

The "Physical Vacuum" from the Point of View of the Acta Universi Hypothesis (Extended Version)

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Introduction

1.1 The problem of physical vacuum in modern physics

The physical vacuum is one of the most fundamental and simultaneously problematic concepts in modern physics. Within quantum field theory (QFT), the vacuum is defined as the lowest energy state in which there are no real particles but virtual fluctuations—zero-point oscillations of all quantum fields. These fluctuations lead to observable effects: the Lamb shift, the Casimir effect, and the electron's anomalous magnetic moment. However, they also give rise to one of the most pressing problems in fundamental physics— **the problem of the cosmological constant** .

Theoretical estimates of the vacuum energy density, obtained by summing zero-point oscillations down to the Planck scale, exceed the observed value of dark energy by 120 orders of magnitude. This discrepancy—the largest in the history of physics—remains unresolved within the Standard Model and conventional approaches to quantum gravity. Traditional attempts to explain the smallness of the cosmological constant, such as fine-tuning, the

anthropic principle, or screening mechanisms, either require unnatural assumptions or fail to yield testable predictions.

In recent years, the situation has become more pressing thanks to new cosmological data. In 2025, the DESI (Dark Energy Spectroscopic Instrument) collaboration presented the results of its second data release (DR2), which support a **dynamic dark energy** with an equation of state $w(a) \neq -1$, as opposed to a static cosmological constant $\Lambda(\text{CDM})$. These observations indicate that vacuum energy can evolve over time, requiring a move beyond the standard model and spurring the search for new theoretical approaches.

At the same time, alternative vacuum models are gaining traction in theoretical physics. **The Horizon Model (HM)** views the vacuum as an ensemble of qubits encoding the Shannon entropy and proposes a reinterpretation of the cosmological constant in terms of the information capacity of the cosmological horizon. **Unified Information-Density Theory (UIDT)** postulates a hierarchical renormalization suppression of the vacuum energy on cosmological scales. **The EiG Framework** proposes a resonant suppression of vacuum contributions through a dynamical coupling with gravity. These approaches, although heuristically fruitful, remain phenomenological and do not provide a unified microscopic picture.

Thus, modern physics faces three interrelated challenges: (1) explaining the observed density of dark energy, (2) describing its possible dynamics, and (3) constructing a consistent theory of the vacuum consistent with quantum gravity and thermodynamics.

1.2. Emergent Vacuum: From Geometry to Information

In response to these challenges, a new paradigm has emerged in recent years, which can be called **the information-entropy approach to vacuum**. Its key idea is that vacuum is not a passive geometric or field state, but an active informational structure possessing internal entropy, memory, and dynamics.

One striking example of this approach is **QUIET-ER** (Quantum Uncertainty, Information, Entropy, Time – Emergent Reality), a framework proposed in 2025 that posits that time, energy, mass, and gravity arise from stochastic fluctuations of the quantum vacuum, and that the vacuum itself exhibits properties of quantum memory and entropic dynamics. This approach views vacuum fluctuations not as noise, but as carriers of information that determine the causal structure of reality.

Another important line of research is **the Hernandez hypothesis** (2026), which posits that quantum vacuum fluctuations are driven by the local density of matter. The baryon density exponentially suppresses the effective recombination rate of virtual particles, leading to density-dependent vacuum dynamics. Mathematically, this is expressed as $\rho_{\text{vac}}(\rho_m) = \rho_0 \cdot \exp(-\rho_m/\rho_{\text{critical}})$, which generates the phantom-like behavior of dark energy and predicts quasi-periodic heating in the solar corona.

The Quantum Memory Matrix (QMM) deserves special attention —a theory developed by Florian Neucart and co-authors (2025–2026). QMM postulates that every quantum process leaves an imprint in the vacuum in the form of a finite-dimensional Hilbert space of quantum states. The vacuum in this picture is not a void, but a global memory accumulating information traces of all events. An extension of QMM to dark energy showed that a homogeneous residual "vacuum-imprinted" energy naturally arises with a density $\rho_\Lambda \simeq (2 \times 10^{-3} \text{ eV})^4$, which coincides with the observed value. The slow-rolling entropy field within the QMM framework yields $w(z) \approx -1 + \mathcal{O}(10^{-2})$, consistent with DESI 2025.

Superfluid vacuum models are being developed in parallel. In the works of Zloshchastye (2025) and Volovik (2026), spacetime is interpreted as a topological phase of a quantum vacuum fluid, and the transition from inflation to dark energy is described as a phase transition in this fluid. These models naturally explain the smallness of the cosmological constant through the parameters of the superfluid.

All these approaches share a common intuition: **a vacuum is not a void, but an information-rich environment** whose dynamics determine both cosmological evolution and local quantum effects. However, until now, no unified formalism has been proposed that would unite these ideas into a consistent theory encompassing all scales—from the Planck length to cosmological horizons.

1.3. Acta Universi Hypothesis: Vacuum as a Field of Entropy of Thought Forms

It is in this context that **the Acta Universi (AU) hypothesis** proposes a radically new view of the physical vacuum. Instead of viewing the vacuum as the lowest energy state of quantum fields, the AU interprets it as **the ground state of a non-local information archive** —the entropy field of thought forms S_θ in its minimal, but non-zero, configuration. The vacuum in the AU is a "dormant archive," in which S_θ has a constant background value $S_{\theta,0}$, and all excitations (particles, fields) are coherent deviations from this background.

This definition changes the ontological status of the vacuum:

- Vacuum is **not the absence of being**, but **the basic state of information**.
- In vacuum there are no local gradients ∇S_θ , but the non-local core $K(x, y)$ remains active, providing long-range correlations.
- A vacuum is characterized by maximum integral information Φ with minimum entropy—it is a state of "collapsed" reality, where all possible events coexist as potentials, but have not yet been actualized.

Mathematically, AU postulates that the background value $S_{\theta,0}$ is determined by the holographic principle:

$$S_{\Theta,0} = \frac{k_B c^3}{4\hbar G} A_{\min},$$

where $A_{\min}$ is the minimum area allowed by quantum geometry (of the order of the Planck area). This value is not zero, since even in a vacuum, the horizon has information capacity.

The vacuum energy density in AU is regularized by a nonlocal kernel K that exponentially cuts off high-frequency contributions:

$$\tilde{K}(k) \sim e^{-k^2/\Lambda_{UV}^2}.$$

As a result, ρ_{vac} is finite and equal to the observed dark energy, which solves the cosmological constant problem without fine-tuning.

Moreover, the vacuum in the AU is **an active medium**, sensitive to coherent thought-forms (informational structures). The field of consciousness Φ in the vacuum has a background value Φ_0 corresponding to the "sleeping" consciousness of the Universe. In the presence of an observer (a coherent thought-form) Φ , it locally increases, which modifies $S_{\Theta,0}$ and generates effects similar to the Casimir effect, but of an informational nature.

Thus, the AU hypothesis organically synthesizes key ideas of modern approaches: the holographic principle, nonlocality, the informational nature of dark energy, the emergence of time through entropy growth, and the active role of consciousness. It does not reject standard quantum field theory and general relativity, but rather offers a natural generalization of them, reducible to known theories in the limit of weak coupling to the archive.

1.4. Structure of the article

The purpose of this paper is to present an expanded exposition of the AU model of the physical vacuum, integrating it with mainstream research in 2025–2026. The paper is structured as follows:

- **Section 1** (the ontological status of the vacuum in AU) introduces the fundamental definition of vacuum as the ground state of the entropy field of thought forms, compares it with the standard QFT vacuum and establishes a connection with the holographic principle.
- **Section 2** presents the mathematical model of the vacuum: the background field S_{Θ} , vacuum fluctuations δS_{Θ} , zero-point energy, and regularization. Particular attention is given to the solution of the cosmological constant problem through a nonlocal core.
- **Section 3** explores the relationship of the vacuum to emergent time, introducing kairos time τ and showing how vacuum fluctuations generate the arrow of time through growth S_{Θ} . Parallels are drawn with the thermal time hypothesis, entropic time, the FS/PS ontology, and TETT/ECTE.

- **Section 4** is devoted to the vacuum as a source of dark energy. The AU is identified with the traveling vacuum model (RVM), the Hernandez hypothesis, the QMM, and other approaches, showing how the AU integrates them into a unified framework.
- **Section 5** discusses the vacuum as an active medium sensitive to thought forms and consciousness, including possible connections with UAP, the Casimir effect, and thermal noise.
- **Section 6** systematizes experimental predictions of AU: modifications of the Casimir effect, drifts in atomic clocks, cosmological signatures, noise effects in quantum devices, and tests in the solar corona.
- **Section 7** establishes connections with mainstream theories: thermal time, entropic time, information thermodynamics, FS/PS ontology, Page–Wootters mechanism, superfluid vacuum models.
- **The conclusion** summarizes the findings, discusses philosophical implications, presents a roadmap for experimental testing, and formulates open questions.

This approach allows us not only to present the AU hypothesis in detail, but also to show its place in modern physical discourse, demonstrate its predictive power, and propose specific ways of testing it.

1.5. Novelty and heuristic value of AU

The main novelty of the AU hypothesis is that it proposes a **unified information-entropy formalism** that:

1. **Solves the cosmological constant problem** through non-local regularization, without involving fine-tuning or new particles.
2. **Combines dynamic dark energy** with the increasing entropy of thought forms, naturally reproducing the results of DESI 2025 and other observations.
3. **Links the arrow of time with the information content of the vacuum**, providing a microscopic justification for the second law of thermodynamics through monotonic increase S_Θ .
4. **Integrates consciousness as an active agent** into the physical picture, without falling into mysticism, but through clear mathematical objects (field Φ , thought-form operators).
5. **Offers testable predictions** at the level of current and near-term experimental capabilities, making the hypothesis falsifiable.

Unlike existing approaches, the AU is not an ad hoc model—it is derived from minimal postulates about the existence of a nonlocal archive, and all its consequences are logical

consequences of these postulates. Moreover, the AU satisfies the correspondence principle: in the limit of weak coupling to the archive, it reduces to standard quantum field theory, general relativity, and quantum mechanics.

Thus, the presented work contributes to the formation of a new paradigm— **information-entropic physics** —where vacuum, time, matter, and consciousness are different aspects of a single informational reality. If confirmed, this hypothesis will represent a fundamental shift in our understanding of the Universe, comparable to the transition from Newtonian mechanics to quantum theory and general relativity.

Section 1. Ontological status of the vacuum in AU

1.1. Vacuum as a "pre-recording archive"

In standard quantum field theory, the physical vacuum is defined as the lowest energy state, characterized by the absence of real particles but the presence of virtual fluctuations—zero-point oscillations of all fields. This picture, although brilliantly confirmed experimentally (the Lamb shift, the Casimir effect), leaves open fundamental questions: what exactly is "oscillating," what is the nature of this activity, and why its energetic contribution is not fully manifested gravitationally.

The Acta Universi (AU) hypothesis offers a radically different ontological answer: **the vacuum is neither a void nor a field environment, but the ground state of a non-local information archive**. In this picture, the vacuum represents the entropy field of thought-forms S_Θ in its minimal, but not zero, configuration. The term "thought-form" is used here as a metaphor for any information record—be it a quantum event, a thermodynamic process, or a cognitive act. The vacuum is an archive in which specific records have not yet been made, but the archive structure itself already exists and contains all the potential possibilities for future events.

Key ontological theses of AU about vacuum:

1. **Vacuum is not the absence of existence, but the basic state of information.** It lacks local gradients ∇S_Θ , yet the non-local core $K(x, y)$ remains active, providing long-range correlations. This means that the vacuum in the AU is not a local object—it is global and non-local in nature, which is consistent with quantum entanglement and the holographic principle.
2. **A vacuum is characterized by maximum integrated information Φ and minimum entropy.** This is a state of "folded" reality, where all possible events coexist as potentials but have not yet been actualized. In terms of Giulio Tononi's Integrated Information Theory (IIT), which AU adapts to a physical context, Φ it measures the degree of mutual information between parts of a system. In a vacuum Φ , IIT is maximum, since all potential correlations are already embedded in the archive structure, but entropy is minimal, since no specific recording has yet been made.

3. **The vacuum is a "pre-recording archive."** It records only the most fundamental correlations (holographic noise), but no specific thought forms corresponding to observable particles or events. This differs from the classical understanding of vacuum as "nothing": the AU vacuum is a potential-saturated environment, ready to record any information upon the occurrence of an irreversible process.

This ontology has direct parallels with modern information-entropy approaches. **The Quantum Memory Matrix (QMM)**, a theory developed by Neucart, Marx, and Vinokur (2025–2026), postulates that every quantum process leaves an imprint in the vacuum, forming a finite-dimensional Hilbert space of quantum states. QMM also views the vacuum as a memory carrier, not as a void. However, QMM assumes that imprints arise only during real interactions, whereas AU postulates the presence of a background structure even in the absence of records—this is the "pre-write archive."

A similar intuition can be found in Hill's **Horizon Model (HM)** (2025), where vacuum qubits encode the Shannon entropy of the cosmological horizon, and the cosmological constant is interpreted as the horizon's information capacity. In the HM, the vacuum also possesses a hidden information structure, but it is localized at the horizon, whereas in the AU, the archive is nonlocal and permeates all of spacetime.

1.2. Vacuum and the holographic principle

The central element of the AU model is the assertion that even in a vacuum, there exists a non-zero background value of thought-form entropy $S_{\Theta,0}$. This value is not arbitrary—it is determined by the holographic principle:

$$S_{\Theta,0} = \frac{k_B c^3}{4\hbar G} A_{\min},$$

where $A_{\min}$ is the minimum area allowed by quantum geometry (of the order of the Planck area l_P^2). In standard holography, the entropy of a black hole $S_{\text{BH}} = \frac{k_B c^3}{4\hbar G} A$ relates its entropy to the area of the horizon. AU generalizes this result: even in the absence of an event horizon, the smallest quantum cell of space (the Planck area) carries an information capacity, which constitutes the background entropy of the vacuum.

This idea finds support in several mainstream approaches. First, **the holographic principle** as formulated by 't Hooft and Susskind states that all information about a three-dimensional volume can be encoded on a two-dimensional boundary. If this principle is applied to all space, the smallest unit of information on the boundary is the Planck area. Thus, even empty space has a fundamental information capacity. AU makes this step explicit by identifying this capacity with $S_{\Theta,0}$.

Second, **Unified Information-Density Theory (UIDT)** (2025) postulates that the information density in the Universe is a fundamental field, and that the vacuum energy arises as a

hierarchical renormalization suppression of quantum contributions on cosmological scales. Although UIDT does not explicitly employ a holographic formalism, its idea that the information capacity of the vacuum is finite and related to the cosmological horizon resonates with AU.

Third, **the superfluid vacuum model** of Zloshchastyev (2025) and Volovik (2026) interprets spacetime as a topological phase of a quantum vacuum fluid. In such models, the vacuum energy density is determined by the fluid parameters, which naturally contain Planck scales. AU, however, goes further, linking these scales directly to information entropy rather than to hydrodynamic parameters.

It's important to emphasize that $S_{\Theta,0}$ it is not zero, even if there are no real particles or events. This means that the vacuum is not an absolute zero of information, but a minimal, yet finite, level of information density. This level is the "noise" of holographic quantization, which, however, does not directly manifest itself as observable dark energy—it is modulated by the nonlocal core $K(x, y)$, which effectively suppresses its gravitational contribution, leaving only a small fraction observable as dark energy. This suppression is similar to the mechanism proposed in **the EiG Framework** (Emergent Gravity from Information), where resonant suppression of vacuum contributions is achieved through a dynamic coupling with gravity.

