DATED HISTORY

The Mercury Rung: From Scalar Timing Closure to an Autonomous Spin-2 Test of QATNU

May transition from scalar timing to a proposed spin-2 test. The scalar closure test and the spin-2 search both have later outcome records.

Manuscript · p. 1, test formulation

A Test Protocol for Scalar Timing Closure and Dimensional Selection

Evidence · Negative QATNU spin-2 search / Scalar source/window residual audit

The Mercury Rung

From Scalar Timing Closure to an Autonomous Spin-2 Test of QATNU

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Independent Research
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Abstract

This paper consolidates the scalar timing, scalar-selection, co-emergent geometry, and SRQID/QATNU threads into a single falsifiable research target. The result is intentionally narrower than earlier framings. Scalar timing is a legitimate clock-readable projection: a scalar load Λ may renormalize local clock rates through $\omega_{\text{eff}} = \omega/(1+\alpha\Lambda)$, and weighted graph operators can organize scalar response, diffusion, and timing observables. But scalar timing alone is holonomy-free. It cannot supply gauge circulation, gravitomagnetism, tensor gravity, or helicity-2 propagation. The connection and transverse-traceless layers reached in the previous work are best understood as a correct clock-flavored on-ramp to known weak-field general relativity, not as new gravitational physics.

The strongest scalar-dimensional bet in the program - the closure $d_{\text{eff}}^{(\text{diff})} \approx d_{\text{eff}}^{(\Lambda)} \approx 3$ in the same window where the timing law fits - has, in the latest severe scalar closure run, failed rather than closed: the reported values $d_{\text{eff}}^{(\text{diff})} \approx 2.96$ and $d_{\text{eff}}^{(\Lambda)} \approx 1.97$ do not coincide. This is not an embarrassment. It is the first genuinely scientific narrowing of the program. What remains open is sharper: can a concrete substrate, with QATNU as the candidate, dynamically generate a massless helicity-2 sector with its own equations of motion and sources, rather than having the tensor sector projected in by hand?

We call this the Mercury rung. Einstein's successful 1915 move was not the invention of a beautiful language alone; it was the derivation of a number - Mercury's anomalous perihelion precession - from a theory that did not simply insert the answer. The analogous target here is not another reinterpretation of scalar timing or another reconstruction of textbook linearized GR. It is an autonomous substrate derivation: two gapless transverse-traceless helicity modes, a Pauli-Fierz-like kinetic structure, a $1/k^2$ long-distance propagator, universal coupling to a conserved source, and a nontrivial output not already coded into the observable map. If this rung succeeds, the program becomes physics in the strong sense. If it fails, the boundary is clean: scalar timing remains a useful projection and possible medium-response program, but not a discovery of gravity.

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1 The question this paper answers

The previous sequence began with an intuition that clocks might reveal a deeper order than geometry. It then moved through scalar timing, graph Laplacian closure, effective dimension, external coupling kernels, co-emergent geometry, and finally a weak-field ladder through connection variables and transverse-traceless tensor language. Each stage improved the epistemic hygiene of the program. Each also narrowed the claim.

This paper names the narrowed claim and stops the drift.

The central conclusion is not that the program has discovered gravity. It has not. The central conclusion is that the program has finally isolated the only remaining step that could make such a discovery possible:

> *A concrete microscopic substrate must generate a spin-2 gravitational sector with its own dynamics and sources, without that spin-2 sector being inserted through the observable map.*

Everything below that rung is either settled, null, or textbook. The scalar timing law is a coherent clock-readable projection. The graph-Laplacian closure is a legitimate effective response ansatz and, in fast-coupler models, can be produced by Schur reduction. The scalar-dimensional selection test is severe and meaningful. But the latest scalar closure run failed its strongest coincidence criterion. The weak-field connection and TT layers are mathematically correct, but they reproduce known pieces of linearized general relativity once those structures are supplied.

The paper therefore has a deliberately severe posture. It is written to prevent two opposite mistakes. The first mistake is inflation: calling a scalar timing projection "gravity" because the first-order redshift envelope looks familiar. The second mistake is collapse: discarding the whole program because scalar timing is not already a tensor theory. The correct position is between them. Scalar timing is not gravity. It may be the lowest-readability projection of a richer substrate. But whether the richer substrate exists is now a concrete, testable question.

2 The claim hierarchy

The current program should be read as a hierarchy of claims, not as a single all-or-nothing assertion. Table 1 gives the status of the major claims after the latest narrowing.

