Einstein and Jacobson in the Elevator:
A Thermodynamic View of Gravity Without Geometry

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Abstract

We present a classical thermodynamic model of gravity based on the concept of negative heat capacity. By treating a freely falling system as an entropically active object, we show that gravitational acceleration emerges as a macroscopic entropy gradient, induced by internal heating and driven by energy loss. Using a temperature field $T(R) = \frac{GM}{k_B R}$ and a logarithmic entropy function $S(R)$, we recover Newton's inverse-square law as a purely thermodynamic effect:

$$F = T(R) \cdot \frac{dS}{dR} = -\frac{GMm}{R^2}.$$

This model requires no curvature, no quantum fields, and no microscopic assumptions. It complements Jacobson's thermodynamic derivation and Verlinde's entropic gravity, but remains fully classical and accessible.

Placing this result into a broader framework, we propose that both gravity and quantum measurement reflect a deeper thermodynamic structure: the global tendency of the universe toward a normal (Gaussian) entropy distribution. While spacetime geometry expands toward equilibrium ($dS \to 0$), localized quantum information follows the opposite direction — toward entropy increase ($dS \to 1$).

Gravitation, motion, and measurement may thus be unified under a single principle: projection into the thermodynamic structure of a Gaussian universe.

1 Introduction — *Jacobson and Einstein in the Elevator*

Einstein's elevator is one of the most iconic thought experiments in physics. An observer in a sealed elevator cannot distinguish whether they are experiencing gravitational attraction or constant acceleration. This led to the formulation of the equivalence principle, the cornerstone of general relativity.

But what happens if we introduce thermodynamics into this scenario?

Ted Jacobson, in his 1995 work, proposed that Einstein's field equations could be derived from thermodynamic principles — specifically, from the relationship between energy flux, entropy, and the Unruh temperature experienced by accelerated observers. In this view, gravity is no longer fundamental but emerges from underlying statistical mechanics. This thermodynamic perspective is further enriched by works like Padmanabhan's exploration of gravity as an emergent phenomenon tied to spacetime thermodynamics [3], suggesting a broader statistical underpinning to gravitational interactions.

In this paper, we explore this idea in a purely classical setting, using the elevator not just as a geometric frame but as a thermodynamic laboratory. We focus on a simple system: a compact object (like a thermometer) freely falling in a gravitational field. While standard physics tells us that such a system experiences no local force, we ask a different question: does it undergo an internal thermodynamic response?

Surprisingly, if gravitational systems exhibit negative heat capacity — as observed in stellar clusters — then energy loss during free fall could lead to an *increase in internal temperature*. This classical heating effect, interpreted thermodynamically, can generate an *entropy gradient* that mimics gravitational attraction.

Our goal is to reframe gravitational acceleration as a *macroscopic entropic effect*, without invoking quantum fields, curvature, or holography. Instead, we derive Newton's inverse-square law from a temperature field and a logarithmic entropy function. The elevator becomes a tool not just for illustrating geometry, but for understanding gravity as a thermodynamic phenomenon.

2 Entropy and Equilibrium — Nature Seeks a Gaussian

In statistical mechanics, the concept of entropy plays a central role in determining the equilibrium state of a system. According to Jaynes' principle of maximum entropy, the most probable macroscopic configuration is the one that maximizes entropy under given constraints.

When only the mean and variance of a distribution are fixed, the entropy-maximizing probability distribution is the Gaussian:

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right).$$

This is not merely a mathematical convenience — it reflects a fundamental tendency of nature toward equilibrium. The Gaussian is the most unbiased, least informative distribution consistent with the given data.

In thermodynamics, this principle manifests in the tendency of isolated systems to evolve toward states of maximal entropy. In gravitational systems, this leads to configurations where energy, temperature, and entropy reach a stable distribution. For example, self-gravitating systems often exhibit entropy maxima that are nonuniform, concentrated around a central mass.

In our setting, the gravitational field generated by a point mass M defines a radial potential that shapes the entropy landscape of a falling test mass m. As the test mass approaches M, it loses potential energy — but in systems with negative heat capacity, this loss can be accompanied by an increase in internal temperature. The resulting entropy gradient may thus be viewed as a manifestation of nature's drive toward a Gaussian-like equilibrium.

At the center of this distribution — conceptually near the gravitational source — the entropy gradient vanishes:

$$\frac{dS}{dR} = 0.$$

This condition defines local thermodynamic equilibrium, where no net entropy flow occurs. It also marks the point of maximum probability in a statistical sense, analogous to the peak of a Gaussian.

