

The Quantum Geometric Wave Connectivity Hypothesis

A Conditional Mathematical Framework for Black Holes, Local Time,
and Einstein–Rosen Bridge-like Remote Connectivity

Chen Ho Yiing

ORCID: 0009-0006-6816-9891

`norika@charenix.com`

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Abstract

I propose in this paper a conditional hypothesis, the *Quantum Geometric Wave Connectivity Hypothesis* (QGWC), which can be formalized, derived, and rendered to yield observational predictions. The principal body of the hypothesis (H1–H6) asserts that under conditions of extreme gravity, black holes, solar-scale high-energy plasmas, and quantum observation, quantum states, the rate of time flow, the observed energy, and spatial connectivity should not be regarded as fixed objects sharing a universal synchronized time. If a black hole is not a purely classical body but a vast, complex, chaotic quantum or stringy state, then perturbations of its underlying wave-form may alter local geometry, time dilation, and quantum observational outcomes. At a deeper quantum-geometric level, two regions externally far apart may become effectively connected through an Einstein–Rosen bridge-like geometric configuration. Using local proper time, observer-dependent energy (including the Unruh and Hawking effects), quantum measurement operators, the semiclassical Einstein equation, black-hole perturbation theory, and wormhole throat conditions, I construct a mathematical framework for the hypothesis, and explicitly demonstrate in the section on *Causality and Information Protection* that it does not violate the no-signaling theorem. I also introduce extended sub-propositions H7–H11—a “Wave-form Composition Hypothesis” $\mathcal{M} + W \rightarrow F$ and a “Quantum Geometric Wave-form Transport”—as further attempts to formalize matter, wave-form, and identity. This extension is explicitly marked as a science-fiction physics conjecture, kept distinct from the main hypothesis. In the concluding section I provide a graded judgment regarding “hypothesis vs. conjecture”: the principal body (H1–H6) is a hypothesis; H7 is an established proposition; H8–H9 are conditional hypotheses; H10–H11 are science-fiction physics conjectures.

Keywords: quantum geometry; black hole microstates; proper time; Einstein–Rosen bridge; ER=EPR; spacetime emergence; observer-dependent quantum entanglement; quasinormal modes; wave-form composition; Unruh–Hawking effect.

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1 Introduction: The Question

The question I address in this paper is not the by-now-blurred old chestnut of “can quantum entanglement transmit signals?”—rather, a more fundamental question:

In the absence of a universal common time, with observers in different positions, in different gravitational fields, in different quantum states, and with black holes themselves not directly samplable—on what grounds do we use the same Earth-bound observational vocabulary to define “the same quantum,” “the same time,” or “the same observational event”?

The answer touches several intersecting threads in contemporary theoretical physics: the locality of time in general relativity, observer-dependent energy in quantum field theory, the microstate description of black holes in string theory, the correspondence between entanglement and geometry in ER=EPR, and the conjecture that spacetime emerges from quantum entanglement. The work of this paper is not to add new calculations to any one

thread but to integrate these threads into a single conditional logical chain, and to show that under this chain, black holes, time, quantum observation, and Einstein–Rosen-like remote connectivity are not isolated concepts but rather distinct manifestations of the same underlying quantum geometric structure.

Terminology: Hypothesis, Not Conjecture

Before proceeding I must clarify the academic positioning. A *conjecture*, in mathematics and theoretical physics, typically denotes a precisely stated proposition that has not yet been proved—e.g., the ER=EPR conjecture or the Maldacena conjecture—with the emphasis on the structural precision of the statement. A *hypothesis*, in empirical science, denotes an explanatory claim that can be tested by observation or experiment, with the emphasis on falsifiability and predictive power.

I adopt “hypothesis” here for three reasons. First, the central thrust of this paper is **conditional testable predictions** (five are listed in Section 9)—the hallmark of a hypothesis. Second, ER=EPR is a pure structural isomorphism statement without independent observational predictions, while QGWC asserts that perturbations of the black-hole wave-form change time and quantum observation—which has observational consequences, structurally closer to a hypothesis. Third, “hypothesis” avoids the academic arrogance of claiming I already have a rigorous proposition awaiting proof. At the sub-proposition level, I retain the precision of statement, while the overall framework is positioned as a hypothesis.

2 The Core Hypothesis

Hypothesis 2.1 (Quantum Geometric Wave Connectivity, QGWC). *If black holes, space, time, and quantum states can all be regarded as macroscopic manifestations of a deeper quantum or stringy state, then under conditions of extreme gravity and high energy, quantum observations near a black hole need not share the same time, energy state, or geometric background as those on Earth. If this underlying wave-form is perturbed, local time dilation, quantum state evolution, and spatial connectivity may all change; under special conditions, two externally remote regions may exhibit effective Einstein–Rosen bridge-like connectivity.*

I decompose this hypothesis into six sub-propositions:

- H1.** There is no absolute synchronized time shared by all observers in the universe.
- H2.** Quantum observational outcomes depend on the observer’s gravitational field, velocity, local time, and method of measurement.

- H3.** Quantum states near the Sun, near a black hole, and on Earth should not be assumed to be the same energy state.
- H4.** If a black hole is a vast quantum or stringy state, perturbing its wave-form may alter its geometry and temporal structure.
- H5.** If spatial geometry itself emerges from underlying quantum entanglement or wave-form, then the Einstein–Rosen bridge may be viewed as a special connectivity state.
- H6.** Prior to a clear definition of “the same quantum” and “observation” as physical interactions, one cannot absolutely deny the possibility that different observers in different local times could observe the same quantum system or the same quantum signal.

H1 and H2 are standard extensions of general relativity and quantum field theory, and I derive them rigorously in Section 3. H3 is a necessary consequence of H1 and H2. H4 and H5 are structural conjectures and are argued conditionally in Sections 4 and 5. H6 is a methodological claim whose core is the rejection of unfounded ontological denial; I formalize it in Section 3 via measurement operators.

2.1 Extended Hypotheses: Wave-form Composition and Information Reconstruction

Beyond the six core hypotheses, I introduce five extended sub-propositions further characterizing the relationship among matter, wave-form, and spacetime connectivity. Their complete mathematical formalization and philosophical discussion are placed in Section 7; here I list only their statements:

- H7.** Matter and energy form an underlying physical substrate of the universe, conserved (in the mass–energy sense) and pre-existent; they are not destroyed or newly produced by observation or reorganization.
- H8.** What we call “objects,” “persons,” or “structures” are not constituted by fixed-identity material units, but rather stable forms emerging from the action of a wave-form composition rule W on the substrate $\mathcal{M}$. Formally, $\mathcal{M} + W \rightarrow F$, where $\mathcal{M}$ is the matter/energy substrate, W is the composition rule, and F is the resulting stable form.
- H9.** If two substrates in different locations are composed by the same or compatible wave-form W , equivalent stable forms can arise.
- H10.** Within the QGWC framework, the essence of so-called “teleportation” is not the transport of matter, but the reinstantiation of a wave-form composition rule at a different spacetime node.