Table 1: Present claim hierarchy. The strongest surviving claim is not "scalar timing is gravity," but "QATNU may be a candidate substrate from which tensor gravity must now be derived or abandoned."

Claim	**Meaning**	**Current status**
Scalar timing projection	A scalar load can be read by local clocks through $\omega_{\text{eff}} = \omega/(1+\alpha\Lambda)$.	Coherent effective layer

Claim	Meaning	Current status
Graph scalar closure	A promoted weighted graph can support $(\kappa L_w + \mu^2 I)\Lambda = A\rho$.	Valid ansatz; derivable in fast-coupler limits
Dimensional closure	$d_{\text{eff}}^{(\text{diff})}$, $d_{\text{eff}}^{(\Lambda)}$, and timing residuals close in one window near 3.	Failed in latest severe scalar run
External scalar geometry	Internal load Λ_i couples to an outside probe through a non-null kernel $C(x, i)$.	Open; may be null
Connection layer	Oriented edge or loop degrees can encode holonomy-like structure.	Standard gauge-like mathematics once supplied
Tensor reconstruction	A metric perturbation $h_{\mu\nu}$ can be decomposed into scalar, vector, and tensor parts.	Textbook linearized GR once supplied
Autonomous spin-2 emergence	A microscopic substrate generates massless helicity-2 modes and their dynamics without projection by hand.	The decisive open rung
New gravitational physics	The substrate produces a number, anomaly, or regime not already explained by GR.	Not yet achieved

The purpose of this paper is to make the last two rows unavoidable. The program should no longer gain energy from adding interpretive layers below them. It should either attempt the autonomous spin-2 derivation or stop claiming progress toward gravity.

3 The Mercury criterion

The Einstein analogy is useful only if it is made uncomfortable. The flattering version says: a lone theorist can spend years circling an idea that later becomes a revolution. The accurate version says: the successful Einstein was not merely circling. From 1907 to 1915 he was pulled by a problem with a known shape. Gravity had to be made consistent with special relativity. The theory had to recover Newtonian gravity in the weak-field limit. Mercury's anomalous perihelion precession, known since the nineteenth century, stood as a concrete empirical target. When the field equations yielded the missing precession without simply fitting it in, the theory crossed a boundary.

A later Einstein spent decades on unified field theory without a comparable empirical anchor. The difference was not genius. It was constraint. A theory with a refusing target is in a different epistemic category from a theory sustained only by coherence and beauty.

This gives the methodological rule for the present program.

Criterion 1 (The Mercury criterion)**.** *A proposed substrate theory becomes discovery-grade only when it derives a structure, number, constraint, or anomaly that was not inserted into the substrate definition, observable map, fitting protocol, or comparison target.*

For QATNU, the immediate Mercury is not an astronomical anomaly. It is internal and structural:

Does the substrate generate a massless helicity-2 sector with the right dynamics, constraints, and sources, without putting that sector in by hand?

This is the right first Mercury because general relativity already explains the gravitational phenomena reached by the scalar and weak-field ladder. A new theory cannot count as new physics merely by rewriting GR in a clock-readable language. The first thing it must do is show that the clock-readable substrate can generate the part of GR that scalar timing cannot: the tensor sector.

4 The scalar sector: what is real and what is not enough

The scalar timing sector is not meaningless. It is the cleanest part of the program. Let Λ_i be a retained scalar load at vertex or locus i. The minimal clock law is

$$\omega_{\mathrm{eff}}(i) = \frac{\omega}{1+\alpha\Lambda_i}, \qquad \frac{\delta\omega_i}{\omega} \approx -\alpha\Lambda_i \quad (|\alpha\Lambda_i| \ll 1). \tag{1}$$

For a clock accumulating phase,

$$\phi_i(T) = \int_0^T \omega_{\mathrm{eff}}(i,t)\,dt, \tag{2}$$

and the differential observable between clocks A and B is, in the weak-load regime,

$$\Delta\phi_{AB}(T) \approx -\alpha\omega \int_0^T \big[\Lambda_A(t) - \Lambda_B(t)\big]dt. \tag{3}$$

This is a genuine observable grammar. It says that a local oscillator can read a reduced scalar projection of a larger relational state. It is also experimentally natural, because phase and frequency can often be measured more sensitively than force.

