The Boundawall: A Proposal on the Nature of Black Holes

Javier Viaña[1]

[1]Department of Physics and Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Abstract

This research suggests a new interpretation of black holes in which the event horizon represents the termination of physical reality. In this view, when curvature approaches a critical threshold, the three-dimensional spatial geometry may undergo a dimensional compression into a two-dimensional manifold—the *boundawall*—that preserves gravitational continuity while preventing further causal evolution. Inside this surface, spacetime would cease to exist. All mass-energy and information would then be confined to the boundawall, forming a structure consistent with the external Schwarzschild geometry and the Bekenstein–Hawking entropy law. We outline a possible *Dimensional Conversion Law* that could govern this phenomenon, and discuss the conservation, causal, and thermodynamic implications of the boundawall. Finally, we comment on potential observational consistency and on limited predictions such as surface-mode signatures. In this theory, the event horizon is viewed not merely as a limit of observation, but as a potential boundary/wall of existence itself.

Keywords: Black holes; event horizon; dimensional transition; holographic scaling; gravitational entropy

1 Introduction

Black holes remain among the most profound predictions of Einstein's General Relativity (GR), combining the elegance of geometric simplicity with the challenge of physical incompleteness. Classical GR predicts that the endpoint of gravitational collapse is a spacetime singularity—a boundary where curvature invariants diverge and the manifold description fails [1, 2]. Such divergences are generally interpreted as indicators that the classical field theory has exceeded its domain of validity, demanding new geometric or quantum principles to describe the high-curvature regime.

A vast body of work has attempted to reconcile these inconsistencies, ranging from quantum-gravity inspired models [3–6] to string-theoretic microstate constructions [7, 8].

Yet all such efforts confront the same geometric challenge: how to remove the singularity while preserving the empirically verified exterior spacetime. The external Schwarzschild or Kerr geometries remain among the best-tested predictions of GR, confirmed through gravitational-wave ringdowns, black-hole shadows, and orbital dynamics [9–11]. Any viable modification must therefore reproduce these external metrics exactly, while addressing the breakdown of the manifold at the center.

In this work, we explore an alternative possibility: *that the interior of a black hole may never form at all.* Rather than concealing a hidden region beyond the event horizon, we propose that spacetime itself terminates once curvature exceeds a critical threshold. At this point, the collapsing three-dimensional (3D) geometry does not continue inward but undergoes a *dimensional compression*: space itself condenses into a continuous two-dimensional (2D) manifold, what we define as the *boundawall*. This surface represents a genuine geometric transition, not a material boundary or quantum correction, but a change in the very dimensional character of reality. All mass-energy and information become confined to this two-dimensional limit, beyond which spacetime and causal structure are no longer defined. In this view, black holes are not volumes of inaccessible space but terminal boundaries of existence, whose surfaces encode all mass-energy and information.

The proposal connects naturally to several established lines of research. The first is the holographic scaling of entropy. The Bekenstein–Hawking relation, $S = k_B A/4L_P^2$ [12, 13], implies that all information associated with a black hole scales with surface area rather than volume. This inspired the holographic principle [14–17], which suggests that the fundamental degrees of freedom of gravity may be encoded on lower-dimensional boundaries. The boundawall framework provides a geometric realization of this notion: the spatial volume does not merely conceal information, it no longer exists, leaving a two-dimensional surface as the sole physical carrier of the system's degrees of freedom.

A second connection arises with thin-shell and surface-layer formalisms. The boundawall can be formally described as a timelike hypersurface Σ embedded in an otherwise classical spacetime, similar to constructions in the Israel junction formalism [18, 19]. This perspective resonates with several horizon-scale alternatives such as *gravastars* [20, 21] and other compact surface or regularity-based models [22–24], where the interior is replaced by a de Sitter core and a thin shell of matter that matches to the external Schwarzschild geometry. In those models, collapse comes to a geometric limit through a transition between positive and negative pressure regions, avoiding both the singularity and the event horizon. However, such scenarios require specific matter equations of state and finely tuned shell properties to remain stable. By contrast, the boundawall does not rely on matter at all: it is a geometric termination of the manifold itself—a surface where spacetime ends rather than where matter accumulates. It thus provides a purely geometric mechanism that prevents further contraction, independent of any exotic energy conditions.