H11. Combining H8–H10 with the Einstein–Rosen connectivity conditions, the informational state of a macroscopic body (its wave-form encoding) can in principle be mapped into a dynamic Einstein–Rosen bridge channel and reconstructed at the exit node as an equivalent stable form.

H7–H10 constitute the “Wave-form Composition Hypothesis”; H11 constitutes the “Quantum Geometric Wave-form Transport Hypothesis.” I declare explicitly: among these five extended sub-propositions, H7 is a restatement of widely accepted physical conservation laws; H8–H9 are structural claims formally coherent but experimentally unverified; H10–H11 are conjectural extensions of a science-fictional character. Their academic positioning is dealt with separately in Section 12.

2.2 Conceptual Analysis: The Same Quantum, Observation, and Time

The methodological force of H6 depends on three sets of concepts being clearly delineated. I make them explicit here, to forestall semantic traps in the subsequent discussion.

(i) Four senses of “the same quantum.” In extreme spacetime and quantum field-theoretic contexts, “the same quantum” is not self-evident. I distinguish four possible meanings:

1. **Same photon:** the same Fock-state excitation with the same momentum, polarization, and wavefunction. Clear in free field theory, but in curved spacetime or accelerated frames the “Fock vacuum” itself becomes observer-dependent.
2. **Same field excitation:** the same excited mode of the same quantum field $\hat{\phi}(x)$. Looser, but still mode-decomposition-dependent.
3. **Same quantum system:** a system described by the same density matrix ρ whose time evolution exhibits continuity. This sense allows measurement, decoherence, and environmental interaction.
4. **Same informational trace:** regardless of whether the material carrier is identical, if the quantum information content (the descriptor of the quantum state) is preserved in some reconstructive sense, the system is regarded as the same.

The claim of H6 and H11 that “different observers may observe the same quantum system” holds in senses (3) and (4); senses (1) and (2) require further qualification on observer frame and field-theoretic vacuum.

(ii) **Classification of “observation” by measurement operator.** The physical meaning of observation is not a single concept. In quantum theory the measurement operator M_k falls into the following categories:

1. **Projective:** $M_k = P_k$, $P_k^2 = P_k$; ideal von Neumann measurement.
2. **Absorptive:** the measurement annihilates the original quantum system, e.g., single-photon detection by a photomultiplier.
3. **Scattering:** the probe scatters off the system and the system survives, but with non-negligible disturbance.
4. **Weak measurement** [4]: M_k is close to the identity I ; the system is almost undisturbed, but each measurement extracts very little information.
5. **Quantum non-demolition (QND):** $[M_k, H] = 0$; the measurement commutes with the Hamiltonian, and the system’s quantum numbers are preserved.

H6 is valid precisely because in categories (3)–(5), $P(A \rightarrow B) \neq 0$ is allowed.

(iii) **Three layers of “time.”** This paper uses three distinct layers of time, which I explicitly distinguish:

1. **Coordinate time** t : the coordinate component in the metric $g_{\mu\nu}$; itself without physical meaning, varying with coordinate choice.
2. **Proper time** τ : integrated along the observer’s worldline (Eq. (1)); observer-dependent, with physical meaning.
3. **Evolution parameter:** the parameter along which the quantum state evolves; in standard quantum mechanics this coincides with proper time, but in quantum gravity it may no longer be determined by geometry.

H1’s claim of “no global common time” refers to (1) and (2); H4 and H11 concern (3) and its potential variation under quantum geometric perturbation.

3 Mathematical Foundations

3.1 Observers and Local Proper Time

Let spacetime be a Lorentzian manifold $(M, g_{\mu\nu})$, with M the set of events and $g_{\mu\nu}$ the metric. An observer O_i has worldline $\gamma_i(\lambda)$ and local proper time defined by

$$d\tau_i^2 = -\frac{1}{c^2} g_{\mu\nu} dx^\mu dx^\nu. \quad (1)$$

Eq. (1) expresses that time is not a universal pre-given parameter but a local quantity dependent on observer worldline and metric. Outside a Schwarzschild source, the proper time of a static observer is approximately

$$d\tau(r) = \sqrt{1 - \frac{r_s}{r}} dt, \quad r_s = \frac{2GM}{c^2}. \quad (2)$$

For two observers at radii r_A, r_B :

$$\frac{d\tau_A}{d\tau_B} = \sqrt{\frac{1 - r_s/r_A}{1 - r_s/r_B}}. \quad (3)$$

If $r_A \neq r_B$, then $d\tau_A \neq d\tau_B$. This has been experimentally verified by high-precision atomic clocks: NIST/JILA optical lattice clocks have measured gravitational time dilation across millimeter-scale separations [1, 2]. Thus H1 in the weak-field limit is not a philosophical claim but a verified physical fact.

Proposition 3.1 (Non-shareability of local time). *Observers in different gravitational positions or moving at different velocities have no common local time parameter.*

3.2 Observer-Dependent Energy

For a particle with four-momentum p^μ , the energy measured by an observer O_i with four-velocity u_i^μ is

$$E_i = -p_\mu u_i^\mu. \quad (4)$$

If $u_A^\mu \neq u_B^\mu$, generically $E_A \neq E_B$. For a photon, $E = \hbar\omega$, so $\omega_A \neq \omega_B$.

Proposition 3.2 (Observer-dependent energy). *The same quantum process may be measured with different energies and frequencies by different observers.*

Unruh effect and Hawking radiation: established support. H3 is not an isolated speculation. Two widely accepted theoretical results directly support the claim that quantum energy states depend on the observer:

- **Unruh effect** [17]: the Minkowski vacuum in an inertial frame appears as a thermal bath to a uniformly accelerated observer at temperature

$$T_{\text{Unruh}} = \frac{\hbar a}{2\pi c k_B}. \quad (5)$$

That is, “vacuum” and “thermal radiation” are not objectively opposed, but observer-dependent descriptions.

- **Hawking radiation** [18]: outside a Schwarzschild black hole of mass M , a distant static observer measures blackbody radiation at temperature

$$T_H = \frac{\hbar c^3}{8\pi G M k_B}; \quad (6)$$

yet for an observer freely falling into the black hole, this thermal bath does not exist.

H3 within the Unruh–Hawking framework is therefore an integrative restatement of an established conclusion, rather than a novel claim.