Thus, the gravitational field can be interpreted as shaping a thermodynamic potential whose equilibrium form reflects the same logic as the normal distribution: maximal entropy under constraint. In this view, gravity is not just geometry — it is the statistical structure of equilibrium itself.

3 Negative Heat Capacity — Heating Up by Falling

In conventional thermodynamics, systems absorb heat to increase their temperature: positive heat capacity. However, gravitationally bound systems often exhibit the opposite behavior — they become hotter as they lose energy. This property is known as *negative heat capacity* and is a well-documented feature in astrophysical systems such as star clusters.

To see this, consider a self-gravitating system in virial equilibrium. According to the virial theorem, the total energy E satisfies:

$$2K + U = 0, \quad \Rightarrow \quad E = K + U = -K.$$

Assuming the kinetic energy is related to temperature via $K = \frac{3}{2}k_B T$, we find:

$$E = -\tfrac{3}{2}k_B T, \quad \Rightarrow \quad C = \frac{dE}{dT} = -\tfrac{3}{2}k_B < 0.$$

Thus, as the system loses energy ($\Delta E < 0$), its temperature *increases* ($\Delta T > 0$). This counterintuitive response is a hallmark of systems governed by long-range interactions, like gravity.

We now apply this concept to a much simpler system: a compact test mass m falling toward a central mass M. As m descends in the gravitational potential $\Phi(R) = -\frac{GM}{R}$, it loses potential energy:

$$\Delta U = -\Delta\Phi = \frac{GMm}{R} - \frac{GMm}{R_0} < 0.$$

In a system with effective negative heat capacity, this energy loss translates into a temperature increase:

$$\Delta T = \frac{\Delta U}{C} < 0 \quad \text{since } C < 0,$$

which yields $\Delta T > 0$. The falling object heats up.

This behavior aligns with Jacobson's thermodynamic framework, in which energy flux through a local horizon gives rise to entropy change via the relation:

$$\delta Q = T\, dS.$$

In our case, $\delta Q = -\Delta U$ represents the internalization of gravitational work into thermal energy. This reinforces the idea that gravity produces a thermodynamic response, even in the absence of microscopic structure.

The key point is this: energy loss in a gravitational field does not merely result in motion — it results in heating. This heating, in turn, generates an entropy gradient that will form the basis for deriving Newton's law in the next section.

4 The Temperature Field of Gravity

To model the thermodynamic response of a test mass in a gravitational field, we introduce a classical temperature field associated with the gravitational potential of a central mass M:

$$T(R) = \frac{GM}{k_B R}.$$

This field is not derived from quantum field theory or tied to the Unruh effect — it is a classical ansatz motivated by the idea that gravitational energy loss can manifest as internal heating in systems with negative heat capacity.

The structure of $T(R)$ reflects the inverse-square nature of the gravitational field. As the test mass m approaches the central mass M, the effective temperature increases, consistent with the energy drop $\Delta U = -\Delta\Phi$ and the corresponding temperature rise $\Delta T > 0$ discussed earlier.

While unconventional, this temperature field serves as a useful tool to describe how gravitational work may be internalized thermodynamically. It is analogous to the classical use of potential fields in electrostatics: not physically observable in isolation, but instrumental in calculating gradients and forces.

We emphasize that this $T(R)$ is not a radiation temperature, nor does it rely on quantum mechanics. It is defined operationally: if a compact thermometer falls freely toward M, and its internal temperature rises due to gravitational work, then $T(R)$ captures that rise as a function of position.

The functional form of $T(R)$ also ensures dimensional consistency with entropy gradients of the form $dS/dR \sim 1/R$. When combined, these quantities yield a force expression with the correct units and structure of Newton's law — as we will demonstrate in the next section.

Thus, the temperature field $T(R)$ provides a bridge between gravitational potential energy and thermodynamic response. It allows us to rephrase gravitational attraction as a classical entropy-driven process.

5 Entropy Gradient and the Gravitational Force

We now combine the temperature field introduced in the previous section with a classical entropy function to derive the gravitational force as an entropic effect.

Let us define the entropy S associated with a test mass m at a distance R from the central mass M as:

$$S(R) = k_B m \ln\left(\frac{R_0}{R}\right),$$

where R_0 is a reference distance (e.g., the initial or maximal radius), and $S \geq 0$ for $R \leq R_0$. This form ensures that entropy increases as the system moves closer to M, consistent with the heating effect discussed earlier.

