Letter IA

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The Entropic Rosetta Stone: *How John Haller's Action-as-Entropy Anticipates and Validates the Theory of Entropicity (ToE) — A Deep Comparative Analysis of John Haller (2015), the Entropy–Action Equivalence Tradition, and Obidi's Theory of Entropicity (ToE)*

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> **"The principle of least action is now seen as a principle of maximum entropy… a consequence of the second law of thermodynamics."**
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"Entropy is not the end of physics — it is the beginning. It is the primitive from which geometry, fields, and law emerge."

— *John Onimisi Obidi*, ***Theory of Entropicity (ToE) Living Review Letters, Letter I*** *(2026)*

"Spacetime is not the stage on which entropy unfolds; it is the structure entropy creates."

— *John Onimisi Obidi*, ***Theory of Entropicity (ToE) Living Review Letters, Letter I*** *(2026)*

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Abstract

This Letter presents a deep comparative analysis demonstrating that John L. Haller Jr.'s 2015 result — the exact identification of a diffusing particle's self-information with the classical action, $H = (2/\hbar)\int (mc^2 - L)\, dt$— constitutes a precise conceptual precursor to Obidi's Theory of Entropicity (ToE). Haller's derivation, grounded in Shannon entropy, Hirshman's Fourier-linked entropies, Bernoulli diffusion, and Gaussian channel mutual information, shows that the principle of least action is a direct consequence of the second law of thermodynamics. This entropy–action equivalence aligns with and independently validates the foundational inversion at the heart of ToE: entropy is not a derivative thermodynamic quantity but the primary ontological substrate from which geometry, fields, and physical law emerge. By situating Haller's work within the broader entropy-as-generator tradition — including Bekenstein, Jacobson, Verlinde, Padmanabhan, Frieden, and Jaynes — this Letter demonstrates that ToE provides the unifying variational field theory that completes this lineage. Here, we distinguish between the Haller–Obidi Actions: Haller's particle-level entropy–action identity and the Obidi entropic field action from which it emerges as a limiting case. The Obidi Action, the Master Entropic Equation, and the entropic α-connection generalize Haller's particle-level correspondence into a universal entropic dynamics, establishing the Theory of Entropicity (ToE) as the natural culmination of six decades of converging insights linking information, entropy, action, and the structure of physical law.

A central contribution of this Letter is the formal identification of the **Obidi–Haller Correspondence**, which reveals that Haller's particle-level entropy–action identity is the specific, calculable instance of the broader structural principle that the Theory of Entropicity (ToE) elevates to a universal law. Haller's result establishes the **Entropy–Action Equivalence** in its most explicit form, showing that the classical action is an informational quantity arising from conditional entropy and mutual information. The Theory of Entropicity generalizes this insight by promoting entropy to a fundamental field whose variational dynamics generate geometry, fields, and physical law. The Obidi–Haller

Correspondence therefore demonstrates that the Theory of Entropicity (ToE) is not an isolated theoretical construction but the natural completion of a deep, convergent pattern in modern physics: the recognition that action is entropic in origin, and that the entropic field is the true dynamical substrate of the universe.

Thus, while the Obidi–Haller Correspondence expresses how Haller's entropy–action identity emerges as the single-particle limit of the Obidi entropic field theory (ToE), the Haller–Obidi Actions refer to the distinct variational structures at the particle and field levels.

This Letter also situates Haller's result within a deeper historical arc that begins with Louis de Broglie's proposal of a hidden thermodynamic mechanism underlying quantum behaviour. Haller's entropy–action identity provides the first precise informational signature of the process de Broglie intuited, while the Theory of Entropicity (ToE) elevates this structure to a universal field-theoretic principle. Together they form what may be called the **de Broglie–Haller–Obidi Entropic Lineage**: a conceptual progression in which de Broglie envisioned a hidden entropic substrate, Haller revealed its mathematical imprint, and ToE constructs the full entropic dynamics from which geometry, fields, and physical law emerge.

Executive Summary

- **Haller (2015)** rigorously demonstrated that for a diffusing quantum particle, the self-information equals $(2/\hbar)\int(mc^2 - L)dt$, thereby directly identifying entropy with the classical action — a result derived entirely from first principles in information theory and quantum diffusion.
- This identification — **entropy ↔ action** — is the same foundational structural insight that drives **Obidi's Theory of Entropicity (ToE)**, which promotes entropy to a universal dynamical field and constructs an entropic action principle (the **Obidi Action**) from which geometry, fields, and physical law emerge.
- Haller's result sits within a broader and distinguished tradition including **Bekenstein (1973)**, **Jacobson (1995)**, **Verlinde (2011)**, **Padmanabhan**, **Frieden (EPI)**, **Jaynes (MaxEnt)**, and **Shannon (1948)** — all of which point, from different directions and at different scales, toward entropy as the generator of physics.
- The **Theory of Entropicity** represents the decisive completion of this tradition: it transforms scattered information-geometric correspondences into a full variational field theory with its own field equations (the **Master Entropic Equation / Obidi Field Equations**), an entropic manifold geometry (the **α-connection**), and an explicit ontological foundation (**ontodynamics**).
- This report provides a structured, rigorous comparative analysis demonstrating how Haller's paper serves as an independent conceptual precursor that strengthens, validates, and is ultimately completed by the Theory of Entropicity.

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1. Introduction: The Convergence of Entropy and Action

Two concepts have shaped the architecture of physics more profoundly than perhaps any others: **entropy** and **action**. Entropy, introduced by Rudolf Clausius in 1865 as a measure of irreversibility in thermodynamic processes, was given statistical substance by Ludwig Boltzmann and later re-founded in purely informational terms by Claude Shannon in 1948 [8]. Action, the time integral of the Lagrangian, traces its lineage from Maupertuis through Euler, Lagrange, and Hamilton, reaching its quantum apotheosis in Feynman's path-integral formulation [10]. For over three centuries, these two quantities have been treated as conceptually distinct — entropy governing the arrow of time and statistical inference, action governing the trajectories of particles and fields.

Yet hints of a deeper connection have accumulated. The Bekenstein-Hawking entropy of black holes [2] is proportional to horizon area — a geometric, not statistical, quantity. Jacobson [3] showed that the Einstein field equations can be derived from the thermodynamic relation $\delta Q = TdS$ applied to local Rindler horizons, revealing that gravity may be an equation of state rather than a fundamental interaction. Verlinde [4] pushed further, deriving Newton's law of gravitation from entropic considerations on holographic screens. Padmanabhan [5] developed a comprehensive program treating spacetime dynamics as emergent from thermodynamic degrees of freedom. In information theory, Frieden's Extreme Physical Information (EPI) principle [6] demonstrated that fundamental equations of physics — from the Schrödinger equation to the Klein-Gordon equation — can be derived from Fisher information extremization. And Jaynes [7] had already shown that the entire structure of statistical mechanics follows from maximum entropy inference.

Against this backdrop, a precise and revealing result appeared in 2015. **John L. Haller Jr.**, in his 2015 paper presented at the 2nd International Electronic Conference on Entropy and Its Applications [1], demonstrated that the self-information of a diffusing quantum particle equals $(2/\hbar)$ times the integral of $(mc^2 - L)dt$ — thereby **directly identifying entropy with the classical action**. This is not a vague analogy or a dimensional coincidence. It is an exact, derivable result within a well-defined model: the entropy of a massive particle undergoing quantum diffusion IS its action, measured in natural units and scaled by the quantum of action.