At the microscopic end of the theoretical spectrum, the *fuzzball* proposal in string theory [7, 8] replaces the classical interior with a vast ensemble of horizonless microstate geometries, each resolving the singularity at the Planck scale. In this framework, the horizon arises only as a coarse-grained statistical description over an exponential number of smooth configurations of compact extra dimensions and string excitations. Fuzzballs eliminate the singularity by appealing to a microscopic structure; the boundawall offers a complementary, macroscopic view: the interior disappears not because of hidden microstates, but because spacetime itself undergoes a curvature-driven loss of dimensionality. While both ideas

confine information to a surface and preserve external consistency with GR, the boundawall treats the horizon as an actual end of spacetime rather than an emergent statistical average. Other microscopic perspectives, such as the quantum N-portrait [25], likewise aim to replace the classical interior with quantum structure, but differ in mechanism and ontology.

Related in spirit, but physically distinct, are the *firewall* proposals [26–28] that posit a breakdown of quantum entanglement at or near the event horizon. In firewall scenarios, infalling observers encounter a high-energy barrier that disrupts smooth horizon crossing, resolving the information paradox through quantum-mechanical nonlocality. Yet even here, spacetime continues beyond the firewall; it is the quantum state, not the manifold, that is discontinuous. The boundawall, in contrast, represents an end to spacetime itself, not a modification of the local quantum field.

Another approach to singularity resolution arises in *Planck star* models [4, 29, 30], where quantum-gravity pressure arrests collapse at Planck density and triggers a subsequent expansion or bounce. In those models, the black hole interior survives as a high-density core that eventually tunnels into a white hole. The boundawall departs sharply from this picture: no bounce, interior, or continued evolution is assumed.

Finally, the conceptual origin of the boundawall aligns with emergent-spacetime and dimensional-reduction frameworks, where the effective dimensionality of spacetime varies with curvature or energy scale [31–33]. The boundawall can be viewed as a macroscopic manifestation of this phenomenon: when curvature exceeds a critical value $\mathcal{R}_c$, the effective dimensionality reduces from three to two, conserving total information while preventing further geometric evolution.

Taken together, these diverse frameworks—from holography to gravastars, fuzzballs, firewalls, and Planck stars—share a common motivation: to replace the classical singularity with a finite, information-preserving structure. Yet they differ fundamentally in their mechanisms. Gravastars rely on exotic matter; fuzzballs on microscopic string geometries; firewalls on quantum entanglement breakdown; and Planck stars on quantum gravitational pressure. In contrast, the boundawall introduces no new matter content, quantum degrees of freedom, or exotic equations of state. It is a purely geometric proposal: a curvature-triggered termination of spacetime in which the interior manifold never forms.

To the author's knowledge, no existing framework describes a curvature-driven end of reality in which the manifold itself ceases to exist and all physical quantities are confined to a two-dimensional boundary. The boundawall hypothesis therefore represents a novel and conservative geometric alternative to both matter-supported and microstate-based models—one that preserves all known exterior predictions of General Relativity while replacing the unobservable interior with a causally complete, information-conserving boundary: the possible geometric endpoint of reality.

2 The Boundawall

2.1 Theory overview

This research proposes that beyond a critical curvature, the gravitational collapse of a mass reaches its geometric limit and can no longer continue inward; as a result, the

singularity never forms. Instead, the spatial region that the mass occupies undergoes a geometric transition: the three-dimensional manifold is compressed into a continuous two-dimensional surface— what we define as the *boundawall*. This surface forms precisely at the locus where the spacetime curvature attains its critical value. From the exterior perspective, one could think of this process as the emergence of a bubble that grows outward, enclosing and absorbing the collapsing mass as the curvature approaches this limit. All mass-energy and information that would otherwise reside within the interior become confined to this surface, consistent with the Bekenstein–Hawking area law [12, 13]. The boundawall therefore represents a curvature-driven end of reality: a conversion of volume into area that terminates spacetime precisely at the critical curvature.