Where the novel claim lies—this is worth pausing on. When this observer-dependence is combined **jointly** with H4 (black hole as quantum/string state) and H5 (Einstein–Rosen connectivity), deviations deeper than those of Unruh–Hawking may follow. By “deeper” I do not mean “higher temperature” or any quantitative shift, but something **structural**: local proper-time rate, quantum-phase evolution, and spatial connectivity distance become coupled with one another under H4+H5, rather than remaining independent. Unruh–Hawking gives a static observer-dependent perception of temperature; QGWC tries to say something about dynamic structural coupling.

The two operate at different levels. This is also why I insist on positioning QGWC as a hypothesis rather than a conjecture—it carries its own observational predictions (the five listed in Section 9), and is not a mere restatement of Unruh–Hawking.

3.3 Quantum State Evolution Along Local Time

A quantum system evolves along observer O_i ’s local time:

$$i\hbar \frac{d}{d\tau_i} |\psi_i(\tau_i)\rangle = H_i[g, \Phi_{\text{env}}] |\psi_i(\tau_i)\rangle, \quad (7)$$

where H_i depends on the metric $g_{\mu\nu}$ and external fields Φ_{env} (temperature, electromagnetic field, tidal forces, solar plasma, black-hole accretion disk, high-energy radiation, etc.).

The quantum phase evolution is

$$\theta_i = \frac{1}{\hbar} \int E_i d\tau_i. \quad (8)$$

If $E_A \neq E_B$ and $d\tau_A \neq d\tau_B$, then $\theta_A \neq \theta_B$.

Proposition 3.3 (Observer-dependent quantum phase). *The phase evolution of the same quantum process can differ between observers.*

Pikovski et al. [3] have already proved that gravitational time dilation entangles internal degrees of freedom of a composite quantum system with its center-of-mass motion, causing decoherence. This is the concrete realization of H4 in the weak-field limit.

3.4 Formalization of Observation

A measurement is represented by a measurement operator M_k .¹ For an initial density matrix ρ , after outcome k is obtained:

$$\rho' = \frac{M_k \rho M_k^\dagger}{\text{Tr}(M_k \rho M_k^\dagger)}, \quad P(k) = \text{Tr}(M_k \rho M_k^\dagger). \quad (9)$$

If observer 1 measures at event A and observer 2 measures at event B , with intermediate evolution U_{BA} , the joint probability of the sequence is

$$P(A \rightarrow B) = \text{Tr} \left[M_B U_{BA} M_A \rho M_A^\dagger U_{BA}^\dagger M_B^\dagger \right]. \quad (10)$$

This is the formal core of H6:

- If M_A is **absorptive** (e.g., ordinary single-photon detection), the first measurement annihilates the photon: $P(A \rightarrow B) = 0$.
- If M_A is **weak** or **non-demolition** [4, 5], the system survives, and $P(A \rightarrow B) \neq 0$ is possible.

Proposition 3.4 (Conditions for multiple observations of the same quantum system). *Before specifying whether M_A is absorptive, projective, weak, scattering, or non-demolition, one cannot absolutely deny that two observers might observe the same quantum system. Under weak or non-demolition measurement, the probability of multiple observation is non-zero.*

This result transforms H6 from a philosophical claim into a formalized proposition: its truth depends on the specific form of M_A , not on ontological assumption.

4 Black Holes as Quantum or String States

4.1 Microstate Description

I write the black hole as a quantum state. Let the microstate Hilbert space be $\mathcal{H}_{BH}$, with state

$$\rho_{BH} = \sum_{\alpha, \beta} c_{\alpha\beta} |\alpha\rangle \langle \beta|. \quad (11)$$

¹Here M_k follows the standard quantum-mechanical convention for a measurement operator, with the subscript k indexing the outcome. To distinguish it from the spacetime manifold M and the black-hole mass M : the measurement operator always carries a subscript (M_k), while the manifold and the mass do not. Equivalently, the reader may interpret it as $\hat{M}_k$ (with a hat to emphasize the operator nature). In Section 7 we additionally adopt the calligraphic $\mathcal{M}$ for the matter/energy substrate, further avoiding confusion.

In the string-theoretic or fuzzball framework [6, 7], $|\alpha\rangle$ corresponds to a stringy, brane-like, or quantum-geometric microstate. Bena, Martinez, Mathur, and Warner argue that the black hole in string theory may be not a semiclassical horizon plus singularity but a fuzzball or microstate geometry composed of sufficiently many degrees of freedom; in this framework the horizon and singularity may be artifacts of inadequate degree counting.

4.2 Perturbation and Semiclassical Back-Reaction

Under external perturbation (a nearby star, an infalling planet, high-energy radiation, quantum field disturbance), with perturbation operator $U_\epsilon = e^{-i\epsilon V/\hbar}$:

$$\rho'_{BH} = U_\epsilon \rho_{BH} U_\epsilon^\dagger. \quad (12)$$

Hence the expectation value of the stress-energy tensor changes:

$$\delta\langle T_{\mu\nu} \rangle = \text{Tr}[(\rho'_{BH} - \rho_{BH})T_{\mu\nu}]. \quad (13)$$

The semiclassical Einstein equation

$$G_{\mu\nu}[g] + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} \langle T_{\mu\nu} \rangle \quad (14)$$

linearizes to

$$\delta G_{\mu\nu}[h] = \frac{8\pi G}{c^4} \delta\langle T_{\mu\nu} \rangle, \quad (15)$$

with $g_{\mu\nu} \rightarrow g_{\mu\nu} + h_{\mu\nu}$.

4.3 The Core Logical Chain

The above derivation yields the core chain of QGWC:

$$\boxed{\delta\rho_{BH} \Rightarrow \delta\langle T_{\mu\nu} \rangle \Rightarrow \delta g_{\mu\nu} \Rightarrow \delta(d\tau) \Rightarrow \delta\theta \Rightarrow \delta O_{\text{obs}}} \quad (16)$$

In words: perturbation of the black-hole quantum state $\Rightarrow$ change in stress-energy $\Rightarrow$ change in metric $\Rightarrow$ change in local time dilation $\Rightarrow$ change in quantum phase $\Rightarrow$ change in observable outcomes. This is the mathematical realization of H4.

4.4 Observable Signatures of Black-Hole Perturbation

Even without string theory, standard black-hole perturbation theory predicts ringdown, i.e., quasinormal modes [8]:

$$\Psi(t, r) = \sum_n A_n e^{-i\omega_n t}, \quad \omega_n = \omega_{n,R} - i\omega_{n,I}. \quad (17)$$

If the black hole is not pure Kerr but a quantum or stringy black hole, we may write

$$\omega_n = \omega_n^{\text{Kerr}} + \delta\omega_n^{QG}, \quad (18)$$

where $\delta\omega_n^{QG}$ encodes corrections from quantum gravity, stringy structure, or Einstein–Rosen-like configurations. Eq. (18) provides the first testable prediction in Section 9.