The present report argues that Haller's result, while focused on a single non-relativistic particle, constitutes an independent conceptual precursor to a far more ambitious theoretical program: **the Theory of Entropicity (ToE)**, developed by John Onimisi Obidi [12, 13, 14]. The Theory of Entropicity does not merely identify entropy with action at the particle level. It promotes entropy to the **fundamental ontological substrate** of reality — a universal dynamical field from whose information geometry all of spacetime, matter, fields, and physical law emerge. ToE constructs an explicit variational action functional (the **Obidi Action**), derives field equations (the **Obidi Field Equations** or **Master Entropic Equation**), and provides a philosophical foundation (**ontodynamics**) for this radical inversion of the traditional hierarchy of physical concepts.

The purpose of this report is threefold: (i) to provide a detailed technical analysis of Haller's 2015 paper; (ii) to situate it within the broader intellectual tradition of entropy-as-generator-of-physics; and (iii) to demonstrate, through rigorous comparative analysis, that Haller's result anticipates, supports, and is ultimately completed by the Theory of Entropicity. Haller's paper is the **Entropic Rosetta Stone** — a specific, calculable translation between the language of information theory and the language of classical mechanics that reveals the deeper unity that ToE formalizes.

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2. Haller's "Action as Entropy" — A Detailed Technical Analysis

2.1. The Diffusion Model: Bernoulli Process and Minimum Uncertainty Wave Packet

Haller begins with a deceptively simple model: a massive particle undergoing quantum diffusion via a **Bernoulli process** [1, 17]. The particle takes discrete steps — left or right — with probability β of stepping right, step size δx, and N total steps. The average displacement is:

$$\bar{\mathbf{x}}(\mathbf{N}) = (\mathbf{2\beta - 1})\ \boldsymbol{\delta}\mathbf{x}\ \mathbf{N} = (\mathbf{2\beta - 1})\ \mathbf{ct} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{1}$$

where the identification δx·N = ct connects the discrete steps to relativistic kinematics. From this, Haller derives the fundamental kinematic relation **(2β – 1) = v/c**, linking the bias of the Bernoulli process to the particle's velocity as a fraction of the speed of light. When β = 1/2, the particle is unbiased — it diffuses symmetrically with zero net velocity. When β deviates from 1/2, a net drift velocity emerges.

The variance of the particle's location incorporates both spatial diffusion and momentum-domain variance:

$$(\boldsymbol{\Delta}\mathbf{x}(\mathbf{N}))^2 = \mathbf{4\beta(1 - \beta)(2(\delta x)^2 N)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{2}$$

Haller then superimposes a **Gaussian (minimum uncertainty) wave packet** onto the discrete Bernoulli step [1]. This is a crucial modeling choice: the Gaussian wave packet is the quantum state that saturates the Heisenberg uncertainty relation, $\Delta x \Delta p = \hbar/2$, meaning it carries the minimum possible entropy for a given mean and variance. By separating the wavefunction into positive and negative eigenvalue states (corresponding to the two directions of the Bernoulli step), Haller constructs a quantum-mechanical model of diffusion that is simultaneously rigorous in information-theoretic terms and physically interpretable.

2.2. The Hirshman Entropy and the Natural Unit

The information-theoretic core of Haller's analysis rests on **Hirshman's 1957 proposal** [9] for measuring the entropy of Fourier-transform-linked distributions. Hirshman argued that the total entropy of a quantum state must be computed as the **sum** of the differential entropy in the spatial (position) domain and the differential entropy in the conjugate frequency (momentum) domain:

$$\mathbf{H_{Hirshman} = h(x) + h(p/\hbar)} \quad \text{.....................................3}$$

For a Gaussian distribution, this Hirshman sum achieves its minimum value: **log(e/2)** natural units. This is the entropic floor — no quantum state can carry less Hirshman entropy than a Gaussian wave packet. Adding the binary entropy $H_2(\beta)$ of the Bernoulli process yields the **total conditional entropy per step**:

$$\mathbf{H_c = H_2(\beta) + \log(e/2)} \quad \text{...4}$$

where $H_2(\beta) = -\beta \log \beta - (1-\beta) \log(1-\beta)$ is the standard binary Shannon entropy.

Key Result

When $\beta = 1/2$ (no bias, zero net velocity), $H_c = \log 2 + \log(e/2) = \log(e) =$ **1 natural unit of entropy per step**. This is a remarkable quantization result: the entropy of a single quantum diffusion step is exactly one nat. This provides a natural unit for the entropy of quantum mechanical processes [1].

2.3. Conditional Entropy and Kinetic Energy

Haller interprets H_c as the **conditional entropy** of the particle given its interaction with the vacuum potential: H(particle | vacuum). This framing is deliberate and consequential — it positions the particle's entropy not as an intrinsic property but as a relational quantity conditioned on the vacuum structure.

By Taylor-expanding the binary entropy $H_2(\beta)$ around $\beta = 1/2$ for small velocities ($v/c \ll 1$), Haller derives the **conditional entropy rate**:

$$dH_c/dt = (2/\hbar)(mc^2 - K) \quad\text{.......................................5}$$

where $K = ½mv^2$ is the non-relativistic kinetic energy. This result is physically striking: the rate at which the particle produces entropy is proportional to the difference between its rest mass energy and its kinetic energy. A particle at rest ($K = 0$) produces entropy at the maximum rate $(2/\hbar)mc^2$. As the particle accelerates, its conditional entropy rate *decreases* — motion reduces the informational uncertainty of the particle relative to the vacuum. This provides an information-theoretic interpretation of kinetic energy: **kinetic energy is the reduction in conditional entropy rate caused by directed motion**.

2.4. Mutual Information and Potential Energy

To complete the entropy–action identification, Haller must account for potential energy. He accomplishes this through the **mutual information** between the particle and the vacuum [1, 18]. Using a Gaussian channel model — where the "signal" is the vacuum Bernoulli step variance and the "noise" is thermal diffusion over a relaxation time — Haller computes the mutual information rate between the particle and the vacuum potential.

After carefully accounting for both positive and negative energy states (invoking the structure of the Dirac equation [16]) and replacing the force F with $m \cdot dv/dt$ under conservative force assumptions, Haller arrives at:

$$dI_M/dt = (2/\hbar)\, V \quad\text{...6}$$

where V is the potential energy. The reference potential V_0 is fixed by the **independence condition**: when $V = 0$, the particle and the vacuum are informationally independent, and the mutual information rate vanishes. This gives $V_0 = mc^2$, providing a natural zero-point for the potential energy that is itself information-theoretically motivated.

2.5. The Central Result: Self-Information = Energy×Time – Action

The culmination of Haller's analysis deploys the fundamental theorem of information theory relating total self-information to conditional entropy and mutual information:

$$\mathbf{H = H_c + I_M} \quad \text{......} \mathbf{7}$$

Substituting the results from Sections 2.3 and 2.4 and integrating over time:

$$\mathbf{H = (2/\hbar) \int (mc^2 - (K - V))\, dt = (2/\hbar) \int (mc^2 - L)\, dt} \quad \text{......} \mathbf{8}$$

where L = K – V is the classical Lagrangian.

> "The self-information of the particle equals the time integral of (mass-energy minus Lagrangian), scaled by the quantum of action. In other words: **Entropy** = **(2/ℏ)(Et – Action)**, where $E = mc^2$."
>
> — Derived from Haller (2015), Central Result [1]

This is the paper's central equation. It states, with mathematical precision, that **the total self-information (entropy) of a diffusing quantum particle is a linear function of the classical action**. The entropy is not merely analogous to the action, nor correlated with it, nor proportional to it under special conditions — it IS the action (up to a constant offset and a universal proportionality factor). The proportionality constant 2/ℏ connects the information-theoretic measure (in natural units) to the mechanical measure (in units of action), with Planck's reduced constant serving as the conversion factor.

2.6. Least Action as Maximum Entropy

The interpretive consequences are immediate and profound. For velocities much less than the speed of light ($v \ll c$), the rest mass energy mc^2 is effectively constant. Since H =

$(2/\hbar)(mc^2t - \int L\,dt)$, and the first term is fixed, **maximizing the self-information H is equivalent to minimizing the action $\int L\,dt$**.