The entropy gradient is then given by:

$$\frac{dS}{dR} = -\frac{k_B m}{R}.$$

Combining this with the temperature field $T(R) = \frac{GM}{k_B R}$ yields an entropic force via:

$$F = T(R) \cdot \frac{dS}{dR}.$$

Substituting both expressions:

$$F = \left(\frac{GM}{k_B R}\right) \cdot \left(-\frac{k_B m}{R}\right) = -\frac{GMm}{R^2}.$$

This result reproduces Newton's inverse-square law of gravitation:

$$F = -\frac{GMm}{R^2},$$

where the negative sign denotes attraction toward the mass M.

Importantly, this derivation is entirely classical. It does not rely on microscopic information storage, holographic screens, or quantum field effects. Instead, it interprets gravity as a thermodynamic consequence of energy flow and entropy gradients in a system with negative heat capacity.

The result also highlights the structural similarity between gravity and entropy-driven diffusion: both arise from gradients in thermodynamic potentials. In this case, the gravitational force emerges not from geometric curvature but from a classical tendency of the system to maximize entropy while conserving total energy.

In the next section, we will analyze this process dynamically by examining how entropy changes during free fall.

6 Entropy Flow in Free Fall

Up to this point, we have treated entropy and temperature as static functions of position. However, the free fall of a test mass m in a gravitational field is a dynamical process. To describe how entropy evolves over time, we consider the entropy flow:

$$\frac{dS}{dt} = \frac{dS}{dR} \cdot \frac{dR}{dt},$$

where $v = \frac{dR}{dt}$ is the radial velocity of the test mass.

Using the entropy gradient derived earlier,

$$\frac{dS}{dR} = -\frac{k_B m}{R},$$

we obtain:

$$\frac{dS}{dt} = -\frac{k_B m}{R} \cdot \frac{dR}{dt}.$$

For a freely falling object approaching the central mass, the radial velocity is negative ($\frac{dR}{dt} < 0$), so:

$$\frac{dS}{dt} > 0.$$

This result confirms that the entropy of the system increases during free fall — even in the absence of friction or external dissipation. The system is thermodynamically active simply due to the gravitational work done on it.

From a classical thermodynamic standpoint, this entropy production reflects an internal energy redistribution: as potential energy is converted into kinetic energy, the system's internal degrees of freedom respond by increasing temperature. If the system has negative heat capacity, the result is self-heating — as already discussed.

This dynamical formulation reinforces the idea that gravity induces an *entropic evolution* rather than a geometric deformation. The system accelerates because entropy increases along its path — not because spacetime tells it to move.

The elevator, in this view, becomes an entropy engine. It converts position-dependent gravitational work into thermal activity, governed by classical thermodynamic principles. The next section will compare this framework with other models of gravity, including Jacobson's thermodynamic derivation and Verlinde's entropic force.

7 Comparison with Other Models

The approach presented here is situated within a growing class of models that describe gravity not as a fundamental interaction, but as an emergent thermodynamic phenomenon. We now compare it to two closely related but conceptually distinct frameworks: Jacobson's derivation of Einstein's equations from local thermodynamics, and Verlinde's entropic gravity scenario based on holographic information.

Jacobson's Local Thermodynamics

In his seminal 1995 paper [2], Ted Jacobson showed that Einstein's field equations can be derived from a local application of the Clausius relation:

$$\delta Q = T\, dS,$$

applied to local Rindler horizons. In Jacobson's framework, gravity arises from the flow of energy across causal horizons, interpreted as heat. His model links spacetime geometry to thermodynamic response functions and implies that curvature is a statistical manifestation of microscopic degrees of freedom.

Our approach shares Jacobson's starting point — the thermodynamic identity — but simplifies the setting: we avoid microscopic assumptions, quantum fields, and local horizons. Instead, we focus on a compact test system in a gravitational potential and show that the classical behavior (i.e., Newton's law) follows from macroscopic thermodynamic principles alone, assuming negative heat capacity.

Verlinde's Entropic Gravity

Verlinde proposed in 2011 [1] that gravity arises from the entropic tendency of information encoded on holographic screens. When a test particle moves toward such a screen, its change in entropy generates a force:

$$F = T\, \frac{dS}{dx}.$$

This model introduces a microscopic informational layer and relies on the holographic principle, linking gravitational dynamics to changes in data representation on boundary surfaces.

In contrast, our framework is purely classical and does not require holography or information-theoretic assumptions. The entropy we use is macroscopic and continuous, associated with energy and temperature fields rather than discrete bits. Nevertheless, both models arrive at the same inverse-square force law — suggesting that the entropic picture may be more general than its specific realizations.

This Work: A Classical, Macroscopic Thermodynamic Model

What distinguishes our model is its minimalism: we assume no microscopic substructure, no curvature, and no quantum effects. We treat gravity as a macroscopic thermodynamic response in a system with negative heat capacity. The key idea is that energy loss leads to self-heating, which generates an entropy gradient. This gradient, when combined with a classical temperature field, yields a force law consistent with Newtonian gravity.