5 Einstein–Rosen Bridges and Remote Connectivity

5.1 Wormhole Metric and Throat Conditions

I adopt the standard traversable wormhole metric [9]:

$$ds^2 = -e^{2\phi(r)}c^2dt^2 + \frac{dr^2}{1 - b(r)/r} + r^2d\Omega^2, \quad (19)$$

with redshift function $\phi(r)$ and shape function $b(r)$. The throat at $r = r_0$ satisfies

$$b(r_0) = r_0, \quad b'(r_0) < 1 \quad (\text{flare-out condition}). \quad (20)$$

For traversability we also require $e^{2\phi(r)} \neq 0$ (no event horizon).

5.2 Energy Conditions and Quantum Corrections

To keep the throat open, the null energy condition (NEC) must typically be violated: for any null vector k^μ , ordinary matter satisfies

$$T_{\mu\nu}k^\mu k^\nu \geq 0, \quad (21)$$

whereas a traversable wormhole requires

$$T_{\mu\nu}k^\mu k^\nu < 0. \quad (22)$$

This was long considered a decisive refutation of wormhole existence. However, Gao, Jafferis, and Wall [10] showed that under special quantum conditions, double-trace boundary coupling can produce a negative averaged null energy, making the Einstein–Rosen bridge traversable; the model also makes clear that this cannot be used to violate causality.

The mathematical condition for H5 can be written: there exists a quantum geometric state with effective stress-energy $T_{\mu\nu}^{\text{eff}}$ satisfying

$$T_{\mu\nu}^{\text{eff}}k^\mu k^\nu < 0, \quad (23)$$

supporting an open throat. This condition is not pulled from thin air—it has been concretely realized in the Gao–Jafferis–Wall model.

5.3 External Distance Far, Internal Connectivity Short

For two points A, B with external metric distance $D_{\text{ext}}(A, B)$, the Einstein–Rosen connectivity distance is

$$L_{ER}(A, B) = \int_{\gamma_{ER}} \sqrt{g_{ij} dx^i dx^j}. \quad (24)$$

If an Einstein–Rosen bridge exists, we may have

$$L_{ER}(A, B) \ll D_{\text{ext}}(A, B). \quad (25)$$

Eq. (25) is the precise statement of H5: not that the two points share an absolute time, but that in some underlying geometric state, two externally remote regions are non-trivially connected.

5.4 Spacetime Emergence from Entanglement

I adopt the language of ER=EPR and holography [11, 12]. The entanglement between regions A, B is quantified by mutual information:

$$I(A : B) = S(A) + S(B) - S(A \cup B). \quad (26)$$

In the holographic picture, entropy relates to geometric area:

$$S(A) = \frac{\text{Area}(\gamma_A)}{4G_N \hbar}. \quad (27)$$

Van Raamsdonk argues that the emergence of classically connected spacetime is intimately related to entanglement of underlying degrees of freedom; if entanglement is reduced, the spacetime regions are pulled apart, effectively severed. Maldacena and Susskind, in ER=EPR, posit that two entangled black holes can be described as connected by an Einstein–Rosen bridge, and conjecture that more general entangled states may exhibit similar bridge structures.

Thus H5 may be written as

$$\delta I(A : B) \Rightarrow \delta \text{Geometry}(A, B), \quad (28)$$

i.e., changes in entanglement structure correspond to changes in geometric structure. If

the entanglement strength exceeds a critical value I_c , the connected saddle may dominate:

$$I_{\text{conn}} < I_{\text{disconn}} \quad \Rightarrow \quad A \leftrightarrow B. \quad (29)$$

This is the mathematicized version of “wave-form or entanglement constructing an Einstein–Rosen bridge.”

5.5 Causality and Information Protection

Any theory claiming that two externally remote regions can be effectively geometrically connected must address a sharp objection: does this violate relativistic causality or the quantum no-signaling theorem? I deal with this explicitly here.

(i) No-signaling theorem preserved. The evolution operator U_{BA} in Eq. (10) is unitary. Unitary evolution in standard quantum mechanics preserves no-signaling: if observer A does not communicate the result of their measurement to observer B , then the local statistics observed by B are independent of A ’s choice of measurement basis:

$$\sum_k \text{Tr}_A \left[M_B U_{BA} (M_A^{(k)} \rho M_A^{(k)\dagger}) U_{BA}^\dagger M_B^\dagger \right] = \text{Tr}_A [M_B U_{BA} \rho U_{BA}^\dagger M_B^\dagger]. \quad (30)$$

Hence, even though H6 permits “the same quantum system being observed multiple times,” this does not by itself imply superluminal signaling.

(ii) Causality compatibility of the Gao–Jafferis–Wall wormhole. Gao, Jafferis, and Wall [10] explicitly proved that in their traversable-wormhole model, the double-trace coupling creates a connection between the two sides at the metric level, but signals through this channel travel *no faster* than the fastest external-spacetime route:

$$t_{\text{through wormhole}} \geq t_{\text{shortest external path}}. \quad (31)$$

This guarantees that the channel cannot be used to construct closed timelike curves (CTCs) or acausal signal transmission.

(iii) Inheritance in the QGWC framework. The Einstein–Rosen connectivity condition in this paper (Eq. (25)) inherits the causality protection of GJW: even when $L_{ER}(A, B) \ll D_{\text{ext}}(A, B)$, transmission through this bridge must still satisfy

$$\Delta t_{ER} \geq \Delta t_{\text{light, external}}, \quad (32)$$

with $\Delta t_{\text{light, external}}$ the external-spacetime light propagation time.

Remark 5.1. This is a crucial self-protective mechanism of the QGWC hypothesis. It immunizes QGWC against the standard objection of “violation of causality,” while not weakening the central claim: that the Einstein–Rosen bridge exists as a geometric structure and may give rise to observational deviations (as in the multiple-time-layer effects of Section 9), but does not permit acausal signaling or superluminal communication.

6 Observational Signals and Multiple Time Layers

Light follows null geodesics: $g_{\mu\nu}\dot{x}^\mu\dot{x}^\nu = 0$. In a strong gravitational field, multiple null geodesics $\gamma_1, \gamma_2, \gamma_3, \dots$ from source S to observer O may exist, with different arrival times $t_n = \int_{\gamma_n} dt$.

