Referee Report on "Black Holes at Exp-Time"

Edoardo Livolsi
Independent Researcher
(Dated: January 2026)

This report provides a critical assessment of the manuscript "Black Holes at Exp-Time". While the paper is presented as a contribution to quantum gravity and black hole physics, it does not introduce any generative dynamical principle, variational framework, or falsifiable physical prediction. The work consists primarily of a narrative reinterpretation of existing assumptions within holographic folklore. As such, it does not meet the standards required for publication as a physics article.

I. SUMMARY OF THE MANUSCRIPT

The manuscript discusses the long-time behavior of black hole interiors and argues that classical geometric descriptions break down at times of order $t \sim e^S$, where S is the black hole entropy. The argument is based on an assumed correspondence between the growth of quantum computational complexity and the growth of interior spacetime volume.

The paper does not derive any equations of motion, does not propose a microscopic dynamical model, and does not introduce any new physical observables.

II. MAJOR CONCEPTUAL DEFICIENCIES

A. Absence of a Generative Principle

The manuscript contains:

- no action or Lagrangian,
- no variational functional,
- no Euler–Lagrange equations,
- no microscopic degrees of freedom,
- no dynamical law generating spacetime geometry.

All conclusions are assumed rather than derived.

B. Conjectural Identification of Complexity and Geometry

The identification of black hole interior volume with quantum computational complexity is conjectural and not derived from any physical principle. No uniqueness or necessity is demonstrated.

C. Non-physical Nature of the Exp-Time Scale

The exponential time scale $t \sim e^S$ is not an operationally meaningful physical time and has no experimental interpretation.

D. Absence of Falsifiable Predictions

The manuscript provides no numerical predictions, no observable effects, and no tests. It therefore fails the criterion of scientific falsifiability.

III. RECOMMENDATION

REJECT

The manuscript does not meet the standards required for publication in a physics journal. It lacks a generative theoretical framework and contains no falsifiable physical content.

APPENDIX A: MATHEMATICAL DEMONSTRATION OF THE NON-PHYSICAL NATURE OF THE CLAIMS

In this Appendix we demonstrate explicitly that the central claims of the manuscript cannot be formulated, derived, or validated within any consistent mathematical framework of theoretical physics.

A. Absence of a Generating Functional

Any physical theory admitting spacetime dynamics must be derivable from a generating functional $F[\Phi]$ of the fundamental degrees of freedom Φ, such that the equations of motion follow from the stationarity condition

$$\frac{\delta F}{\delta \Phi(x)} = 0.$$

In the manuscript under review no functional $F[\Phi]$ is provided. Consequently:

- no equations of motion can be derived,
- no stability analysis can be performed,
- no notion of dynamical necessity exists.

All geometric statements are therefore postulated rather than generated.

B. Non-Existence of a Physical Complexity Operator

The manuscript treats "quantum complexity" as if it were a physical observable. However, no Hermitian operator $\hat{C}$ acting on a Hilbert space is defined such that

$$C = \langle \psi | \hat{C} | \psi \rangle.$$

Instead, the quantity referred to as complexity depends explicitly on arbitrary choices, including gate sets, cost functions, and reference states. Quantities depending on such choices are not invariant and therefore cannot correspond to physical observables.

C. Arbitrary Identification of Complexity with Geometry

The manuscript assumes an identification of the form

$$V_{\text{interior}}(t) \sim C(t),$$

where V_{interior} is a geometric volume and C denotes computational complexity.

No derivation is provided showing that both quantities arise from the same generating functional or satisfy the same variational extremum condition. Without such a derivation, the identification is mathematically unconstrained and physically meaningless.

D. Non-Operational Nature of the Exponential Time Scale

The exponential time scale

$$t_{\text{exp}} \sim e^{S}$$

is introduced as physically relevant. Here S denotes a thermodynamic entropy. However, the quantity t_{exp} is not associated with any observable clock, detector, or operational measurement procedure.

A quantity that cannot be operationally accessed cannot serve as a physical boundary for the validity of a theory. The claimed breakdown of geometry at this scale therefore has no physical meaning.

E. Failure of Falsifiability

A physical framework is meaningful only if it implies at least one falsifiable statement of the form

$$O_{\text{theory}} = O_{\text{measured}} \pm \delta O.$$

The manuscript provides no numerical predictions, no observable effects, and no experimental or observational tests. All statements remain qualitative and internally defined, rendering the framework immune to empirical refutation.

F. Conclusion of the Appendix

We conclude that the manuscript does not satisfy the minimal mathematical requirements for a physical theory. The claims regarding complexity, geometry, and long-time behavior of black holes are not derivable from any variational principle, do not correspond to well-defined physical observables, and cannot be falsified.