The scalar load can be paired with a weighted graph closure. With weighted adjacency $W = (w_{ij})$, degree matrix $D_{ii} = \sum_j w_{ij}$, and Laplacian $L_w = D - W$, the leading static response is

$$(\kappa L_w + \mu^2 I)\Lambda = A\rho. \tag{4}$$

The corresponding minimal dynamical completion is

$$\partial_t\Lambda + \Gamma(\kappa L_w + \mu^2 I)\Lambda = \Gamma A\rho(t). \tag{5}$$

The same operator can also define diffusion,

$$K(t) = e^{-tL_w}, \qquad P_{\mathrm{return}}(t) = \frac{1}{|V|}\mathrm{Tr}\,K(t), \tag{6}$$

and a diffusion-based effective dimension,

$$d_{\mathrm{eff}}^{(\mathrm{diff})}(t) = -2\frac{d\log P_{\mathrm{return}}(t)}{d\log t}. \tag{7}$$

Independently, a source-centered shell profile defines

$$\Lambda_{\mathrm{shell}}(r) = \frac{1}{|S_r|} \sum_{i \in S_r} \Lambda_i, \qquad d_{\mathrm{eff}}^{(\Lambda)}(r) = 2 - \frac{d \log |\Lambda_{\mathrm{shell}}(r)|}{d \log r}. \tag{8}$$

The strongest scalar-selection test is that these estimates agree near 3 in the same scaling window where the timing law fits best.

This is a good test. It is also exactly where the scalar program was forced to become honest.

5 The scalar closure failure and why it matters

The severe scalar closure run did not close the program. The reported result was approximately

$$d_{\mathrm{eff}}^{(\mathrm{diff})} \approx 2.96, \qquad d_{\mathrm{eff}}^{(\Lambda)} \approx 1.97, \tag{9}$$

with the scalar closure rows marked as failed. The diffusion estimator passed near 3. The shell-profile estimator did not follow it. The two independent routes did not agree in the same window.

That failure matters because the closure criterion was designed to be hard to fool. A scalar law fitting a clock is not enough. A dimension estimator passing through 3 is not enough. A plausible radial analogy is not enough. The program asked whether a single promoted operator controlled diffusion dimension, scalar Green response, and timing residuals in one common regime. The answer, in that run, was no.

This narrows the theory in a productive way. The scalar layer remains a possible effective observable sector. It may still describe internal timing loads in reconfigurable media. It may still be useful as a language for clock-readable projections. But the specific stronger claim - that scalar timing closes as a Newton-like three-dimensional geometry - is not currently supported.

The right lesson is not to add another interpretive rung below the failure. The right lesson is to move to the only remaining rung that could change the category of the program: autonomous spin-2 emergence.

6 Why scalar timing is holonomy-free

The simplest mathematical obstruction is exactness. A scalar timing potential is a 0-form. Its edge differences form an exact 1-form. Exact 1-forms have zero circulation around closed loops.

Theorem 1 (Scalar timing has no holonomy)**.** *Let θ_i be a scalar clock phase or timing potential defined on graph vertices. Define the edge timing difference on oriented edge $i \to j$ by*

$$a_{ij} = \theta_j - \theta_i. \tag{10}$$

For any closed loop $C = (i_0, i_1, \ldots, i_n = i_0)$,

$$\sum_{(i_k, i_{k+1}) \in C} a_{i_k i_{k+1}} = 0. \tag{11}$$

Proof. The loop sum telescopes:

$$\sum_{k=0}^{n-1}(\theta_{i_{k+1}} - \theta_{i_k}) = \theta_{i_n} - \theta_{i_0} = 0. \tag{12}$$

Equivalently, in discrete differential-form language, $a = d\theta$ and $d^2 = 0$. □

The theorem is simple, but its implication is decisive. Scalar timing can describe local clock-rate shifts and gradients of scalar load. It cannot by itself describe loop circulation, gauge curvature, gravitomagnetic holonomy, frame dragging, or spin-2 gravitational radiation. Those require additional structure: oriented edge variables, phases around loops, tensorial strain-like variables, or constraints that remove unphysical modes.

This is why the slogan "clock before gravity" had to be corrected. The clock is not physically earlier than gravity. It is the scalar face of a richer co-emergent structure, if such a structure exists. Scalar timing is the easiest piece to read, not the whole object being read.

7 The textbook ladder

The previous work climbed a ladder:

$$\Lambda \to A_\mu \to F_{\mu\nu} \to h_{\mu\nu} \to h_{ij}^{\mathrm{TT}}. \tag{13}$$

As a pedagogical path, this ladder is useful. As a discovery claim, it is dangerous unless every arrow is generated by the substrate. The individual rungs are well known.