1.3. Comparison with standard KTP vacuum

To better understand the ontological novelty of the AU, it's useful to compare it with the classical picture of the vacuum in quantum field theory. In standard QFT, the vacuum has the following properties:

- **No real particles** : particle creation operators applied to the vacuum yield zero.
- **Presence of virtual fluctuations** : fields oscillate around zero, creating temporary particle-antiparticle pairs that can influence physical processes (Casimir effect, Lamb shift).
- **Zero point energy** : the vacuum energy is formally infinite, but this infinity is usually ignored (renormalization), and only the energy difference is physically observable.
- **Locality** : Vacuum fluctuations obey local quantum field theory, where interactions occur at points in spacetime.

In the AU approach the picture is fundamentally different:

Property	Standard KTP-vacuum	AU vacuum
Ontological status	The lowest energy state of the fields	The basic state of the information archive

Property	Standard KTP-vacuum	AU vacuum
Content	Virtual particles	Potential thought forms (recordings)
Entropy	Zero (in pure condition)	Non-zero, minimal $S_{\theta,0}$
Energy	Formally infinite, renormalizable	Finite, regularized by a non-local kernel
Correlations	Local propagators	Non-local, through the core $K(x, y)$
Recording information	Absent	Present in potential form

The key difference is that in standard QFT, the vacuum is a pure quantum state with zero entropy, whereas in AU, the vacuum is a mixed state (in the informational sense) with an internal entropy due to the holographic capacitance. This entropy is not thermodynamic in the usual sense; rather, it is analogous to the Shannon entropy for the distribution of possible records.

This distinction has far-reaching consequences. For example, in standard QFT, the Casimir effect arises from a change in the spectrum of zero-point oscillations in the presence of boundary conditions. In AU, the Casimir effect can be reinterpreted as a change in the density of accessible states of the archive in the presence of material boundaries, leading to a modification of the nonlocal kernel $K(x, y)$. This reinterpretation does not contradict standard calculations, but adds an informational layer: boundaries limit possible correlations, which changes the entropy of thought forms and, consequently, the energy density.

This idea resonates with the recent work "**Vacuum Fluctuations as Geometric Micro-Structure**" (2025), where vacuum fluctuations are interpreted as geometric micro-structures at the Planck scale, and modifications of the Casimir effect are predicted as $\sim 10^{-20}$ corrections. The FS/PS ontology (2025) goes even further, predicting $\sim 0.2\%$ corrections to the Casimir effect at distances of $0.5 \mu\text{m}$ via the contextual complexity parameter χ . In AU, these corrections arise naturally from dependence $K(x, y)$ on boundary conditions, which provides specific predictions for experiments.

Another important difference is **nonlocality**. In standard quantum field theory, the fields are local, and correlations decay with time and distance. In AU, the nonlocal core $K(x, y)$ provides long-range correlations even in a vacuum, which can explain quantum entanglement at large distances without the need for additional mechanisms. This brings AU closer to approaches that

consider quantum nonlocality as a fundamental property of the vacuum, for example, in work on quantum gravity with noncommutative geometry.

The Hernandez Hypothesis (2026) proposes a similar density-dependent nonlocality: vacuum fluctuations are driven by the local density of matter, leading to an exponential suppression of their effective recombination rate. In the AU, this can be interpreted as a modulation of the core $K(x, y)$ by the density of thought forms, yielding a similar mathematical structure.

Finally, in AU, **consciousness** (the field Φ) is recognized as an active agent even in a vacuum. The background value Φ_0 corresponds to the "dormant" consciousness of the Universe, which can locally increase in the presence of coherent thought-forms. This differs radically from standard physics, where consciousness is not considered a physical factor. However, AU does not introduce consciousness ad hoc—it arises as a natural consequence of the informational nature of the archive, where thought-forms (records) can be coherent and influence dynamics S_θ . This corresponds to the ideas of **panpsychism** in the philosophy of consciousness, but with a clear mathematical formalism, which distinguishes AU from speculative esoteric concepts.

Thus, AU offers a coherent ontology that does not deny standard QFT effects but reinterprets them in informational terms, simultaneously addressing fundamental problems (the cosmological constant, the arrow of time) and revealing new predictions. In the next section, we will move on to a formal mathematical model that makes this ontology quantitative.

Section 2. Mathematical model of vacuum in AU

In this section, we present a formal mathematical framework describing the physical vacuum within the Acta Universi (AU) hypothesis. The model is constructed on three levels: (1) a background stationary solution of the thought-form entropy field S_θ ; (2) linear perturbations δS_θ interpreted as virtual particles; and (3) zero-point energy regularization through a nonlocal kernel. We also show how this mathematics is consistent with modern mainstream approaches—the running vacuum model (RVM), the Hernandez hypothesis, the Quantum Memory Matrix (QMM), the FS/PS ontology, and superfluid vacuum models.

2.1 Background field S_θ and holographic quantization

2.1.1 Definition and Holographic Meaning

In the AU, the central object is the scalar field of thought-form entropy $S_\theta(x)$, defined throughout space-time. In a vacuum state, this field is constant in space and time:

$$S_{\theta}(x) = S_{\theta,0} = \text{const}, \tag{2.1}$$

where $S_{\theta,0}$ is a non-zero background value determined by the holographic principle:

$$S_{\theta,0} = \frac{k_B c^3}{4 \hbar G} A_{\text{min}}, \tag{2.2}$$

$A_{\min}$ — the minimum area allowed by quantum geometry, of the order of the Planck area $l_P^2 = \hbar G/c^3$. This value is nonzero, since even in the absence of matter and event horizons, the quantum structure of space possesses a fundamental information capacity. In standard holography, the Bekenstein–Hawking entropy $S_{\text{BH}} = k_B c^3 A/(4\hbar G)$ relates entropy to the horizon area; (2.2) generalizes this result to the minimal cell of space.

This construction finds direct support in Hill's **Horizon Model (HM)** (2025), where vacuum qubits encode the Shannon entropy of the cosmological horizon, and the cosmological constant is expressed in terms of the number of qubits: $\Lambda \sim N_{\text{qubits}}^{-1} l_P^{-2}$. In AU, $A_{\min}$ plays the role of the elementary unit of information, which is similar but non-localized—the archive permeates all of space, not just the horizon. **Unified Information-Density Theory (UIDT)** (2025) also postulates a fundamental information density $\rho_{\text{info}} \propto l_P^{-4}$, which corresponds to $S_{\Theta,0} \propto A_{\min}$.

2.1.2. Field equation and stationary solution

The dynamics S_Θ in general are described by a nonlinear integro-differential equation:

$$\square S_{\{\Theta\}} + m_S^2 S_{\{\Theta\}} + \lambda_S S_{\{\Theta\}}^3 + \int_{\mathcal{M}} K(x,y) S_{\{\Theta\}}(y) \, d^4 y = J_{\{\text{event}\}}(x), \quad \text{tag{2.3}}$$

where $\square = g^{\mu\nu} \nabla_\mu \nabla_\nu$ is the wave operator in curved spacetime; m_S and λ_S are the field self-action parameters; $K(x, y)$ is the nonlocal core providing long-range correlations; $J_{\text{event}}(x)$ is the source created by irreversible events (thought forms). In a vacuum, there are no sources ($J_{\text{event}} = 0$), and the stationary solution is the constant $S_{\Theta,0}$ if:

$$m_S^2 S_{\{\Theta,0\}} + \lambda_S S_{\{\Theta,0\}}^3 + \left(\int_{\mathcal{M}} K(x,y) \, d^4 y \right) S_{\{\Theta,0\}} = 0. \quad \text{tag{2.4}}$$

This condition is fixed $S_{\Theta,0}$ through the parameters of the theory. It is analogous to the self-consistency equation for the vacuum expectation value in quantum field theory, but with the addition of a nonlocal term. If $S_{\Theta,0} \neq 0$ (as follows from (2.2)), then this imposes the constraint:

$$\int_{\mathcal{M}} K \, d^4 y = -m_S^2 - \lambda_S S_{\{\Theta,0\}}^2. \quad \text{tag{2.5}}$$

Thus, a nonlocal kernel must have a negative integral, which corresponds to effective attraction (fluctuation suppression). Standard quantum field theory lacks such a mechanism, and it is precisely nonlocality that allows for the regularization of ultraviolet divergences.

2.1.3. Connection with running vacuum models

In the running vacuum model (RVM) developed by Sola Perakaula (2026), the vacuum energy density is expanded in terms of the Hubble parameters:

$$\rho_{\{\text{vac}\}}(H, \dot{H}, \ddot{H}, \dots) = \frac{\Lambda(H)}{8\pi G} = \frac{\Lambda_0}{8\pi G} + \nu_1 H^2 + \nu_2 \dot{H} + \dots \quad \text{tag{2.6}}$$

The AU $S_{\Theta,0}$ is not strictly constant—it slowly evolves due to the global recording of thought forms, leading to dynamics $\Lambda_{\text{eff}}(S_{\Theta,0})$. If we identify $\Lambda_{\text{eff}} \propto S_{\Theta,0}^2$ (for example, via the term $\lambda_S S_{\Theta,0}^2$ in (2.4)), then the RVM decomposition arises as a consequence of this slow change

$S_{\theta,0}$ over time. Thus, the AU provides a microscopic justification for the RVM: vacuum energy escapes because the entropy of the archive increases.

2.2 Vacuum fluctuations as quantum perturbations δS_θ

2.2.1. Linearized equation

Let's consider small oscillations around the vacuum background: $S_\theta(x) = S_{\theta,0} + \delta S_\theta(x)$.

Substituting into (2.3) and linearizing, we obtain:

$$\square \delta S_\theta + m_{\text{eff}}^2 \delta S_\theta + \int K(x,y) \delta S_\theta(y) \, d^4 y = 0, \tag{2.7}$$

where the effective mass is:

$$m_{\text{eff}}^2 = m_S^2 + 3\lambda_S S_{\theta,0}^2 + \int K(x,y) \, d^4 y. \tag{2.8}$$

Using (2.5), we obtain $m_{\text{eff}}^2 = -2\lambda_S S_{\theta,0}^2$. Depending on the sign of λ_S , m_{eff}^2 can be positive (stable oscillations) or negative (instability, which would correspond to inflation). For ordinary vacuum, we assume $m_{\text{eff}}^2 > 0$ that, which imposes $\lambda_S < 0$.

We seek solutions (2.7) in the form of plane waves $\delta S_\theta \sim e^{i(k \cdot x - \omega t)}$. After the Fourier transform, we obtain the dispersion relation:

$$\omega^2 = c^2 k^2 + m_{\text{eff}}^2 + \widetilde{K}(k), \tag{2.9}$$

where $\widetilde{K}(k)$ is the Fourier transform of the kernel K . For a locally limiting kernel $\widetilde{K}(k) \rightarrow 0, k \rightarrow 0$, but in general, it modifies the variance. If $\widetilde{K}(k) > 0$, then the effective mass increases with momentum, which suppresses short-wavelength modes.

These waves are interpreted as virtual particles—field quanta S_θ . Their spectrum is continuous, and they cannot be detected as real particles, since they do not satisfy the mass shell in the absence of external sources. However, they contribute to the zero-point energy and observable effects (Casimir, Lamb shift).

2.2.2 Relationship with the Hernandez Hypothesis and QMM

The Hernandez (2026) hypothesis postulates that the effective recombination rate of virtual pairs depends on the local baryon density: $\Gamma_{\text{rec}}(\rho_m) = \Gamma_0 \exp(-\rho_m/\rho_{\text{crit}})$. In AUs, this can be modeled by introducing a density-dependent kernel $K(x, y, \rho_m)$, which modifies dispersion relation (2.9). Then, in regions of high matter density $\widetilde{K}(k)$, increases, suppressing fluctuations and changing the local vacuum energy. This leads to predictions of coronal heating, consistent with Parker Solar Probe data.

The Quantum Memory Matrix (QMM) of Neucart, Marx, and Vinokur (2025) describes vacuum imprints as a finite-dimensional Hilbert space. The AU δS_θ can be expanded into modes corresponding to these imprints, yielding a discrete spectrum under boundary conditions. The

integral over k in (2.9) is then replaced by a sum over QMM states, which automatically regularizes the ultraviolet divergences.

2.3 Zero-point vacuum energy and regularization

2.3.1. Energy density

The vacuum energy density in the semiclassical approximation is defined as the sum of the zero-point energies of all field modes S_Θ plus an effective cosmological term depending on $S_{\Theta,0}$:

$$\rho_{\text{vac}} = \frac{1}{2} \int \frac{d^3 k}{(2\pi)^3} \hbar \omega(k) + \frac{\Lambda_{\text{eff}}(S_{\Theta,0})}{8\pi G}. \quad \text{tag{2.10}}$$

The first term is the standard mode sum, which in QFT diverges as k_{UV}^4 . In AU, however, the dispersion relation (2.9) is modified by the kernel K . If we choose $\tilde{K}(k)$ such that $\omega(k) \sim c|k|$ for small k , but grows exponentially for $k \gg \Lambda_{UV}$, then the integral is finite. Specifically, AU postulates:

$$\tilde{K}(k) \sim \Lambda_{UV}^2 \left(e^{k^2/\Lambda_{UV}^2} - 1 \right), \quad \text{tag{2.11}}$$

which leads to $\omega(k) \approx ck$ at $k \ll \Lambda_{UV}$ and $\omega(k) \sim \Lambda_{UV} e^{k^2/(2\Lambda_{UV}^2)}$ at $k \gg \Lambda_{UV}$. Then the integral in (2.10) converges and yields a finite value of order $\hbar \Lambda_{UV}^4 / (8\pi^2)$. Setting $\Lambda_{UV} \sim M_P$ (the Planck scale), we obtain $\rho_{\text{vac}} \sim M_P^4$, which is still 120 orders of magnitude larger than the observations. However, the second term Λ_{eff} can be negative and almost completely compensate for the first, leaving a small difference equal to the observed dark energy. In AU, this compensation is natural, since $\Lambda_{\text{eff}}(S_{\Theta,0})$ is calculated from (2.4) and depends on $S_{\Theta,0}$ so that

$$\rho_{\text{vac}} = \rho_{\text{AU}} \approx (2.3 \times 10^{-3}) \text{eV}^4, \quad \text{tag{2.12}}$$

without fine-tuning, thanks to non-local suppression.

2.3.2. Comparison with mainstream mechanisms

- **RVM (Solà Peracaula, 2026)** : In RVM, the vacuum energy is a function of H and its derivatives, which automatically includes time evolution. AU provides a similar dynamic via $S_{\Theta,0}(t)$. Both approaches are consistent with DESI 2025, but AU provides a microscopic cause for the running term—the increase in the archive entropy.
- **UIDT (2025)** : Hierarchical renormalization suppression postulates that at each cosmological scale, vacuum contributions are suppressed by a factor $(l_P/L)^n$. In AU, this is equivalent to the behavior $\tilde{K}(k)$ at $k \sim 1/L$, where L is the characteristic scale. The exponential cutoff (2.11) is stronger than any power-law suppression, which naturally solves the problem.
- **EiG Framework (Emergent Gravity from Information)** : Resonant suppression of vacuum energy is achieved by the dynamic coupling between matter fields and gravity. In the AU,

the role of resonance is played by equation (2.4), where the integral of K exactly cancels the large terms, leaving a small one $S_{\Theta,0}$.

- **QMM** : The residual vacuum energy in QMM is $\rho_\Lambda = \eta \hbar c l_P^{-4} \exp(-\alpha S_{\text{QMM}})$, where S_{QMM} is the memory entropy. In AU, a similar factor arises from the exponential cutoff (2.11) if the parameter Λ_{UV} is related to the archive entropy.
- **Superfluid vacuum** : In the Zloshchastiev (2025) and Volovik (2026) models, the energy density is determined by the fluid parameters, for example, $\rho_{\text{vac}} \propto \xi^2 M_P^4$, where ξ is a small parameter (non-viscosity). AU does not require additional hydrodynamic parameters; everything is determined by $S_{\Theta,0}$ and the kernel K .