The identified issues are structural and cannot be resolved by clarification or minor revision.

APPENDIX B: DIRECT COMPARISON WITH A CLOSED VARIATIONAL FRAMEWORK

In this Appendix we provide a direct comparison between the framework adopted in the manuscript under review and a genuine closed variational scheme, in order to clarify the structural deficiencies identified in the main text.

A. Structure of a Closed Variational Theory

A closed variational theory is defined by the existence of a generating functional $F[\Phi]$ depending on a complete set of fundamental degrees of freedom Φ, such that all physical equations follow from the stationarity condition

$$\frac{\delta F}{\delta \Phi(x)} = 0.$$

In such a framework:

- the dynamical equations are uniquely determined,
- conserved quantities follow from symmetries via Noether identities,
- stability and consistency can be analyzed systematically,
- physical observables are unambiguously defined.

No additional postulates are required beyond the functional itself.

B. Absence of Variational Closure in the Manuscript

In the manuscript under review no functional $F[\Phi]$ is introduced. Consequently, none of the following elements are defined:

- fundamental degrees of freedom,
- equations of motion,
- symmetry structure,
- conserved quantities,
- variational stability conditions.

All geometric and dynamical statements are therefore external assumptions rather than logical consequences of a generating principle.

C. Emergence Versus Postulation

In a closed variational framework, quantities such as spacetime geometry, entropy, or characteristic time scales must emerge as solutions of the variational equations. Symbolically,

$$\Phi \longrightarrow \text{solutions} \longrightarrow \text{physical observables}.$$

In the manuscript, by contrast, the logical direction is reversed:

$$\text{assumed observables} \longrightarrow \text{narrative interpretation}.$$

This inversion replaces derivation with interpretation and removes predictive power.

D. Comparison of Time Scales

Within a variational framework, characteristic time scales must arise from the spectrum of the linearized equations of motion around a solution. Such scales are therefore intrinsic, physical, and in principle observable.

The exponential time scale $t_{\exp} \sim e^S$ introduced in the manuscript does not arise from any linear or nonlinear dynamical analysis. It is imposed externally and lacks a physical origin within a closed mathematical structure.

E. Predictive Power

A closed variational theory produces predictions of the schematic form

$$O_i = O_i(\text{parameters}),$$

which can be compared with observation or experiment.

The framework discussed in the manuscript produces no such relations. All conclusions remain qualitative and internally defined, precluding empirical validation or falsification.

F. Conclusion of the Comparison

The comparison demonstrates that the manuscript does not constitute a closed theoretical framework. It lacks a generating functional, fails to derive its central claims, and does not exhibit the minimal structural properties required of a physical theory.

By contrast, a genuine variational scheme provides necessity, predictability, and internal consistency. The absence of such a scheme in the manuscript is therefore not a minor omission but a fundamental deficiency.

REFEREE CONFIDENTIAL NOTE TO THE EDITOR

This manuscript should not be considered a scientific contribution to theoretical physics. Despite the reputation of the author, the work does not meet the minimal standards required for publication in a physics journal.

The manuscript contains no generating functional, no variational principle, no equations of motion, and no microscopic dynamical model. All central claims are asserted rather than derived. The work reorganizes existing folklore within the holographic community into a narrative framework, without producing new physics.

The identification between black hole interior geometry and quantum computational complexity is entirely conjectural and lacks any mathematical necessity. No uniqueness, invariance, or physical derivation is provided. Different choices of complexity measures would lead to inequivalent conclusions, undermining the universality of the claims.

The introduction of an exponential time scale $t_{\text{exp}} \sim e^S$ does not correspond to any operationally meaningful physical quantity. No observer, detector, or experimental protocol can access or measure this scale. As a result, statements about the "breakdown of geometry" at this time lack physical content.

The manuscript provides no falsifiable predictions, no numerical estimates, and no constraints on competing theories. Its conclusions are immune to experimental or observational refutation and therefore fall outside the domain of empirical science.

In its current form, the manuscript functions as a speculative conceptual essay rather than a physics article. The reliance on the author's authority and on established narrative themes should not substitute for mathematical derivation or physical predictability.

For these reasons, I strongly recommend rejection. Accepting this manuscript would lower the methodological standards of the journal by legitimizing speculative narrative in place of derivation, dynamics, and falsifiability.

Declaration of Authorship and Conceptual Integrity

This referee report, including all technical critiques and appendices, has been written independently by the undersigned author. The analysis reflects the author's own methodological standards for theoretical physics, based on closed variational principles, explicit mathematical derivations, and falsifiable physical content.

Any reproduction, citation, or reuse of this document must explicitly acknowledge its authorship and conceptual origin.

Edoardo Livolsi – Independent Researcher

ORCID: `https://orcid.org/0009-0009-1266-8204`