Revisiting Verlinde's Entropic Gravity: Correct — but in a other Direction?

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Abstract

We revisit Verlinde's entropic gravity by reversing its conceptual direction. Instead of deriving gravity from entropy gradients on a holographic screen, we interpret the screen as the thermodynamic projection of a field Φ — an event horizon interface where quantum information becomes classically readable [1]. No entropic force is required; gravity appears as a thermodynamic imprint of informational asymmetry.

Building on the Unruh effect and the behavior of self-heating systems in free fall, we identify the central peak of Φ as an informational event horizon: a region of entropy-neutral superposition, where quantum states remain undecided until an entropy gradient emerges. Projection is not driven by decoherence, but by thermodynamic symmetry breaking. Verlinde's force law remains valid in form, but becomes a diagnostic expression of projection — not its cause.

Our framework aligns naturally with entropic quantum gravity (EQG) models such as Bianconi's, in which geometry and time emerge from information constraints. The EH field Φ offers a classical realization of this idea, embedding quantum information and thermodynamic projection within a dual AdS/dS geometry. Rather than replacing Verlinde's insight, we unfold its deeper structure — from coherence to curvature.

1 Introduction

Can gravity be interpreted not as a fundamental interaction, but as a thermodynamic signature of information flow? This question, raised by Verlinde [2], sparked widespread interest in connecting entropy, geometry, and quantum information. His approach derives Newton's law from entropy gradients on a holographic screen, combining acceleration, Unruh temperature, and an information-based interpretation of mass. Yet the physical nature of the screen — and the meaning of the "bits" it stores — remained elusive.

In a previous work [3], we examined Verlinde's construction from a purely classical perspective. Using the example of a freely falling system with negative heat capacity — such as a compact thermometer in an elevator — we showed that self-heating arises from energy balance alone. This mechanism reproduces the formal structure of Newtonian gravity without invoking microscopic degrees of freedom or entropic forces. The result suggests a classical bridge between gravity and thermodynamics, grounded in entropy flow and temperature response.

In this paper, we build on that idea and propose a conceptual inversion of Verlinde's logic. Rather than deriving gravity from entropy, we interpret gravitational phenomena as the thermodynamic projection of quantum information. We introduce the notion of an event horizon field Φ, separating two geometric regimes — typically AdS and dS — and defining a landscape across which projection becomes physically meaningful.

This perspective reverses Verlinde's direction: the screen is no longer the source of gravity, but the surface where superposition is broken. Information becomes measurable through projection — and entropy appears not as a force generator, but as a condition for classicality. Our framework provides a thermodynamically consistent description of this transition and situates it within a dual-holographic AdS/dS geometry.

In the following sections, we outline this reinterpretation in detail. We revisit Verlinde's derivation, embed it in the field Φ, identify the central entropy peak as an informational horizon, and link this to the structure of entropic quantum gravity (EQG). The transition from quantum coherence to classical curvature — from "unbestimmt" to "bestimmt" — becomes the guiding principle of the geometry.

2 Verlinde and the Entropic Force: A Quantum-Compatible Interpretation

Verlinde's original argument [2] does not derive gravity from microscopic principles — it demonstrates that gravity is formally compatible with thermodynamic reasoning and quantum information. Starting from a holographic screen that encodes N bits of information, proportional to the screen area A in Planck units,

$$N = \frac{A}{\ell_P^2},$$

he assumes an equipartition of energy among these degrees of freedom. Each bit carries $\frac{1}{2}k_B T$ of energy, yielding a total energy

$$E = \frac{1}{2} N k_B T.$$

Combined with the Unruh temperature and $E = Mc^2$, this leads to Newton's law [2]:

$$F = G\frac{Mm}{r^2}.$$

This derivation is formally elegant but conceptually subtle. No assumptions are made about the physical nature of the bits, or about the internal structure of the screen. The result does not imply that gravity *emerges* from information — only that gravitational behavior is consistent with a thermodynamic information framework.

In this light, Verlinde's screen is better understood as a coarse-grained interface: a thermodynamic boundary where information becomes readable. The entropic force $F = T\,\frac{dS}{dR}$ expresses how entropy gradients manifest macroscopically — but it does not prescribe a microscopic cause.

