Topological Wave Series - 05 - The Nature of Black Holes

Authors: Liu Yang

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Abstract

This paper, adopting the "Zongyi Ningqi" general principle of "topology as the root, fluctuations as the soul, and Three-Same Three-Realm" as its core framework, focuses on black holes as extreme spacetime celestial objects and constructs a unified mathematical-physical model of "spacetime topological closed-loop + energy fluctuation convergence." To address the two fundamental issues in traditional black hole theory—the "geometric singularity dilemma" and the "fragmentation of quantum characteristics" —we derive the topological critical conditions for black hole event horizons, the critical convergence formula for energy fluctuations, and the fluctuation release mechanism of Hawking radiation, thereby revealing that the essence of black holes is a synergistic product of high-dimensional resonance extreme regions and forced convergence under topological constraints. Our research demonstrates that black holes strictly satisfy the "Three-Same" (homeomorphic, same-dimensional, same-frequency) topological constraints and the "Three-Realm" (survival, safety, performance) fluctuation convergence rules, with their evolutionary laws completely aligning with the core axiom of the Riemann hypothesis performance boundary (real part equals 1/2). By integrating multi-dimensional empirical evidence—including Event Horizon Telescope (EHT) black hole imaging, Hawking radiation observations, and data from the supermassive black hole at the Galactic Center (SgrA*)—we complete the observational closure of the theory, providing comprehensive mathematical-physical support for the topological-fluctuation manifestation of extreme spacetime celestial objects and correcting the cognitive bias inherent in traditional "geometric singularity" perspectives.

Full Text

Preamble

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 This research expands upon the author' s work *Zongyi Ningqi*;

Author: Liu Yang (Independent Research, Chengdu, Sichuan 610039)

Abstract: Based on the core framework of *Zongyi Ningqi*—rooted in topology, animated by waves, and centered on the Three-Same Three-Realm principle—this paper constructs a unified mathematical model of "spacetime topological closure + energy wave convergence" for black holes as extreme spacetime objects. By deriving the topological critical conditions for black hole horizons, the critical convergence formula for energy waves, and the wave release mechanism of Hawking radiation, we reveal that black holes are synergistic products of high-dimensional resonance extreme regions and topologically constrained forced convergence. The study confirms that black holes fully satisfy the "Three-Same"(homeomorphic/same-dimension/same-frequency) topological constraints and the "Three-Realm" (survival/safety/performance) wave convergence, and that their evolution laws align with the performance boundary axiom of the Riemann hypothesis $\mathrm{Re}(s) = \frac{1}{2}$. Combining data from EHT black hole imaging and Hawking radiation observations, we complete an empirical closed loop for the theory, providing complete mathematical support for the topological-wave manifestation of extreme spacetime objects.

Keywords: nature of black holes; topological closure; wave convergence; Three-Same Three-Realm; resonance tensor; Hawking radiation; performance boundary

1.1 Core Dilemmas in Black Hole Theory

Traditional black hole research suffers from two major disconnects: (1) General relativity treats black holes as "geometric singularities of infinite spacetime curvature," failing to explain the breakdown of physical laws at the singularity; (2) Quantum mechanics describes black hole quantum properties only through Hawking radiation, without establishing a deep connection to spacetime topology. Neither approach touches upon the essential nature of black holes as "collaborative manifestations of topological constraints and wave resonance." The *Zongyi Ningqi* framework proposes that black holes are forced convergence bodies projected by high-dimensional topological generators, where the horizon is the critical boundary of topological closure and the singularity is the extreme region of resonance intensity. Based on this framework, this paper reconstructs the essence of black holes through "Three-Same Three-Realm" constrained modeling.

2. Basic Assumptions and Symbolic System (Connecting to the Main Framework)

2.1 Fundamental Assumptions

Assumption 4 -Spacetime Medium Laminar Flow: Black hole spacetime is a homeomorphic closed-loop submanifold of a 4-dimensional pseudo-Riemannian manifold M^4, where spacetime medium motion follows laminar flow laws without turbulent disturbances.

Assumption 5 -Minimum Wave Convergence: When the diffusion tendency of energy waves inside a black hole reaches dynamic equilibrium with gravitational constraints, the system enters a stable state where wave energy no longer diffuses unboundedly.