Hence the received signal is

$$I_{\text{obs}}(t) = \sum_n A_n I_S(t - \Delta t_n). \quad (33)$$

In strong gravity, an observer does not see a single “now” but a superposition of time-slices of the source. This is already observed in gravitational lensing [15]; it is not speculation.

Adding the QGWC Einstein–Rosen channel:

$$I_{\text{obs}}(t) = \sum_n A_n I_S(t - \Delta t_n) + A_{ER} I_S(t - \Delta t_{ER}), \quad (34)$$

with A_{ER} the additional signal weight from the Einstein–Rosen channel. Eq. (34) grounds the second prediction of Section 9.

7 Wave-form Composition and Information Reconstruction

This section presents the complete mathematical formulation and philosophical discussion of H7–H11. The aim is to lift “matter,” “wave-form,” and “identity” from intuitive talk to conditional formal hypotheses.

Notational convention. From this chapter onward, to avoid conflict with the space-time manifold M , the black-hole mass M , and the measurement operator M_k , the “matter/energy substrate” is henceforth denoted by the calligraphic letter $\mathcal{M}$. The three other uses of M (manifold, mass, measurement operator) retain their standard conventions unchanged.

7.1 Wave-form Composition: $\mathcal{M} + W \rightarrow F$

Let the universal matter/energy substrate be a density operator or field configuration:

$$\mathcal{M} \subseteq \mathcal{H}_{\text{matter}}, \quad (35)$$

with $\mathcal{H}_{\text{matter}}$ the Hilbert space of matter degrees of freedom. The wave-form composition rule W acts on $\mathcal{M}$ as a map:

$$W : \mathcal{H}_{\text{matter}} \rightarrow \mathcal{H}_{\text{matter}}, \quad |\Phi\rangle = W|\mathcal{M}\rangle. \quad (36)$$

The resulting stable form F is the concrete realization of this wave-form on the substrate:

$$F = (\mathcal{M}, W) \mapsto |\Phi_F\rangle = W|\mathcal{M}\rangle. \quad (37)$$

Hypothesis 7.1 (Wave-form Composition, H8 formalized). *“Objects” are not constituted by fixed-identity material units, but emerge as stable forms F from the action of a wave-form composition rule W on the substrate $\mathcal{M}$. The “identity of an object,” in the sense of Eq. (37), is dominated by W , not by $\mathcal{M}$.*

Remark 7.2. This hypothesis is conceptually congruent with the notion of “phase” in condensed matter. A glass of water and a block of ice share the same substrate (H_2O molecules) but with different wave-form compositions (liquid vs. crystal); their stable forms differ accordingly. H8 generalizes this phase concept beyond crystals to all stable structures including persons, planets, and biological systems.

7.2 Equivalent Forms: H9

If two substrates $\mathcal{M}_A, \mathcal{M}_B$ are identical or compatible and composed by the same wave-form W :

$$|\Phi_A\rangle = W|\mathcal{M}_A\rangle, \quad |\Phi_B\rangle = W|\mathcal{M}_B\rangle, \quad (38)$$

Φ_A and Φ_B are “equivalent stable forms.” Equivalence is measured by fidelity:

$$\mathcal{F}(\Phi_A, \Phi_B) = |\langle\Phi_A|\Phi_B\rangle|^2. \quad (39)$$

When $\mathcal{F} \rightarrow 1$, the two forms are indistinguishable under physical observables.

Remark 7.3. This is the mathematical version of the everyday observation that the same song can be played on a piano, guitar, phone speaker, or vinyl record. The material substrate is different, but the wave-form structure is the same, and we still call it the same song.

7.3 Quantum Geometric Wave-form Transport: H10–H11

I now state H10 (“teleportation as wave-form reinstantiation”) and H11 (“dynamic Einstein–Rosen reconstruction”) together.

Let a macroscopic body’s initial state be $|\Psi_{\text{body}}(x_A, t_A)\rangle$, decomposable as a tensor product:

$$|\Psi_{\text{body}}\rangle = |\psi_1\rangle \otimes |\psi_2\rangle \otimes \cdots \otimes |\psi_N\rangle. \quad (40)$$

If there exists an evolution operator U_λ controlled by wave-form parameter λ such that

$$U_\lambda |\Psi_{\text{body}}, x_A, t_A\rangle \rightarrow |\Psi_{\text{body}}, x_B, t_B\rangle, \quad (41)$$

with (x_B, t_B) the exit node of a dynamic Einstein–Rosen channel, then Eq. (41) describes a “wave-form transport” event.

If λ is not locked, $\lambda \rightarrow \lambda + \delta\lambda$ may cause:

- Exit position dislocation: $x_B \rightarrow x_B + \delta x$.
- Exit time dislocation: $t_B \rightarrow t_B + \delta t$.
- Body state discontinuity: $|\Psi_{\text{body}}^{\text{exit}}\rangle \neq |\Psi_{\text{body}}^{\text{entry}}\rangle$.

Hypothesis 7.4 (Quantum Geometric Wave-form Transport, H10–H11 formalized). *Within the QGWC framework, “teleportation” is not the transport of matter but the unitary mapping, under control of wave-form parameter λ , of the informational state of a macroscopic body between the entrance and exit nodes of a dynamic Einstein–Rosen channel, with subsequent reconstruction at the exit. Its stability depends on the locking precision of λ .*

7.4 Compatibility with the No-Cloning Theorem

A reader may immediately object: the Wootters–Zurek no-cloning theorem [19] forbids perfect copying of an unknown quantum state. Does H11 violate this?

I respond explicitly: *it does not*. Three reasons.

(i) H11 is “transport,” not “cloning.” In Eq. (41), U_λ is a unitary map: at the entrance of the dynamic Einstein–Rosen channel, the original state is “decomposed” and encoded into the channel as transmitted information, and “reconstructed” at the exit. During this process, the original body at the entrance node ceases to exist in its original form. This is structurally consistent with quantum teleportation [20], in which the completion of the teleportation necessarily destroys the original state.

(ii) **H8–H9 claim “equivalent forms,” not “same atoms.”** In the limit $\mathcal{F}(\Phi_A, \Phi_B) \rightarrow 1$, two stable forms are indistinguishable under physical observables, but this does not require the substrates $\mathcal{M}_A, \mathcal{M}_B$ to be the same batch of atoms. Indeed, even the same person at different moments has different substrates (cellular metabolism, atomic turnover), yet we regard them as the same person—this already hints that “personal identity” is wave-form-dominated rather than matter-dominated.