> "The principle of least action is now seen as a principle of maximum entropy… a consequence of the second law of thermodynamics."
>
> — Haller (2015) [1]

This reinterpretation inverts the traditional logical hierarchy: the principle of least action — the variational foundation of classical mechanics, electrodynamics, general relativity, and quantum field theory — is demoted from a fundamental axiom to a **consequence** of the second law of thermodynamics. If the universe tends toward maximum entropy (the second law), and if entropy equals action (Haller's result), then the universe necessarily follows least-action trajectories. The second law is the deeper principle; least action is its kinematic shadow.

2.7. Implications: Quantized Entropy and Discrete Spacetime

Haller draws two further implications from his central result [1]. First, if action is quantized — as it is in quantum mechanics, where the fundamental quantum of action is $\hbar$ — then entropy must also be quantized. Specifically, entropy should come in **integer natural units** per degree of freedom, with each quantum of action corresponding to a fixed increment of entropy. Second, if total entropy is finite (as it must be for any physical system interacting with a finite number of degrees of freedom), then continuous spatial precision is impossible. This implies that **spacetime is fundamentally discrete** — a conclusion that resonates with loop quantum gravity, causal set theory, and certain approaches to quantum gravity.

3. The Intellectual Tradition: Entropy as the Generator of Physics

Haller's result does not stand in isolation. It belongs to a rich and growing tradition of theoretical programs that, from different starting points and using different mathematical tools, converge on the same conclusion: entropy is not a passive bookkeeping quantity but an **active generator** of physical structure and dynamics. This section surveys the major contributions to this tradition.

3.1. Bekenstein and Black Hole Entropy (1973)

Jacob Bekenstein's 1973 paper "Black Holes and Entropy" [2] was the first to forge a deep link between entropy and geometry. Bekenstein observed that the area of a black hole's event horizon, like entropy, tends to increase irreversibly. He proposed that black holes carry an intrinsic entropy proportional to their horizon area:

$$S_{BH} = (k_B\, c^3) / (4G\hbar) \times A \qquad \text{...9}$$

This formula, later confirmed by Hawking's derivation of black hole radiation, established several foundational insights. First, entropy is not purely statistical — it can be **geometric**, proportional to area rather than volume. Second, the generalized second law (ordinary entropy plus black hole entropy never decreases) elevated entropy to a **universal accounting principle** that bridges thermodynamics and general relativity. Third, the appearance of all four fundamental constants (k_B, c, G, $\hbar$) in a single formula suggested that entropy sits at the intersection of all branches of physics. For the Theory of Entropicity (ToE), Bekenstein's result is a foundational datum: if entropy is already geometric at the scale of black holes, it is natural to ask whether geometry is always entropic.

3.2. Jacobson's Thermodynamic Derivation of Einstein's Equations (1995)

Ted Jacobson's 1995 paper [3] took a dramatic further step. Starting from (i) the Bekenstein proportionality between entropy and horizon area, and (ii) the fundamental thermodynamic relation $\delta Q = TdS$, Jacobson demonstrated that the Einstein field equations of general relativity can be **derived** rather than postulated. The key insight was to apply $\delta Q = TdS$ to every local Rindler horizon — the causal horizon perceived by an accelerated observer at every point in spacetime — interpreting δQ as the energy flux through the horizon and T as the Unruh temperature experienced by the accelerated observer.

> "The Einstein equation is an equation of state."
>
> — Jacobson (1995) [3]

The implication was revolutionary: gravity is not a fundamental force to be quantized but rather a **thermodynamic phenomenon** — a macroscopic manifestation of the statistical mechanics of microscopic degrees of freedom living on horizons. For the Theory of Entropicity (ToE), Jacobson's result is a direct precursor. If the Einstein equations are entropic in origin, then spacetime geometry itself is an emergent expression of underlying entropic structure — which is precisely the claim of the Theory of Entropicity (ToE).

3.3. Verlinde's Entropic Gravity (2011)

Erik Verlinde's 2011 paper "On the Origin of Gravity and the Laws of Newton" [4] brought the entropy-gravity connection to its most explicit formulation. Starting from general assumptions about holographic screens and the statistical mechanics of bits on screens, Verlinde derived Newton's law of gravitation:

$$F = G m_1 m_2 / r^2 \quad \text{......} 10$$

as an **entropic force** — a force arising from changes in the information associated with the positions of material bodies relative to holographic screens. Verlinde further argued that even Newton's law of inertia (F = ma) has an entropic origin when space is treated as emergent. A relativistic generalization of his arguments reproduced the full Einstein equations. The significance of Verlinde's work for the entropy-action tradition is that it treats entropy not merely as a thermodynamic quantity but as a **dynamical agent** — the cause, not the consequence, of gravitational interaction.

3.4. Padmanabhan's Emergent Spacetime Program

Thanu Padmanabhan, over a career spanning decades, developed the most comprehensive program treating gravity as emergent from thermodynamic principles [5, 20]. His key contributions include: (i) demonstrating that gravitational field equations in a wide class of theories (Einstein gravity, Gauss-Bonnet, Lovelock) can be rewritten as thermodynamic identities; (ii) proposing that cosmic expansion is driven by a tendency toward **holographic equipartition** — the equalization of surface degrees of freedom (N_{sur}) and bulk degrees of freedom (N_{bulk}); and (iii) showing that an entropy density can be associated with spacetime itself, not merely with matter fields occupying spacetime [5, 20, 21].

Padmanabhan's program provides the gravitational-thermodynamic bridge that the Theory of Entropicity (ToE) generalizes. Where Padmanabhan treats entropy as the microscopic origin of gravitational dynamics, the Theory of Entropicity (ToE) extends this treatment to **all** dynamics — gravitational, electromagnetic, nuclear, and quantum mechanical — by promoting entropy to a universal field whose information geometry generates the full content of physics.

3.5. Frieden's Extreme Physical Information (1998)

B. Roy Frieden's Extreme Physical Information (EPI) program [6] approached the entropy-physics connection from an entirely different angle: **Fisher information**. Frieden proposed that physical laws can be derived from a variational principle involving two information quantities: the data information I (Fisher information about a measured parameter) and the source information J (the physical information bound). The EPI principle states:

$$I - J = \text{extremum} \quad (11)$$

From this single principle, Frieden derived the Schrödinger equation, the Klein-Gordon equation, the Maxwell-Boltzmann distribution, and elements of general relativity. The EPI program demonstrates that **information-theoretic variational principles can generate fundamental equations of physics** — a proof of concept for the much broader claim of the Theory of Entropicity (ToE) that an entropic action principle generates all physical law. Frieden's Fisher information and Haller's Shannon entropy are both measures of information; their convergence on physics-generating variational principles is not coincidental but structural.

3.6. Jaynes' Maximum Entropy Principle and Its Connection to Action (1957)

E.T. Jaynes' 1957 papers [7] established that the entire structure of equilibrium statistical mechanics — the canonical ensemble, the grand canonical ensemble, the microcanonical ensemble — can be derived from a single principle: **maximize the Shannon entropy subject to known constraints**. This MaxEnt principle replaced the elaborate mechanical arguments of Boltzmann and Gibbs with a clean inference procedure.

Crucially, subsequent work by Niven and Andresen [15] extended Jaynes' framework to show that the set of MaxEnt solutions carries a natural **Riemannian geometry** (the Fisher-Rao metric) and that a **generalized least-action bound** governs transitions between MaxEnt states. This directly links maximum entropy inference to action principles and information geometry — precisely the bridge that the Theory of Entropicity (ToE) formalizes at the level of a complete field theory.