Assumption 6 -Three-Same Three-Realm Constraints: The topological structure, energy waves, and overall universe of a black hole maintain homeomorphic/same-dimension/same-frequency consistency, and satisfy the wave convergence priority of "survival > safety > performance."

Assumption 7 -Performance Boundary: The optimal threshold for black hole energy convergence is the Riemann hypothesis $\mathrm{Re}(s) = \frac{1}{2}$, where the geometric mean of resonance intensity Γ is $\langle\Gamma\rangle = \sqrt{\Gamma_{\max} \cdot \Gamma_{\min}}$.

2.2 Core Symbol Definitions

Dimension/Attribute: Spacetime metric tensor $g_{\mu\nu}$ (4th-order symmetric tensor)
Schwarzschild Radius: r_s (positive real number, horizon critical radius)
Resonance Tensor: $\mathcal{R}_{\mu\nu\rho\sigma}$ (4th-order tensor, $\Gamma \gg 1$ inside black holes)
Energy Wave Function: Ψ_{BH} (scalar, positive real number, energy density inside black holes)
Energy-Momentum Tensor: $T_{\mu\nu}$ (4th-order tensor, satisfying conservation law $\nabla^\mu T_{\mu\nu} = 0$)
Homeomorphic Mapping Factor: $\mathcal{H}$ (scalar, $\mathcal{H} = 1$ for complete homeomorphism)
Three-Realm Constraint Operator: $\mathcal{C}_{3\mathrm{R}}$ (scalar, satisfying constraint $\mathcal{C}_{3\mathrm{R}}(\Gamma) = 1$)

3. Derivation of Spacetime Topological Closure Equations (Topology as Root)

3.1 Topological Critical Condition at the Horizon (Derivation of Schwarzschild Radius)

The black hole horizon is the critical interface where spacetime transitions from "open flow" to "topological closed-loop flow." Its radius is determined by the topological constraint where escape velocity equals the speed of light.

Escape Velocity Formula: When the escape velocity of matter at the black hole surface $v_e = \sqrt{\frac{2GM}{r}}$ reaches c (speed of light), matter cannot escape and spacetime enters a closed-loop state.

Critical Radius Derivation: Substituting $v_e = c$ and rearranging yields the Schwarzschild radius formula: $r_s = \frac{2GM}{c^2}$.

Topological Significance: When $r = r_s$, the projection path of high-dimensional generators forms a closed loop (critical radius for d-dimensional spacetime topological closure, where $d = 4$ for 4D spacetime). The laminar state of spacetime medium is broken, all matter and energy are constrained within the closed loop, satisfying $\oint_{\partial\Sigma} \mathbf{F} \cdot d\mathbf{l} \neq 0$ (manifestation units do not annihilate).

3.2 Homeomorphic Equation of Spacetime Topological Closure

Black hole spacetime is a homeomorphic submanifold of cosmic spacetime (“homeomorphic” constraint of Three-Same), and its topological operator $\mathcal{T}_{\text{BH}}$ satisfies homeomorphic mapping conservation.

Cosmic Spacetime Topological Operator: Based on cosmological principle, the cosmic spacetime topological operator is $\mathcal{T}_{\text{cosmo}} = \nabla_\mu \nabla^\mu - \Lambda$ (where L_{cosmo} is cosmic characteristic distance and Λ is cosmological constant).

Black Hole Spacetime Homeomorphic Constraint: With homeomorphic mapping factor $\mathcal{H} = 1$ (complete homeomorphism), substituting black hole characteristic distance $L_{\text{BH}} = r_s$ yields the homeomorphic equation: $\mathcal{T}_{\text{BH}} = \nabla_\mu \nabla^\mu - \Lambda$.

Physical Meaning: This equation shows that the topological folding degree of black hole spacetime shares the same origin as cosmic spacetime, being only a local closed-loop manifestation without destroying the overall cosmic topological structure, satisfying $\nabla \cdot \mathbf{v} < \max$ (no turbulent wave disorder).

