

Spacetime as Polar Optics: A 4D Radial-Angular Geometry for Unifying Gravity and Quantum

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This paper aims to formalize a unification ansatz in which both gravitational dynamics and quantum phenomena inhabit the *same* four-dimensional geometry: time is represented as a radial coordinate $r = ct$ emanating from a start event, while distinct “versions” (appearances) of that event correspond to different angular perspectives $\theta \in [0, 2\pi)$ of a single history. A universal complex field $\mathcal{A} = |\mathcal{A}|e^{i\phi}$ models compactified standing-frequency excitations (“light”, broadly speaking) whose phase gradients generate stress and whose stress sources curvature through Einstein’s equations. Measurement is recast as selecting frequency/phase within an angular kernel, so Born weights appear as geometric *angular* weights on 4D light-cone slices. We articulate *luck as polar optic mechanics*: apparent luck is angular/phase selection of a deterministic 4D propagation under finite signal speed. We provide a common action, a polar metric adapted to causal flow, a prime-indexed standing-mode ansatz yielding compounded (composite) tension on each “ring of time”, and a mapping between Feynman graphs [13] and 4D tension networks. For each major claim we add a rigorous status assessment vs. modern GR, QFT, LQG, and String Theory, cite peer-reviewed literature, and include short proofs and test proposals.

I. PRINCIPLE: ONE GEOMETRY, TWO THEORIES

Hypothesis. (i) Spacetime $(\mathcal{M}, g_{\mu\nu})$ is the *same* stage for gravity and quantum kinematics; (ii) use a radial-angular chart (r, ϑ) adapted to causality with $r \equiv ct \geq 0$ and $\vartheta \in S^2$ labeling “perspectives” (Bondi-Sachs-type null/angular foliations justify this viewpoint near light cones); (iii) distinct observed “versions” of events are different ϑ -slices of one 4D history; (iv) a universal complex field \mathcal{A} underlies compactified standing modes.

[Assessment: Aligned: One 4D Lorentzian manifold for both GR dynamics and quantum kinematics is standard (quantum fields on curved backgrounds) [4, 24]. Using light-cone-adapted angular coordinates is orthodox (Bondi-Sachs framework) [6, 28]. Novel: interpreting Born weights as angular weights and casting “luck” as polar optics. Determinism in GR is subtle (global hyperbolicity, Cauchy horizons) [30]. Constraint: any hidden-variable determinism must respect Bell tests [15, 17, 29]; Bohm’s nonlocal theory is a classic example [5].]

II. RADIAL-ANGULAR METRIC AND CAUSALITY

Adopt a polar-like line element centered on a reference event:

$$ds^2 = c^2 dr^2 - a^2(r, \vartheta) d\Omega^2, \quad d\Omega^2 = \gamma_{AB}(\vartheta) d\vartheta^A d\vartheta^B, \quad (1)$$

with areal factor $a(r, \vartheta)$ encoding curvature/anisotropy; in flat space $a \rightarrow r$. This is consistent with light-cone/retarded-time (à la Bondi-Sachs) foliations used in gravitational radiation theory [6, 28]. Radial nulls ($ds^2 = 0$) trace ordinary light cones; see also analyses

of null cones in Minkowski backgrounds for GR reconstructions [27].

[Assessment: Aligned (as a coordinate choice). Globally, Eq. (1) is not unique nor always regular, but null-foliation/angle charts are standard near null infinity and in wave zones [32].]

III. UNIFIED ACTION AND PHASE TENSION

Let $\mathcal{A} = |\mathcal{A}|e^{i\phi}$ with action

$$S[\mathcal{A}, g] = \int d^4x \sqrt{-g} \left[\frac{1}{2\kappa} R + \frac{\xi}{2} \nabla_\mu \mathcal{A} \nabla^\mu \mathcal{A}^* - V(|\mathcal{A}|) \right], \quad (2)$$

yielding Einstein $G_{\mu\nu} = \kappa T_{\mu\nu}^{(\mathcal{A})}$ and a curved-space Klein-Gordon equation. Writing $\mathcal{A} = |\mathcal{A}|e^{i\phi}$ separates *phase tension*

$$T_{\mu\nu}^{(\phi)} = \xi \left(\nabla_\mu \phi \nabla_\nu \phi - \frac{1}{2} g_{\mu\nu} (\nabla \phi)^2 \right), \quad (3)$$

so phase gradients source curvature (akin to scalar-field stress in GR). String excitations interacting with strong gravitational waves exhibit resonant behavior [21], supporting the broader wave/tension picture (though not this specific model).

[Assessment: Aligned: minimally coupled scalar fields sourcing curvature are textbook GR/QFTCS [4, 24]. Novel: treating all matter as one complex “light” field departs from the Standard Model (SM); PDG reviews summarize the established multi-field SM [33].]