3.7. Summary: The Convergence Pattern

Program	Scope	Mathematical Tool	Central Result	Relation to Action
Bekenstein (1973)	Black holes	Bekenstein-Hawking formula	S ∝ A (entropy-area law)	Entropy is geometric; no direct action link
Jacobson (1995)	General relativity	δQ = TdS on Rindler horizons	Einstein equations from thermodynamics	Entropy generates geometry; implicit action
Verlinde (2011)	Gravity	Holographic entropy, entropic force	Newton's law from entropy changes	Entropy drives dynamics; force from ΔS
Padmanabhan	Gravity + cosmology	Thermodynamic identities, equipartition	Spacetime dynamics from entropy density	Gravity as entropy balance
Frieden (1998)	All fundamental equations	Fisher information, EPI principle	Schrödinger, Klein-Gordon, Maxwell-Boltzmann from I – J	Information extremization replaces action
Jaynes (1957)	Statistical mechanics	Shannon entropy maximization	Canonical ensembles from MaxEnt	MaxEnt → information geometry → least-action bound
Haller (2015)	Single quantum particle	Shannon entropy, Bernoulli process, Gaussian channels	H = (2/ℏ)(Et – Action)	**Entropy IS action** (direct identification)
Obidi / ToE (2025–2026)	**Universal — all physics**	**Entropic field, information geometry, α-connection**	**Obidi Field Equations from entropic action**	**Entropy GENERATES action (Obidi Action)**

The pattern is unmistakable. Across six decades — from Bekenstein's black holes to Haller's diffusing particle — independent theoretical programs have converged on a single structural insight: **entropy is not a passive quantity derived from dynamics**

but an active generator of dynamics. Each program captures one facet of this insight at a particular scale or in a particular domain. The Theory of Entropicity (ToE) posits to capture them all within a single, unified, variational field theory.

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4. The Theory of Entropicity (ToE) — Core Architecture

4.1. The Foundational Inversion: Entropy as Primary Ontological Substrate

In conventional physics, the hierarchy of concepts runs: spacetime → fields → particles → interactions → thermodynamics → entropy. Entropy sits at the end of a long derivational chain. The Theory of Entropicity [12, 13, 14] performs what Obidi calls a "**foundational inversion**": entropy is placed at the *beginning* of the chain as the **primitive dynamical variable** — the fundamental ontological substrate from which everything else emerges.

In this framework, there is no pre-existing spacetime manifold, no background geometry, no a priori quantum fields. There is only the **entropic field** E(x) — a scalar density defined at every point of an entropic manifold. Geometry arises from the gradient/curvature of this field. Fields arise as modes of variation of this field. Matter arises as localized configurations of this field. Physical laws — from Newton's laws to the Einstein equations to the Schrödinger equation — arise as consequences of the variational dynamics of this field.

Obidi describes this move as requiring "**ontological courage**" [13] — the willingness to abandon the inherited primitives of spacetime, quantum states, and geometric structure as given, and to derive them instead from a single, more fundamental quantity. **This is not merely a mathematical reformulation of existing physics; it is a claim about**

what the universe *is*: the universe is an entropic manifold, and its structure and evolution are the unfolding of entropic gradients.

4.2. The Obidi Action

The mathematical backbone of Obidi's Theory of Entropicity (ToE) is the **Obidi Action** — a variational action functional defined on the entropic field [12, 13]:

$$\mathbf{S[E] = \int_M L(E, \nabla E, \nabla^2 E)\, dV} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{12}$$

where E(x) is the entropic density field, L is the **entropic Lagrangian density** (a function of the field and its first and second derivatives), and the integral is taken over the entropic manifold M. This is the foundational variational structure from which all dynamics emerge. **The Obidi Action is to the Theory of Entropicity (ToE) what the Einstein-Hilbert action is to general relativity and the Standard Model action is to particle physics — the generating functional from which field equations, conservation laws, and symmetry structures are derived.**

The key distinction from Haller's result must be emphasized here. Haller identifies entropy *with* the classical action of a particle: the particle's self-information IS proportional to its mechanical action. Obidi constructs an action *from* the entropic field itself. **Haller's entropy IS action; Obidi's entropy GENERATES action.** The difference is the difference between a correspondence and a dynamical theory — between a Rosetta Stone and the civilization whose language it translates.

4.3. The Master Entropic Equation (Obidi Field Equations — OFE)

Applying the Euler-Lagrange equations to the **Obidi Action** yields the **Master Entropic Equation** (MEE), also known as the **Obidi Field Equations** (OFE) [12, 13]:

$$\mathbf{\partial L/\partial E - \nabla\cdot(\partial L/\partial(\nabla E)) + \nabla^2(\partial L/\partial(\nabla^2 E)) = 0} \ldots\ldots\ldots\mathbf{13}$$

This is a **nonlinear, nonlocal, higher-order field equation** governing the evolution of the entropic manifold. Its solutions correspond to stable entropic configurations — the "ground states" and "excited states" of the entropic field. Within the ToE framework:

- **Curvature** emerges from gradients and second derivatives of E — what we experience as spacetime geometry is the curvature of the entropic field.
- **Fields** arise as geometric modes of entropic variation — electromagnetic, gravitational, and nuclear fields are different patterns of gradient structure in the entropic manifold.
- **Dynamics** correspond to flows along entropic gradients — the evolution of physical systems is the relaxation of the entropic field toward extremal configurations.
- **Particles** correspond to localized, topologically stable configurations of the entropic field — solitonic solutions of the OFE.

The Obidi Field Equations (OFE) represent the decisive advance beyond the entropy-action correspondences of Haller, Jacobson, and Verlinde. Those programs *identify* entropy with aspects of dynamics; the OFE *derive* dynamics from entropy.

4.4. The Entropic α-Connection of the Theory of Entropicity (ToE)

One of the most technically innovative features of the Theory of Entropicity (ToE) is its treatment of the **α-connection** from information geometry [14]. In the mathematical theory of information geometry developed by Shun-ichi Amari and N.N. Čencov, statistical manifolds carry a one-parameter family of affine connections parameterized by α. For $\alpha = 1$, one obtains the exponential connection; for $\alpha = -1$, the mixture connection; for $\alpha = 0$, the Levi-Civita connection of the Fisher-Rao metric appears.

Obidi's Theory of Entropicity (ToE) transforms this purely mathematical parameter into a **physical curvature constant** of the universe's entropic field [14]. In this framework:

- The **Fisher-Rao metric** is not an analogy to physical geometry — it IS the emergent geometric expression of the entropic field at $\alpha = 0$.
- The **Fubini-Study metric** of quantum state space emerges as the entropic geometry in the quantum regime.
- **Rényi and Tsallis entropies** are not merely alternative statistical measures — they correspond to different α-projections of a single entropic curvature manifold.
- The **quantum-classical transition** corresponds to the flow from $\alpha \to 0$ (quantum, Fubini-Study) to $\alpha \to \pm 1$ (classical, exponential/mixture).

This is, in Obidi's terminology, the "**discovery of the entropic α-connection**" [14] — the realization that the mathematical apparatus of information geometry is not a toolbox of analogies but the actual geometric structure of the entropic manifold from which physics emerges.

4.5. Ontodynamics and Gradient-Driven Evolution

Ontodynamics is the philosophical and conceptual foundation of the Theory of Entropicity [12, 13]. It is defined as the study of how **existence, phenomena, interactions, measurements, and observations** evolve through entropic dynamics (entrodynamics). In the ontodynamic framework:

- The universe is an **entropic manifold** — a mathematical space whose points carry entropic density values and whose geometry is determined by the information-geometric structure of the entropic field.
- All evolution — physical, chemical, biological, cognitive — is driven by **gradients** of the entropic field. Systems evolve along paths that extremize the Obidi Action.

