# The Radiation Content of General Relativity from a Monitored Substrate: Two Polarizations by Constraint Counting

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**Abstract**

In the audited-vacuum framework — a substrate whose couplings are dynamical and whose vacuum monitors only violations of local conservation constraints — we derive the radiative sector of gravitation and find it to be exactly that of General Relativity: two transverse-traceless polarizations, massless, propagating on the matter cone, transparent to the monitor. The derivation is forced at every step by existing data. Four no-go computations close the naive routes (free two-phonon composites carry no transverse-traceless spectral weight at the cone; the passive strain sector is gapped and flat; substrate phonons are pure gauge; Gaussian noise dressing cannot soften a metric gap). Masslessness then arises from a thermostat argument: the shear channel is exactly invisible to the monitor, so its only cooling is threshold rearrangement, and self-organized marginality is its unique steady state. Isotropy bounds force a bare substrate elasticity; LARES-2 and the Hulse–Taylor pulsar independently force the constraint set to include momentum budgets. The resulting four constraint rows — derived from the substrate's own conservation laws, not chosen — leave a dark (unmonitored, hence marginal) kernel of dimension exactly two, equal to the $\{+, \times\}$ tensor pair at every momentum (exactly, once the edge weights are fixed by fourth-moment isotropy — a derived condition, not a choice), with every scalar and vector channel watched. If a consistent massless spin-2 excitation with universal coupling is established — which this paper does *not* establish — Weinberg's soft-graviton theorem and Deser's bootstrap would supply universal coupling, the Einstein–Infeld–Hoffmann structure, the quadrupole formula, and the nonlinear completion, with one calibrated constant ($G$). Their premises are exactly the open program below. This is a *structural* closure — the polarization content and channel structure; positivity of the norm, causal propagation, and the amplitude-level match to the Einstein–Hilbert action are enumerated as the remaining program, not claimed. A full conditions ledger is included; every structural link is falsifiable and several nearly were.

## 1 The framework

The substrate is a graph carrying a matter amplitude $\varepsilon_i$ on sites and a coupling field $k_e = 1+\delta k_e$ on edges; the coupling field *is* the metric. The action is

$$S = \tfrac{1}{2}\dot{\varepsilon}^2 - \tfrac{1}{2}\textstyle\sum_e k_e(\nabla\varepsilon)_e^2 \;-\; \xi \sum_e \varepsilon_{t(e)}(\nabla\varepsilon)_e^2 \;+\; S_{\text{monitor}} + S_{\text{pump}},$$

where the derivative anharmonicity $\xi$ was previously selected against a cubic alternative by three independent gates (a Nordtvedt-type identity, Mercury's perihelion calibration, and infrared protection of emergent Lorentz symmetry), and the monitor couples only to *violations* of the local budget constraint, so that constraint-satisfying configurations are exact dark states. Newtonian statics, the post-Newtonian locks, and a laboratory decoherence signature (a Lorentzian knee at $\gamma = \alpha mc^2/\hbar$) are obtained elsewhere in the program; this paper concerns radiation.

## 2 Four no-go results

Numerical and analytic computations on the lattice close every naive radiative route: (i) the transverse-traceless spectral weight of free field-pairs vanishes at the lightlike edge as $(\omega - cq)^{2.7}$ — collinear pairs are longitudinal — so no free composite graviton pole exists, and none may be tuned in ($m_g < 1.3 \times 10^{-23}$ eV); (ii) giving the strain field inertia fails jointly: the passive stiffness spectrum is gapped ($5.7 \times 10^{-3}$) and flat ($\kappa_{\text{band}} = -3.7 \times 10^{-5}$), so no inertia satisfies the graviton-mass and speed bounds simultaneously; (iii) substrate displacement modes are gapless but vector-polarized and, as metric perturbations, pure gauge; (iv) an exact lemma: an isotropically driven Gaussian block is metric-transparent (its stationary energy is independent of the modulated stiffness), and colored-noise dressing is convex — always hardening. Quadratic-coupling noise of any spectrum cannot soften a metric gap.

## 3 Masslessness: the blind-channel thermostat

The shear channel has unsigned incidence zero: $(\mathbf{A} \cdot \text{shear})(r) = 0$ identically — the monitor cannot see uniform shear, hence cannot cool it. The pump leaks energy into every channel (through the $\xi$ vertex, slowly); the monitor is the vacuum's only dissipation; instability above threshold rearranges at substrate rates. With this timescale separation, the shear sector's unique steady state is the *threshold*: heated but unwatched, it ratchets soft until rearrangement sheds the excess. Marginality — hence masslessness — is not tuned; it is the inevitable steady state of the one channel the vacuum cannot cool by watching. The same invisibility makes gravitational waves exactly transparent to the monitor. (A fifty-four–digit fine-tuning that would otherwise afflict the bare elasticity dissolves: any bare stiffness above the vacuum's own shear softness yields the same pinned marginal state.)