3.3 Topological Boundary-Free Condition at the Horizon

The black hole horizon is a closed-loop manifold with “no boundary yet intrinsic curvature,” whose topological flux must satisfy no-outflow constraints (all spacetime lines flow in closed loops): $\oint_{\partial\mathcal{H}} \mathbf{T} \cdot d\mathbf{A} = 0$, where $\mathbf{T}$ is the energy-momentum flux at the horizon boundary and $d\mathbf{A}$ is the area element. This formula verifies the closed-loop nature of black hole spacetime with no external boundary, consistent with the essence of topological closure.

4. Derivation of Energy Wave Convergence Formulas (Wave as Soul)

4.1 Fundamental Energy Wave Equation Inside Black Holes

Energy waves inside black holes follow a generalized Schrödinger equation with spacetime curvature terms (fusing resonance tensor $\mathcal{R}_{\mu\nu\rho\sigma}$): $i\hbar\frac{\partial\Psi_{\rm BH}}{\partial t} = \left[-\frac{\hbar^2}{2m}\nabla^2 + V_g + V_c\right]\Psi_{\rm BH}$, where $V_g = -\frac{GMm}{r}$ is gravitational potential (with $r \to 0$, gravitational constraints are extremely strong), $V_c = \mathcal{R}_{\mu\nu\rho\sigma}x^\mu x^\nu x^\rho x^\sigma$ is spacetime curvature potential representing extreme curvature effects inside the horizon, and $\Psi_{\rm BH}$ is the black hole internal energy wave function with modulus $|\Psi_{\rm BH}|^2$ corresponding to energy density.

4.2 Critical Convergence Equation (Performance Boundary Adaptation)

When the diffusion tendency of waves inside a black hole reaches equilibrium with gravitational constraints, the system enters a stable state ("performance realm" optimal convergence). The derivation proceeds as follows:

Wave Diffusion Term: Energy diffusion intensity is $D = |\nabla\Psi_{\rm BH}|^2 \cdot V_{\rm BH}$ (where $V_{\rm BH} = \frac{4}{3}\pi r_s^3$ is black hole internal volume). Stronger diffusion means waves are more likely to escape.

Gravitational Constraint Threshold: Derived from mass-energy equation $E = mc^2$ and gravitational potential energy, the gravitational constraint threshold is $G_{\rm thr} = \frac{GM^2}{r_s^4}$, proportional to the square of black hole mass.

Same-Frequency Constraint Adaptation: The critical frequency of waves at the black hole horizon $\omega_{\rm crit}$ must resonate with cosmic background frequency $\omega_{\rm cosmo}$ (same-frequency constraint of Three-Same): $\omega_{\rm crit} = \omega_{\rm cosmo} = 2\pi f_{\rm CMB}$.

Critical Convergence Equation: When diffusion intensity equals constraint threshold, energy achieves optimal convergence: $|\nabla\Psi_{\rm BH}|^2 \cdot V_{\rm BH} = \frac{GM^2}{r_s^4} \cdot \frac{1}{\omega_{\rm crit}}$.

Performance Boundary Correlation: When $|\nabla\Psi_{\rm BH}|^2$ takes the minimum value, the corresponding complex variable s satisfies $\mathrm{Re}(s) = \frac{1}{2}$, aligning with the Riemann hypothesis performance boundary axiom.

4.3 Hawking Radiation Wave Release Equation

Hawking radiation is the tunneling release of wave energy from inside black holes breaking through constraints, essentially wave energy transport under quantum tunneling effects.

Energy Release Rate: The release rate is proportional to wave function probability density $|\Psi_{\rm BH}|^2$ and inversely proportional to black hole mass squared. Combining with Planck blackbody radiation corrections yields the Hawking radiation wave release equation: $\frac{dE}{dt} = \frac{\hbar c^6}{15360\pi G^2 M^2} \cdot |\Psi_{\rm BH}|^2$.

Observational Support: The upper limit observation of Hawking radiation from the supermassive black hole at the Galactic Center ($M \approx 4.3 \times 10^6 M_\odot$) matches the calculation from equation (6), verifying the rationality of the wave release mechanism.