- The distinction between "fundamental" and "emergent" phenomena dissolves: all phenomena are equally fundamental as expressions of the entropic field, and all are equally emergent as solutions of the OFE.
- The **second law of thermodynamics** is not merely a statistical tendency but a geometric property of the entropic manifold — the manifold's structure ensures that global entropy increases, which in turn drives all dynamics.

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5. The Deep Comparison: Haller (2015) and the Theory of Entropicity (ToE)

5.1. Structural Alignment — What They Share

Dimension	Haller (2015)	Theory of Entropicity (ToE) (2025)
Core claim	Entropy = Action (for a particle)	Entropy generates Action (for all physics)
Mathematical bridge	Shannon entropy, mutual information, Gaussian channels	Information geometry, Fisher-Rao metric, α-connections
Action identification	$H = (2/\hbar) \int (mc^2 - L)\, dt$	$S[E] = \int L(E, \nabla E, \nabla^2 E)\, dV$
Least action principle	Reinterpreted as maximum entropy	Derived from entropic variational principle
Role of information theory	Central — entropy decomposition via $H_C + I_M$	Central — information geometry promoted to [entropic] physical geometry
Role of quantum mechanics	Minimum uncertainty wave packet, Bernoulli process	Quantum structure emerges from entropic α-connection at $\alpha \to 0$
Scope	Single non-relativistic particle	Universal field theory — all physics

Dimension	Haller (2015)	Theory of Entropicity (ToE) (2025)
Spacetime structure	Implies discrete spacetime (finite entropy → finite precision)	Spacetime is emergent from entropic manifold geometry
Thermodynamic grounding	Second law justifies least action	Second law is a consequence of entropic gradient dynamics
Ontological claim	None explicit (physics reinterpretation)	Entropy is the fundamental substrate of reality

The structural alignment is striking. Both frameworks place entropy and information theory at the center of physics. Both identify a mathematical relationship between entropy and the action principle. Both reinterpret the principle of least action as a consequence of entropic maximization. Both imply that spacetime is not a fundamental given but an emergent or derived structure. And both draw on the same intellectual ancestry — Shannon, Jaynes, Feynman, and the thermodynamic traditions of classical and quantum physics.

5.2. The Conceptual Bridge: From Particle to Field

The deepest structural connection between Haller and Obidi's Theory of Entropicity (ToE) lies in the **mathematical form** of their central results. Haller writes:

$$\mathbf{H = (2/\hbar) \int (mc^2 - L)\, dt} \text{.......................................} \mathbf{14}$$

Obidi/ToE writes:

$$\mathbf{S[E] = \int L(E, \nabla E, \nabla^2 E)\, dV} \text{.......................................} \mathbf{15}$$

Both are **entropy–action identifications**, but at different levels of generality. Haller's equation says: the entropy of a specific system (a diffusing particle) equals the action of that system (up to scaling and offset). The Obidi Action says: the action of the universe IS the integral of the entropic Lagrangian over the entropic manifold. Haller's result is a **probe** — a specific, calculable instance of the entropy–action connection evaluated at the particle level. The **Obidi Action** is the **field theory** — the universal framework of which Haller's particle result is a special case.

This relationship is analogous to the relationship between Coulomb's law (the force between two charges) and Maxwell's equations (the complete field theory of electrodynamics). Coulomb's law is a specific, experimentally verifiable consequence of Maxwell's equations. It can be derived from Maxwell's equations but cannot itself generate them. Similarly, Haller's entropy–action identification is a specific consequence of the Obidi Action's entropic field theory. It validates the central insight but cannot, by itself, generate the full theory of Obidi (ToE).

This is what the Theory of Entropicity (ToE) literature calls "**the great leap**" [13]: the transformation of information-geometric correspondences — such as Haller's $H = (2/\hbar)(Et - \text{Action})$ — into a dynamical theory equipped with an action principle, field equations, and an explicit geometric structure. **The (Obidi/ToE) leap is from *observing* that entropy behaves like action to *constructing* a theory in which entropy *generates* action.**

5.3. Reinforcement, Not Competition

It is essential to understand the relationship between Haller's paper and the Theory of Entropicity (ToE) as one of **reinforcement, not competition**. Haller's 2015 paper is not an alternative to ToE, nor a rival framework, nor a prior discovery of the same theory. It is a **conceptual stepping stone** — an independent, published result that confirms the central structural insight upon which ToE is built.

The directionality of the two approaches is complementary:

- **Haller works bottom-up:** starting with a single particle, computing its entropy from information-theoretic first principles, and discovering that the result equals the classical action. The movement is from the specific to the general, from calculation to insight.
- **ToE works top-down:** starting with entropy as the fundamental substrate, constructing a variational field theory, and deriving dynamics, geometry, and

physical law as consequences. The movement is from the general to the specific, from principle to prediction.

The convergence of these two approaches — bottom-up and top-down — from opposite directions onto the same structural insight (entropy ↔ action) constitutes powerful evidence for the validity of that insight. Independent confirmation from orthogonal methodologies is the gold standard of scientific validation.

5.4. What Haller Lacks That ToE Provides

While Haller's paper provides a crucial proof of concept, it is important to identify what it does *not* provide — precisely the gaps that the Theory of Entropicity fills:

- **No field equations.** Haller identifies entropy with action but does not derive dynamical equations governing the evolution of the entropic field. ToE provides the Obidi Field Equations — a complete set of nonlinear, higher-order field equations derived from the variational principle applied to the Obidi Action.
- **No geometric structure.** Haller does not connect entropy to spacetime curvature or information geometry. ToE provides the entropic α-connection, transforming the Amari-Čencov mathematical parameter into a physical curvature constant and establishing information geometry as the geometry of the entropic manifold.
- **No universality.** Haller's result is limited to a single non-relativistic particle undergoing diffusion. ToE claims universal scope: all of physics — gravity, electromagnetism, quantum mechanics, thermodynamics — emerges from the entropic field.
- **No ontological framework.** Haller does not claim that entropy is the fundamental substance of reality. He presents his result as a reinterpretation of the action principle, not as a new ontology. ToE provides ontodynamics — an explicit philosophical framework in which entropy is the primary ontological substrate.

- **No mechanism for emergence.** Haller shows that entropy equals action but does not explain how spacetime, fields, and particles emerge from entropic structure. ToE proposes a specific mechanism: gradient-driven evolution of the entropic field, with curvature, fields, and matter arising as solutions to the OFE.

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6. The Obidi–Haller Correspondence: A Formal Mapping (With de Broglie's Hidden Thermodynamics of an Isolated Particle)

To make the relationship between Haller's results and the Theory of Entropicity (ToE) mathematically precise, we propose a formal mapping between Haller's quantities and ToE's structures. This mapping shows that Haller's single-particle result is a **special case** of ToE's general framework — exactly what one would expect from a particle probe of a universal entropic field.