IV. PARTICLES AS COMPACTIFIED STANDING MODES

On an angular loop at fixed r with length $L_\vartheta(r) = \int \sqrt{a^2 d\Omega^2}$, standing modes satisfy

$$n\lambda = L_\vartheta(r), \quad k_n = \frac{2\pi n}{L_\vartheta(r)}, \quad n \in \mathbb{N}. \quad (4)$$

Mode energies $E_n = \hbar\omega_n$ follow local dispersion set by V and curvature. As an analogy for spectral selection in structured media, quasiperiodic arrays exhibit localization bands and nontrivial selection rules [31].

[Assessment: Aligned as a cavity/potential analogy. Novel if claimed literally for the SM spectrum; empirically, SM particle content is not explained as compactified photon modes [33].]

V. BORN WEIGHTS AS ANGULAR WEIGHTS; LUCK AS POLAR OPTIC MECHANICS

Define an angularly normalized field on each ring of time

$$\tilde{\Psi}(r, \vartheta) \equiv \sqrt{\frac{1}{\Omega_r}} \mathcal{A}(r, \vartheta), \quad \Omega_r \equiv \int a^2(r, \vartheta) d\Omega. \quad (5)$$

Detection with instrument kernel K_ω yields

$$P(\omega, \vartheta | r) \propto \left| \int d\Omega' K_\omega(\vartheta, \vartheta') \tilde{\Psi}(r, \vartheta') \right|^2. \quad (6)$$

Luck as polar optics: apparent randomness reflects finite- c access to phases from only part of S^2 ; probability is an angular under-sampling of an underlying interference field.

[Assessment: Complementary interpretive layer; compatible with decoherence/Born usage in quantum optics [22]. Constraint: local hidden-variable completions are excluded by loophole-free Bell tests; any deterministic completion must be explicitly nonlocal/contextual [5, 15, 17, 29].]

VI. PRIME-INDEXED STANDING MODES & COMPOUNDED TENSION ON THE RING OF TIME

Let

$$f(\theta) = \sum_{n \geq 1} a_n \cos(n\theta + \varphi_n), \quad t(\theta) = \frac{\eta}{2} (\partial_\theta f)^2. \quad (7)$$

If we *seed* only prime harmonics $p \in \mathbb{P}$, quadratic mixing and weak nonlinearities generate composite indices via sum/difference identities; see Appendix B. A von Mangoldt-weighted “sieve” operator,

$$\mathcal{S}[f](\theta) = \sum_{n \geq 1} \Lambda(n) a_n e^{i(n\theta + \varphi_n)}, \quad (8)$$

diagnoses missing primes: adding a missing p reduces composite-phase error at multiples of p . Average tension obeys

$$\mathcal{E}_{\text{avg}}[t] = \frac{\eta}{4} \sum_{n \geq 1} n^2 a_n^2, \quad (9)$$

so rarity ($\sim 1/\ln p$) versus energy ($\propto p^2 a_p^2$) trade off (Prime Number Theorem background; spectral analogies with prime statistics are suggestive [3, 23]).

[Assessment: Aligned: Fourier analysis and nonlinear wave-mixing (sum/difference frequency generation) are standard in nonlinear optics/fluids [7]. Novel: using prime seeding as a design ansatz for compounded tension and “prime events”.]

VII. TENSION NETWORKS AND FEYNMAN GRAPHS

Define the phase-tension scalar $\mathcal{R} = (\nabla\phi)^2$. High- \mathcal{R} filaments define a graph $\mathcal{G} \subset \mathcal{M}$: edges follow large phase gradients, vertices are compactification knots, sheets are interference membranes. Feynman graphs then serve as bookkeeping shadows of stress/propagation on \mathcal{G} .

[Assessment: Heuristic mapping. Aligned in spirit with path-integral/diagrammatics [10, 12]. Novel as a literal identification of spacetime tension filaments with diagrammatic edges.]

VIII. BLACK/WHITE HOLES AS CONDENSATES OF THE SAME JELLY

When phase tension and energy focus, $a(r, \vartheta)$ shrinks and null congruences converge (black-hole trapping: Kerr etc.) [18, 19]. The Kruskal extension of Schwarzschild includes a white-hole region as the time-reverse of a black hole [20]. Higher-dimensional analogs (5D black holes/rings) display rich surface geometry [14].

[Assessment: Aligned: black holes; white holes exist as time-reversed regions in extended solutions. Novel/speculative: “mutual reopening/repulsion” of nearby white-hole-like sources in nature. No observational support; GR allows white-hole regions mathematically but they are unstable/unobserved.]

IX. RECOVERING LIMITS AND CONFRONTATION WITH DATA

GR limit. With weak ϕ gradients, $T_{\mu\nu}^{(\phi)}$ is a standard scalar source and Einstein’s equations reduce to GR with known tests (perihelion advance, Shapiro delay, frame dragging, gravitational waves) [1, 11, 19, 32].