## 4 Data force the constraint set

Three observational executions fix the structure. Isotropy bounds ($\Delta c/c < 10^{-18}$) force a bare substrate elasticity: the matter-induced shear potential alone is unstable (the vacuum energy's shear curvature is negative, an exact concavity effect), and a slumped vacuum is anisotropic. LARES-2's one-per-mille frame-dragging measurement and the Hulse–Taylor pulsar's $1.3 \times 10^{-4}$ orbital decay independently kill the energy-budget-only monitor: a single constraint row always leaves one scalar-polarized dark mode, and an eccentric binary sources it at 5.5% of the tensor channel — excluded by forty years of pulsar timing. The substrate must audit momentum as well as energy.

## 5 The derived rows and the closure

A dynamical coupling field sources violations of the matter sector's own conservation laws; computing these from the action gives the monitored combinations directly:

$$v_0 \;\propto\; \omega \sum_a w_a\,\delta k_a, \qquad v_i \;\propto\; \sum_a (q\cdot\hat{d}_a)(\hat{d}_a)_i\, w_a\,\delta k_a,$$

with $w_a$ the vacuum stress per direction: a *moving* trace is billed, a *directed flux* is billed; static configurations remain dark. On the nine-direction complex (axes and face diagonals, all $h_{ab}$ present), these four derived rows leave a physical dark space of dimension exactly two at every momentum:

| $q_z$ | $P(+)$ | $P(\times)$ | $P(h_{xx}{+}h_{yy})$ | $P(h_{zz})$ |
|---|---|---|---|---|
| 0.2 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |
| 0.5 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |
| 1.0 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |

The radiative sector is $\{+,\times\}$ and nothing else: General Relativity's radiation content is the unique dark sector of the derived constraints. With a massless, coupled spin-2 pair propagating on the matter cone, Weinberg's theorem forces universal coupling to $T_{\mu\nu}$ — yielding the gravitomagnetic factor four, the Einstein–Infeld–Hoffmann velocity terms, and the quadrupole formula — and Deser's bootstrap supplies the nonlinear completion. One constant, $G$, is calibrated by Newton, as in General Relativity itself.

## Discovery order, stated plainly

The momentum constraints were adopted *after* the single-constraint model's scalar mode was excluded by pulsar timing — the discovery order is data-first, and we state it rather than let the reader infer it. A structure adopted under data pressure earns the word "derived" only through consequences it was not fitted to: here, the conservation-law derivation of the constraint rows, and the momentum-channel prediction (a second decoherence channel entering the bridge as $c\,|dp_{\rm diff}/dt|$, sharing one knee with the energy channel). If that prediction fails, the four-budget repair was curve fitting, and this paper's central claim falls with it. We also state what kernel counting does not establish: the propagator, positivity of the norm, the helicity-$\pm 2$ representation content, the source coupling and its amplitude, the gravitomagnetic factor four, and the quadrupole formula are constructions this paper does not contain; the Weinberg and Deser theorems constrain such a structure once it exists — they do not create it.

## Related work

Self-organized criticality as a route to emergent spacetime was proposed by Ansari and Smolin (hep-th/0412307); composite-graviton masslessness and its entanglement with cosmological-constant tuning appear in Carone, Erlich and Vaman (arXiv:1710.09367); the obstructions we measure in-toy are the lattice faces of Weinberg–Witten (1980) and of the emergent-Lorentz fine-tuning problem (Collins et al.). The closure chain is textbook: Weinberg (1964), Deser (1970). What our searches found unclaimed is the selection mechanism — masslessness because the monitor cannot cool the channel it cannot see, with marginality as the unique steady state of a heated, unwatched sector — and the derivation of the four-constraint structure from data pressure (isotropy, LARES-2, PSR B1913+16) rather than by postulate. Searches are not proofs of absence.

## 6 Conditions ledger and falsifiability

The chain rests on: the thermostat premises (structural, not yet simulated in the full driven steady state); tree-level derived rows with an isotropic vacuum (loop corrections unexamined); the speed lock's coherence condition, met structurally because rearrangement is stress-triggered; and the cited Weinberg–Deser theorems. Each structural link is falsifiable and the program's public record (`https://emergent-gravity.com/journal.html`) shows several nearly failing: the scalar mode survived two suppression attempts before the momentum constraint killed it, and one intermediate claim (a Landau-damping selection) was refuted by its own verification run and is recorded as such. The framework's laboratory signature (zero decoherence at rest; a Lorentzian knee at $\gamma = \alpha m_e c^2/\hbar$; the absolute amplitude is an open derivation — earlier milliwatt-scale targets were retracted when the derived form factor failed its preregistered interval) distinguishes it from continuous-collapse–sourced gravity, which carries a rest floor.