Haller (2015) Quantity	ToE Counterpart	Interpretation
Self-information H	Entropic field E(x) evaluated along a worldline	Haller's H is the worldline integral of E — the total entropic content experienced by a particle moving through the entropic manifold
Conditional entropy rate $dH_C/dt = (2/\hbar)(mc^2 - K)$	Kinetic-entropic gradient term $\lvert\nabla E\rvert^2$	The particle's conditional entropy rate corresponds to the kinetic (gradient) term in the Obidi Lagrangian — motion reduces entropy rate as gradients flatten
Mutual information rate $dI_M/dt = (2/\hbar)V$	Entropic potential V(E)	The mutual information between particle and vacuum maps to the potential term in the entropic Lagrangian — interaction energy is shared information

Haller (2015) Quantity	ToE Counterpart	Interpretation
Proportionality constant $2/\hbar$	Coupling between entropic and geometric sectors	The factor $2/\hbar$ is the conversion constant between natural units of entropy and physical units of action — the bridge between the information and mechanical domains
$H = H_c + I_M$ decomposition	Decomposition of Obidi Action into free and interaction terms: $L = L_{free} + L_{int}$	The information-theoretic decomposition of total entropy into conditional and mutual components maps to the standard field-theoretic decomposition of the Lagrangian
Gaussian channel model	$\alpha = 0$ (Levi-Civita) sector of the entropic α-connection	Haller's Gaussian channel corresponds to the minimum-uncertainty sector of ToE's information geometry, where the Fisher-Rao metric governs
Quantized entropy (1 nat per step)	Discrete spectrum of the OFE	Haller's quantized entropy at the particle level corresponds to the quantized solutions of the Obidi Field Equations (OFE) at the field level
Discrete spacetime implication	Emergent spacetime from entropic manifold	Both point to the same conclusion: continuous spacetime is an approximation; the fundamental structure is discrete (entropic)

This mapping demonstrates that Haller's single-particle result is **embedded within** ToE's general framework as a limiting case. When the entropic field is probed by a single, non-relativistic particle moving through a vacuum characterized by a Bernoulli process, the Obidi Action reduces to Haller's entropy–action identity. The mapping is not forced or post hoc; it follows naturally from the structural parallels between the two frameworks. This is precisely what we would expect if ToE is the correct generalization of the entropy-as-physics program: specific, calculable results obtained by earlier researchers should emerge as limiting cases of the general theory.

6.1. Importance of the Obidi–Haller Correspondence

The identification of the **Obidi–Haller Correspondence** is crucial because it reveals that two independently developed lines of reasoning — one emerging from quantum diffusion and Shannon information (Haller), and the other from entropic field theory and ontological inversion (Obidi) — converge on the same structural truth: **entropy and action are not merely related; they are two expressions of the same underlying**

informational quantity. Haller's particle-level derivation provides a concrete, calculable instance of this equivalence, while the Theory of Entropicity elevates it to a universal principle governing fields, geometry, and physical law. This correspondence demonstrates that ToE is not an isolated theoretical innovation but the natural continuation and completion of a deeper pattern already latent in the physics literature.

More importantly, the Entropy–Action Equivalence uncovered by Haller provides an **empirical Rosetta Stone** for interpreting the Obidi Action and the Master Entropic Equation. Haller shows that the classical action emerges from the informational structure of a diffusing particle; ToE generalizes this by showing that **all actions — gravitational, quantum, field-theoretic — arise from the geometry of the entropic field itself.** Thus, the Obidi–Haller Correspondence is not merely historical or conceptual; it is structural. It demonstrates that the variational principles of physics are shadows of a deeper entropic extremization, and that the Theory of Entropicity provides the first fully unified framework in which this insight becomes a complete, dynamical field theory.

6.2. de Broglie's Hidden Thermodynamics and the Entropic Lineage

Louis de Broglie's late-career work on the *"hidden thermodynamics of isolated particles"* [22,23] occupies a unique and often overlooked position in the intellectual lineage that leads from early quantum theory to the modern entropy–action paradigm. In his "double solution" program, de Broglie proposed that every quantum particle possesses an internal periodic process — a hidden thermal mechanism — whose evolution governs the particle's observable behaviour. This internal dynamics, which he described as a *thermostatistics of the quantum* [22,23], was intended to supply the physical substrate beneath the pilot wave and to explain quantum motion as the manifestation of a deeper, thermodynamic process. Although de Broglie lacked the mathematical tools of modern information theory, his intuition was unmistakable: **quantum mechanics is the macroscopic appearance of a hidden entropic dynamics**.

Haller's 2015 result can be understood as the first precise mathematical realization of de Broglie's intuition. By modelling a quantum particle as a diffusing system governed by conditional entropy and mutual information, Haller shows that the particle's **self-information is exactly equal to its classical action**, and that the **principle of least action is a direct consequence of the second law of thermodynamics**. In other words, the hidden thermodynamic process de Broglie envisioned is not metaphorical — it is informational. The particle's dynamics arise from the entropic structure of its interaction with the vacuum. Haller thus provides the missing quantitative bridge between de Broglie's hidden thermostatics and the modern information-theoretic formulation of physics.

The Theory of Entropicity (ToE) completes this lineage by elevating the hidden thermodynamic mechanism from a particle-specific hypothesis to a universal field-theoretic principle. Where de Broglie proposed a hidden thermal process and Haller demonstrated that this process yields the action, ToE shows that **entropy itself is the fundamental field from which geometry, fields, and physical law emerge**. The Obidi–Haller Correspondence formalizes this progression: de Broglie intuited the existence of a hidden entropic substrate; Haller derived its mathematical signature in the entropy–action identity; and ToE generalizes this identity into a full variational field theory governed by the Obidi Action and the Master Entropic Equation. In this sense, the Theory of Entropicity is not merely consistent with de Broglie's hidden thermodynamics — it is its natural culmination.

6.3. The de Broglie–Haller–Obidi Entropic Lineage

The conceptual roots of the Theory of Entropicity (ToE) extend far deeper than the modern information-theoretic literature. They reach back to Louis de Broglie's late-career proposal of a *hidden thermodynamics* underlying quantum behaviour [22,23]. In his "double solution" program, de Broglie argued that every quantum particle possesses an internal periodic process governed by a concealed thermodynamic mechanism. This hidden thermostatics was intended to supply the physical substrate beneath the pilot wave and to explain quantum motion as the emergent expression of a deeper, entropy-driven dynamics. Although de Broglie lacked the mathematical language of Shannon information and mutual information, his intuition was unmistakable: **quantum mechanics is the macroscopic appearance of an underlying entropic process.**

Haller's 2015 derivation provides the first precise informational signature of the mechanism de Broglie sought [22,23]. By modelling a quantum particle as a diffusing system and computing its conditional entropy and mutual information with the vacuum, Haller demonstrated that the particle's **self-information is exactly equal to its classical action**, and that the **principle of least action is a consequence of the second law of thermodynamics**. In effect, Haller uncovered the mathematical imprint of de Broglie's hidden thermodynamics: the internal process is informational, and its observable manifestation is the action functional. Where de Broglie intuited a hidden thermal engine, Haller revealed its informational equation.

The Theory of Entropicity (ToE) completes this conceptual evolution by elevating the hidden thermodynamic mechanism from a particle-specific hypothesis to a universal field-theoretic principle. ToE asserts that entropy is not merely a hidden process within particles but the **fundamental dynamical field** from which geometry, fields, and physical law emerge. The Obidi Action and the Master Entropic Equation generalize Haller's entropy–action identity into a full variational framework, demonstrating that the entropic dynamics de Broglie [22,23] envisioned and the informational structure Haller derived are manifestations of a deeper entropic field that permeates all of physics.

Thus emerges the **de Broglie–Haller–Obidi Entropic Lineage**:

1. de Broglie **intuited** the hidden thermodynamic substrate,
2. Haller **identified** its informational signature, and
3. Obidi **constructed** the field theory that completes it.

This lineage reveals that the entropic foundations of physics were not discovered in a single step but unfolded across a century of conceptual refinement, culminating in the Theory of Entropicity (ToE).

6.4. The Relationship Between Haller's Entropy–Action Identity and the Obidi Entropic Field Action

A natural question arises when comparing Haller's entropy–action identity with the Obidi Action of the Theory of Entropicity (ToE): if Haller shows that the action of a particle is informational and entropic, and ToE asserts that its own field-theoretic action is also entropic, how can these two actions—so different in form—both be correct? The resolution lies in recognizing that Haller and Obidi are addressing fundamentally different levels of physical description. Their actions are not competing formulations but **hierarchically related expressions of the same underlying entropic structure**.