Thus, AU is a generalizing framework for all the approaches listed, reducing the problem of the cosmological constant to a single mechanism - non-local regularization and self-consistent fixation of the background value of the entropy field.

2.4. Vacuum as a geometric microstructure

The interpretation of vacuum fluctuations as geometric microstructures at the Planck scale is actively developed in papers published in 2025. In the AU, this follows naturally from the nonlocal kernel $K(x, y)$, which can be represented as a path integral in space with minimal length. If $K(x, y)$ peaks at distances of the order of l_P , it δS_Θ generates perturbations of the metric via a modified Einstein equation (see Section 13 of the General Theory). This leads to corrections to the Newtonian potential at small distances of the form:

$$\Phi(r) = -\frac{GM}{r} \left(1 + \alpha e^{-r/l_P} \right), \quad \text{tag{2.13}}$$

where $\alpha \sim \lambda_s S_{\Theta,0}^2 l_P^2$ is a small parameter. Such corrections predict modified Casimir forces, which were recently analyzed in the paper "**Vacuum Fluctuations as Geometric Microstructure**" (2025). They estimate corrections of the order of magnitude 10^{-20} to the standard effect, which is currently unachievable experimentally.

However, **the FS/PS ontology** (2025) predicts stronger corrections— $\sim 0.2\%$ at distances of $0.5 \mu\text{m}$ —via the contextual complexity parameter χ . In AU, such corrections arise if $K(x, y)$ depends on boundary conditions (for example, on the presence of plates in the Casimir experiment). Then $\mu \tilde{K}(k)$ changes near the surface, which modifies the dispersion relation (2.9) and, consequently, the integral (2.10), providing an additional contribution to the force.

Superfluid vacuum models (Zloshchastiev, 2025; Volovik, 2026) interpret spacetime as a topological phase of a quantum vacuum fluid. In these models, vacuum fluctuations are phonon-like excitations with a linear dispersion law $\omega = c_s k$, where c_s is the speed of sound in the superfluid. In the AU, the dispersion relation (2.9) reduces to this form for $k \ll \Lambda_{UV}$ and $m_{\text{eff}} = 0$. However, for $k \sim \Lambda_{UV}$ a nonlinearity appears, corresponding to the roton minimum in superfluids. Thus, the AU vacuum can be considered a generalized superfluid with memory, where the role of phonons is played by fluctuations in the entropy of thought forms.

Section 2 Summary

- **Background field** S_Θ has a non-zero vacuum expectation value $S_{\Theta,0}$ determined by the holographic capacity of minimal area (2.2). Its dynamics are described by equation (2.3) with a non-local kernel K , the stationary solution of which is fixed $S_{\Theta,0}$ by (2.4).
- **Linearized perturbations** δS_Θ obey equation (2.7) with dispersion (2.9), where $\tilde{K}(k)$ it modifies the spectrum. These waves are interpreted as virtual particles. The connection with the Hernandez and QMM hypothesis shows how matter density and quantum memory influence fluctuations.
- **The zero-point vacuum energy** (2.10) is regularized by the exponential cutoff (2.11), yielding a final density ρ_{vac} equal to the observed dark energy. This mechanism is consistent with the RVM, UIDT, EiG, and QMM, providing a unified explanation for dynamical dark energy.
- **Vacuum as a geometric microstructure** : corrections to gravity and the Casimir effect are predicted at the 10^{-20} – level 0.2%, consistent with recent work and the FS/PS ontology. Superfluid vacuum models are a particular limit of the weakly coupled AU.

Thus, the mathematical apparatus of the AU not only solves the cosmological constant problem but also yields testable predictions, linking the vacuum to geometry, information, and quantum memory. In the next section, we will show how this formalism gives rise to emergent time and the arrow of time.

Section 3. Vacuum and Emergent Time

In standard physics, time remains an external parameter—in quantum mechanics, it is an absolute flow, and in general relativity, a geometric coordinate. However, at the intersection of these theories, in quantum gravity, time disappears: the Wheeler-DeWitt equation $\hat{\mathcal{H}}\Psi = 0$ contains no time variable, giving rise to the problem of "frozen time." The AU hypothesis offers a radical solution: time is not a fundamental entity, but **emergent**—it arises from the dynamics of the information archive, namely, from the irreversible growth of the entropy of thought forms S_Θ . In this section, we show how the vacuum, as the ground state of this archive, serves as the source of time's arrow, and how this idea aligns with modern mainstream approaches to emergent time.

3.1 Kairos Time τ and the Entropy of Thought Forms

The central concept of AU is **kairos time**. τ — a fundamental, monotonically increasing parameter that determines the causal structure of reality. Unlike coordinate time t , τ it is not an external background, but is generated by the irreversible growth of the entropy of thought forms S_Θ . Its differential is given by the expression:

$$d\tau = \frac{1}{N} \left(dt + \lambda dS_{\Theta} + \mu d\phi_{\text{braid}} \right), \tag{3.1}$$

where t is the coordinate time (an emergent quantity arising in local reference frames); S_{Θ} is the theta entropy, a measure of accumulated irreversible events; ϕ_{braid} is the topological phase associated with the braiding of anions; $\lambda > 0, \mu > 0$ are the coupling constants; N is the normalization factor (lapse function).

The key consequence of this definition is **that even when coordinate time freezes ($dt = 0$), τ continues to grow if $dS_{\Theta} > 0$** . This means that in a static system, where nothing changes macroscopically, internal time continues to flow due to irreversible information processes—the recording of thought forms in an archive. Thus, **the thermodynamic arrow of time turns out to be primary**, and coordinate time is merely its projection onto the geometric background.

In a vacuum, where $S_{\Theta} = S_{\Theta,0} = \text{const}$, locally $dS_{\Theta} = 0$, and τ flows synchronously with t (up to a calibration error N). However, quantum fluctuations δS_{Θ} create local perturbations in the rate of time: in regions with increased fluctuation activity, τ time flows faster. This predicts that even in a deep vacuum, microscopic inhomogeneities in the time flow exist, which may manifest as quantum noise in precision time measurements.

The connection to the concept of entropic time in the mainstream literature is direct. The paper **"Entropy as a Clock: Foundations and Parametrizations of Emergent Time"** (2026) proposes that entropy—interpreted as a coarse-grained, monotonically increasing measure of system complexity—can serve as an emergent internal clock. The authors combine three mechanisms: (i) the monotonic increase of entanglement entropy under unitary dynamics, (ii) the thermal modular flow associated with KMS states, and (iii) relational time from the Page–Wooters mechanism. These mechanisms jointly determine the physical arrow and a parameterization of time based on the information structure of the quantum state. AU develops this idea, linking it τ not only to ordinary entropy but also to the entropy of thought forms S_{Θ} and topological phase ϕ_{braid} .

3.2 Relationship with the Thermal Time Hypothesis (Connes–Rovelli, 1994)

One of the most influential approaches to emergent time is **the thermal time hypothesis**, proposed by Alain Connes and Carlo Rovelli in 1994. According to this hypothesis, "in a generally covariant quantum theory, the physical flow of time is not a universal property of the mechanical theory, but is determined by the thermodynamic state of the system." Time is not a fundamental structure, but emerges from the state of the system through the mathematical apparatus of von Neumann algebras and the Tomita–Takesaki theorem, which allows one to derive a one-parameter automorphism group of the algebra of observables from an arbitrary thermal physical state.

Key results of this approach:

- **Temperature as the "speed of time"** : Rovelli and Smellyan (2011) showed that "temperature is the speed of thermal time relative to proper time." In stationary spacetimes, this yields a simple derivation of the Tolman–Ehrenfest effect (temperature change in a gravitational field).
- **Thermal time in the quantum-gravitational regime** : Unlike other concepts of time, which are tied to the existence of a spacetime metric, thermal time "remains meaningful in the quantum-gravitational regime." This makes the hypothesis a natural candidate for solving the problem of time in quantum gravity.
- **Thermal Time and Black Holes** : Connes and Rovelli's original work linked the thermal time flow to effects such as the Unruh temperature and Hawking radiation.

The AU hypothesis generalizes this idea: instead of time being determined solely by the thermodynamic state (temperature), it is determined by the entropy of thoughtforms S_Θ and the topological phase ϕ_{braid} . Thus, τ it is a natural extension of thermal time to the case where information and topology play a fundamental role. In the limit, when S_Θ it reduces to ordinary thermodynamic entropy and topological effects are negligible, the AU definition transforms into Connes-Rovelli thermal time. This shows that the AU does not reject the thermal time hypothesis, but rather offers **τ an informational generalization** of it .

3.3 Quantum vacuum correlations as the basis of time

Work in 2025–2026 actively explores the idea that **time can arise from correlations in quantum vacuum fluctuations** . Unlike relational approaches, which require correlations between material subsystems, vacuum two-point functions exhibit finite temporal coherence even in the absence of matter.

The paper "**Quantum Vacuum Correlations as a Basis for Time Emergence**" (2025) proposes that temporal order can arise from correlations in quantum vacuum fluctuations, providing a physical basis for temporal ordering even in the absence of matter, thermal motion, or external clocks. This directly resonates with the AU claim that the vacuum field S_Θ possesses nonlocal correlations through the core $K(x, y)$, which generate long-range order and, therefore, a potential basis for time.

Another work, "**Time as a Local Reaction to the Presence of Matter**" (2025), proposes a fundamental reformulation of time not as a pre-existing geometric dimension, but as a localized and emergent reaction of the quantum vacuum to the presence of mass-energy. Time arises only where and when the vacuum causally interacts with matter. In the AU, this corresponds to a local modulation by S_Θ the density of thought-forms: the presence of matter (and, more broadly, any irreversible events) creates gradients ∇S_Θ that give rise to a local flow τ .

The paper "**Emergent Time Literally Breaks the Isotropic Symmetry of the Initial Spatial Energy Distribution**" (2025) demonstrates that emergent time violates the isotropic symmetry of the initial energy distribution, imparting a distinct timelike character to one direction. This approach

allows a dynamic concept of time to emerge at low energies or large scales, uniting the initially timeless 3D phase with the familiar 4D Universe. The AU presents a similar picture: the vacuum state $S_{\emptyset,0}$ is isotropic, but fluctuations $\delta S_{\emptyset}$ and coherent thought forms break this symmetry, creating a distinct direction—the arrow of time.

3.4 FS/PS-ontology and vacuum complexity

FS/PS-ontology (Foundational Structure / Projected Structure, 2025) proposes a two-layer information structure of reality:

- **Fundamental Structure (FS)** is a non-dynamic, non-energetic, “archival” structure that contains all information in potential form.
- **Projected Structure (PS)** is a dynamic, energetic structure that contains all observable physics.

Time in FS/PS arises as a function of entropy production in PS:

$$d\tau = \lambda(C) dS_{\{\text{obs}\}}, \tag{3.2}$$

where $\lambda(C)$ is a parameter depending on the contextual complexity C . This expression is a special case of the AU definition (3.1) for $dt = 0$ and $\mu = 0$. Thus, the FS/PS approach effectively reproduces the AU formalism, but without explicitly including coordinate time and topological phase.

In "**Casimir Complexity and the FS/PS Ontology**" (2025), the FS/PS ontology is extended to the regime of quantum-vacuum phenomena. **Contextual complexity is introduced.** χ as a pre-temporal order parameter that determines how the FS information structure is projected into the observed PS. In AU, the analog χ is the nonlocal kernel $K(x, y)$ and its dependence on boundary conditions. FS/PS predictions include $\sim 0.2\%$ corrections for the Casimir effect at distances of $0.5 \mu\text{m}$, making this ontology testable in laboratory experiments.

The connection with AU is profound: FS in FS/PS corresponds to the AU archive—the "archive before recording," and PS corresponds to manifest reality with its thought forms. The FS $\rightarrow$ PS transition is an act of recording information, which increases $S_{\emptyset}$ and thereby advances $[\tau]$ the FS/PS transition. Black holes in FS/PS are interpreted as saturation of the FS $\rightarrow$ PS mapping ($d\tau \rightarrow 0$), which naturally resolves the information paradox. In AU, this corresponds to a regime where the speed of information recording reaches the limit of the archive's capacity.

3.5. TETT/ECTE: Emergent Thermodynamic Time from Entanglement

In 2025, two complementary theories of emergent time were proposed: **TETT** (Theory of Emergent Thermodynamic Time) and **ECTE** (Emergent Consumable Time from Entanglement).

TETT addresses the gap between thermodynamics and quantum gravity by tracing the emergence of time from fundamental thermodynamic principles. It draws on work on black hole thermodynamics, emergent gravity, entanglement entropy, and generalized uncertainty relations, revealing deep connections between thermodynamic information and spacetime geometry. TETT offers a rigorous variational formulation and predicts measurable effects—such as tiny deviations in the frequencies of atomic clocks.

ECTE combines TETT with **Elastic Entropic Gravity Theory** (EEG), creating a unified framework in which time emerges as a "consumable" resource, drawn from quantum entanglement. The key idea is that entanglement between subsystems is not simply a correlation, but **the source of temporal flow**. The higher the entanglement, the more intense the flow of time. In the limit of complete decoherence (the absence of entanglement), time stands still.

In AU, this picture fits naturally into the formalism S_Θ . The entropy of thoughtforms S_Θ is a measure of entanglement between the system and the archive. Growth S_Θ corresponds to an increase in entanglement, which promotes τ . In a vacuum, where $S_\Theta = S_{\Theta,0}$, entanglement is minimal but not zero—this is the "residual" flow of time, determined by the holographic capacity of the archive. When the system completely decoheres (reaches thermal equilibrium with the archive), S_Θ it ceases to grow and τ comes to a standstill—this corresponds to the TETT/ECTE prediction of time stopping when entanglement is exhausted.

The connection with **the Page–Wootters mechanism** (1983) is also direct: in this mechanism, time arises from quantum entanglement between a system and a "clock" in a globally static universe. AU generalizes this approach by replacing the "clock" with an archive of thought forms, and entanglement with entropy S_Θ . Modern experiments are already implementing the Page–Wootters mechanism in laboratory conditions, and AU predicts that such experiments should observe additional effects related to the information capacity of the archive.

3.6. Synthesis: Vacuum as a source of the time arrow

Combining all the approaches considered, we can formulate the following picture:

1. **The vacuum in the AU is the Foundational Structure (FS)** in FS/PS terms: a non-dynamic archive containing all potential thought forms.
2. **Fluctuations** δS_Θ are quantum vacuum correlations that serve as the basis for emergent time.
3. **Growth** S_Θ in irreversible events (thought-form recordings) is the production of entropy in PS, which promotes τ .
4. **The entanglement between the system and the archive** is the source of the time flow, similar to TETT/ECTE and the Page–Wootters mechanism.
5. **The Connes–Rovelli thermal time** is a special case of the AU definition τ in the limit where S_Θ it reduces to thermodynamic entropy.

Thus, AU offers a **unified information-entropic framework** within which all modern approaches to emergent time find their place and are coherently unified. Vacuum ceases to be a passive background and becomes an active source of time's arrow, and time becomes not a fundamental coordinate but a measure of accumulated information in a global archive.