This opens the possibility to reverse the logic. Instead of asking how entropy generates gravity, we ask: what does gravity tell us about entropy and projection? What if the screen is not a source of force, but a signature of thermodynamic transition? In this case, Verlinde's bit is not a primitive unit of geometry — it is the marker of a quantum state being projected. Gravity is not emergent, but indicative: it reflects that information has become classical.

In the next section, we develop this reversal explicitly, interpreting Verlinde's screen not as origin, but as outcome — not as microstructure, but as thermodynamic manifestation.

3 Reversing Verlinde: From Force to Projection

If Verlinde's derivation demonstrates that gravitational dynamics are compatible with information-theoretic reasoning, then the causal chain can be inverted. Rather than viewing entropy gradients as the source of gravity, we propose to interpret gravity as the macroscopic imprint of information becoming projectable.

In this reinterpretation, the screen is not a storage surface — it is a thermodynamic interface. A system near the screen does not accelerate because it seeks entropy. It accelerates because its thermodynamic configuration aligns with a pre-existing entropy gradient. When no such gradient exists, no motion occurs — and no projection is favored.

To make this precise, we introduce a scalar field Φ, the *event horizon field*, which defines a thermodynamic landscape across an interface between two geometric domains [1]: typically an AdS-like interior and a dS-like exterior. This field is not postulated as a microscopic construct, but as a coarse-grained projection field that determines where and how entropy gradients manifest.

In this picture, Verlinde's entropic force

$$F = T\frac{dS}{dR}$$

is no longer the mechanism that generates motion — it is the diagnostic signature that a projection has occurred. Force does not create gravity; projection produces thermodynamic asymmetry, which *appears* as gravity to the observer.

This shift in interpretation also reframes the meaning of Verlinde's bits. They are not fundamental constituents of space. They are markers — outcomes of a thermodynamic selection process in the presence of Φ. The bit is not a cause of curvature, but its informational residue.

The next section introduces the field Φ in its geometric context, illustrating how its structure encodes thermodynamic neutrality and directional entropy flow — culminating in the identification of its central peak as an informational event horizon.

4 The EH Field in AdS/dS Geometry

The event horizon field Φ, first described by A. Schubert (2025) [1], acts as an interface between two complementary geometric domains: a stable AdS-like interior and an expanding dS-like exterior. These domains differ not only in curvature, but in thermodynamic behavior — particularly in entropy content, temperature profile, and heat capacity.

The field Φ interpolates between these regimes, forming a thermodynamic potential landscape that governs projection. Its structure can be visualized as an entropic potential with a central saddle point — the region of maximal symmetry and minimal directional bias.

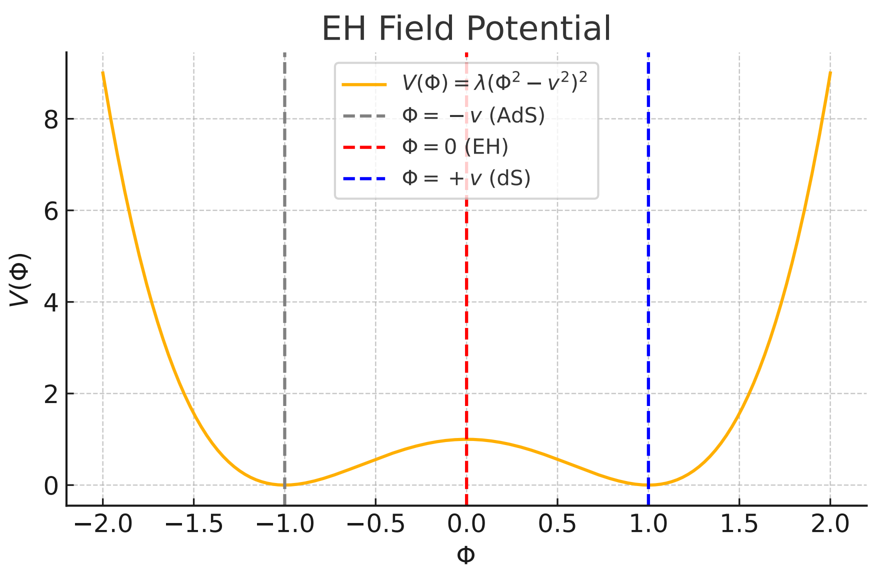

Figure 1: Entropy potential associated with the event horizon field Φ. The central saddle represents a region of thermodynamic neutrality, where no entropy gradient exists and no projection is favored. Projection occurs only when asymmetry arises, guiding the system into either the AdS or dS domain.