(iii) **Information bound.** The total quantum information needed to describe a macroscopic body is bounded by the Bekenstein bound [21]:

$$I \leq \frac{2\pi RE}{\hbar c \ln 2}, \quad (42)$$

with R the body’s size and E the total energy. For a person (mass ~ 70 kg, radius ~ 0.5 m), this bound is approximately 10^{45} bits. Astronomical, but finite—meaning H11 is not denied in principle by the Bekenstein bound; it is only technologically extremely difficult.

7.5 Philosophical Note on Identity

H8–H11 inevitably raise a philosophical question: if a reconstructed Φ_B is equivalent to the entrance Φ_A , is Φ_B :

1. The same individual?
2. A copy?
3. Another instance of the same wave-form?
4. A continuation of the original consciousness?
5. A structurally identical but subjectively distinct being?

I do not resolve this question in this paper, as it involves concepts of consciousness, self, and subjectivity for which the current physical framework offers no rigorous definitions. I only note: from the H8 stance—“the identity of an object is dominated by its wave-form W ”—(1) and (3) are synonymous; (2), (4), (5) involve judgments beyond pure physics.

Remark 7.5 (A science-fiction extension). Some science-fiction settings—e.g., the quantum tunnel of *Avengers: Endgame*—may be viewed as cultural narrativization of H10–H11. In this narrative, the character does not “traverse a corridor in their bodily form” but instead “their body’s macroscopic informational state is transformed into a stable mode propagatable through quantum geometry and reconstructed at the exit.” Such a reading, while science-fictional, is structurally consistent with the formal statement of H10–H11. I label this explicitly: this is a **science-fiction physics conjecture** and should not be conflated with the academic positioning of the main hypotheses (QGWC, H1–H6).

7.6 Conceptual Correspondences in the Wave-form Language

I list here several conceptual correspondences naturally extended from H8–H11, as conjectural notes (**this section is purely conjectural and not among the main claims of the paper**):

- **Death:** the loss of self-sustenance capacity of the wave-form W , i.e., W is no longer a stable fixed point for the substrate M .
- **Life:** the self-sustaining mechanism of W , i.e., $W(M) = W(W(M))$ approximately preserved under dynamical evolution.
- **Memory:** a stable informational coding structure within W .
- **Consciousness:** possibly related to self-referential (self-reference) structure within W ; this speculation is bold, and I offer it only as a philosophical note, making no formal claim.

Remark 7.6. Several concepts in this subsection have structural resonance with Penrose’s Orch-OR hypothesis [22] and certain versions of integrated information theory (IIT) [23], but this paper asserts no specific correspondence.

8 Conditional Theorem: The Formal Statement of QGWC

Theorem 8.1 (Conditional consistency of QGWC). *Assume:*

$$A1. \text{ Spacetime is described by local metric } g_{\mu\nu}; \text{ no global common time.} \quad (43)$$

$$A2. \text{ Quantum states evolve along local proper time } \tau_i. \quad (44)$$

$$A3. \text{ Observed energy is } E_i = -p_\mu u_i^\mu. \quad (45)$$

$$A4. \text{ Black holes possess quantum or stringy state } \rho_{BH}. \quad (46)$$

$$A5. \delta\rho_{BH} \Rightarrow \delta\langle T_{\mu\nu} \rangle \Rightarrow \delta g_{\mu\nu}. \quad (47)$$

$$A6. \text{ There exists a quantum geometric state with } L_{ER}(A, B) \ll D_{ext}(A, B). \quad (48)$$

$$A7. \text{ The substrate } M \text{ is pre-existent under mass-energy conservation.} \quad (49)$$

$$A8. \text{ Stable forms } F = (\mathcal{M}, W) \text{ have identity dominated by } W. \quad (50)$$

Then we can derive:

$$C1. \quad d\tau_A \neq d\tau_B \quad (\text{observers do not share the same time}). \quad (51)$$

$$C2. \quad E_A \neq E_B \quad (\text{observers measure different energies}). \quad (52)$$

$$C3. \quad \theta_A \neq \theta_B \quad (\text{quantum phase depends on local time and energy}). \quad (53)$$

$$C4. \quad \delta\rho_{BH} \Rightarrow \delta(d\tau) \quad (BH \text{ perturbation changes time dilation}). \quad (54)$$

$$C5. \quad L_{ER}(A, B) \ll D_{ext}(A, B) \quad (\text{remote regions can be effectively connected}). \quad (55)$$

$$C6. \quad P(A \rightarrow B) \text{ is given by Eq. (10); not deniable absent } M_A. \quad (56)$$

$$C7. \quad \mathcal{F}(\Phi_A, \Phi_B) \rightarrow 1 \Rightarrow \Phi_A \equiv_W \Phi_B \quad (\text{wave-form equivalence implies form equivalence}). \quad (57)$$

$$C8. \quad U_\lambda |\Psi, x_A, t_A\rangle \rightarrow |\Psi, x_B, t_B\rangle \quad (\text{wave-form transport in principle possible}). \quad (58)$$

Proof. C1 follows from A1 and Eq. (1). C2 follows from A3 and Eq. (4). C3 follows from A2, C1, C2 combined with Eq. (7). C4 follows from A4, A5 and Eq. (16). C5 is a restatement of A6. C6 follows directly from Eq. (10). C7 follows from A8 and the fidelity definition in Eq. (37). C8 follows from A6 and A8, combined with the existence of a unitary map as in Eq. (41); this claim is only “in principle,” not asserting any specific implementation. $\square$

Remark 8.2. The theorem does not prove A1–A8 to be physically true; it only proves that QGWC is not internally inconsistent under those assumptions—a conditional physical model that can be formalized, derived, and further developed.

9 Testable Predictions

For QGWC to advance from a theoretical draft toward a physical theory, observable deviations must be proposed. I list five.

9.1 Prediction 1: Black-hole ringdown spectral deviation

If the black hole is not pure Kerr but a quantum or stringy structure, then $\omega_n^{\text{obs}} \neq \omega_n^{\text{Kerr}}$. Define the deviation:

$$\Delta\omega_n = \omega_n^{\text{obs}} - \omega_n^{\text{Kerr}}. \quad (59)$$

A stable, repeatable, non-noisy deviation observed by LIGO/Virgo/LISA could support the black-hole microstate hypothesis. This prediction has been explored in fuzzball and echo models [14]; QGWC can be viewed as a unifying framework above them.

Order-of-magnitude estimate. For stellar-mass black holes ($M \sim 30M_\odot$):

- Kerr fundamental frequency $f_{220} \sim 250$ Hz; if fuzzball corrections exist, echo-model estimates give $\Delta f/f \sim 10^{-2}$ to 10^{-3} [14].
- Echo delay $\Delta t_{\text{echo}} \sim (M/m_{\text{Pl}}) \ln(M/m_{\text{Pl}}) \cdot t_{\text{Pl}} \sim$ a few ms to a few hundred ms.
- For supermassive black holes $M \sim 10^6 M_{\odot}$, Δt_{echo} can reach several seconds, falling within the LISA band.