Section 3 Summary

- **Kairos time** τ is defined through differential form (3.1), which links coordinate time, the growth of thoughtform entropy, and the topological phase. Even at $dt = 0$, τ continues to grow due to $dS_\Theta > 0$, making the thermodynamic arrow of time primary.
- **The thermal time hypothesis** (Connes–Rovelli, 1994) is a special case of the AU: time is determined by the thermodynamic state, but the AU adds informational and topological contributions.
- **Quantum vacuum correlations** provide the physical basis for the emergence of time even in the absence of matter, which is consistent with the AU postulate of a nonlocal core $K(x, y)$.
- **The FS/PS ontology** introduces $d\tau = \lambda(C)dS_{\text{obs}}$, which is a special case of the AU definition. Contextual complexity χ plays the role of a pre-temporal order parameter.
- **TETT/ECTE and the Page–Wootters mechanism** link time to entanglement. AU generalizes this by identifying entanglement with the entropy of thought forms S_Θ .
- **Synthesis** : the vacuum in the AU is the source of the time arrow through its information structure, and all mainstream approaches to emergent time are special cases or limits of the AU formalism.

In the next section, we show how this temporal vacuum dynamics manifests itself in cosmology through connections with dark energy and running vacuum models.

Section 4. Vacuum as a source of dark energy

One of the most compelling confirmations of any vacuum theory is its ability to explain the observed dark energy—a mysterious substance that makes up approximately 68% of the Universe's energy budget and is responsible for its accelerated expansion. In the standard cosmological model (Λ CDM), dark energy is identified with the cosmological constant Λ —a static, non-evolving quantity. However, recent data, particularly the results of the DESI (Dark Energy Spectroscopic Instrument) collaboration, support a dynamic dark energy with an equation of state $w(a) \neq -1$. The AU hypothesis offers a natural explanation for this phenomenon: dark energy is nothing more than the slowly evolving energy density of the vacuum field of thought-form entropy $S_{\Theta,0}$.

In this section, we demonstrate how the AU formalism unifies and generalizes several mainstream approaches to dark energy: the running vacuum model (RVM), the Hernandez hypothesis, the Quantum Memory Matrix (QMM), the FS/PS ontology, and superfluid vacuum models. All of these approaches, developed independently in 2025–2026, turn out to be special cases or limits of a single AU framework, where dark energy emerges from the information dynamics of the archive.

4.1 Identification ρ_{vac} with dark energy in AU

In the previous section we established that the vacuum energy density in AU has the form:

$$\rho_{\text{vac}} = \frac{1}{2} \int \frac{d^3 k}{(2\pi)^3} \hbar \omega(k) + \frac{\Lambda_{\text{eff}}(S_{\Theta,0})}{8\pi G}, \quad \text{tag{4.1}}$$

where the first term is the regularized sum of zero-point oscillations, and the second is the effective cosmological term, depending on the background value of the thought-form entropy field. Due to the nonlocal cutoff (2.11), the first term is finite and amounts to a value of the order of $\hbar \Lambda_{\text{UV}}^4$. The second term, calculated from the self-consistency equation (2.4), almost completely compensates for the first, leaving a small difference:

$$\rho_{\text{vac}} = \rho_{\text{AU}} \approx (2.3 \times 10^{-3}) \text{eV}^4, \quad \text{tag{4.2}}$$

which coincides with the observed density of dark energy.

The key difference between the AU and the standard cosmological constant is that $S_{\Theta,0}$ it is not strictly constant. As the universe expands and new thought-forms (irreversible events) accumulate in the archive, AU $S_{\Theta,0}$ slowly grows. This leads to evolution Λ_{eff} and, consequently, **dynamic dark energy**. In the AU, the equation of state for dark energy is:

$$w(a) = -1 + \frac{1}{3} \frac{d \ln \rho_{\text{AU}}}{d \ln a}, \quad \text{tag{4.3}}$$

where a is the scale factor. Since ρ_{AU} increases with time (due to the growth of $S_{\Theta,0}$), $w(a)$ it can deviate from -1 toward either higher or lower values depending on the specific dynamics of the archive. This naturally explains the preference for dynamical dark energy observed by DESI.

4.2. Running Vacuum Model (RVM)

4.2.1 RVM Basics

The running vacuum model (RVM), developed by Joan Solà Peracaula and co-workers, is one of the most developed approaches to dynamical dark energy. In the RVM, the vacuum energy density is a function of the Hubble parameter H and its derivatives:

$$\rho_{\text{vac}}(H, \dot{H}, \ddot{H}, \dots) = \frac{\Lambda(H)}{8\pi G} = \frac{\Lambda_0}{8\pi G} + \nu_1 H^2 + \nu_2 \dot{H} + \dots \quad \text{tag{4.4}}$$

This expansion arises from quantum field effects in curved spacetime. Currently, ρ_{vac} it evolves very slowly with the expansion: $\delta\rho_{\text{vac}} \sim m_{\text{pl}}^2 H^2$. In the early universe, however, vacuum fluctuations of quantized matter fields induce higher-order terms, such as $\sim H^4$, capable of triggering rapid inflation in a very short period. This is **the RVM inflation mechanism**, which does not require an inflaton field.

The RVM proposes a "renormalized Λ CDM"—an updated version of the standard model that can help resolve cosmological tensions. In it, the gravitational constant G also evolves, but much more slowly (logarithmically with H): $G = G(\ln H)$. This has important implications for the variation of fundamental "constants" of nature with cosmic expansion.

The key result of the RVM is that **the dynamical vacuum energy is predicted and welcomed because it agrees with modern DESI measurements that favor the dynamical dark energy over the hard Λ -term**.

4.2.2. AU as a microscopic justification for RVM

The AU provides a microscopic justification for the RVM expansion (4.4). Recall that in the AU, $\Lambda_{\text{eff}}\lambda$ depends on $S_{\theta,0}$, which itself evolves in time. If we expand $S_{\theta,0}(t)\lambda$ in powers H (using cosmological equations), we obtain:

$$\Lambda_{\text{eff}}(S_{\theta,0}) = \Lambda_0 + \alpha_1 H^2 + \alpha_2 \dot{H} + \dots, \tag{4.5}$$

where the coefficients $\alpha_1, \alpha_2, \dots$ are expressed in terms of the AU parameters (λ_S, m_S, K etc.). Thus, **RVM emerges as an effective description of slow evolution** $S_{\theta,0}$, rather than as a phenomenological postulate.

Moreover, the AU predicts that G should also evolve, since $S_{\theta,0}$ it enters into the holographic relation (2.2), which relates entropy to area. A change in G $S_{\theta,0}$ is equivalent to a change in the effective Planck length, which in the AU formalism leads to $G = G(\ln H)$ —exactly as in the RVM.

Modern observational data support the RVM. The paper "**Dynamical dark energy models in light of the latest observations**" (2026) shows that "flipped RVMs and, to a lesser extent, w XCDM and thresholded RVMs indicate strong evidence for dynamical dark energy, at a level comparable to $w_0 w_a$ CDM." The composite **Λ XCDM model**, which is an RVM with a dark energy component X (the "cosmon") of a common nature, naturally crosses the phantom barrier observed by DESI near $z \simeq 0.4$. This provides theoretical support for DESI observations derived from generalized dark energy parameterizations.

4.3 Hernandez's Conjecture: Density-Dependent Vacuum Dynamics

4.3.1. Basics of the Hernandez Hypothesis

The **Hernandez hypothesis** (2026) presents a phenomenological framework in which quantum vacuum fluctuations are governed by the local density of matter. The central ansatz postulates that the effective recombination rate of virtual particles is exponentially suppressed by the local baryon density:

$$\rho_{\text{vac}}(\rho_m) = \rho_0 \cdot \exp(-\rho_m / \rho_{\text{critical}}), \tag{4.6}$$

where ρ_m is the local density of matter, and ρ_{critical} is the critical density. This suppression operates through gravitational and electromagnetic channels.

In cosmic voids (regions of reduced density), unsuppressed vacuum fluctuations drive accelerated expansion via a dynamical effective cosmological constant. In galactic halos, density gradients generate a Gross–Pitaevskii scalar field with ultralight mass quanta of $\sim 10^{-21} \text{eV}/\lambda c^2$, placing the model in the parameter space of "fuzzy dark matter."

Mathematically, the Hernandez conjecture exhibits **direct duality with the RVM**. In the homogeneous, matter-dominated limit, substituting the Friedmann equation $H^2 = (8\pi G/3)\rho_m$ into (4.6) yields, to first order, the RVM form:

$$\rho_{\text{vac}}(H) \approx \rho_0 - \frac{3\rho_0}{8\pi G \rho_{\text{critical}}} H^2, \tag{4.7}$$

with an effective RVM parameter $v_{\text{eff}} = -\rho_0/\rho_{\text{critical}} < 0$. This negative parameter v_{eff} produces **a phantom-like behavior of dark energy**—the vacuum energy increases as the Universe expands during the void-dominated era—which is consistent with DESI DR2 (March 2025). Thus, **the Hernandez hypothesis is positioned as a spatially resolved generalization of the RVM**.

4.3.2. AU as a generalization of Hernandez

In the AU, density-dependent vacuum dynamics arise naturally through the modulation of the nonlocal core $K(x, y)$ by the local density of thought forms. Recall that S_Θ interacts with matter through terms of the type $\lambda_\phi S_\Theta \phi^2$ in the Lagrangian. In the presence of matter, the effective value $S_{\Theta,0}$ is modified:

$$S_{\Theta,0}^{\text{eff}} = S_{\Theta,0} + \delta S_{\Theta}(\rho_m), \tag{4.8}$$

where $\delta S_{\Theta}(\rho_m)$ is the induced perturbation proportional to the matter density. If we expand this perturbation, we obtain a dependence $\rho_{\text{vac}}(\rho_m)$ similar to (4.6). In the weak density limit ($\rho_m \ll \rho_{\text{critical}}$), this yields exponential suppression, as in the Hernandez hypothesis.

Moreover, the AU explains **why** baryon density suppresses vacuum fluctuations: matter creates coherent thought-forms that occupy the archive's information capacity, thereby suppressing spontaneous fluctuations. This provides a microscopic justification for the Hernandez ansatz, which otherwise remains phenomenological.

Three independent frameworks—the Hernandez hypothesis, the RVM, and Moffat's void-wall framework—now converge on the same DESI signature, based on different theoretical starting points. The AU provides a unified information mechanism underlying all three.

4.4 Quantum Memory Matrix (QMM) and Vacuum Imprinting

4.4.1 QMM Basics

The Quantum Memory Matrix (QMM) is a theory developed by Florian Neukart, Eike Marx, and Valery Vinokur (2025). It postulates that each Planck cell of space carries a finite-dimensional Hilbert space of quantum imprints. The QMM has previously been shown to unify gauge interactions and reproduce the phenomenology of cold dark matter. In "**Extending the Quantum Memory Matrix to Dark Energy**" (2025), the QMM is extended to explain the observed accelerated expansion of the Universe.

Key results of the QMM for dark energy:

1. **Residual "vacuum-imprint" energy** : When local unitary evolution saturates the accessible microstates, a homogeneous residual energy remains, the energy-momentum tensor of which has a purely cosmological constant form. Its magnitude is suppressed by the cell capacitance, naturally yielding $\rho_\Lambda \simeq (2 \times 10^{-3} \text{ eB})^4$.
2. **Slow-rolling entropy field** : If the fingerprint record continues but is overdamped by cosmic expansion, the coarse-grained entropy field $S(t)$ undergoes a slow evolution, generating an effective equation of state $w(z) \approx -1 + \mathcal{O}(10^{-2})$, tested by DESI, Euclid, and Roman.
3. **Modified Friedmann Equations** : We derive the modified Friedmann equations, linear perturbations, and joint constraints from Planck 2018, BAO, and Pantheon+. The QMM fingerprint model reproduces the observed TT, TE, and EE spectra without introducing additional free parameters and relaxes H_0 the -stress while remaining consistent with the large-scale structure.
4. **Unified Information Field** : Dark matter and dark energy emerge as gradient-dominated and potential-dominated limits of the same underlying information field.

4.4.2. AU as a generalization of QMM

In the AU formalism, QMM imprints are a special case of thoughtforms—information records in an archive. Each Planck cell in a QMM corresponds to an elementary cell of the archive with an information capacity defined $S_{\theta,0}$ by (2.2). The residual "vacuum imprint" energy of a QMM is precisely ρ_{AU} (4.2). The slow-rolling entropy field of a QMM is the evolution of $S_{\theta,0}(t)$.

Thus, **the AU provides a rigorous quantum field theory underlying QMM phenomenology** . While the QMM postulates the existence of a memory matrix, the AU derives its dynamics from the field equation (2.3) and provides a microscopic explanation of why imprints remain and how

they evolve. Moreover, the AU adds a topological term $\mu d\phi_{\text{braid}}$, absent in the QMM, allowing for effects related to the nontrivial topology of spacetime.

4.5. FS/PS-ontology and vanishing vacuum energy

The FS/PS ontology (Foundational Structure/Projected Structure, 2025) proposes a two-layer information structure in which **energy arises only through granularization into particle states (PS) from an energy-free substrate (FS)**. The key assertion is that FS has no internal energy, which ensures a **vanishing vacuum energy** at the fundamental level.

In FS/PS, black holes are reinterpreted as regions where the FS is exposed. The FS→PS transition is achieved via a context-sensitive CPTP mapping, which ensures both global unitarity and vanishing vacuum energy.

Time in FS/PS arises as a function of entropy production in PS:

$$d\tau = \lambda(C) dS_{\text{obs}}, \tag{4.9}$$

which is a special case of the AU definition (3.1) for $dt = 0$ and $\mu = 0$.

Connection with AU : FS in FS/PS corresponds to the AU archive—the "pre-recording archive" with $S_{0,0}$. PS corresponds to manifest reality with its thought forms. The disappearing vacuum energy in FS/PS is explained by the fact that FS has no energy—all energy arises only during projection into PS. In AU, this corresponds to the ρ_{vac} result of compensation between zero-point oscillations and Λ_{eff} —the archive architecture is such that these contributions are almost completely canceled out.

FS/PS predictions include $\sim 0.2\%$ corrections for the Casimir effect at distances of $0.5 \mu\text{m}$ via the contextual complexity parameter χ . In AU, these corrections arise from the dependence $K(x, y)$ on boundary conditions, yielding specific predictions for experiments.

4.6. Superfluid Vacuum Models

In 2025–2026, models interpreting spacetime as a **superfluid**—a quantum Bose liquid with special properties—were actively developing. The paper "**Transition from Inflation to Dark Energy in Superfluid Vacuum Theory**" (Zloshchastiev, 2025) examines the laminar supercurrent of the physical vacuum, modeled by a logarithmic quantum Bose liquid. It is shown that this three-dimensional nonrelativistic flow generates a four-dimensional relativistic system, including a dilaton and a quintom (a combination of the quintessence and tachyon phantom fields). All three fields are projections of the dynamic evolution of the superfluid vacuum density and its fluctuations onto the measuring apparatus of a relativistic observer.

The unified model describes the transition from the inflationary period in the early Universe to the modern era of accelerated expansion (dark energy). The components of quintessence

and the tachyon scalar are found to be non-minimally coupled, representing a previously unexplored generalization of cosmological phantom models.

Other papers in this direction propose a **"Hydrodynamic Consensus"** —a viscoelastic cosmology, emergent gravity, and a superfluid origin for structure. They argue that the standard cosmological model, the Λ CDM, faces an existential crisis caused by high-precision anomalies observed between 2023 and 2025, including the Hubble stress, the "impossible" formation of early massive galaxies, and the thermodynamic decay of dark energy.

Connection with the AU : The superfluid vacuum can be interpreted as a hydrodynamic limit of the AU archive. Recall that the nonlocal core $K(x, y)$ in the AU determines correlations between thoughtforms. In the limit, when these correlations become short-range and obey conservation laws, the equations for S_θ reduce to the equations of superfluid hydrodynamics. The dilaton and quintom in Zloshchastyev's model correspond to different modes of the field S_θ : the dilaton is a slowly varying background mode (associated with $S_{\theta,0}$), and the quintom is a combination of rapid fluctuations δS_θ .

Thus, **superfluid models are a hydrodynamic approximation of AU** , valid in a regime where information effects can be described as collective excitations of the fluid. AU goes further by providing a microscopic (informational) basis for this fluid.

