernels for Internal Scalar Loads,' note (2026).