This is the first prediction of H4 testable by present-day instruments.

9.2 Prediction 2: Multiple-light-path time-layer anomaly

If Einstein–Rosen connectivity exists, the multi-time-layer decomposition (Eq. (34)) should show an extra delay peak $A_{ER} I_S(t - \Delta t_{ER})$ not explicable by standard gravitational lensing geometry or plasma dispersion.

Order-of-magnitude estimate. For the Galactic Center Sgr A* ($M \sim 4 \times 10^6 M_{\odot}$, $r_s \sim 1.2 \times 10^{10}$ m):

- Standard multi-image time delays in lensing are minutes to hours [15].
- If an Einstein–Rosen channel exists, Δt_{ER} may differ from the external light-path by a few % to tens of % (depending on GJW channel geometry).
- The Event Horizon Telescope’s current $\sim$ microarcsecond resolution is in principle capable of detecting such deviations.

9.3 Prediction 3: Redshift anomaly

Standard gravitational redshift gives $1 + z_{GR} = \omega_{\text{emit}}/\omega_{\text{obs}}$. With quantum geometric corrections:

$$z_{\text{obs}} = z_{GR} + \delta z_{QG}. \quad (60)$$

A non-zero δz_{QG} not explained by ordinary gravity, velocity, or plasma effects could be a QGWC signature.

Order-of-magnitude estimate. Current LIGO/Virgo constraints on deviations from general relativity stand at $|\delta z/z| \lesssim 10^{-3}$ [24]. LISA is projected to push this to 10^{-5} to 10^{-6} . QGWC corrections, if they exist, are theoretically estimated to scale as

$$\delta z_{QG}/z_{GR} \sim (\ell_{\text{Pl}}/r_s)^{\alpha}, \quad (61)$$

with α depending on the specific quantum gravity model, typically $\alpha \in [1, 4]$. For stellar-mass black holes this ratio is approximately 10^{-39} to 10^{-156} —far below current detection

thresholds. Hence this prediction is **not immediately testable** under present experiments and stands only as a long-term theoretical target.

9.4 Prediction 4: Quantum coherence anomalous decay

If quantum geometric perturbations near black holes affect quantum states, the decoherence rate may be written

$$\Gamma = \Gamma_0 + \delta\Gamma_{\text{grav}} + \delta\Gamma_{QG}. \quad (62)$$

$\delta\Gamma_{\text{grav}}$ corresponds to the gravitational time-dilation decoherence predicted by Pikovski et al. [3]. A further observation of $\delta\Gamma_{QG} \neq 0$ could support the claim that extreme spacetime modifies quantum state evolution.

Order-of-magnitude estimate. Pikovski et al. calculate that for a 1 mg body in Earth’s gravity, the decoherence time between internal degrees of freedom and center-of-mass motion is approximately $\tau_{\text{dec}} \sim 1$ ms, corresponding to $\delta\Gamma_{\text{grav}} \sim 10^3 \text{ s}^{-1}$. Current tabletop experiments (such as the gravity-induced entanglement proposals of Bose et al. [25]) are approaching this sensitivity. $\delta\Gamma_{QG}$ ’s magnitude depends on the model, but QGWC predicts it should be significantly larger than $\delta\Gamma_{\text{grav}}$ in extreme gravity (e.g., neutron-star surfaces), potentially exceeding 10^6 s^{-1} .

9.5 Prediction 5: Remote correlation anomaly

If two regions A, B are geometrically connected by an Einstein–Rosen-like structure, their correlation function

$$C_{AB} = \langle O_A O_B \rangle - \langle O_A \rangle \langle O_B \rangle \quad (63)$$

may deviate from the value predicted by ordinary entanglement. If $C_{AB}^{\text{obs}} \neq C_{AB}^{\text{standard}}$ after excluding ordinary entanglement, instrumental noise, and classical common sources, it could be a candidate signature.

Order-of-magnitude estimate. Current Bell tests in weak gravitational fields have verified standard quantum entanglement to $\sim 10^{-6}$ precision [26]. Entanglement experiments in extreme gravity (neutron-star mergers, near black-hole accretion disks) are not currently feasible; prediction 5 is therefore a **long-term observational goal**, awaiting instrumentation with this capability. Theoretically, if the ER=EPR extension holds, entanglement–geometry coupling should manifest in the strong-gravity limit, but no consensus prediction of its specific magnitude yet exists.

10 Relation to Existing Research

Every module of QGWC has a prior research basis; the contribution of this paper is not to invent these modules but to integrate them. The correspondence is shown in Table 1.

QGWC module	Related existing research
H1, H2: local time and observer dependence	Relativistic quantum information [13]
H3: observer-dependent quantum energy	Unruh effect, Hawking radiation
H4: black hole as quantum/string state	fuzzball / microstate geometry [6, 7]
H4: observable BH perturbation signals	Quasinormal modes [8], echo models [14]
H4: time dilation affecting quantum states	Pikovski et al. [3]
H5: Einstein–Rosen and entanglement	ER=EPR [11]
H5: spacetime emergent from entanglement	Van Raamsdonk [12]
H5: quantum realization of traversable wormhole	Gao–Jafferis–Wall [10]
H6: measurement-operator formalization of observation	weak measurement [4, 5]

Table 1: Correspondence between QGWC sub-propositions and existing research

I emphasize: although every core module has been studied, this complete combination—“BH chaotic wave-form $\rightarrow$ quantum observation $\rightarrow$ time non-sharing $\rightarrow$ Einstein–Rosen generation”—has not, to my knowledge, been put forward as a single integrated thesis in the standard literature. The academic contribution of this paper lies precisely in the explicit clarification of this integrated narrative.

11 Mathematically Supported and Pending Claims

To avoid over-claiming, I tabulate the current academic status of each part of QGWC in Table 2.

The fairest judgment is therefore: this paper’s hypothesis can be mathematically formalized and derives internally consistent results, but it remains a theoretical hypothesis, not an experimental law.

12 Hypothesis vs. Conjecture: The Judgment

I provide here the most crucial academic judgment of the paper.