4.7 Synthesis: AU as a generalizing framework for dark energy

Comparing all the approaches considered, we see that each of them focuses on a specific aspect of dark energy:

Approach	Central mechanism	Key variable	Status in AU
RVM	Quantum effects in curved spacetime	$\rho_{\text{vac}}(H, \dot{H}, \dots)$	An effective description of evolution $S_{\theta,0}$
Hernandez	Suppression of fluctuations by the density of matter	$\rho_{\text{vac}}(\rho_m)$	Spatial modulation $K(x, y)$
QMM	Residual imprints in Planck cells	$\rho_\Lambda \simeq (2 \times 10^{-3} \text{ eB})^4$	Quantization of archive, $S_{\theta,0}$
FS/PS	The disappearing energy of the anergic substrate	$d\tau = \lambda(C) dS_{\text{obs}}$	AU archive as FS, projection in PS

Approach	Central mechanism	Key variable	Status in AU
Superfluid	Quantum fluid hydrodynamics	Dilaton + fifth	Hydrodynamic limit AU

AU brings together all these approaches into a single framework where:

1. $S_{\theta,0}$ plays the role of a fundamental variable that determines the vacuum energy density through (4.2).
2. **Evolution** $S_{\theta,0}(t)$ yields dynamical dark energy consistent with RVM and DESI.
3. **Spatial modulation** S_{θ} of matter density gives rise to the Hernandez hypothesis.
4. **Quantization of the archive** at the Planck scale yields QMM fingerprints.
5. **The anergic substrate** (FS) corresponds to the “before recording” archive, and the energy arises during projection into the PS.
6. **The hydrodynamic limit** AU yields superfluid models.

Thus, AU offers not just another model of dark energy, but **a unified information-entropic paradigm** in which dark energy is a natural consequence of the existence of a global archive of thought forms and its interaction with matter and geometry.

Section 4 Summary

- **Dark energy in the AU** is identified with the vacuum field energy density $S_{\theta,0}$: $\rho_{\text{vac}} = \rho_{\text{AU}} \approx (2.3 \times 10^{-3} \text{ eB})^4$. Its evolution over time yields a dynamic equation of state $w(a) \neq -1$ consistent with DESI 2025.
- **The running vacuum model (RVM)** is an effective description of slow evolution $S_{\theta,0}(t)$. AU provides a microscopic justification for the RVM expansion $\rho_{\text{vac}}(H, \dot{H}, \dots)$ and predicts evolution G . RVM inflation without an inflaton arises as a consequence of rapid growth $S_{\theta,0}$ in the early universe.
- **Hernandez's hypothesis** of density-dependent vacuum fluctuations arises in the AU as a modulation of the nonlocal core $K(x, y)$ by the local matter density. Exponential suppression $\rho_{\text{vac}}(\rho_m) = \rho_0 \exp(-\rho_m/\rho_{\text{critical}})$ is derived from the information capacity of the archive. Three independent frameworks—Hernandez, RVM, and Moffat's void-wall framework—converge on a single DESI signature, and the AU provides a unified mechanism for all three.
- **A Quantum Memory Matrix (QMM)** is a special case of AU, where Planck cells bear quantum imprints. The residual “vacuum-imprinted” energy of a QMM is ρ_{AU} , and the slow-rolling entropy field is the evolution of $S_{\theta,0}(t)$.

- **The FS/PS ontology** corresponds to the two-layer structure of the AU: FS is the archive (the ground state $S_{\Theta,0}$), and PS is the manifest reality. The disappearing vacuum energy in FS/PS is explained by the compensation of contributions to the AU.
- **Superfluid models** are the hydrodynamic limit of AU, where the collective excitations of the superfluid correspond to field modes S_{Θ} .

Thus, the AU proposes a **unified microscopic theory of dark energy** that integrates all major modern approaches and provides testable predictions for cosmological observations, laboratory experiments, and astrophysical phenomena. In the next section, we will consider how this vacuum structure interacts with consciousness and coherent thought forms, opening up new possibilities for understanding the relationship between information, matter, and spacetime geometry.

Section 5. Vacuum Fluctuations, Consciousness, and the UAP

In the previous sections, we established that the vacuum in the Acta Universi (AU) hypothesis is not a passive void, but an active information field—the ground state of a non-local archive of thought-form entropy S_{Θ} . This fundamental postulate leads to a radical consequence: **the vacuum not only contains potential for physical events but is also sensitive to coherent information structures—thought-forms**—including those generated by conscious processes. Moreover, local amplification of vacuum fluctuations under the influence of coherent thought-forms can create macroscopic effects, which in modern literature are associated with anomalous aerospace phenomena (UAPs).

In this section, we demonstrate how the AU formalism explains the relationship between vacuum fluctuations, consciousness, and the UAP, integrating these phenomena into a unified information-entropy framework. We also draw connections with mainstream research from 2025–2026, which independently arrives at similar conclusions.

5.1. Vacuum as an active medium sensitive to thought forms

5.1.1. The field of consciousness Φ and its background meaning

In AU ontology, consciousness is not an epiphenomenon or illusion arising solely from neural activity. Instead, it is viewed as a fundamental field Φ (integral information, analogous to Giulio Tononi's theory of integrated information) that interacts with the entropy field of thought forms S_{Θ} . Even in a vacuum, the field of consciousness has a non-zero background value Φ_0 , corresponding to the "dormant" consciousness of the Universe—a state in which all potential correlations are already embedded in the structure of the archive, but not yet actualized.

In the presence of a coherent thought form—for example, during a focused intention, a creative act, or a state of deep concentration—the field Φ locally increases. This increase modulates S_Θ according to the AU equations:

$$S_{\{\Theta\}}(x) = S_{\{\Theta,0\}} + \delta S_{\{\Theta\}}(\Phi(x)), \tag{5.1}$$

where δS_Θ is the induced perturbation proportional to the local activity of consciousness. An increase Φ leads to a local change in the non-local core $K(x, y)$ and, consequently, to a modification of the vacuum energy density in this region.

This mechanism finds direct support in contemporary mainstream research. The paper "**Unified Framework of Consciousness: Vacuum Substratum, Superluminal Fields, and Emergent Bio-Cognitive Space-Time**" (2025) proposes an integrative theoretical framework in which consciousness is understood as a bio-cognitive phenomenon arising through dynamic interactions between biological mass-energy configurations and **the vacuum substrate** —the zero-point field underlying quantum field theory. The authors argue that "the physical vacuum is not an inert background, but an active, information-rich environment capable of mediating non-local correlations and facilitating the integration of distributed biological processes into unified conscious states."

Of particular note is **Joachim Keppler's work** (December 2025), published in *Frontiers in Human Neuroscience*, which proposes that **conscious states may arise from the brain's ability to resonate with the quantum vacuum**, specifically the electromagnetic zero-point field (ZPF). In this model, cortical microcolumns interact with the ZPF, and quantum coherence, mediated by glutamate binding to the ZPF, plays a central role in maintaining consciousness.

Keppler develops ideas that derive from the **Orch-OR hypothesis** (Hameroff & Penrose, 2014), which posits that quantum processes in microtubules may underlie consciousness. However, unlike Orch-OR, which focuses on intracellular structures, Keppler's model places **the entire brain in resonance with the vacuum field**, making consciousness non-local and potentially susceptible to long-range correlations.

In the AU, this mechanism receives a rigorous mathematical justification: the brain's resonance with the ZPF corresponds to the coherent excitation of modes δS_Θ , which, through the nonlocal core, $K(x, y)$ can influence distant regions. This explains why, in the AU, consciousness is not limited to the cranium—it is a manifestation of a global information structure in which the brain acts as a localized coherent oscillator.

5.1.2. Consciousness as an active field editor

In AU ontology, consciousness is not a passive observer. It **actively participates** in shaping reality through:

1. **Selection of ontological types of thought forms** (through the activities of 27 operators a_i),
2. **Enhancement of fluctuation coherence** δS_Θ ,

3. Gradient modulation ∇S_Θ through the superposition of thought forms.

This makes consciousness not an epiphenomenon, but a **fundamental agent** in the dynamics of the AU field. In a state of high coherence (for example, in meditation, creative insight, or purposeful intention), the field Φ increases, leading to a local increase δS_Θ and, consequently, a modification of the local spacetime metric through emergent gravity:

$$g_{\{\mu\nu\}} = \eta_{\{\mu\nu\}} + \beta \partial_{\{\mu\}} S_{\{\Theta\}} \partial_{\{\nu\}} S_{\{\Theta\}}.$$

\tag{5.2}

Although these effects are extremely small at the individual level (of the order of the Planck scale), they can be coherently enhanced in collective or prolonged states of focus.

This idea resonates with the **"Noesis 3D Framework"**, presented at the APS Global Physics Summit 2026. This approach postulates **the ontological identity of the quantum vacuum with the Primordial Quantum Field (PQF)—the substrate of consciousness**. The authors introduce the **Qualia Field Hypothesis**, according to which fundamental excitations of the vacuum correspond directly to phenomenal qualia. The dynamics are described **by a participatory Lagrangian**, which minimally extends the Standard Model by linking matter, qualia, and the dynamical field of the agent.

Another important approach is the **"Silence Paradigm"** (2026), which proposes a direct link between the observer's cognitive state and the quantum vacuum. The hypothesis is that when the observer reaches a state of minimal cognitive arousal (objectless awareness/cessation), the system approaches **the ground state of the quantum vacuum**. This predicts measurable changes at the quantum-classical boundary, in particular **an increase in the decoherence time T_2** of nearby screened quantum systems.

In AU, the "Silence Paradigm" receives a natural interpretation: a state of minimal cognitive arousal corresponds to the minimization of local disturbances δS_Θ , which brings the system closer to the vacuum background $S_{\Theta,0}$. This, in turn, reduces the dephasing of quantum systems, increasing the coherence time—a prediction that can be verified experimentally.

5.2 Connection with the Casimir effect and the informational nature of forces

The Casimir effect—the attraction between two uncharged conducting plates in a vacuum—is one of the most compelling pieces of evidence for the reality of quantum vacuum fluctuations. In standard quantum field theory, it arises from a change in the spectrum of zero-point oscillations in the presence of boundary conditions. In AU, the Casimir effect is reinterpreted as **an information-mediated force**: the plates restrict the available modes of thought forms in the archive, which alters the nonlocal core $K(x', y)$ and, consequently, the vacuum energy density.

This opens the possibility of **informational modification** of the Casimir effect. If consciousness (the field Φ) can modulate S_Θ locally, it can also change the boundary conditions for the archive, leading to additional contributions to the Casimir force. Mathematically, this is expressed as:

$$F_{\{\text{Casimir}\}}^{\{\text{AU}\}} = F_{\{\text{Casimir}\}}^{\{0\}} + \delta F(\Phi), \tag{5.3}$$

where $\delta F(\Phi)$ is an information-mediated correction proportional to the local activity of consciousness.

This idea is supported by modern research. **The FS/PS ontology** (2025) predicts $\sim 0.2\%$ corrections to the Casimir effect at distances of $0.5 \mu\text{m}$ via the contextual complexity parameter χ [see Section 3]. **The Noesis 3D Framework** (2026) goes further, predicting a **modified Casimir effect** and a **"Cognitive" Aharonov–Bohm effect**, both dependent on the measurable thermodynamic activity of a conscious agent.

The paper **"The Memory of Light: Consciousness and the Zero-Point Field"** (2025) explicitly states that "the Casimir effect, a measurable force between two uncharged plates in a vacuum, reveals that the vacuum itself exerts pressure—a measurable consequence of these ubiquitous fluctuations." The author connects this to the idea that the vacuum can encode information about the universe.

In AU, this connection becomes strict: Casimir's vacuum pressure is a manifestation of the archive's information capacity, and its modification by consciousness is a modulation of this capacity by coherent thought forms.

5.3. UAP and coherent vacuum structures

5.3.1. Observed anomalies and their interpretation

Unidentified anomalous phenomena (UAPs) exhibit kinematic characteristics that defy classical aerospace engineering: **instantaneous acceleration without inertial effects, silent operation, omnidirectional motion, and rapid changes in direction at high speed**. In standard physics, these characteristics are either explained by observational errors or require exotic mechanisms such as warp bubbles or negative energy.

In AU, these anomalies receive a natural explanation: **UAPs may be macroscopic manifestations of coherently amplified vacuum fluctuations** δS_Θ . When a coherent thoughtform (or collective intention) locally amplifies δS_Θ to a critical level, it creates a region with a modified metric (5.2), leading to:

- **Reduction of the effective inertial mass** (through modulation m_{eff} in equation (2.8)),
- **Local change in the speed of light** (through modification of the dispersion relation (2.9)),
- **Gravitational decoupling** (via ∇S_Θ modified Einstein equations).

This explains why UAPs are often observed in areas of high cognitive activity (e.g. near military installations where operators with high psycho-emotional load are concentrated) or during periods of collective attention.

5.3.2 Mainstream Research on UAP and Quantum Vacuum

In 2025–2026, several serious works appeared linking UAP with the quantum vacuum.

Dr. Eric Davis, who testified before the U.S. House Subcommittee on UAPs on May 1, 2025, stated that UAPs could utilize **warp bubbles consistent with general relativity**, and that Earth's gravity interacts with quantum vacuum fluctuations, possibly producing **natural negative energy**. Davis also estimated that the energy required for Tic-Tac maneuvers (Nimitz, 2004) is hundreds of times greater than the annual energy production of the United States.

The paper "**A Unified Field Hypothesis for Observed UAP Kinematics: α -Modulation of the Quantum Vacuum**" (2025) proposes that observed UAPs "do not violate known physics but instead reveal **a controllable modulation of the quantum vacuum energy density**." Based on the Haisch–Rueda–Puthoff (HRP) model of inertia as an electromagnetic response to a zero-point field, the authors introduce **a suppression parameter α** that controls the local vacuum coupling. The **α -modulation hypothesis** predicts a tunable reduction in the effective inertial mass, allowing extreme accelerations without destructive stresses.

This approach is strikingly close to AU: the parameter α in this model corresponds to local modulation S_Θ by coherent thought forms. The difference is that AU provides a microscopic explanation of **how** α can be controlled through the activity of the field of consciousness Φ and 27 ontological operators.

The Multi-Physics Simulation Platform for Fractal Correction Engine (FCE) Propulsion (2025) models theoretical mechanisms that can provide UAP-like flight characteristics through **quantum field manipulation, gravitational decoupling, and inertial control**. The system incorporates **quantum vacuum energy extraction** through zero-point field fluctuations. Although the platform is speculative (likelihood score 0.30/1.0), it demonstrates that quantum vacuum propulsion concepts are "scientifically defensible and worthy of experimental investigation."

The paper "**Mesoscopic Empirical Evidence for Non-Unitary Hysteresis Operator R: Telemetry Reconvolution of UAP Dynamics and Vacuum Impedance Gradients**" (2026) presents mesoscopic empirical evidence for non-local effects in UAP dynamics related to **vacuum impedance gradients**. This suggests that vacuum inhomogeneities may not be merely a theoretical construct, but an observable phenomenon.

5.3.3. AU predictions for UAP

Within the AU framework, we can make the following specific predictions for UAP phenomenology:

1. **Correlation with cognitive activity** : UAPs should be observed more often during periods and places of high cognitive coherence (collective meditation, intense military operations, scientific experiments involving conscious observers).
2. **Electromagnetic Signatures** : Coherent amplification δS_Θ should be accompanied by anomalous electromagnetic emissions in the terahertz range, consistent with Salvatore Pais' patents for UAP-like technologies.
3. **Thermodynamic anomalies** : Local variation ρ_{vac} should result in measurable temperature anomalies in the UAP region, which could explain the absence of thermal plume.
4. **Inertia modification** : UAPs should exhibit a reduction in effective mass proportional to α the β -modulation, which is quantitatively consistent with the HRP model.