2.2 Reality and non-reality

We define Reality (R) as the region where a Lorentzian metric exists and supports causal propagation. On the contrary, Non-reality (NR) denotes the absence of manifold structure; no distances, durations, or fields are defined. The boundawall Σ is the interface between R and NR.

2.3 Induced geometry on the boundawall

Let $(M, g_{\mu\nu})$ denote the four-dimensional external spacetime. The boundawall Σ is described as a three-dimensional timelike hypersurface—a worldtube tracing the evolving boundary between reality and non-reality—embedded in M. It admits a single unit spacelike normal vector n^μ, with $n_\mu n^\mu = +1$. The geometry intrinsic to Σ is obtained by projecting the spacetime metric orthogonally to n^μ, while its bending within the ambient spacetime is determined by the variation of the normal along tangential directions:

$$h_{\mu\nu} = g_{\mu\nu} - n_\mu n_\nu, \qquad K_{\mu\nu} = h_\mu{}^\alpha h_\nu{}^\beta \nabla_\alpha n_\beta. \tag{1}$$

Formally, these relations are identical to those defining any timelike hypersurface, such as the surface of a planet or star. However, in this case the ambient spacetime exists only on one side of Σ: the interior corresponds to non-reality, where the manifold itself terminates. The normal vector therefore points toward a region where spacetime is non-existent, and the quantities $h_{\mu\nu}$ and $K_{\mu\nu}$ are defined solely from the exterior. Unlike an ordinary surface with interior and exterior curvatures to match, the boundawall is a one-sided geometric termination of reality. Together, $h_{\mu\nu}$ and $K_{\mu\nu}$ capture both the intrinsic structure of this boundary and its embedding within the external region of spacetime.

2.4 Operational meaning

A local observer can *probe* Σ only from the exterior. All physical measurements (clocks, rods, fields) terminate at Σ. No continuation of geodesics into NR is defined; thus, no boundary conditions need be specified "inside." This is consistent with the view that the theory should be restricted to quantities that are operationally definable. In essence, the three-dimensional volume has been replaced by a two-dimensional surface where all the measurable structures reside.

3 Dimensional Conversion Law: Content and Consequences

3.1 Statement of the law

When the curvature of spacetime grows beyond a critical threshold, the three-dimensional manifold undergoes a conversion into a two-dimensional surface; such a process must obey a corresponding conservation principle, otherwise it would entail the creation or destruction of space as the black hole expands or contracts. We therefore postulate that the transition between 3D and 2D reality obeys a conservation law for spatial capacity. In this picture, spatial volume is not lost but re-expressed as surface area when the curvature reaches a critical value, and can revert if the boundawall shrinks. Formally, this can be written as a curvature-driven map

$$V_{3D} \xrightarrow{\mathcal{R}\geq\mathcal{R}_c} A_{2D}, \tag{2}$$

where $\mathcal{R}$ is a scalar curvature measure and $\mathcal{R}_c$ the critical threshold. The map should conserve a global spatial capacity $\mathcal{C}$:

$$\mathcal{C} = \int_R dV_{3D} + \int_\Sigma f(\mathcal{R})\, dA_{2D} = \text{const.} \tag{3}$$

Here $f(\mathcal{R})$ converts 3D capacity to 2D capacity as curvature rises.

The function $f(\mathcal{R})$ acts as a geometric conversion factor between three-dimensional volume and two-dimensional area once the curvature exceeds the critical threshold $\mathcal{R}_c$. Before this point, f has no physical meaning, as no dimensional conversion has yet begun. Once the boundawall forms at $\mathcal{R} = \mathcal{R}_c$, f becomes a continuous and well-defined function of curvature, describing how spatial capacity is redistributed across the surface. In a spherically symmetric case such as the Schwarzschild black hole, f scales with the curvature radius ($f \propto R$), expressing the relation between volume and area once the manifold collapses into a sphere. In short, f characterizes the post-threshold regime-where the three-dimensional manifold admits no further extension and is re-expressed as a two-dimensional boundary of reality.