Specifically, we define a temperature field

$$T(R) = \frac{GM}{k_B R}$$

and an entropy function

$$S(R) = k_B m \ln\left(\frac{R_0}{R}\right),$$

from which the gravitational force arises as

$$F = T(R) \cdot \frac{dS}{dR} = -\frac{GMm}{R^2}.$$

This model may thus be viewed as a bridge between Jacobson's local thermodynamic gravity and Verlinde's entropic force scenario — offering a classical, accessible, and experimentally intuitive perspective on the same underlying principle.

8 Outlook — The Gaussian at the Heart of Reality

The model developed in this work began with a simple question: can gravity be understood as a purely classical thermodynamic effect? By considering a freely falling thermometer and invoking the notion of negative heat capacity, we showed that entropy gradients can reproduce the inverse-square law of Newtonian gravity — without invoking curvature, holography, or quantum fields.

But this classical picture fits into a larger conceptual framework that connects thermodynamics, information theory, and spacetime itself. In previous work [9], we proposed that both quantum measurement and gravitational interaction may emerge from a common structure: a dynamically active event horizon (EH) field Φ that encodes an entropic potential with a Gaussian profile.

This structure appears not only in cosmology [8], where the expansion of space can be interpreted as a thermodynamic smoothing process ($dS \to 0$), but also in quantum mechanics, where measurement outcomes align with statistically permitted ”channels” in a global entropy landscape.

In both contexts, the Gaussian distribution plays a central role:

- In thermodynamics, it represents the state of maximal entropy under minimal assumptions — a natural equilibrium configuration.
- In quantum theory, it defines the statistical background against which measurement projections are realized.
- In gravity, as shown here, it defines the shape of the entropy gradient that drives motion toward thermodynamic equilibrium.

This suggests a deeper principle: *the fundamental processes of nature — measurement, motion, and expansion — may all reflect a common statistical tendency toward entropic neutrality, modeled by the Gaussian form.*

Seen in this light, the elevator thought experiment is more than a teaching device. It is a window into the statistical structure of reality. Whether in the macroscopic heating of a falling system, the projection of quantum states, or the large-scale geometry of the universe, the same mathematical logic seems to reappear: the Gaussian, as nature's preferred distribution, governs what is probable, what is stable, and ultimately, what is real.

Future work may further explore this connection — for instance, by reformulating path integrals as entropic projection sums, or by identifying experimental systems in which entropic gradients and Gaussian structures visibly influence classical dynamics. If successful, such developments could unify the domains of thermodynamics, quantum theory, and gravity under a single statistical principle.

9 Discussion and Challenges

Our macroscopic exploration of entropic gravity provides an intuitive perspective on the equivalence principle, interpreting gravitational attraction as a thermodynamic effect driven by gravitational work and negative heat capacity ($C < 0$). This aligns conceptually with Jacobson's thermodynamic framework [2], where gravity emerges from energy and entropy dynamics, yet we pursue a fully classical path without quantum assumptions. Its strength lies in its accessibility: employing a temperature field $T = \frac{GM}{k_B R}$ and an entropy gradient $\frac{dS}{dR} = -\frac{k_B m}{R}$, we recover Newton's law without recourse to holographic screens, as in Verlinde's approach [1], or spacetime curvature. Grounded in gravitational work, this ties to established physics like the virial theorem's role in bound systems [**?**], enhancing its conceptual appeal.

Challenges persist, however. Assigning $C < 0$ to a single test mass m in M's field is unconventional—while the virial theorem justifies $C < 0$ for self-gravitating systems, its extension to an individual test mass lacks direct evidence. We propose that gravitational work ($\Delta U < 0$) mirrors an energy loss akin to a 'negative acceleration,' where the mass-energy relation $E/c^2 = m$ suggests a thermodynamic shift: as energy decreases, temperature rises ($\Delta T > 0$), consistent with $C < 0$. A test mass without intrinsic acceleration lacks a Rindler horizon, implying T originates solely from M's gravitational field, akin to Jacobson's local horizons [2]. The field $T = \frac{GM}{k_B R}$ finds conceptual support in gravitational blueshift—photons gain energy ($\Delta E > 0$) nearer M—though its classical thermal role for m remains hypothetical. A central question is how this energy loss ($\Delta U < 0$) becomes thermal

($\Delta T > 0$)—classically, it converts to kinetic energy, necessitating further exploration of this thermodynamic transition. These points frame our work as a discussion, open to refinement. *This is a conceptual lens—not a settled theory, but a plausible thermodynamic view of gravity..*

References

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