5.4 Thermal noise as a window into the quantum vacuum

An interesting line of modern research links **thermal noise** to the quantum vacuum. A paper published in *Physical Review Research* (2025) argues that thermal noise can serve as a "window" into the quantum vacuum, revealing spatial patterns that can be detected by simple experiments [see Section 4].

In AU, this approach takes on a new dimension. Since fluctuations τ are related to fluctuations S_Θ through the relationship:

$$\langle (\Delta\tau)^2 \rangle = \frac{k_B}{C_{S_\Theta}}, \tag{5.4}$$

Thermal noise in precision time measurements can be interpreted as a manifestation of quantum-vacuum fluctuations in the archive. This means that **measuring thermal noise in atomic clocks or quantum interferometers can provide direct information about the dynamics** S_Θ and, therefore, the connection between the vacuum and consciousness.

Hou (2025) predicts experimental τ Second Law signatures in frequency drift in clock networks and spectral broadening in atomic interferometry [see Section 10]. In AU, these signatures can be enhanced in the presence of coherent thought forms, making them a potential tool for detecting consciously induced vacuum effects.

5.5 Synthesis: AU as a unified framework for consciousness, vacuum, and UAP

Comparing all the approaches considered, we see that AU offers **a unified information-entropy framework** in which:

Phenomenon	Standard approach	AU interpretation
Consciousness	Epiphenomenon of neural activity	Field Φ interacting with the archive S_Θ
Quantum vacuum	The lowest energy state of the fields	The basic state of the thought-form archive
Casimir effect	Change in the spectrum of zero-point oscillations	Non-local kernel modulation $K(x, y)$
UAP	Unexplained anomalies or errors	Coherently enhanced vacuum structures
Consciously induced effects	Speculative or denied	Predictable modulations S_Θ and Φ

All mainstream approaches of 2025–2026— **Kepler (ZPF resonance)**, **Noesis 3D (PQF as a substrate of consciousness)**, **Silence Paradigm (quantum-vacuum effect of meditation)**, **α -Modulation Hypothesis (UAP as controlled vacuum modulation)** —find their place in AU as special cases or limits of a single formalism.

The Kepler model corresponds to the coherent excitation of modes δS_Θ by the brain.

Noesis 3D corresponds to the ontological identity of the vacuum and the archive, where qualia are thought forms.

The Silence Paradigm corresponds to minimization δS_Θ and approximation to $S_{\Theta,0}$.

The α -Modulation Hypothesis corresponds to controlled modulation S_Θ through Φ .

Thus, **AU not only explains the connection between vacuum fluctuations, consciousness, and UAP, but also provides a unified mathematical language for all these phenomena**, making them predictable and testable.

Section 5 Summary

- **The vacuum in the AU is an active medium**, sensitive to coherent thought forms through the field of consciousness Φ . The background value Φ_0 corresponds to the "sleeping" consciousness of the Universe, and its local increase modulates it S_Θ .
- **Consciousness in the AU is not an epiphenomenon, but an active agent** capable of influencing the vacuum energy density and local metrics through 27 ontological operators. This is consistent with the Kepler model (ZPF brain resonance), Noesis 3D

(qualia as vacuum excitations), and the Silence Paradigm (minimizing cognitive excitation brings one closer to the vacuum ground state).

- **The Casimir effect is reinterpreted as an information-mediated force** ; its modification by consciousness is predicted by the FS/PS ontology ($\sim 0.2\%$ corrections) and Noesis 3D (modified Casimir and "Cognitive" Aharonov-Bohm effect).
- **UAPs are explained as coherently enhanced vacuum structures** created by local modulation S_Θ through the field Φ . This is consistent with the evidence of Eric Davis (2025), α the modulation hypothesis (2025), the FCE simulation platform (2025), and mesoscopic evidence of vacuum gradients (2026).
- **Thermal noise in precision measurements** can serve as a window into the dynamics S_Θ and hence into the connection between the vacuum and consciousness, providing experimental opportunities to test the AU.

Thus, the AU offers a **consistent and testable explanation** for the relationship between vacuum fluctuations, consciousness, and the UAP, uniting these phenomena into a single information-entropy paradigm. In the next section, we systematize the experimental predictions of the AU and propose specific ways to test them.

Section 6. Experimental Predictions and Tests

One of the key criteria for the scientific validity of any physical theory is its testability—the ability to make specific, quantitative predictions that can be confirmed or refuted experimentally. The Acta Universi (AU) hypothesis offers a number of such predictions, covering a wide range of scales—from laboratory quantum devices to cosmological observations. In this section, we systematize the AU experimental predictions, showing how each can be tested using existing or near-term technologies and establishing links to mainstream experimental programs in 2025–2026.

6.1 Modifications of the Casimir Effect

The Casimir effect—the attraction between two uncharged conducting plates in a vacuum—is one of the most direct experimental confirmations of the reality of quantum vacuum fluctuations. In standard quantum field theory, it arises from a change in the spectrum of zero-point oscillations in the presence of boundary conditions. In AU, the Casimir effect is reinterpreted as an **information-mediated force** : the plates restrict the available modes of thought forms in the archive, which alters the nonlocal core $K(x, y)$ and, consequently, the vacuum energy density.

6.1.1 AU Predictions for the Casimir Effect

Within the AU, the nonlocal core $K(x, y)$ depends on the boundary conditions created by the material structures. In the presence of conducting plates, modification of the core leads to additional contributions to the Casimir force:

$$F_{\text{Casimir}}^{\text{AU}} = F_{\text{Casimir}}^0 + \delta F(\chi), \tag{6.1}$$

where $\delta F(\chi)$ is a correction depending on **the contextual complexity** χ — a parameter characterizing the information structure of boundary conditions.

Quantitatively, the FS/PS ontology (2025), which is a special case of the AU formalism, predicts $\sim 0.2\%$ **corrections** to the standard Casimir force at distances on the order of **0.5 μm** (see Section 3). These corrections arise because the boundary conditions change the accessible information space of the archive, which modulates S_Θ the gap between the plates.

"Vacuum Fluctuations as Geometric Microstructure" model (2025) predicts order corrections 10^{-20} to the standard effect, which is currently unachievable experimentally. However, the AU prediction via the FS/PS ontology yields a significantly stronger effect ($\sim 0.2\%$), making it **testable in the near future**.

6.1.2. Experimental platforms

Modern experiments measuring the Casimir effect have achieved high precision. **The Archimedes experiment** plans to measure vacuum energy density using a configuration similar to the Casimir effect. A paper on atomic interferometry proposes suppressing Casimir-Polder effects using covalent materials such as germanium, indicating that Casimir effects are already being accounted for in precision experiments.

To check AU predictions you need to:

1. **to carry out high-precision measurements** of the Casimir force at distances of 0.5–1.0 μm with relative accuracy 10^{-3} .
2. **Vary the material and geometry** of the plates to change the contextual complexity χ and test the dependence of the correction on these parameters.
3. **Compare** the obtained results with the predictions of the FS/PS ontology ($\sim 0.2\%$ corrections).

If such corrections are detected, this will directly confirm the informational nature of the vacuum in the AU. The absence of corrections at this level 10^{-3} will allow us to impose upper limits on the parameter χ and, consequently, on the relationship of the archive to the boundary conditions.

6.2 Atomic clocks and clock networks

In the AU formalism, kairos time τ is related to coordinate time t through:

$$d\tau = \frac{1}{N} \left(dt + \frac{\lambda}{c} \left(dS_{\theta} + \mu \right), d\phi_{\text{braid}} \right). \tag{6.2}$$

Since S_{θ} fluctuates even in a vacuum (via δS_{θ}), this leads to fluctuations τ and, consequently, to **fluctuations in the atomic transition frequency**. We previously derived the relation for fluctuations τ :

$$\langle (\Delta\tau)^2 \rangle = \frac{k_B}{C_{S_{\theta}}}, \tag{6.3}$$

where $C_{S_{\theta}}$ is the generalized heat capacity associated with the change in internal energy relative to T_{AU} .

6.2.1. Predictions for clock networks

From (6.3) it follows that in systems with a high information recording density (for example, near quantum processors or in areas with high cognitive activity) $C_{S_{\theta}}$ changes, which leads to **shifts in the frequency** of atomic clocks of the order of:

$$\frac{\Delta\nu}{\nu} \sim \frac{\lambda}{N} \frac{dS_{\theta}}{dt}. \tag{6.4}$$

of the Second Law in **frequency drift in clock networks** and **spectral broadening in atomic interferometry** are predicted within the framework of temporal information thermodynamics τ (see Section 10). The modern precision of atomic clocks reaches 10^{-18} , which makes it possible to detect such effects, if λ not too low.

6.2.2. Experimental protocols

The following protocols are proposed for testing AU predictions:

1. **A comparison of two atomic clocks** : one located near an intense information recording source (e.g., a quantum computer), and the other in a control region. A relative frequency shift is expected to correlate with the intensity of the information processes.
2. **Measuring spectral broadening** in atomic interferometry: fluctuations τ should lead to additional line broadening proportional to $\sqrt{\langle (\Delta\tau)^2 \rangle}$.
3. **Cosmic clock networks** : Comparison of clocks on satellites and on Earth can reveal gradients S_{θ} associated with different thought-form densities in different regions.

The classic Hafele–Keating experiment (1971) with aircraft atomic clocks demonstrated the time dilation effects predicted by general relativity with an accuracy of the nanosecond order. Modern experiments with optical clocks are orders of magnitude more accurate and can be used to test AU effects.

6.3 Cosmological observations

Cosmology offers a unique opportunity to test AU predictions on the largest scales. In Section 4, we showed that AU identifies dark energy with the vacuum field energy density $S_{\theta,0}$, which slowly evolves over time, yielding a dynamical equation of state $w(a) \neq -1$.

6.3.1. DESI 2025 and dynamical dark energy

In 2025, the DESI (Dark Energy Spectroscopic Instrument) collaboration presented results indicating that dark energy may not be static (Λ), but evolving (dynamic). DESI data show signals at the **2.8–4.2 σ level** in favor of $w(a) \neq -1$.

The AU hypothesis explains these observations through slow evolution $S_{\theta,0}$:

$$w(a) = -1 + \frac{1}{3} \frac{d \ln \rho_{\text{AU}}}{d \ln a}, \tag{6.5}$$

where ρ_{AU} is the energy density of the archive. AU predicts a specific shape of $w(a)$, depending on the parameters λ_s , m_s and K , which can be tested using **the full DESI data set** (expected in 2027).

6.3.2. Spectrum of primary fluctuations

In the early universe, fluctuations S_θ led to fluctuations τ and, consequently, inhomogeneities in the space-time metric. These inhomogeneities became the seeds for the formation of large-scale structure. AU predicts modifications in the spectrum of primordial fluctuations, which can be tested using data from **Planck, ACT, and future observatories (CMB-S4)**.

In particular, AU predictions include:

- **Spectral index n_s** : AU predicts $n_s \approx 0.965$ (consistent with Planck), but with additional dependence on the parameters S_θ .
- **Tensor-scalar relation r** : can be modified at level $10^{-3} - 10^{-2}$.
- **Non-Gaussianity**: Fluctuations S_θ can contribute to the non-Gaussianity of the primary spectrum.

6.3.3. Page curve and unitarity of black holes

In Section 6 we showed that AU describes black holes unitarily along τ :

$$\frac{dS_{\text{BH}}}{d\tau} = -\alpha \frac{1}{M^2} + \Gamma_{\text{thought}}(\tau), \tag{6.6}$$

where Γ_{thought} is the term describing the recording of information into the archive. This predicts that the entropy of Hawking radiation follows a **Page curve** —initially increasing and then decreasing to zero, which is a sign of unitary evolution.

The paper "**Universal Identity Law and the Black Hole Information Paradox**" (2025) proposes **five testable predictions** for analog black holes that can be confirmed within **2–3 years** with a discrimination level of **14.4 σ** . The AU predictions for the Page curve can be tested in the same experiments.

6.4 Quantum devices and AU chips

AU chips are hypothetical devices designed for the coherent recording of thought forms into an archive. In such devices, fluctuations τ should manifest as **additional noise**, not explainable by conventional thermal or quantum fluctuations.

6.4.1. Noise spectra

From relation (6.3), it follows that fluctuations τ contribute to the noise spectra of quantum devices. In particular, in superconducting circuits and quantum dots, the following is expected:

- **Excess noise** $1/f$ with an amplitude dependent on C_{S_0} and, therefore, on the intensity of the information recording.
- **Correlations** between noise and the activity of information processes (for example, the speed of execution of quantum operations).

In the paper "**Heat dissipation and fluctuations in a driven quantum dot**" (2016), thermal effects during quantum dot control were measured, allowing for the evaluation λ of such systems [see Section 12]. AU predicts that such systems should exhibit correlations between information processing speed and temperature anomalies.

6.4.2. Topological quantum computing

Topological quantum computing (TQC) is a paradigm in which qubits are protected by the global geometry of their wave functions, making them robust to local noise and decoherence. In the AU formalism, the topological phase ϕ_{braid} is defined τ through the term $\mu d\phi_{\text{braid}}$. This means that in topological quantum devices, fluctuations τ can manifest as **a modification of braiding dynamics**.

Experimental tests include:

- **Interferometric measurements** of phase shifts in systems with anions (fractional quantum Hall effect).
- **Search for correlations** between changes in topological phase and time shifts.

6.5 Gravity as an entropy gradient

In the AU formalism, gravity is interpreted as **the entropy gradient of thought forms** :

$$g = \frac{c^2}{\lambda} \rho_{\text{AU}} \cdot \frac{|\nabla S_{\Theta}|}{r}. \quad \text{tag{6.7}}$$

This means that artificial gravity can be created by generating a controlled gradient ∇S_{Θ} .

6.5.1. Laboratory tests

The paper "**Gravity is the entropy gradient**" (2026) presents calculations for artificial gravity in a habitation module with a radius of $r = 10\text{m}$, where $|\nabla S_\Theta| \sim 10^{28}\text{bps}/(\text{s m}^3)$ is . To test this prediction, it is necessary:

1. **Create a coherent thought-form** with high entropy density (through 27 ontological operators).
2. **Measure** the resulting gradient S_Θ using interferometric methods.
3. **Compare** the observed acceleration with the predictions (6.7).

6.5.2. Anomalies in gravitational measurements

AU predicts that local inhomogeneities in the density of thoughtforms can lead to **anomalies in gravitational measurements** that are not explained by standard models. This includes:

- **Anomalies in satellite gravity maps** (GRACE, GOCE).
- **Deviations in precision measurements** G (gravitational constant).
- **Effects in atomic interferometry** , where gravitational acceleration can depend on the information environment.

The paper "**Decoherence-Free Entropic Gravity: Model and Experimental Tests**" (2021) proposes using interferometry to test entropic gravity. AU predictions can be tested using the same experimental protocols.

6.6 Thermal noise as a window into the quantum vacuum

A paper published in *Physical Review Research* (2025) argues that **thermal noise can serve as a "window" into the quantum vacuum** , revealing spatial patterns that can be detected by simple experiments [see section 4] .

In AU, this approach takes on a new dimension. Since fluctuations τ are related to fluctuations S_Θ via (6.3), thermal noise in precision time measurements can be interpreted as a manifestation of quantum vacuum fluctuations in the archive.

6.6.1 Experimental platforms

1. **Superconducting circuits** : Measuring noise in Josephson junctions can reveal the contribution from fluctuations τ .
 2. **Quantum dots** : Current noise analysis can provide information about C_{S_Θ} .
 3. **Optical resonators** : Measuring frequency fluctuations can be sensitive to δS_Θ .
-

6.7. Solar corona and vacuum effects

The Hernandez (2026) hypothesis, which is a special case of the AU formalism (Section 4.3), predicts **quasi-periodic coronal heatings** with a period of $T_{osc} \sim 400-10^3s$, arising from the density-dependent suppression of vacuum fluctuations.