At the center of this potential, the entropy gradient vanishes:

$$\frac{dS}{dR} = 0, \quad T \text{ undefined}, \quad F = 0.$$

This is the projective equilibrium: a zone where quantum information can remain in superposition, unconstrained by classical directionality or thermodynamic pressure. The system experiences no net force — not because it is at rest, but because it is undecided.

This configuration is not merely conceptual. A detailed formulation of the EH field within a dual AdS/dS geometry — including matching conditions, thermodynamic stability, and entropy gradients — is developed in [1]. The present paper focuses on the interpretational structure: how Φ defines the conditions under which projection becomes measurable.

In the next section, we explore this central region as an *informational event horizon*, connecting the neutrality of entropy gradients to quantum superposition and classical measurement.

5 The Informational Event Horizon: Two Faces of Entropy

At the center of the EH field Φ, the entropy gradient vanishes. No force is experienced, and no projection is favored. This point of thermodynamic neutrality defines a projective equilibrium: a state where quantum information remains suspended — not collapsed, not localized, not classically measurable.

To understand this condition, we distinguish between two perspectives on entropy:

- **Structural entropy:** The von Neumann entropy $S = 0$ of a pure quantum state, such as $|\psi\rangle = \frac{1}{\sqrt{2}}(|\uparrow\rangle + |\downarrow\rangle)$. This entropy reflects internal coherence and informational symmetry.
- **Projective entropy:** The Shannon entropy $S = 1$ associated with the outcome probabilities of a measurement. This reflects classical uncertainty over mutually exclusive results.

At the entropy-neutral saddle of Φ, both views coexist. The system is structurally pure, yet poised for projection. Only when an entropy gradient develops — due to fluctuation, boundary condition, or interaction — does the system resolve into a measurable outcome. This transition from superposition to classicality defines the function of the informational horizon.

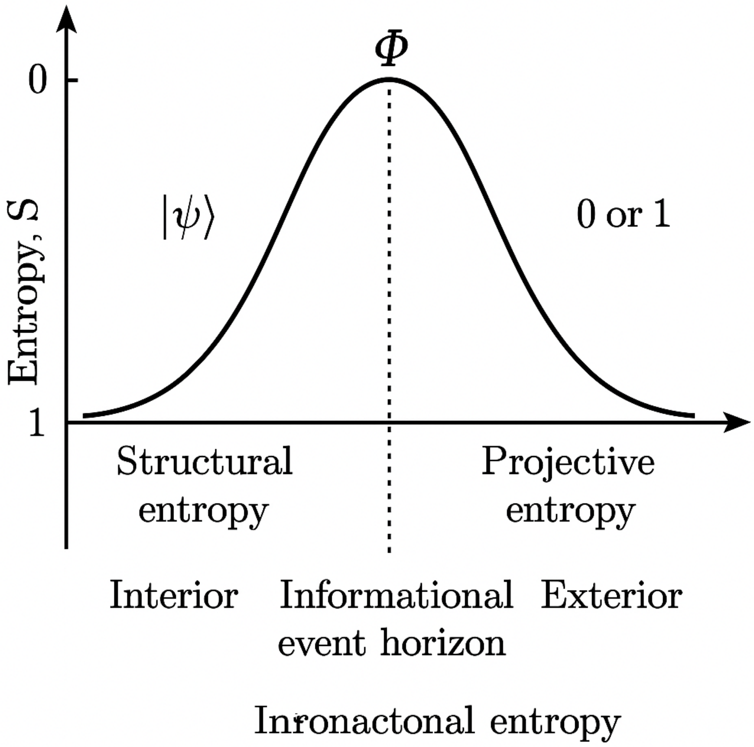

Figure 2: Informational event horizon realized by the EH field Φ. A quantum state (center) rests in superposition at the entropy saddle. No projection occurs unless an entropic asymmetry emerges. Once present, the information flows into either the AdS or dS domain, producing classical observables. The figure illustrates the transition from coherent structure (S = 0) to projected uncertainty (S = 1).