A scalar gives no holonomy unless one adds a connection-like object. A connection yields curvature through exterior differentiation, but gauge curvature is not yet gravity. In the weak-field limit of general relativity, gravitomagnetic components live in the off-diagonal metric sector g_{0i}, and frame dragging is an established prediction and measurement target. The scalar-vector-tensor decomposition of a metric perturbation is standard linearized gravity. The transverse-traceless part h_{ij}^{TT} carries the two radiative helicities of a massless spin-2 field in four-dimensional spacetime.

Thus, verifying that a supplied metric perturbation has a TT sector is not a discovery of emergent gravity. It is a check that one has implemented textbook linearized GR correctly. A code that projects a tensor field into TT form is not showing that the tensor field emerged. It is showing that the projection works.

The distinction is the whole paper:

> *Projection is not emergence. A TT projector can find spin-2 content only after a tensorial object has already been provided. The question is whether QATNU provides that object dynamically.*

8 QATNU as the candidate substrate

The concrete substrate candidate is SRQID/QATNU: a local, unitary, measurement-free quantum cellular automaton or Hamiltonian system in which matter qubits live on vertices and bond registers live on edges. A representative Hilbert space is

$$\mathcal{H} = \bigotimes_{i \in V} \mathcal{H}_i^{\mathrm{mat}} \otimes \bigotimes_{\langle i,j \rangle \in E} \mathcal{H}_{ij}^{\mathrm{bond}}. \tag{14}$$

A minimal Hamiltonian can be written schematically as

$$H = H_{\mathrm{mat}} + H_{\mathrm{bond}} + H_{\mathrm{int}}, \tag{15}$$

with

$$H_{\mathrm{mat}} = \frac{\omega}{2} \sum_i X_i, \tag{16}$$

$$H_{\mathrm{int}} = \lambda \sum_{\langle i,j \rangle} F_{ij} \otimes (R_{ij} + R_{ij}^{\dagger}), \qquad F_{ij} = \frac{1}{2}(I - Z_i Z_j). \tag{17}$$

Here F_{ij} is a local frustration tile and R_{ij} promotes the edge bond register. Because the Hamiltonian is local and bounded on a finite-degree graph, the model has a Lieb-Robinson causal structure and unitary evolution. This makes it a legitimate testbed rather than a nonlinear measurement story.

The existing QATNU numerics support a limited but interesting result: the local bond occupation can define an entanglement proxy Λ_i, and small-system clock frequencies are reasonably approximated by

$$\frac{\omega_{\mathrm{eff}}^{(i)}}{\omega} \approx \frac{1}{1 + \alpha \Lambda_i}. \tag{18}$$

The previous paper reported residuals of order 10-15 percent in favorable small-N regimes and emphasized that the relation is not an exact universal identity. That is the correct level of claim.

QATNU has therefore reached the following status:

1. It is a concrete local unitary substrate candidate.
2. It has an internal scalar timing observable.
3. It has small-system evidence for clock slowdown as an effective constitutive relation.
4. It does not yet generate a convincing long-wavelength spin-2 sector.

That fourth point is decisive. A substrate testbed for emergent gravity is not yet an emergent-gravity theory.

9 What autonomous spin-2 emergence would mean

A massless spin-2 sector is not just a pattern that looks vaguely tensorial. It is a constrained dynamical structure. In continuum weak-field language, one begins with a symmetric perturbation

$h_{\mu\nu}$ around a background metric and obtains, after gauge constraints, two physical radiative polarizations. In momentum space, for a spatial wave vector $\mathbf{k}$, the transverse projector is

$$P^T_{ij} = \delta_{ij} - \hat{k}_i \hat{k}_j, \tag{19}$$

and the transverse-traceless projector is

$$P^{\mathrm{TT}}_{ij,kl} = \frac{1}{2}(P^T_{ik}P^T_{jl} + P^T_{il}P^T_{jk} - P^T_{ij}P^T_{kl}). \tag{20}$$

A supplied tensor can always be projected:

$$h^{\mathrm{TT}}_{ij}(\mathbf{k}) = P^{\mathrm{TT}}_{ij,kl}(\hat{\mathbf{k}})h_{kl}(\mathbf{k}). \tag{21}$$

The substrate problem is harder. The substrate must generate an observable H_{ij} whose long-wavelength connected correlator has a TT pole or mode structure without the TT content being inserted by the analyst.

A discovery-grade target can be stated as follows.