3.2 Minimal consistency checks

Any geometric reinterpretation of black holes must remain compatible with well-tested exterior physics and with the causal structure of General Relativity. To ensure this, two minimal consistency requirements must be satisfied.

1. **Exterior invariance.** The external spacetime must remain effectively indistinguishable from the classical Schwarzschild or Kerr solution. The proposed dimensional conversion occurs only at or inside the boundawall Σ, and does not alter the vacuum Einstein equations in the exterior domain R. All observables derived from the metric outside Σ—including light deflection, orbital precession, redshift, and gravitational-wave emission—therefore coincide with those predicted by standard General Relativity to within current experimental precision. In this sense, the boundawall represents an inner geometric modification that leaves the external gravitational field intact.

2. **Causal completeness.** The spacetime must remain globally causal, with all timelike and null geodesics terminating at a well-defined boundary rather than encountering a singularity. In the present framework, no geodesic can extend into the non-reality region, because beyond Σ there is no manifold on which the geodesic equations could be defined. In conformal diagrams, the classical spacelike singularity is therefore replaced by a terminal surface Σ that marks the end of causal propagation. From the perspective of any external observer, infalling matter asymptotically approaches Σ but never evolves beyond it in proper time. This ensures that the theory remains causally closed and free from incomplete trajectories or undefined boundary conditions.

Together, these two conditions guarantee that the dimensional conversion model is both observationally conservative and causally well-posed. The boundawall modifies only the inaccessible interior geometry while preserving the empirical and mathematical structure of General Relativity in all observable domains.

3.3 Local picture near the threshold

Near $\mathcal{R}_c$ the lapse between exterior proper time and boundawall proper time grows without bound; thus, from the exterior, collapse asymptotically approaches Σ. The conversion (2) is then not an abrupt "tearing" but a geometric reallocation of degrees of freedom onto the surface as the interior capacity is exhausted.

4 Entropy, Information, and Conservation

4.1 Area law as a consequence of confinement

If all microstates reside on Σ, the number of accessible configurations N scales exponentially with its area rather than with the enclosed volume. In this view, the Bekenstein–Hawking relation,

$$S_{\mathrm{BH}} = \frac{k_B A_\Sigma}{4L_P^2}, \tag{4}$$

emerges naturally as the entropy of the boundawall. This scaling is not postulated but arises as the only consistent measure of information for a system whose physical degrees of freedom are confined to a two-dimensional manifold of finite information density.

This perspective provides a geometric reconciliation of the long-standing entropy puzzle of black holes. In conventional matter, entropy scales with volume because microscopic configurations occupy a three-dimensional domain. By contrast, the entropy of a black hole scales with surface area, an apparent anomaly if one assumes the mass-energy is distributed throughout an interior volume. Within the present framework, this anomaly disappears: the mass and information content are both confined to the boundawall itself. The black hole is therefore a genuinely superficial object, and its entropy–area proportionality follows directly from its dimensional nature rather than from any statistical coincidence.

The area law can thus be interpreted as a manifestation of the dimensional conversion process: when curvature exceeds the critical threshold, the spatial manifold that would

have supported volumetric degrees of freedom collapses into a two-dimensional carrier of information. Entropy then quantifies the number of distinguishable microstates available on this surface, fully determined by its area and by the Planck-scale limit on information density. In this sense, the area scaling of black-hole entropy is not mysterious but a geometric signature of reality being reduced from three to two dimensions at the boundawall.

4.2 Information conservation in conversion

Let ρ_I denote the information density within three-dimensional reality and σ_I the corresponding surface density on the boundawall Σ. During the dimensional conversion, all information that was previously encoded in the bulk is transferred onto the two-dimensional surface. Conservation of information is therefore expressed as

$$\int_R \rho_I \, dV_{3D} = \int_\Sigma \sigma_I \, dA_{2D}. \tag{5}$$

This relation ensures that the total informational content of the system is preserved even though its geometric support has changed from a volume to an area.