This dynamic mirrors the essence of the uncertainty principle — not in terms of position and momentum, but in terms of informational locality and thermodynamic directionality. A system at the saddle is "nowhere" and "everywhere" until it chooses — or is chosen — by the field.

Such behavior is consistent with entropic quantum gravity models, notably Bianconi's [4, 5], in which geometry arises from statistical transitions within information networks. In our setting, Φ provides a macroscopic realization of this idea — a continuous projection field that governs where information becomes classical. Projection is not a collapse — it is a thermodynamic transition.

We may thus read Verlinde's bit not as a unit of spacetime, but as a thermodynamic boundary condition: the sign that a decision has occurred, that information has passed from informational superposition to measurable outcome

Thermodynamic Analogy to Quantum Uncertainty. The entropy-neutral saddle of the EH field Φ structurally mirrors the logic of the Heisenberg uncertainty principle. In quantum mechanics, a system cannot simultaneously possess definite position and momentum — its state is spread across complementary observables. Here, we observe a similar relation: a state at the entropy saddle is neither thermodynamically localized (no dS/dR) nor informationally projected. The absence of directional entropy flow renders both "informational position" and "entropic motion" undefined. The field Φ thus hosts the thermodynamic analogue of uncertainty — not as a measurement limit, but as a natural equilibrium preceding projection.

6 Conclusion: From Coherence to Curvature

We have revisited Verlinde's entropic gravity by inverting its logical direction. Instead of treating entropy as the origin of gravitational force, we interpret gravitational phenomena as signatures of thermodynamic projection — where quantum information becomes classically measurable through the structure of an event horizon field Φ.

This reinterpretation reframes the holographic screen not as a microscopic source of gravity, but as a macroscopic expression of informational transition. The EH field defines a thermodynamic landscape in which entropy gradients emerge or vanish, and with them the possibility of measurement. When the entropy gradient is zero, the system rests in a state of coherence — unprojected, undecided. When asymmetry arises, projection occurs, and information becomes geometrically expressed.

Verlinde's bit is thus not a fundamental unit of spacetime, but a marker of thermodynamic finality: the decision point at which quantum uncertainty gives way to classical observability. What appears as gravity is the thermodynamic residue of this informational asymmetry.

Our framework aligns naturally with entropic quantum gravity approaches such as Bianconi's, in which geometry, time, and causal structure arise from statistical transitions within informational networks. The EH field Φ provides a classical, field-based realization of this idea — without requiring a commitment to microscopic structure or discrete substrates.

Ultimately, we show that Verlinde's entropic logic not only survives reversal — it deepens. What he demonstrated is not how gravity arises, but that quantum information and spacetime geometry are formally compatible. We extend this compatibility into a field-theoretic picture, where thermodynamic equilibrium and projection define the boundary between coherence and curvature — from "unbestimmt" to "bestimmt."

Outlook

The interpretation proposed here offers a bridge between three complementary approaches to the nature of gravity and information: Verlinde's thermodynamic formalism, Bianconi's entropic quantum geometry (EQG), and our own dual-holographic AdS/dS-CFT model. Each of these frameworks highlights a different facet of a deeper structure — projection, emergence, or duality — yet all converge on the insight that geometry is not fundamental, but informational.

Verlinde's original argument shows that quantum information and classical gravity are formally compatible — even without assuming a microstructure. EQG proposes that geometry arises from entropic relations within evolving networks. Our AdS/dS approach embeds both aspects within a field-theoretic description, where the EH field Φ acts as the projective medium through which curvature and entropy become visible.

Future work may focus on how these perspectives intersect. Can the symmetry-breaking mechanisms of Φ be mapped to entropic transitions in EQG networks? Could Verlinde's bit be understood as the boundary marker between network states and thermodynamic observables? And does the AdS/dS structure merely encode geometry — or also the process of informational decision?

These questions point beyond classical reasoning, yet arise naturally from thermodynamic foundations. By viewing projection, not force, as the operative principle behind gravity, we may discover that coherence and curvature are not opposites — but two faces of the same informational geometry.

References

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