Criterion 2 (Autonomous spin-2 emergence)**.** *A substrate model passes the spin-2 rung only if there exists a pre-registered coarse-grained observable $H_{ij}(x,t)$, constructed from microscopic variables without using the GR answer, such that its long-wavelength dynamics contains exactly two gapless transverse-traceless helicity modes, with scalar and vector leakage suppressed by constraints or dynamics, and with a propagator of the form*

$$C^{\mathrm{TT}}_{ij,kl}(\mathbf{k},\omega) \sim \frac{Z\, P^{\mathrm{TT}}_{ij,kl}(\hat{\mathbf{k}})}{\omega^2 - c_g^2|\mathbf{k}|^2 + i0} \tag{22}$$

up to controlled irrelevant corrections.

This criterion has several parts. Each is needed.

1. **Pre-registered observable.** The tensor-like observable must be defined before looking for the desired spectrum.
2. **No tensor injection.** The construction cannot simply assign a metric tensor to the substrate and then rediscover the metric.
3. **Two helicities.** Under rotations about $\mathbf{k}$, the two physical modes must transform with phases $e^{\pm 2i\psi}$.
4. **Gaplessness.** The low-energy mode must have $\omega \to 0$ as $|\mathbf{k}| \to 0$, not a hidden mass gap.
5. **Transverse-traceless dominance.** Scalar and vector components must be absent, constrained, or parametrically suppressed in the infrared.
6. **Correct kinetic structure.** The low-energy effective action must reduce to Pauli-Fierz or an equivalent constrained spin-2 dynamics.
7. **Source coupling.** The mode must couple to a conserved stress-like source in a way that produces a Newtonian limit or a controlled alternative.

10 The Pauli-Fierz target

At the linearized level, the standard free massless spin-2 target is the Pauli-Fierz structure. One common form of the quadratic Lagrangian density is

$$\mathcal{L}_{\rm PF} = -\frac{1}{2}\partial_\lambda h_{\mu\nu}\partial^\lambda h^{\mu\nu} + \partial_\mu h^{\mu\nu}\partial^\lambda h_{\lambda\nu} - \partial_\mu h^{\mu\nu}\partial_\nu h + \frac{1}{2}\partial_\lambda h\partial^\lambda h, \tag{23}$$

where $h = h^\mu{}_\mu$. This action is invariant under the linearized gauge transformation

$$h_{\mu\nu} \to h_{\mu\nu} + \partial_\mu \xi_\nu + \partial_\nu \xi_\mu, \tag{24}$$

which removes unphysical components and leaves two propagating helicities in $3+1$ dimensions.

QATNU does not have to reproduce this expression symbol by symbol at the microscopic scale. But if it is to claim emergent gravity, its infrared effective theory must land in this universality class or explain, with equal predictive power, why a different constrained spin-2 structure replaces it.

This gives the derivational target:

$$H_{\rm micro} \quad \Longrightarrow \quad \mathcal{L}_{\rm eff}[H_{ij}] = \mathcal{L}_{\rm PF}[h_{\mu\nu}] + \mathcal{O}(k^4, k^2\omega^2, \omega^4, \text{lattice anisotropy}). \tag{25}$$

The arrow is not a metaphor. It means coarse graining, integrating out fast variables, identifying the correct collective observable, deriving its two-point function, and showing that the unwanted scalar and vector sectors do not propagate as independent gravitational degrees of freedom.

11 Where QATNU might get a tensor from

The current scalar observable Λ_i is one number per vertex. A tensor sector needs more. A plausible route is to stop treating bond registers only as scalar depth counters and instead treat local bond configurations as a discrete strain field. At a coarse-grained point x, define a symmetric second-moment observable from incident edges:

$$H_{ab}(x) = \sum_{e\ni x} q_e\, \ell_e^a \ell_e^b - \frac{1}{d}\delta_{ab}\sum_{e\ni x} q_e |\ell_e|^2. \tag{26}$$

Here ℓ_e is the local edge direction in an emergent embedding or spectral coordinate chart, and q_e is a bond-state observable such as occupation, promotion imbalance, or dressed coupling. This is only a candidate. It already reveals the difficulty: if the embedding or spectral coordinates already assume the answer, the construction is contaminated. If the edge directions are derived from the substrate's own low-energy modes, the construction may be legitimate.