In this framework, information is not destroyed or radiated into a hidden region but is geometrically re-encoded on the boundawall. The apparent loss of information inside the event horizon is a consequence of the disappearance of the manifold itself rather than a violation of unitarity. Once the interior is no longer part of physical reality, there is simply no domain in which information could be lost; it is instead carried and preserved on the two-dimensional surface that replaces it [28, 34]. This perspective provides a geometric resolution to the black-hole information problem without the need to specify microscopic dynamics beyond the surface.

From an informational standpoint, the boundawall acts as a perfect ledger of the system's past: every degree of freedom that would have entered the interior is re-expressed as a configuration of the surface. The process conserves total information while changing only the dimensional form of its representation—from a distributed three-dimensional encoding to a confined two-dimensional one.

5 Causality and the "End of Reality"

5.1 Geodesic termination

The geodesic equations are defined only for the exterior manifold R, and their maximal extensions end at the boundawall Σ. Beyond this surface, no manifold exists on which further evolution could take place; proper time and causal structure both terminate there. In this sense, Σ serves as a terminal surface for all causal curves, removing the classical singularity while preserving the principle of strong cosmic censorship: no observer encounters an ill-defined or incomplete evolution within spacetime itself.

5.2 Penrose diagram (descriptive)

In conformal representation, the classical spacelike singularity of a Schwarzschild black hole is replaced by a terminal boundary segment labeled Σ, which is null or nearly null in the stationary limit. Ingoing null rays asymptotically approach this surface but never extend beyond it, since the region inside corresponds to non-reality. The external causal structure—horizons, light cones, and asymptotic infinity—remains identical to that of the Schwarzschild or Kerr solution. Only the unobservable interior is modified, replaced by a well-defined boundary where spacetime itself terminates.

6 Limitations and Clarifications

6.1 Compatibility with external tests

All classical exterior tests (light bending, perihelion precession, shadow diameter, ringdown frequencies to leading order) are unaffected at current precision, as the exterior geometry is unchanged. The proposal is therefore observationally conservative.

6.2 What this model does not claim

We do not propose a microphysical substrate, quantize gravity, or offer a complete action principle. We avoid speculating about cosmology or multiverse extensions. Our aim is geometric clarity: define the boundary, articulate conservation and causality, and prove that a surface description suffices to remove singularities while preserving exterior physics.

6.3 Model dependence and open parameters

The precise functional form of $f(\mathcal{R})$ remains open. It may eventually be constrained by a more fundamental theory or by observational data. Our conclusions about dimensional conversion, information confinement, and causal termination are robust to these details.

7 Conclusions

We have developed a framework in which the event horizon is reinterpreted as a terminal boundary of existence rather than a gateway to an interior. At a critical curvature, spatial dimensionality is compressed: the three-dimensional manifold collapses into a two-dimensional *boundawall* that confines all mass-energy and information. This surface upholds the Bekenstein-Hawking area law naturally, replaces the singularity with a causal termination, yielding a self-sustained thin-shell black hole whose geometry requires no internal support, and leaves the external Schwarzschild geometry intact. The resulting model is conservative in its empirical predictions yet conceptually radical: it preserves causality and information without invoking hidden interiors, firewalls, or exotic matter. Instead, it treats the disappearance of the manifold as a geometric transition governed by a proposed *Dimensional Conversion Law*. By reframing black holes as the points where

spacetime itself ceases to exist, this approach offers a unifying geometric explanation for entropy scaling, information confinement, and cosmic censorship. It provides a coherent and testable conceptual foundation for future studies seeking to link classical relativity, holography, and emergent spacetime ideas through the geometry of dimensional termination.

Acknowledgements

The author thanks the theoretical physics community for discussions that emphasize clarity, consistency, and operational meaning in high-curvature regimes.

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A Notation and symbols

$g_{\mu\nu}$: exterior metric; $h_{\mu\nu}$: induced metric on Σ; $K_{\mu\nu}$: extrinsic curvature; σ: surface mass density; p: tangential pressure; A: area of Σ; L_P: Planck length; $\mathcal{R}$: curvature scalar used in the threshold; $\mathcal{R}_c$: critical curvature threshold.