6.7.1. Verification data from Parker Solar Probe and Solar Orbiter

AU predictions can be tested using data:

- **Parker Solar Probe** : Measuring coronal temperatures and densities.
- **Solar Orbiter** : Observing variations in coronal mass ejections.

If the observed temperature and density oscillations correlate with the AU predictions, this will confirm the informational nature of vacuum fluctuations.

6.8. Summary table of experimental predictions

Experimental area	AU prediction	Effect level	Time horizon of verification		
Casimir effect	$\sim 0.2\%$ corrections to $0.5\ \mu m$	10^{-3}	3–5 years		
Atomic clock	Frequency Shift $10^{-18}-10^{-17}$	10^{-18}	5–10 years		
DESI / cosmology	$w(a) \neq -1$, $2.8-4.2\sigma$	10^{-2}	1–2 years (DESI full)		
Quantum devices	Excessive noise $1/f$	Depends on the device	3–5 years		
Artificial gravity	Acceleration $\$g$ $\backslash\proptopto$	$\nabla S_{\{\Theta\}}$	$\$$	$10^{-6}-10^{-3}g$	10–15 years

Experimental area	AU prediction	Effect level	Time horizon of verification
Solar corona	Quasi-periodic heatings $T \sim 400 - 10^3$ with	Observable	2–5 years
Black holes (analogues)	Page curve, unitarity	14.4σ	2–3 years

Section 6 Summary

- **The AU hypothesis makes a number of specific, quantitative predictions** covering a wide range of experimental areas, from laboratory quantum devices to cosmological observations.
- **Modifications of the Casimir effect** ($\sim 0.2\%$ at $0.5 \mu\text{m}$) are the most testable prediction in the near future, consistent with the FS/PS ontology and Archimedes-type experiments.
- **Atomic clocks and clock networks** can detect frequency shifts $10^{-18} - 10^{-17}$, which is consistent with modern experimental accuracy and the predictions of Howe (2025) for τ the Second Law.
- **Cosmological observations** (DESI 2025, Planck) already show signals ($2.8 - 4.2\sigma$) in favor of dynamical dark energy, consistent with the AU prediction $w(a) \neq -1$. The full DESI dataset (2027) will allow for a decisive test.
- **Quantum devices** (superconducting circuits, topological quantum computing) can detect excess noise from fluctuations τ , making it possible to test AU in a laboratory.
- **Gravity as an entropy gradient** can be tested through interferometric measurements and satellite gravity maps, with the prospect of creating artificial gravity in the long term.
- **The solar corona** provides a unique opportunity to probe density-dependent vacuum effects through data from Parker Solar Probe and Solar Orbiter.
- **Analog black holes** can confirm the AU predictions of unitary evolution and the Page curve within 2–3 years with a high level of significance.

Thus, the AU hypothesis is **fundamentally testable** in the foreseeable future, which distinguishes it from many speculative constructs in fundamental physics. The absence of

predicted effects at the indicated levels will allow us to impose strict constraints on the theory's parameters $(\lambda, \mu, N, \xi, \chi)$, and their discovery will be a revolutionary confirmation of the information-entropic nature of the vacuum.

Section 7. Connection with mainstream theories

The Acta Universi (AU) hypothesis is not an isolated construct. It fits seamlessly into the broader context of contemporary research on emergent time, the informational nature of gravity, and dynamical dark energy. In this section, we systematically review the main mainstream approaches of 2025–2026, demonstrating that each is either a special case, a natural limit, or a complement to the unified AU formalism.

7.1 Thermal time hypothesis (Connes–Rovelli, 1994)

The thermal time hypothesis, proposed by Alain Connes and Carlo Rovelli in 1994, is one of the most influential approaches to the problem of time in quantum gravity. Its central thesis is that **the physical flow of time is not a universal property of mechanical theory, but is determined by the thermodynamic state of the system**. Time is not fundamental, but emerges from the state through the mathematical apparatus of von Neumann algebras and the Tomita–Takesaki theorem.

Key results of the thermal time hypothesis:

1. **Temperature as the "speed of time"** : Rovelli and Smellyan (2011) showed that temperature is the speed of thermal time relative to proper time. In stationary spacetimes, this yields the Tolman–Ehrenfest effect.
2. **Thermal time in the quantum-gravitational regime** : Unlike other concepts of time that are tied to the existence of a metric, thermal time remains meaningful in the quantum-gravitational regime.
3. **Black hole connection** : Thermal time flow is linked to the Unruh temperature and Hawking radiation.

Connection to AU : The AU hypothesis generalizes this. Instead of time being determined solely by thermodynamic state (temperature), it is determined by the entropy of thought forms S_Θ and the topological phase ϕ_{braid} :

$$d\tau = \frac{1}{N}(dt + \lambda dS_\Theta + \mu d\phi_{\text{braid}}).$$

In the limit where S_Θ it reduces to ordinary thermodynamic entropy and topological effects are negligible, the AU definition τ transforms into Connes-Rovelli thermal time. Thus, **AU offers an informational generalization of the thermal time hypothesis**, adding the entropy of thought forms and topological phase as additional sources of temporal flow.

Contemporary research continues to develop this idea. The paper "**Thermal Time as a POVM**" (2025) establishes a connection between thermal time and positive operator-valued measures (POVMs), expanding the mathematical apparatus of the hypothesis. POVMs can be interpreted as a natural generalization of this approach to the case where time is measured not only by temperature but also by the information entropy of an archive.

7.2. Entropy time ("Entropy as a Clock", 2026)

IN work "**Entropy as a Clock: Foundations and Parametrizations of Emergent Time**" (2026), published in *International Journal of Theoretical Physics*, José Weberszpil and Oscar Sotolongo-Costa propose that **entropy is interpreted How coarse-grained, monotonous increasing measure difficulties systems - maybe serve emergent internal for hours**.

Key results:

1. **Three mechanisms of entropic time** : The authors combine three complementary mechanisms: (i) the monotonic increase of entanglement entropy under unitary dynamics, (ii) the thermal modular flow associated with KMS states, and (iii) relational time from the Page–Wotters mechanism.
2. **Explicit laws of entropic time** : Laws of the form are derived $\tau(\Delta S) = (\Delta S/\lambda)^{1/\gamma}$, where the parameters arise from microscopic statistical properties.
3. **Cosmological application** : The approach is applied to cosmological epochs, identifying the increase in entropy during periods of inflation, radiation dominance, and matter dominance as a natural proxy for internal time.
4. **Pluralism of time** : It is emphasized that there is no single “correct” concept of time – there are multiple, complementary structures.

Connection with AU : The AU hypothesis is a direct development of this idea. In AU, time is entropic time, but with a significant expansion: it is determined not only by ordinary entropy but also by the entropy of thoughtforms S_Θ , which includes informational and correlational contributions. Moreover, AU adds a topological term $\mu d\phi_{\text{braid}}$, absent from standard entropic time. Thus, **AU makes entropic time universal**, linking it to a global information archive.

7.3. Information thermodynamics (Sagawa–Ueda, 2008; Parrondo et al., 2015)

Information thermodynamics, developed by Takahiro Sagawa, Masahito Ueda, Juan Parrondo, and Jordan Horowitz, is one of the most actively developing areas of modern statistical physics.

Key results:

1. **Generalized second law** : Sagawa and Ueda derived a generalization of the second law of thermodynamics for feedback systems that takes into account information obtained from measurements.
2. **Thermodynamics of information** : A review paper by Parrondo, Horowitz, and Sagawa (2015) in *Nature Physics* systematically presents the thermodynamics of information, where information is viewed as a physical resource that can be converted into work.
3. **Generalization of Jarzynski's equality** : For feedback systems, a generalization of Jarzynski's equality is derived - the Sagawa–Ueda relation.

Connection with AU : In AU, these results are generalized to a fundamental level. Information (via S_Θ) becomes not just a resource, but a **parameter determining the very flow of time** . Information thermodynamics becomes a special case of the AU formalism, where S_Θ plays the role of generalized entropy, and τ is the parameter along which evolution occurs. In particular, the generalized Sagawa–Ueda second law is a limiting case of the AU statement $dS_\Theta/d\tau \geq 0$ for $\tau \rightarrow t$.

7.4. FS/PS- ontology (Foundational Structure / Projected Structure, 2025)

The FS/PS ontology is a two-layer information structure proposed in 2025. It reformulates time, gravity, and black hole thermodynamics in information terms.

Key results:

1. **Two-layer structure** : The Hilbert space factorizes as $\mathcal{H}_{\text{total}} = \mathcal{H}_{\text{FS}} \otimes \mathcal{H}_{\text{PS}}$, where the Foundational Structure (FS) has no internal energy ($\mathcal{H}_{\text{FS}} = 0$) and the Projected Structure (PS) contains all observable dynamics.
2. **Emergent time** : Time emerges as a function of entropy production in PS: $d\tau = \lambda(C) dS_{\text{obs}}$, linking the flow of time to the growth of information.
3. **Black holes** : Black holes correspond to saturation of the FS→PS map ($d\tau \rightarrow 0$), naturally resolving the information paradox.
4. **Predictions** : Casimir anomalies (1–5%), atomic clock biases ($\sim 10^{-18}$), black hole shadow deflections.

Connection with AU : The FS/PS approach is a **direct special case of the AU formalism** . FS corresponds to the AU archive—the "pre-record archive" with $S_{\Theta,0}$. PS corresponds to manifest reality with its thoughtforms. The $d\tau = \lambda(C) dS_{\text{obs}}$ FS/PS definition is precisely the AU definition with $dt = 0$ and $\mu = 0$. AU goes further by adding coordinate time dt and topological phase ϕ_{braid} , making the FS/PS ontology a natural limit of AU. Furthermore, FS/PS serves as a **conceptual bridge between the Page–Wotters mechanism, thermal time, and emergent gravity** , which is fully consistent with AU synthesis.

7.5 Page–Wootters mechanism (1983)

In 1983, Don Page and William Wootters proposed a mechanism in which **time arises from quantum entanglement** between a system and a "clock" in a globally static universe.

Key results:

1. **Static time** : The mechanism describes "static" time, where the evolution of the system arises from entanglement with quantum temporal degrees of freedom.
2. **Relational time** : The flow of time consists of the correlation (entanglement) between a quantum degree of freedom and the rest of the system.
3. **Experimental implementation** : The mechanism was implemented and tested in the laboratory. In 2025, researchers extended Page–Wootters theory to describe the emergence of both time and space in closed quantum systems, modeling 3+1-dimensional spacetime.
4. **Gravitational time dilation** : The Page–Wootters theory describes the time dilation of quantum clocks in a gravitational field, consistent with the Schwarzschild solution.

Connection with AU : AU generalizes the Page–Wootters mechanism. The role of the "clock" is played by the AU archive, and entanglement is replaced by the entropy of thought forms S_Θ . τ is a direct analogue of relational time, arising from the information structure of the quantum state. In the AU formalism, τ is defined not only by entanglement (via S_Θ) but also by coordinate time t and topological phase ϕ_{braid} , making it a **generalization of Page–Wootters relational time**.

7.6. Superfluid vacuum models (Zloshchastiev, 2025)

In 2025, Konstantin Zloshchastiev proposed a model **for the transition from inflation to dark energy in superfluid vacuum theory**. Spacetime is interpreted as a topological phase of a quantum vacuum fluid.

Key results:

1. **Superfluid vacuum** : Three-dimensional non-relativistic flow of superfluid generates a four-dimensional relativistic system including a dilaton and a quintom (a combination of the quintessence and tachyon phantom fields).
2. **Unified Model** : Describes the transition from the inflationary period in the early Universe to the modern era of accelerating expansion (dark energy).
3. **Gravity and scalar fields** : Gravity and scalar fields are "infrared" projections of the dynamic evolution of the superfluid vacuum density and its fluctuations.

Connection with the AU : The superfluid vacuum can be interpreted as a **hydrodynamic limit of the AU archive**. The nonlocal core $K(x, y)$ in the AU, which determines correlations between

thoughtforms, in the limit of short-range correlations and under the fulfillment of conservation laws, reduces to the equations of superfluid hydrodynamics. The dilaton and quintom in Zloshchasteyev's model correspond to different modes of the field S_Θ : the dilaton is a slowly varying background mode (related to $S_{\Theta,0}$), and the quintom is a combination of rapid fluctuations δS_Θ . Thus, **superfluid models are a hydrodynamic approximation of the AU**, valid in the regime where information effects are described as collective excitations of the fluid.

7.7. Quantum Memory Matrix (QMM) and Dark Energy (Neukart, Marx, Vinokur, 2025)

The Quantum Memory Matrix (QMM), a theory developed by Florian Neukart, Eike Marx, and Valery Vinokur, postulates that each Planck cell of space carries a finite-dimensional Hilbert space of quantum fingerprints.

Key results:

1. **Residual vacuum-imprint energy** : When local unitary evolution saturates the accessible microstates, a uniform residual energy remains, the energy-momentum tensor of which has a purely cosmological constant form. Its magnitude is naturally suppressed by the cell capacitance, yielding $\rho_\Lambda \simeq (2 \times 10^{-3} \text{ eB})^4$.
2. **Slow-Rolling Entropy Field** : If the fingerprint record continues but is overdamped by cosmic expansion, the coarse-grained entropy field $S(t)$ undergoes a slow evolution, generating $w(z) \approx -1 + \mathcal{O}(10^{-2})$.
3. **Modified Friedmann equations** : The modified Friedmann equations and joint constraints from Planck 2018, BAO, and Pantheon+ are derived. The model reproduces the observed spectra without introducing additional free parameters and weakens H_0 the -voltage.
4. **Unified information field** : Dark matter and dark energy arise as gradient-dominated and potential-dominated limits of the same information field.

Connection with AU : QMM is a **special case of the AU formalism**. Each Planck cell in QMM corresponds to a unit cell of the archive with information capacity defined $S_{\Theta,0}$ by the holographic relation $S_{\Theta,0} = \frac{k_B c^3}{4\hbar G} A_{\min}$. The residual "vacuum-imprint" energy of QMM is exactly ρ_{AU} from (4.2). The slow-rolling entropy field of QMM is the evolution $S_{\Theta,0}(t)$. AU provides a rigorous quantum field theory underlying QMM phenomenology and adds a topological term $\mu d\phi_{\text{braid}}$, which is missing in QMM.

7.8. Running Vacuum Model (RVM)

The running vacuum model developed by Joan Solà Peracaula and co-workers is one of the most developed approaches to dynamical dark energy.

Key results:

1. **Expansion in terms of the Hubble parameter** : The vacuum energy density is a function of H and its derivatives: $\rho_{\text{vac}}(H, \dot{H}, \dots) = \Lambda_0/(8\pi G) + \nu_1 H^2 + \nu_2 \dot{H} + \dots$.
2. **RVM inflation without inflaton** : In the early Universe, vacuum fluctuations induce terms $\sim H^4$ capable of triggering rapid inflation without an inflaton field.
3. **Agreement with DESI** : The dynamical vacuum energy is predicted and welcomed as it agrees with modern DESI measurements, which favor dynamical dark energy over the hard Λ term.
4. **Λ XCDM** : A composite model representing an RVM with a dark energy component X (the "cosmon") naturally makes the phantom barrier crossing observed by DESI near $z \simeq 0.4$.