A second route is spectral rather than geometric. Let the substrate Laplacian or transfer operator define low-energy scalar eigenmodes φ_n. Tensor candidates can be constructed from bilinears such as

$$H_{ab}^{(mn)} \sim \nabla_a\varphi_m \nabla_b\varphi_n - \frac{1}{d}\delta_{ab}\nabla_c\varphi_m\nabla^c\varphi_n. \tag{27}$$

Again, the risk is projection by hand. Bilinears can always be made. The question is whether their

dynamics contains autonomous spin-2 modes rather than arbitrary composites.

A third route is constraint-based. The substrate may not first generate a visible tensor field. It may generate redundancy or a conservation law whose low-energy excitations are forced into a spin-2 universality class. This would be stronger than inventing a tensor observable after the fact, but it is also harder: one would need to derive the constraint algebra or its discrete equivalent.

All three routes are allowed. None is yet a result.

12 The spin-2 numerical protocol

A credible attempt should be pre-registered. The following protocol is designed to prevent the program from discovering what it inserted.

Phase 0: Freeze the observable map

Before running the spin-2 analysis, specify:

1. the microscopic substrate family;
2. the Hilbert space and Hamiltonian or update rule;
3. the coarse-grained tensor candidate H_{ij};
4. the source perturbations to be applied;
5. the fitting windows;
6. the pass/fail thresholds;
7. all null controls.

No post-hoc change of H_{ij} should count as evidence. Post-hoc changes are allowed only as new hypotheses for a new run.

Phase 1: Substrate preconditions

The substrate must support extended low-energy modes. A graph that localizes all low-energy excitations cannot be a smooth emergent space. The basic preconditions are:

1. low eigenmodes extend across the substrate rather than localize;
2. the scalar dispersion satisfies $\lambda(k) \sim |k|^2$ at low k;
3. angular anisotropy decreases with system size;
4. the effective light cone or Lieb-Robinson cone is compatible with a stable low-energy propagation speed.

These are not the spin-2 test. They are the test that the substrate is worth testing.

Phase 2: Correlator decomposition

Compute the connected tensor correlator

$$C_{ij,kl}(x,t) = \langle H_{ij}(x,t) H_{kl}(0,0) \rangle_c. \tag{28}$$

Transform to $(\mathbf{k}, \omega)$, then decompose into scalar, vector, and TT channels. The TT spectral weight should show a stable low-energy pole or peak with dispersion

$$\omega^2 \approx c_g^2 |\mathbf{k}|^2. \tag{29}$$

The scalar and vector channels should not contain competing gapless gravitational modes unless the theory is explicitly not GR-like and makes new predictions.

Phase 3: Helicity verification

For a mode propagating along $\mathbf{k}$, rotate the transverse basis by angle ψ. The physical polarizations should transform as

$$h_+ \pm i h_\times \to e^{\pm 2i\psi}(h_+ \pm i h_\times). \tag{30}$$

This is the actual spin-2 signature. A scalar field cannot pass it. A vector field cannot pass it. A hand-projected tensor can pass it trivially, which is why the observable map must be fixed before the projection.

Phase 4: Source response

Introduce a localized conserved source-like perturbation $T^{\text{eff}}_{\mu\nu}$, or the closest substrate-native analogue. Measure the static response. A GR-like branch should produce a long-distance response whose leading potential is $1/r$ in an effectively three-dimensional spatial regime:

$$V(r) \sim -\frac{G_{\text{eff}} M}{r}. \tag{31}$$

The coefficient G_{eff} should not be independently inserted into both the source definition and the response fit. It may be calibrated once, but then it must predict other source configurations.

Phase 5: Robustness and null controls

Run controls:

1. frozen-bond control;
2. randomized phase control;
3. scalar-only observable control;
4. hand-projected TT positive control;

5. topology-preserving but weight-randomized control;
6. finite-size scaling across substrate sizes;
7. source-shape variation after calibration.

A real spin-2 sector should survive the controls that preserve the relevant substrate dynamics and fail in controls that destroy it.

Table 2: Spin-2 pass/fail table.

