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

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(Dated: August 2025)

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 $\boldsymbol{\vartheta}$ 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 ([**?**]) 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 $(r, \boldsymbol{\vartheta})$ adapted to causality with $r \equiv ct \geq 0$ and $\boldsymbol{\vartheta} \in S^2$ labeling "perspectives" (Bondi-Sachs-type null/angular foliations justify this viewpoint near light cones); (iii) distinct observed "versions" of events are different $\boldsymbol{\vartheta}$-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) [**? ?**]. Using light-cone-adapted angular coordinates is orthodox (Bondi-Sachs framework) [**? ?**]. Novel: interpreting Born weights as* angular *weights and casting "luck" as polar optics. Determinism in GR is subtle (global hyperbolicity, Cauchy horizons) [**?**]. Constraint: any hidden-variable determinism must respect Bell tests [**? ? ?**]; Bohm's nonlocal theory is a classic example [**?**].]*

II. RADIAL-ANGULAR METRIC AND CAUSALITY

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

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

with areal factor $a(r,\boldsymbol{\vartheta})$ encoding curvature/anisotropy; in flat space $a \to r$. This is consistent with light-cone/retarded-time (à la Bondi-Sachs) foliations used in gravitational radiation theory [**? ?**]. Radial nulls ($ds^2 = 0$) trace ordinary light cones; see also analyses of null cones in Minkowski backgrounds for GR reconstructions [**?**].

*[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 [**?**].]*

III. UNIFIED ACTION AND PHASE TENSION

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

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

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

$$T^{(\phi)}_{\mu\nu} = \xi\Big(\nabla_\mu\phi\,\nabla_\nu\phi - \tfrac{1}{2}g_{\mu\nu}(\nabla\phi)^2\Big), \tag{3}$$

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

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

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

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

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 [**?**].

[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 [**?**].]*

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

Define an angularly normalized field on each ring of time

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

Detection with instrument kernel K_ω yields

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

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 [**?**]. Constraint: local hidden-variable completions are excluded by loophole-free Bell tests; any deterministic completion must be explicitly nonlocal/contextual [**? ? ? ?**].]*

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

Let

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

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,

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

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

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

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 [**? ?**]).

*[Assessment: Aligned: Fourier analysis and nonlinear wave-mixing (sum/difference frequency generation) are standard in nonlinear optics/fluids [**?**]. 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 [**? ?**]. 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, $a(r,\boldsymbol{\vartheta})$ shrinks and null congruences converge (black-hole trapping: Kerr etc.) [**? ?**]. The Kruskal extension of Schwarzschild includes a white-hole region as the time-reverse of a black hole [**?**]. Higher-dimensional analogs (5D black holes/rings) display rich surface geometry [**?**].

[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, $T^{(\phi)}_{\mu\nu}$ is a standard scalar source and Einstein's equations reduce to GR with known tests (perihelion advance, Shapiro delay, frame dragging, gravitational waves) [**? ? ? ?**].

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

SM precision. Any unification must not spoil QED's precision (electron $g-2$ and tenth-order calculations) [? ? ?]. 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 [? ?].

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

X. PHENOMENOLOGY AND TESTS

Analog fluids/photonics. 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 [?]).

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

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

[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 spacetime; QED precision; Kerr/Schwarzschild/Kruskal basics [? ? ? ? ? ? ? ? ?].

- **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 [? ? ? ?].

- **Far-fetched/ruled-out as stated:** "Everything is compactified light" (conflicts with SM content [?]); 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 [? ? ?]). Historical proposals like a neutrino theory of photons are not consistent with current electroweak theory [? ?].

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

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

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 $\partial_\theta f = \sum_n (-n a_n) \sin(n\theta + \varphi_n)$ and

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

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 [? ? ?]. Any deterministic completion must be nonlocal/contextual (or accept retrocausality), which we leave outside scope.