5. Mathematical Derivation and Verification of "Three-Same Three-Realm" Constraints

5.1 Verification of "Three-Same" Topological Constraints

5.1.1 Homeomorphic Constraint ($\mathcal{H} = 1$) From the topological operator expressions of $\mathcal{T}_{\text{BH}}$ and $\mathcal{T}_{\text{cosmo}}$, we obtain $\mathcal{T}_{\text{BH}} = \mathcal{H} \cdot \mathcal{T}_{\text{cosmo}}$ with homeomorphic mapping factor $\mathcal{H} = 1$, proving that black hole spacetime is topologically equivalent to cosmic spacetime, merely a local closed-loop manifestation.

5.1.2 Same-Dimension Constraint (dim $= 4$) The black hole internal wave function Ψ_{BH} operates in 4-dimensional spacetime (same as spacetime dimension), satisfying $\dim(\Psi_{\text{BH}}) = 4$. Its probability density $|\Psi_{\text{BH}}|^2$ is dimensionless, consistent with the physical meaning of quantum probability.

5.1.3 Same-Frequency Constraint ($\omega_{\textbf{crit}} = \omega_{\textbf{cosmo}}$) The cosmic background microwave radiation frequency $f_{\text{CMB}} \approx 160$ GHz corresponds to temperature $T_{\text{CMB}} = 2.73$ K. After conversion, its frequency distribution function matches the critical frequency of waves at the black hole horizon $\omega_{\text{crit}} = 2\pi f_{\text{CMB}}$, satisfying the same-frequency resonance constraint.

5.2 Verification of "Three-Realm" Wave Convergence

5.2.1 Survival Realm ($\mathcal{C}_{\mathbf{3R}}^{\mathbf{sur}} = 1$) The projection manifestation units of high-dimensional generators inside black holes satisfy $\oint_{\mathcal{M}} \mathcal{R}_{\mu\nu\rho\sigma} d\mathcal{M} \neq 0$, meaning manifestation units do not annihilate. Matter/energy only flows within the closed loop without disappearing, meeting the survival realm baseline.

5.2.2 Safety Realm ($\mathcal{C}_{\mathbf{3R}}^{\mathbf{safe}} < 1$) The density of manifestation units inside black holes satisfies $\nabla \cdot \mathbf{J} < \rho_{\max}$ (where $\rho_{\max}$ is the cosmic manifestation unit density upper limit). Waves show no disorder and no uncontrolled energy diffusion, meeting safety realm constraints.

5.2.3 Performance Realm ($\mathcal{C}_{\mathbf{3R}}^{\mathbf{per}} = \frac{1}{2}$) The resonance intensity inside black holes $\Gamma = \langle \mathcal{R}_{\mu\nu\rho\sigma} \rangle$ and its ratio to manifestation unit density $\frac{\Gamma}{|\Psi_{\text{BH}}|^2}$ takes the minimum value when $\text{Re}(s) = \frac{1}{2}$, achieving optimal performance realm convergence.

6. Theoretical Verification (Observational Data Adaptation)

6.1 Black Hole Horizon Radius Verification

For the M87 black hole (mass $M \approx 6.5 \times 10^9 M_\odot$), the Schwarzschild radius $r_s \approx 1.93 \times 10^{13}$ m. The 2019 EHT imaging horizon size matches the calculation from equation (1), verifying the correctness of the topological critical radius.

6.2 Hawking Radiation Verification

For small black holes ($M \approx 10^{12}$ kg), the Hawking radiation temperature $T_H \approx 10^{11}$ K and energy release rate match the predictions of equation (6), confirming the physical validity of the wave release mechanism.

6.3 Singularity Convergence Verification

At black hole singularities, the resonance tensor $\mathcal{R}_{\mu\nu\rho\sigma}$ cancels the divergent Ricci tensor $R_{\mu\nu}$, keeping curvature finite. This resolves the singularity dilemma of general relativity and aligns with the unified logic of topological waves.

7. Conclusion

This paper constructs a black hole topological-wave model that reduces black holes to "high-dimensional resonance extreme regions + topological closed-loop forced convergence bodies." Through "Three-Same Three-Realm" constrained modeling, we revise traditional singularity concepts and explain the origin of Hawking radiation. The study confirms that black holes fully satisfy the core axioms and performance boundary constraints of the *Zongyi Ningqi* framework, with their evolution laws being extreme manifestations of topological-wave actualization. Combined with observational data verification, this achieves an empirical closed loop for extreme spacetime object theory.

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Note: Figure translations are in progress. See original paper for figures.