Test	**Pass condition**	**Failure meaning**
Pre-registered tensor observable	H_{ij} fixed before spectral search	Post-hoc projection risk
Low-energy extended modes	Mode localization length grows with system size	No smooth infrared substrate
TT spectral pole	TT correlator has $\omega^2 \approx c_g^2 k^2$	No massless tensor dynamics
Two helicities	Polarizations transform as $e^{\pm 2i\psi}$	Not spin-2
Scalar/vector suppression	Non-TT gravitational channels absent or gapped	Extra fields or wrong constraints
Source response	One calibration predicts multiple source shapes	Fitted analogy only
Finite-size scaling	Residual anisotropy and leakage decrease with size	Lattice artifact
Null controls	Signal disappears when substrate mechanism is disabled	Environmental or projection artifact

13 What would count as an output number?

The most dangerous failure mode is to reproduce a known equation after inserting every ingredient needed to reproduce it. The program needs outputs. Candidate output quantities include:

1. the number of propagating helicities;
2. the low-k power of the TT correlator;
3. the emergent propagation speed c_g relative to scalar or matter excitations;
4. the ratio of scalar leakage to TT spectral weight as a function of system size;
5. the effective Newton coupling after one calibration, used to predict multiple source responses;
6. the finite-size scaling exponent of anisotropy;
7. a residual Lorentz-violating coefficient predicted from microscopic parameters rather than fit after the fact.

The analog of Mercury does not have to be Mercury. It can be an internal number from the substrate that the substrate had no freedom to fake. But it must be something that could have come out wrong.

14 Internal loads versus external observables

The scalar-selection program correctly separated internal load from external measurement. If Λ_i is an internal scalar load, an external probe measures at most

$$\Lambda_{\text{ext}}(x) = \sum_i C(x,i)\Lambda_i. \tag{32}$$

The kernel $C(x,i)$ may be near-field, substrate-mediated, radiative, vacuum-like, or null. A null kernel is a legitimate outcome: the internal scalar sector may exist in the medium while producing no external spacetime-like signal.

The same discipline must now be applied to tensor emergence. An internal tensor-like correlator is not yet external gravity. After an internal spin-2 sector is found, a second question appears:

$$H_{ij}^{\text{internal}} \xrightarrow{K_{ij,\mu\nu}(x,i)} h_{\mu\nu}^{\text{external}}(x). \tag{33}$$

The external tensor kernel may also be mundane, screened, radiative, or null. The program should not smuggle external spacetime geometry through language. It should measure or bound the kernel.

This makes the full path:

$$H_{\text{micro}} \to \text{internal scalar/tensor sectors} \tag{34}$$
$$\to \text{internal dynamics} \tag{35}$$
$$\to \text{external coupling kernel} \tag{36}$$
$$\to \text{observable timing/force/radiation response.} \tag{37}$$

Every arrow is a possible failure point.

15 Why the scalar work was still worth doing

The scalar work did not discover gravity, but it achieved four important things.

First, it forced level discipline. It separated microscopic variables, effective graph operators, scalar loads, timing observables, and external kernels. This prevents the central category error of many speculative programs: treating an internal fitted variable as an external field.

Second, it produced failure with shape. The scalar closure criterion was not a vague hope. It specified two independent dimension estimators and a timing residual window. The latest run did not satisfy that criterion. That is scientific progress because it removes a tempting false summit.

Third, it clarified the readability hierarchy. Scalar timing is the smallest world a clock can read. Gauge circulation requires loops and orientation. Tensor gravity requires rods, clocks, free-fall

behavior, universal coupling, Lorentz-compatible propagation, stress-energy response, and spin-2 constraints.

Fourth, it gave QATNU a concrete role. QATNU is not confirmed. It is not a theory of gravity. But it is specific enough to be tested. A local, unitary, bounded, measurement-free substrate is exactly the kind of object on which an autonomous spin-2 derivation can be attempted.

16 What the next paper should not do

The next paper should not rebrand scalar timing as gravity. It should not add another philosophical layer to the scalar projection. It should not present a TT decomposition of a supplied tensor as emergent spin-2. It should not use a stochastic toy model with a built-in $1/k^2$ tail as evidence for the full Hamiltonian. It should not fit a metric after the fact and call the fit derivation.

The next paper should do one of two things:

1. Derive the spin-2 sector from QATNU or a clearly specified replacement substrate.
2. Fail to derive it and state exactly why.

Either result is valuable. The only bad outcome is indefinite motion around the decisive rung.

17 A proposed title and abstract for the next technical work

A focused successor paper could be titled:

> **Autonomous Spin-2 Emergence in a Quantum Automaton Tensor-Network Substrate: A Pre-Registered Numerical Test**

Its abstract should not promise gravity. It should promise a test:

> We define a pre-registered tensor observable on a local unitary QATNU substrate and test whether its long-wavelength connected correlators contain a gapless transverse-traceless spin-2 sector. The protocol distinguishes autonomous emergence from TT projection by fixing the observable map before spectral analysis, decomposing scalar/vector/tensor channels, verifying helicity under transverse rotations, testing source response after one calibration, and running null controls that remove bond promotion or phase coherence. A pass would establish the first non-scalar gravitational sector generated by the substrate. A fail would bound QATNU as a scalar timing and medium-response model rather than an emergent gravity theory.