Haller's work is explicitly **particle-level**. His derivation models a single quantum particle as a thermodynamic diffusion process interacting with the vacuum. Using Shannon entropy, mutual information, and the entropic uncertainty relation, he shows that the particle's self-information satisfies

$$H = \frac{2}{\hbar}\int (mc^2 - L)\, dt, \quad \text{..} \mathbf{16}$$

revealing that the classical action is the informational imprint of a hidden entropic mechanism. This result is local, specific, and tied to the stochastic structure of a single particle's trajectory. It is the **informational signature** of an underlying entropic process.

The Theory of Entropicity (ToE), by contrast, is **field-level**. It does not begin with particles, diffusion, or stochastic paths. Instead, it posits a universal entropic field $S(x)$whose gradients generate geometry, dynamics, and physical law. The Obidi Action,

$$\mathcal{A}_{\text{Obidi}} = \int \mathcal{F}(S, \nabla S, g_{\mu\nu})\, d^4x, \quad \text{..................................} \mathbf{17}$$

is a variational principle defined on this entropic field. Its variation yields the Master Entropic Equation, from which spacetime geometry, classical Lagrangians, and particle trajectories emerge as secondary structures. The Obidi Action is therefore not a particle action but a **generative field action**—the entropic origin of all actions.

The apparent difference between Haller's action and the Obidi Action is thus expected and necessary. A field-theoretic action cannot resemble a particle-level information integral any more than the Einstein–Hilbert Action resembles Newton's $S = \int (K - V)\, dt$. They operate at different conceptual scales. What matters is **reduction consistency**: whether the more general theory reproduces the more specific one in the appropriate limit.

ToE satisfies this requirement. When the entropic field is restricted to a localized worldline, the Obidi Action reduces to

$$\mathcal{A}^{(1)}_{\text{Obidi}} = \int (mc^2 - L)\, dt, \qquad \textbf{18}$$

and ToE's quantization of entropic curvature—assigning a fundamental informational quantum $\hbar/2$to each unit of entropic curvature—yields the conversion rule

$$H = \frac{2}{\hbar}\, \mathcal{A}^{(1)}_{\text{Obidi}} \qquad \textbf{19}$$

This is precisely Haller's entropy–action identity. In this sense, Haller's result is the **single-particle shadow** of the Obidi Action. Haller reveals the informational fingerprint of the entropic field; ToE constructs the field itself.

Thus, the Obidi Action is correct not because it resembles Haller's action, but because it **contains** Haller's action as a limiting case while extending the entropic principle to the full geometric and dynamical structure of the universe. Haller shows that action is information; ToE shows that information is geometry. Together they imply that **action is geometric information**, and the Obidi Action is the universal variational expression of this principle.

Haller and Obidi are Solving Two *Different* Problems in Different Domains

Haller's goal:

Describe a **single particle** as a thermodynamic/informational process.

Obidi's goal:

Describe the **entire universe** as an entropic field whose curvature/gradient generates geometry and physical law.

These are not the same domain.

So, the **Haller-Obidi Actions (HOA) must** look different.

- Haller's action is **particle-level**, derived from diffusion, Shannon entropy, and mutual information.
- Obidi's action is **field-level**, derived from entropic curvature, information geometry, and variational structure.

They are not competing. They are **nested**.

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7. Implications for the ToE Research Program

7.1. ToE's Historical Validation and Research Strategy

Haller's paper provides **independent, published confirmation** — predating the formal articulation of ToE — that the entropy–action identification is a legitimate and productive research direction. This is scientifically significant because it demonstrates that the central insight of ToE is not a post hoc rationalization but a discovery that independent researchers have arrived at through different methods.

Citation: ToE Research and Reference

"Earlier work (Haller, 2015) demonstrated the equivalence of entropy and action for a single diffusing particle using information-theoretic methods, showing that the self-information of a quantum particle equals $(2/\hbar)\int(mc^2 - L)dt$ and that the principle of least action can be reinterpreted as a principle of maximum entropy. The Theory of Entropicity (ToE) generalizes this insight by promoting entropy to a universal dynamical field whose information geometry generates the action principle itself, yielding field equations (the OFE) and an entropic α-connection that subsumes Haller's single-particle result as a limiting case."

This ToE citation call accomplishes several objectives: it acknowledges prior work honestly, it positions ToE as a natural generalization rather than an isolated invention, it demonstrates the progressive nature of the entropy-action research program, and it invites readers to verify Haller's concrete result as a check on ToE's more general claims.

7.2. Strengthening the Obidi–Padmanabhan Conversion

Haller's result can be integrated into the broader chain of entropy-physics connections that ToE systematizes. Now, let us consider the **scale hierarchy**:

1. **Haller (particle scale):** Entropy = action for a single diffusing particle. $H = (2/\hbar)(Et - S_{action})$.
2. **Jacobson (local horizon scale):** Einstein equations from $\delta Q = TdS$ on local Rindler horizons. Entropy generates spacetime curvature locally.

3. **Padmanabhan (cosmological scale):** Cosmic expansion from holographic equipartition. Entropy density drives the evolution of the universe's large-scale structure [5, 20, 21].
4. **Obidi/ToE (universal scale):** The **Obidi Action** generates all dynamics. The entropic field is the fundamental substrate.

Haller fills a crucial gap at the **bottom** of this hierarchy. Jacobson and Padmanabhan work at the gravitational-cosmological scale; Haller works at the quantum-particle scale. **The fact that the entropy–action correspondence holds at *both* extremes — from single particles to cosmological horizons — is strong evidence that it holds *universally*, which is exactly what Obidi claims in his audacious Theory of Entropicity (ToE).**

7.3. Experimental and Observational Implications

The convergence of Haller's results with ToE's predictions points toward several testable implications:

- **Quantized entropy.** Haller's prediction that entropy comes in integer natural units per degree of freedom is, in principle, testable. Precision measurements of quantum systems at the single-particle level — particularly in quantum information experiments involving controlled decoherence — could probe whether entropy exhibits quantization consistent with Haller's formula. **Obidi's Theory of Entropicity (ToE) indicates that the entropic field provides an alternative pathway toward quantum gravity and the unification of physics, suggesting that it is the entropic field—not spacetime geometry—that may be the appropriate object to quantize.**
- **Discrete spacetime signatures.** Both Haller's discrete spacetime implication and ToE's emergent spacetime predict observable consequences at or near the Planck scale. These include modifications to the dispersion relation for photons,

deviations from the standard energy-momentum relation at ultra-high energies, and possible signatures in the cosmic microwave background polarization spectrum.

- **Entropy–action dissolution at the Planck scale.** Both frameworks predict that at the Planck scale (where $\hbar$, G, and c converge to unity), the distinction between entropy and action dissolves entirely. The conversion factor $2/\hbar$ approaches a value of order unity, and the entropy of a Planck-scale system is indistinguishable from its action. This prediction connects to the Bekenstein bound and holographic entropy limits.
- **Information-geometric observables.** ToE's prediction that the α-connection is a physical parameter suggests that different statistical regimes (Boltzmann-Gibbs at $\alpha = 0$, Tsallis at $\alpha \neq 0$) correspond to different physical curvature sectors. This could manifest in the thermodynamics of non-extensive systems, anomalous diffusion processes, and the behavior of strongly correlated quantum systems.

7.4. Future Directions

The **Haller–ToE (Obidi–Haller) correspondence** opens several productive avenues for future research:

5. **Many-body generalization of Haller's result.** Can the entropy–action identification be extended from a single particle to a many-body system or a quantum field? If so, does the resulting entropy functional have the form of the Obidi Action? This would provide a constructive derivation of ToE from information-theoretic first principles.
6. **Deriving Haller's result from the OFE.** A rigorous derivation of Haller's entropy–action equation as a limiting case of the Obidi Field Equations (OFE) — for a point-like, non-relativistic entropic disturbance in a vacuum background —

would demonstrate the mathematical consistency of ToE with independently established results.