Quantum limit. On fixed (\mathcal{M}, g) , small-amplitude \mathcal{A} obeys the curved-space KG equation [4, 24]; standard interference/Born rule are recovered.

SM precision. Any unification must not spoil QED’s precision (electron $g - 2$ and tenth-order calculations) [2, 16, 25]. Our construction stays agnostic about SM gauge content (to be added atop \mathcal{A} if needed). Historical alternatives like a “neutrino theory of photons” are noted but not compatible with the modern SM [26, 33].

[Assessment: Aligned: these limits are standard. Constraint: extremely tight QED/GR tests bound any new couplings.]

X. PHENOMENOLOGY AND TESTS

Analog fluids/photronics. Drive superfluids or optical cavities with prime-indexed phase masks; verify composite lines appear by mixing and that adding a “missing prime” reduces sieve error (nonlinear mixing calibrated by [7]).

Interferometry as angular tomography. Multi-aperture interferometers resolving ϑ should exhibit curvature-dependent reweighting of fringe envelopes consistent with $a(r, \vartheta)$ (a geometric calibration of angular Born weights).

Hydrodynamic quantum analogs. Examine whether droplet pilot-wave analogs show prime-seeded stability bands [8, 9].

[Assessment: Falsifiable lab signatures exist for the prime-sieve/tension story and for angular tomography. Astrophysical deviations from GR lensing would tightly bound any new phase-tension couplings.]

XI. STATUS MAP: WHAT ALIGNS, WHAT’S NEW, WHAT’S SKEPTICAL

- **Fully aligned with modern science:** One 4D Lorentzian manifold; null/angle foliations (Bondi–Sachs); GR tests including frame-dragging and gravitational waves; QFT on curved space-time; QED precision; Kerr/Schwarzschild/Kruskal basics [1, 4, 11, 18–20, 24, 32, 33].
- **New but complementary (conceptual):** Born weights as angular weights; “luck as polar optics”; tension-network interpretation of diagrams; prime-seed design ansatz for compounded tension (intended for analog systems). Must be checked against Bell tests and precision constraints [5, 15, 17, 29].
- **Far-fetched/ruled-out as stated:** “Everything is compactified light” (conflicts with SM content [33]); white-hole repulsion in nature (no evidence; white holes are non-astrophysical regions of

extended solutions); any *local* hidden-variable determinism (excluded by loophole-free Bell tests [15, 17, 29]). Historical proposals like a neutrino theory of photons are not consistent with current electroweak theory [26, 33].

XII. CONCLUSION

Assuming one 4D geometry with time as radius and angles as perspectives produces a clean synthesis: the “material” of many apparent worlds is an oscillatory field observed through angular kernels; particles are standing-mode knots (in analogy), and Born weights can be recast as angular weights. We provided a scalar-GR action, a polar metric, a prime-sieve standing-mode mechanism that deterministically compounds into composite tension on each ring of time, and a tests list. The decisive next step is empirical: cavity/superfluid/photonic analogs and angular tomography that can confirm or falsify the prime-sieve and polar-optic predictions.

Appendix A: Polar Normalization and Perspective Weights

With $r = ct$ and $\vartheta \in S^2$ with area element $a^2(r, \vartheta) d\Omega$, define $\tilde{\Psi}$ by Eq. (5). Then

$$\int_{S^2} |\tilde{\Psi}(r, \vartheta)|^2 a^2(r, \vartheta) d\Omega = \frac{1}{\Omega_r} \int_{S^2} |\mathcal{A}(r, \vartheta)|^2 a^2 d\Omega = 1, \quad (\text{A1})$$

so angular detection weights are properly normalized on each radial slice.

Appendix B: Prime Mixing & Average Tension

Let $f(\theta) = \sum_{n \geq 1} a_n \cos(n\theta + \varphi_n)$. Then $\partial_\theta f = \sum_n (-na_n) \sin(n\theta + \varphi_n)$ and

$$t(\theta) = \frac{\eta}{2} (\partial_\theta f)^2 = \frac{\eta}{2} \sum_{m,n} mn a_m a_n \sin(m\theta + \phi_m) \sin(n\theta + \phi_n).$$

Using $\sin u \sin v = \frac{1}{2} [\cos(u-v) - \cos(u+v)]$, quadratic mixing generates indices $|m \pm n|$. If f is seeded only at primes, composites appear in t automatically. Averaging over θ kills cross terms, yielding Eq. (9).

Appendix C: Bell Constraints on “Polar Luck”

Any claim that probabilities arise from inaccessible but *local* angular phases is equivalent to a local hidden-variable model and violates loophole-free Bell inequalities [15, 17, 29]. Any deterministic completion must be nonlocal/contextual (or accept retrocausality), which we leave outside scope.

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