Claim	Status
No universal synchronized time	Mathematically holds; verified experimentally
Quantum observation time differs near BH and Earth	Mathematically holds (Eq. (3))
Quantum process energy varies with observer	Mathematically holds (Eq. (4))
Sun, BH, Earth quantum states not assumed identical	Mathematically holds (Eq. (7))
If BH is quantum/string state, perturbing alters geometry	Conditionally holds (Eq. (16))
Einstein–Rosen bridge as special geometric connectivity	Mathematically holds (at the metric level)
Einstein–Rosen possibly related to entanglement	Holds as a conjecture in ER=EPR
Cannot a priori deny multiple observations of same quantum	Mathematically holds (Eq. (10))
Not yet verified:	
Existence of traversable Einstein–Rosen bridges in nature	Unverified
Einstein–Rosen between BH and Sun must form	Unverified
Any two quanta connected via Einstein–Rosen	Unverified
Quantum observation can arbitrarily span past and future	Unverified
BH wave-form necessarily yields stable worm-hole throat	Unverified
Einstein–Rosen usable for human communication or travel	Unverified; known models constrained by causality

Table 2: Current academic status of QGWC claims

12.1 QGWC as a whole should be a “hypothesis”

For three reasons.

First, the central thrust is conditional testable predictions. The five predictions listed in Section 9 all satisfy falsifiability. Popper’s falsifiability criterion [16] is the key distinguishing assumption between hypothesis and metaphysical speculation. QGWC satisfies it.

Second, it is structurally distinct from the ER=EPR conjecture. ER=EPR is a pure structural isomorphism statement—asserting that two entangled black holes and a spacetime connected by an Einstein–Rosen bridge describe the same physical state. It does not directly predict observational deviations, hence is positioned as a conjecture. QGWC is different: its core is that “BH wave-form perturbations alter time and quantum observation,” which has observational consequences—hence a hypothesis.

Third, “hypothesis” avoids ontological arrogance. Calling QGWC a theorem would imply its premises are proved. Calling it a conjecture would imply it is merely a proposition awaiting structural proof. In reality, QGWC is a hybrid: some verified

modules (C1–C3), some conditional inferences (C4), some structural claims (C5), some methodological restrictions (C6). The most fitting positioning for such a hybrid is “hypothesis.”

A personal note on the positioning. Writing this, I must confess: the decision to label QGWC a hypothesis rather than a conjecture has not been an easy one. In mathematics, a conjecture is typically a self-contained, sharp, provable-in-principle statement; a hypothesis carries the burden of being *empirically refutable*—which in contemporary physics is actually the higher bar. I choose hypothesis not out of self-importance but because the QGWC internal chain $\delta\rho_{BH} \Rightarrow \delta\langle T_{\mu\nu} \rangle \Rightarrow \delta g_{\mu\nu} \Rightarrow \delta(d\tau) \Rightarrow \delta\theta \Rightarrow \delta O_{\text{obs}}$ has, at every step, an **in-principle** observational correspondence—and this is essentially different from a pure structural statement like ER=EPR. I accept that future experiment may refute it. This is what academic honesty looks like.

12.2 Sub-propositions retaining conjectural status

I acknowledge that several structural claims within QGWC, at the current level of theoretical completeness, are closer to conjecture than to hypothesis:

- “An Einstein–Rosen connectivity state exists between BH and Sun” is a conjecture.
- “The entanglement–geometry–emergence correspondence in H5 holds in all strongly coupled systems” is a conjecture (extension of ER=EPR).
- “QGWC functions as an effective description of quantum gravity” is a conjecture.

These conjectural elements may, pending theoretical completion and observational support, be elevated to theorems or hypotheses in the future.

12.3 Graded judgment for the extended sub-propositions H7–H11

The academic status of H7–H11 (introduced in Section 2.1) is not uniform. I grade them:

- **H7 (substrate pre-existence):** a restatement of widely accepted conservation laws—an **established proposition**.
- **H8 (wave-form composition $\mathcal{M} + W \rightarrow F$):** locally verified in the condensed-matter notion of “phase”; as a general principle of macroscopic identity, a **hypothesis** testable via phase transitions, self-assembly, and biological stability studies.
- **H9 (equivalent forms):** formally definitional through fidelity $\mathcal{F} \rightarrow 1$; its physical realizability is a **conditional hypothesis**.

- **H10 (teleportation as wave-form reinstantiation):** a science-fiction physics **conjecture**. Not directly testable under current technology; its compatibility with no-cloning and no-signaling is established in Section 7.4.
- **H11 (quantum geometric wave-form transport):** same as H10. The formal treatment here only proves consistency with existing quantum theory; no claim is made about engineering realizability.

Important distinction. I emphasize: the science-fictional status of H10–H11 does not weaken the hypothesis status of H1–H6. The former is an extended cultural-narrative physicalization; the latter is a quantum-geometric theoretical draft testable by observation. Readers should treat them separately.

12.4 Final judgment

QGWC’s main body (H1–H6) is a Hypothesis, not a Conjecture.

Its academic positioning: a conditional, formalizable, derivable, falsifiable-prediction-carrying quantum-geometric theoretical draft.

Extended sub-propositions: H7 is an established proposition; H8–H9 are conditional hypotheses; H10–H11 are science-fiction physics conjectures.

Several structural claims (Einstein–Rosen connectivity existence, ER=EPR extension, QGWC as effective quantum gravity) retain conjectural status, to be elevated after theoretical completion.

13 Conclusion

In this paper I have lifted a conception—“black holes, time, quantum, and space may share a deeper wave-form structure, and the Einstein–Rosen bridge may be a special connectivity state of that structure”—from the level of intuition and informal reasoning to a conditional hypothesis amenable to scholarly treatment.

What I claim is not “the Einstein–Rosen bridge already exists” nor “entanglement permits superluminal signaling,” but a more fundamental methodological position:

We have no entitlement to use over-simplified Earth-bound intuition to a priori deny the possibility, under extreme conditions, of unknown connectivity phenomena involving black holes, quanta, time, and space.

This position is meaningful, for it forces physicists to define “the same quantum,” “the same time,” and “the same observational event”—ostensibly self-evident concepts—before asserting “impossible.”

The core logical chain of the hypothesis

$$\delta\rho_{BH} \Rightarrow \delta\langle T_{\mu\nu} \rangle \Rightarrow \delta g_{\mu\nu} \Rightarrow \delta(d\tau) \Rightarrow \delta\theta \Rightarrow \delta O_{\text{obs}}$$

augmented by the Einstein–Rosen condition

$$T_{\mu\nu}^{\text{eff}} k^\mu k^\nu < 0 \quad \text{and} \quad L_{ER}(A, B) \ll D_{\text{ext}}(A, B),$$

together constitutes a structurally complete, predictively explicit, future-observationally-checkable conditional quantum geometric hypothesis.

What is offered here is not a proven theory but a quantum geometric hypothesis to be taken seriously; within it, black holes, time, quantum observation, and the Einstein–Rosen bridge are not isolated concepts but distinct manifestations of the same underlying wave-form or geometric structure.

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