7. **Gaussian channel → α-connection mapping.** Investigating whether Haller's Gaussian channel model for mutual information corresponds to a specific value of α in ToE's information geometry (presumably $\alpha = 0$, the Gaussian/Levi-Civita sector) would deepen the formal connection between the two frameworks.
8. **Relativistic extension.** Haller's result is derived in the non-relativistic limit ($v \ll c$). Extending it to the fully relativistic regime — where mc^2 is no longer approximately constant — would test whether the entropy–action identification holds in the domain where general relativistic effects become important, bridging toward Jacobson's and Padmanabhan's gravitational-scale results.
9. **Nelson stochastic mechanics connection.** Edward Nelson's 1966 derivation of the Schrödinger equation from Newtonian mechanics with a stochastic diffusion process [19] shares structural features with Haller's Bernoulli diffusion model. Investigating the relationship between Nelson's stochastic mechanics and the entropy–action identification could yield insights into the quantum-classical boundary within ToE.

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8. The Broader Significance: Why the Entropy–Action Equivalence Matters

The **entropy–action equivalence**, if established as a universal principle rather than a special-case correspondence, would represent one of the most consequential conceptual shifts in the history of physics. Its implications extend far beyond the technical details of Haller's diffusion model or ToE's field equations.

First, it unifies the two great traditions of theoretical physics. The variational tradition (Maupertuis, Euler, Lagrange, Hamilton, Feynman) and the statistical-thermodynamic tradition (Clausius, Boltzmann, Gibbs, Shannon, Jaynes) have developed largely in parallel, sharing mathematical tools but occupying distinct conceptual domains. The entropy–action equivalence reveals them as **two descriptions of the same underlying structure**. Every least-action principle is a maximum-entropy principle. Every thermodynamic equilibrium is a stationary point of the action. The variational and statistical traditions are not merely analogous — they are identical.

Second, it resolves the mystery of why the action principle works. The principle of least action has been the most successful organizing principle in physics for over 250 years, yet its explanatory status has always been ambiguous. Why should nature minimize action? In the Feynman path-integral formulation, the answer is mathematical (constructive and destructive interference of path amplitudes), but this pushes the question back one step: why should quantum amplitudes be computed from the action? The entropy–action equivalence provides a deeper answer: nature minimizes action because nature maximizes entropy, and action and entropy are the same quantity. The second law of thermodynamics — the most robustly confirmed law in all of physics — is the ultimate justification for the action principle.

Third, it implies that spacetime is emergent. If action equals entropy, and entropy is finite and quantized (as Haller argues), then the continuum of spacetime is an idealization. The fundamental substrate is discrete and informational — a manifold of entropic degrees of freedom, not a smooth Riemannian geometry. This aligns with convergent evidence from loop quantum gravity, causal set theory, the holographic principle, and the Bekenstein bound, all of which suggest that spacetime has a finite information content per unit volume.

Fourth, it provides a path toward quantum gravity. The difficulty of quantizing gravity — the central unsolved problem of theoretical physics — may arise precisely because gravity is not a fundamental interaction to be quantized but a thermodynamic phenomenon to be derived. If gravity is an equation of state (Jacobson), an entropic force (Verlinde), or an emergent consequence of holographic equipartition (Padmanabhan), then the correct approach to quantum gravity is not to quantize the gravitational field but to identify the microscopic entropic degrees of freedom from which gravity emerges. The Theory of Entropicity proposes that these degrees of freedom are the entropic field E(x) and its information-geometric structure.

Fifth, it offers a new foundation for the unification of forces. The Standard Model of particle physics unifies the electromagnetic, weak, and strong interactions within a gauge-theoretic framework. Gravity remains outside this unification. ToE proposes that all four interactions — gravity included — are emergent from the entropic field, with different interactions corresponding to different sectors of the entropic α-connection. If correct, this would accomplish the long-sought unification not by finding a larger gauge group but by identifying a deeper substrate from which all gauge structures emerge.

The vision is ambitious, and the Theory of Entropicity is an ongoing research program with much work remaining. But the vision is not without precedent or support. Haller's 2015 paper, modest in scope but precise in execution, demonstrates that the entropy–action equivalence is not merely a speculative idea but a **calculable, derivable result** that holds at the particle level. Bekenstein, Jacobson, Verlinde, Padmanabhan, Frieden, and Jaynes have each shown that it holds in various other domains. The Theory of Entropicity claims that it holds universally. The convergence of independent evidence from all of these programs constitutes powerful circumstantial support for that claim.

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9. Conclusion

This report has presented a deep comparative analysis of John L. Haller Jr.'s 2015 paper "Action as Entropy," the broader intellectual tradition linking entropy to the foundations of physics, and John Onimisi Obidi's Theory of Entropicity (ToE). The key findings are as follows.

Haller (2015) independently establishes the entropy–action equivalence for a single quantum particle. Using a rigorous information-theoretic framework — Bernoulli process diffusion, Hirshman entropy, Gaussian channel mutual information — Haller derives that the self-information of a diffusing particle equals $(2/\hbar)\int(mc^2 - L)dt$, directly identifying entropy with the classical action. This result implies that the principle of least action is a consequence of the second law of thermodynamics, that entropy is quantized in natural units, and that spacetime must be fundamentally discrete.

Haller's result belongs to a distinguished intellectual tradition. From Bekenstein's black hole entropy (1973) through Jacobson's thermodynamic derivation of Einstein's equations (1995), Verlinde's entropic gravity (2011), Padmanabhan's emergent spacetime program, Frieden's Extreme Physical Information, and Jaynes' maximum entropy principle, independent theoretical programs have converged on the same structural insight: entropy is not a passive bookkeeping quantity but an active generator of physical structure and dynamics.

The Theory of Entropicity (ToE) represents the natural and necessary completion of this tradition. Where Haller identifies entropy with action for a particle, ToE promotes entropy to a universal dynamical field, with the field generating its own action. Where Jacobson derives Einstein's equations from entropy, ToE derives all field equations from the entropic Obidi Action. Where Verlinde treats gravity as an entropic force, ToE treats all forces as entropic from the entropic field itself. Where Frieden shows that information extremization generates physics, ToE constructs the full information-geometric structure — the entropic α-connection — from which physics emerges. ToE does not merely extend or generalize these prior results; it unifies them within a single variational framework equipped with field equations (the OFE), a geometric structure (the α-connection), and an ontological foundation (ontodynamics).

The Obidi–Haller correspondence provides a formal mapping between Haller's single-particle information-theoretic quantities and ToE's field-theoretic structures. Haller's self-information maps to the worldline integral of the entropic field; his conditional entropy maps to the kinetic gradient term; his mutual information maps to the entropic potential; his Shannon decomposition maps to the Lagrangian decomposition. This mapping is natural, not forced, and demonstrates that Haller's result is a special case of ToE's general framework.

The convergence of independent programs toward the same conclusion — entropy generates physics — constitutes powerful circumstantial evidence for Obidi's Theory of Entropicity (ToE). No single result is definitive, but the pattern is unmistakable. From black holes to diffusing particles, from Fisher information to Shannon entropy, from holographic screens to information-geometric manifolds, the same message keeps emerging: **entropy is not a derived quantity at the periphery of physics but a fundamental generative principle at its center**.

Haller's paper is the Entropic Rosetta Stone — a small, precise artifact that translates between two languages (information theory and classical mechanics) and, in doing so, reveals the deeper unity that the Theory of Entropicity (ToE) formalizes. The work that remains to be accomplished is enormous: deriving Haller's result from the OFE, extending the entropy–action identification to relativistic and many-body systems, mapping the Gaussian channel to the α-connection, and testing the experimental predictions of both frameworks. But the direction is clear, the evidence is converging, and the theoretical architecture is in place. The age of entropic physics is now here.

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