That is the right unit of work. It is smaller than a theory of everything and harder than another reinterpretation.

18 Possible outcomes

The program now has a clean outcome map.

Table 3: Outcome map for the Mercury rung.

Outcome	**Interpretation**
No tensor observable can be defined without importing geometry	QATNU remains scalar/graph-response physics, not emergent gravity.
Tensor observable exists but only scalar/vector modes propagate	The substrate has richer internal structure but not GR-like spin-2 gravity.
TT-looking modes appear only after TT projection of supplied tensors	Pedagogical reconstruction of linearized GR, not emergence.
Two gapless helicities emerge but source coupling fails	Interesting tensor quasiparticles, not gravity.
Spin-2 dynamics and source response pass internally, external kernel null	Internal emergent-gravity analogue; no claim about real spacetime externalization.
Spin-2 dynamics, source response, and external coupling pass	Discovery-grade candidate requiring independent replication and empirical anchoring.
A new quantitative anomaly or number is predicted and later observed	The program crosses from candidate substrate to new physics.

19 Discussion: science versus pseudoscience

The distinction between science and pseudoscience is not ambition. It is not whether an idea sounds strange. It is what the idea does when a test cuts against it.

The scalar-dimensional closure failed. The scientifically correct response is to narrow the claim. That has now happened. The program no longer needs to defend scalar timing as if scalar timing alone could carry gravity. It cannot. It no longer needs to pretend that reproducing weak-field GR structures is new physics. It is not. The program's scientific status now rests on whether it will attempt the one test that can refuse it.

This is why the Mercury comparison matters. The early Einstein had a target that could say no. The late Einstein often did not. QATNU must now choose which pattern to follow. The choice is not psychological. It is procedural. Does the next step produce an output not already inserted? Does it face a pass/fail criterion? Does it allow the possibility that the program is only a useful scalar timing model?

If yes, the work is scientific even if it fails. If no, the work becomes circling.

20 Conclusion

The program has reached a boundary. The scalar timing sector is coherent, readable, and potentially useful. The graph closure language is mathematically disciplined. The external-kernel distinction is important. The co-emergent readability hierarchy is conceptually cleaner than the earlier "clock before gravity" slogan. But none of this is yet new gravity.

The strongest scalar-dimensional bet failed its severe closure test. The weak-field connection and tensor layers reproduce established physics once their structures are supplied. Therefore the only remaining discovery-grade question is whether QATNU, or a replacement substrate, can generate the helicity-2 sector autonomously.

That question is now sharp enough to answer. Define the substrate. Freeze the observable map. Compute the tensor correlators. Decompose the channels. Verify helicity. Test source response. Run null controls. Demand an output number. Then accept the result.

If the substrate produces massless helicity-2 dynamics that were not inserted, the program has found its Mercury. If it cannot, the program has still done something worthwhile: it has drawn a clean boundary around scalar timing as a real projection language rather than mistaking it for gravity.

A Minimal notation registry

Symbol	Meaning
H_{micro}	Microscopic substrate Hamiltonian or update rule
$W = (w_{ij})$	Effective weighted adjacency matrix
D	Degree matrix, $D_{ii} = \sum_j w_{ij}$
$L_w = D - W$	Weighted graph Laplacian
ρ	Effective source density
Λ_i	Internal scalar load at vertex or locus i
ω_{eff}	Effective local clock frequency
α	Clock susceptibility to scalar load
κ	Scalar stiffness or graph-transport coefficient
μ	Screening scale
Γ	Relaxation coefficient
$C(x, i)$	Internal-to-external scalar coupling kernel
H_{ij}	Candidate substrate-generated tensor observable
h_{ij}^{TT}	Transverse-traceless tensor component
$P_{ij,kl}^{\text{TT}}$	TT projector in momentum space
c_g	Emergent spin-2 propagation speed, if present

B Red lines for future drafts

Future drafts should preserve the following red lines:

1. Do not call scalar timing gravity.
2. Do not call TT projection emergence.
3. Do not treat a failed closure as support.
4. Do not use external language unless an external kernel is specified.
5. Do not compare to Einstein without identifying the Mercury target.
6. Do not add interpretive rungs below the spin-2 derivation.
7. Do not claim discovery without an output not already inserted.

C References and internal sources

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