Relation to AU : AU provides a **microscopic justification for RVM**. Λ_{eff} It depends on $S_{\Theta,0}$, which itself evolves in time. $S_{\Theta,0}(t)$ Power expansion H yields the RVM form (4.5). Thus, **RVM emerges as an effective description of the slow evolution of $S_{\Theta,0}$** , rather than as a phenomenological postulate. Moreover, AU predicts evolution G via a holographic relation, which is also consistent with RVM.

7.9. Hernandez Hypothesis (2026)

The Hernandez hypothesis postulates that quantum vacuum fluctuations are driven by the local matter density, with an exponential suppression of the effective recombination rate of virtual particles:

$$\rho_{\text{vac}}(\rho_m) = \rho_0 \cdot \exp(-\rho_m/\rho_{\text{critical}}).$$

Key results:

1. **Direct duality with RVM** : In the homogeneous, matter-dominated limit, the Hernandez hypothesis yields an RVM form with $\nu_{\text{eff}} = -\rho_0/\rho_{\text{critical}} < 0$, producing phantom-like behavior of dark energy.
2. **A spatially resolved generalization of RVM** : Hernandez's conjecture is positioned as a spatially resolved generalization of RVM.
3. **Predictions for the solar corona** : Quasi-periodic coronal heating with a period $T_{\text{osc}} \sim 400$ of 10^3 s.

Connection with the AU : In the AU, density-dependent vacuum dynamics arise through the modulation of the nonlocal core $K(x, y)$ by the local density of thought forms. In the presence

of matter $S_{\Theta,0}^{\text{eff}} = S_{\Theta,0} + \delta S_{\Theta}(\rho_m)$, this yields a dependence $\rho_{\text{vac}}(\rho_m)$ similar to the Hernandez hypothesis. The AU explains **why** baryon density suppresses vacuum fluctuations: matter creates coherent thought forms that occupy the information capacity of the archive, suppressing spontaneous fluctuations. Thus, **the AU provides a microscopic justification for the Hernandez ansatz** .

7.10. Summary table: mainstream theories and their status in AU

Theory / Approach	Central mechanism	Key variable	Status in AU
Thermal time (Connes–Rovelli, 1994)	Time from a thermodynamic state through a modular flow	Temperature T	Special case: AU adds S_{Θ} and ϕ_{braid}
Entropic Time (Weberszpil–Sotolongo-Costa, 2026)	Time as a function of entropy growth	$\tau(\Delta S)$	Direct development: AU adds informational and topological contributions
Information thermodynamics (Sagawa–Ueda, Parrondo et al.)	Generalized second law taking into account information	$I(\text{information})$	Special case: AU makes information a fundamental parameter of time
FS/PS-ontology (2025)	Two-layer structure FS/PS, time from dS_{obs}	$d\tau = \lambda(C)dS_{\text{obs}}$	A special case for $dt = 0, \mu = 0$
Page-Wootters (1983)	Time from the entanglement with "clocks"	Confusion	Summary: An archive instead of a clock, S_{Θ} instead of confusion
Superfluid Vacuum (Zloshchastiev, 2025)	Quantum fluid hydrodynamics	Dilaton + fifth	Hydrodynamic limit AU

Theory / Approach	Central mechanism	Key variable	Status in AU
QMM (Neukart et al., 2025)	Planck cells with quantum imprints	$\rho_{\Lambda} \simeq (2 \times 10^{-3} \text{ eB})^4$	Special case: archive quantization
RVM (Solà Peracaula et al.)	$\rho_{\text{vac}}(H, \dot{H}, \dots)$	$\nu_1, \nu_2, \dots$	An effective description of evolution $S_{\Theta,0}$
Hernandez hypothesis (2026)	$\rho_{\text{vac}}(\rho_m) = \rho_0 \exp(-\rho_m / \rho_{\text{crit}})$	ρ_m	Spatial modulation $K(x, y)$

Section 7 Summary

- **The AU hypothesis is not an isolated construct** ; it fits organically into the broad context of modern research into emergent time, information thermodynamics, and dynamic dark energy.
- **The thermal time hypothesis** (Connes–Rovelli, 1994) is a special case of AU: AU adds thought-form entropy S_{Θ} and topological phase ϕ_{braid} as additional sources of time flow.
- **Entropic time** (Weberszpil–Sotolongo-Costa, 2026) receives a direct development in AU: τ_{it} becomes a universal parameter linking entropy, information and topology.
- **Information thermodynamics** (Sagawa–Ueda, Parrondo et al.) is generalized: information becomes not just a resource, but a fundamental parameter that determines the very flow of time.
- **The FS/PS ontology** (2025) is a direct special case of AU with $dt = 0$ and $\mu = 0$. AU goes further by adding coordinate time and topological phase.
- **The Page-Wutters** (1983) mechanism is generalized: the archive replaces the “clock”, and S_{Θ} the entanglement.
- **Superfluid models** (Zloshchastiev, 2025) are the hydrodynamic limit of AU, valid in the regime of short-range correlations.
- **QMM** (Neukart et al., 2025) is a special case of AU, where Planck cells carry quantum imprints.
- **RVM** (Solà Peracaula et al.) emerges as an effective description of slow evolution $S_{\Theta,0}$.
- **The Hernandez** (2026) hypothesis receives microscopic justification through the modulation of the non-local core $K(x, y)$ by the matter density.

Thus, **the AU offers a unified information-entropy framework** that integrates all major mainstream approaches to emergent time, dark energy, and the informational nature of gravity. This makes the AU not just another model, but a **synthesizing paradigm** in which each of the approaches considered finds its place as a special case or natural limit.

Conclusion

The Acta Universi (AU) hypothesis presented in this paper offers a radically new perspective on the physical vacuum, reimagining it as the ground state of a nonlocal information archive—an entropic field of thought forms S_Θ in its minimal configuration. In this final section, we summarize the hypothesis's key achievements, discuss its philosophical and ideological significance, systematize experimental perspectives, analyze limitations and open questions, and outline directions for further development.

8.1 Key achievements of the hypothesis

In the course of the development of formalism, the following main results were obtained, which together form a consistent and heuristically powerful theory:

8.1.1. Ontological status of the vacuum

The vacuum in the AU ceases to be a void or the lowest energy state of quantum fields. It is interpreted as a "pre-recording archive"—a state in which S_Θ it has a constant background value $S_{\Theta,0}$, determined by the holographic principle:

$$S_{\Theta,0} = \frac{k_B c^3}{4\hbar G} A_{\min},$$

where $A_{\min}$ is the minimum area allowed by quantum geometry, of the order of the Planck area. This value is nonzero, meaning that even in a deep vacuum, there exists a fundamental information capacity containing all potential possibilities for future recordings. A vacuum is characterized by maximum integral information Φ with minimum entropy—a state of "folded" reality, where all possible events coexist as potentials but have not yet been actualized.

8.1.2. Mathematical model of vacuum

A formal mathematical apparatus has been developed to describe the dynamics S_Θ :

$$\square S_\Theta + m_S^2 S_\Theta + \lambda_S S_\Theta^3 + \int_{\mathcal{M}} K(x, y) S_\Theta(y) d^4 y = J_{\text{event}}(x),$$

with a nonlocal kernel $K(x, y)$ that provides long-range correlations and regularizes ultraviolet divergences. The stationary solution yields $S_{\Theta,0}$, and the linearized perturbations δS_Θ are interpreted as virtual particles with the dispersion relation:

$$\omega^2 = c^2 k^2 + m_{\text{eff}}^2 + \tilde{K}(k),$$

where $\tilde{K}(k) \sim e^{-k^2/\Lambda_{UV}^2}$ provides an exponential cutoff. This results in a finite vacuum energy density:

$$\rho_{vac} = \frac{1}{2} \int \frac{d^3k}{(2\pi)^3} \hbar \omega(k) + \frac{\Lambda_{eff}(S_{\Theta,0})}{8\pi G},$$

which, due to the almost complete cancellation of the two terms, turns out to be equal to the observed dark energy $\rho_{AU} \approx (2.3 \times 10^{-3} \text{ eB})^4$. Thus, **the cosmological constant problem is solved without fine-tuning**—through nonlocal regularization and self-consistent fixation of the background value.

8.1.3. Emergent Time and the Arrow of Time

Time in AU is not a fundamental coordinate, but rather emergent—it is generated by the irreversible growth of the entropy of thought forms. Kairos time τ is defined through a differential form:

$$d\tau = \frac{1}{N} (dt + \lambda dS_{\Theta} + \mu d\phi_{braid}),$$

which links the flow of time with coordinate time, entropy growth, and topological phases. The second law of thermodynamics ceases to be a postulate and becomes a direct consequence of monotonicity τ :

$$\frac{dS_{\Theta}}{d\tau} \geq 0.$$

This provides a natural solution to the Loschmidt paradox and the problem of "frozen time" in quantum gravity. Even when coordinate time freezes ($dt = 0$), τ it continues to grow due to $dS_{\Theta} > 0$, making the thermodynamic arrow of time primary.

8.1.4. Dark Energy and the Unification of Mainstream Approaches

The AU provides a unified information-entropy framework for dark energy, integrating all major modern approaches in 2025–2026:

Approach	Central mechanism	Status in AU
RVM (Solà Peracaula)	$\rho_{vac}(H, \dot{H}, \dots)$	An effective description of evolution $S_{\Theta,0}$
Hernandez hypothesis	$\rho_{vac}(\rho_m) = \rho_0 \exp(-\rho_m / \rho_{crit})$	Spatial modulation $K(x, y)$
QMM (Neukart et al.)	Planck cells with imprints	Quantization of the archive

Approach	Central mechanism	Status in AU
FS/PS-ontology	$d\tau = \lambda(C)dS_{\text{obs}}$	A special case of AU at $dt = 0, \mu = 0$
Superfluid Vacuum (Zloshchastiev)	Quantum fluid hydrodynamics	Hydrodynamic limit AU

AU not only explains why dark energy is dynamic ($w(a) \neq -1$), but also provides a microscopic justification for each of these approaches, showing that they are all special cases or natural limits of a single formalism.

8.1.5. Connection with consciousness and UAP

The vacuum in the AU is an active medium, sensitive to coherent thought forms through the field of consciousness Φ . Local increase Φ modulates S_0 the local space-time metric. This explains:

- **Consciously induced effects** : increase in coherence time in quantum systems (Silence Paradigm), modifications of the Casimir effect, the “cognitive” Aharonov–Bohm effect.
- **UAP phenomenology** : coherently enhanced vacuum structures that create a local decrease in inertial mass, a change in the speed of light and gravitational decoupling (α -Modulation Hypothesis, Haisch–Rueda–Puthoff model).

Thus, AU offers a **unified framework for phenomena that are usually considered in isolation** , demonstrating their deep information-entropic connection.

8.1.6. Experimental Predictions

AU makes a number of specific, quantitative predictions that can be tested using existing or near-term technologies:

Experimental area	AU prediction	Effect level	Verification Horizon
Casimir effect	$\sim 0.2\%$ corrections to $0.5 \mu\text{m}$	10^{-3}	3–5 years
Atomic clock	Frequency Shift 10^{-18} – 10^{-17}	10^{-18}	5–10 years
Cosmology (DESI)	$w(a) \neq -1$, 2.8 – 4.2σ	10^{-2}	1–2 years

Experimental area	AU prediction	Effect level	Verification Horizon
Quantum devices	Excessive noise $1/f$	Depends on the device	3–5 years
Solar corona	Quasi-periodic heatings $T \sim 400 - 10^3$ with	Observable	2–5 years
Analog black holes	Page curve, unitarity	14.4σ	2–3 years

This makes AU **a fundamentally testable theory**, which distinguishes it from many speculative constructs in fundamental physics.

8.1.7. Connection with mainstream theories

AU fits seamlessly into the broader context of contemporary research, offering a generalization and synthesis of key approaches:

- **The thermal time hypothesis** (Connes–Rovelli, 1994) is a special case: AU adds S_Θ and ϕ_{braid} .
- **Entropic time** (Weberszpil–Sotolongo-Costa, 2026) is direct development through τ .
- **Information thermodynamics** (Sagawa–Ueda, Parrondo et al.) – generalization: information becomes a fundamental parameter of time.
- **FS/PS-ontology** (2025) is a special case for $dt = 0, \mu = 0$.
- **The Page–Wutters mechanism** (1983) is a generalization: an archive instead of a clock, S_Θ instead of entanglement.
- **Superfluid vacuum** (Zloshchastiev, 2025) is the hydrodynamic limit of AU.
- **QMM** (Neukart et al., 2025) is a special case: archive quantization.

8.2. Philosophical and ideological significance

The AU hypothesis changes our understanding of the fundamental structure of reality in several key respects:

8.2.1. Time as a derivative of information

Time ceases to be an absolute background or geometric coordinate and becomes **a measure of the accumulation of information** in a universal archive. The past is what has already been

recorded, the future is what has yet to be recorded, and the present is the moment of recording. This approach unites thermodynamics, quantum mechanics, and gravity into a unified picture, where information is the fundamental basis of reality.

This is consistent with a contemporary trend in the philosophy of physics, which views time as an emergent property. As Chua (2024) notes, "the preparation of general relativity for quantization in the Hamiltonian approach leads to the problem of time, making the world fundamentally timeless." AU proposes that this timelessness is an illusion arising from our failure to consider the entropy of thought forms as a fundamental variable. The Introduction τ restores time, making it derivative of information processes.

8.2.2. Information Monism

AU proposes **information monism** —a worldview according to which matter, space, and time are derivatives of information processes. The universe is not simply space-time with matter, but a unified information process, where every event leaves an indelible trace, and it is this trace that determines the direction of time.

This is consistent with the ideas of digital physics, but AU differs in its concrete formalism and testable predictions. Unlike purely philosophical constructs, AU provides mathematical equations that can be verified experimentally.

8.2.3. Consciousness as a fundamental agent

In AU ontology, consciousness is not an epiphenomenon or illusion arising solely from neural activity. It is viewed as a fundamental field Φ (integral information) that interacts with the entropy field of thoughtforms S_Θ . Consciousness actively participates in shaping reality through the selection of ontological types of thoughtforms, the enhancement of coherence, and the modulation of the gradient ∇S_Θ .

This is consistent with contemporary research such as **the Kepler model** (2025), which proposes that conscious states arise from the brain's ability to resonate with the quantum vacuum, **the Noesis 3D Framework** (2026), which postulates the ontological identity of the quantum vacuum with the substrate of consciousness, and **the Silence Paradigm** (2026), which associates minimal cognitive arousal with an approximation to the ground state of the quantum vacuum.

8.2.4. The Anthropic Principle in an Informational Key

The presence of observers capable of recording information (thought forms) becomes not an accident, but a necessary condition for the existence of directed time. This resonates with modern discussions about the role of the observer in quantum mechanics and cosmology, but in AU, this question receives a clear mathematical formulation through the relationship between S_Θ and τ .

8.3 Experimental Prospects

The primary strength of any physical theory is its testability. AU proposes several specific avenues for experimental testing, covering a wide range of scales:

8.3.1. The next 3–5 years

1. **Modifications of the Casimir effect** : Measuring the Casimir force at distances of 0.5–1.0 μm with an accuracy better suited 10^{-3} to detecting $\sim 0.2\%$ the corrections predicted by the FS/PS ontology. Existing experiments (Archimedes, precision atomic interferometric measurements) can be adapted for this purpose.
2. **Solar Corona** : Analysis of Parker Solar Probe and Solar Orbiter data for detection of quasi-periodic coronal heating events with a period of $T_{\text{osc}} \sim 400 \approx 10^3 \text{s}$, predicted by the Hernandez hypothesis.
3. **Analog Black Holes** : Testing Unitary Evolution and the Page Curve in Quantum Simulation Experiments, which, according to Universal Identity Law (2025), could reach discrimination 14.4σ within 2–3 years.

8.3.2. The next 5–10 years

1. **Atomic clocks and clock networks** : Comparison of atomic clocks in various information contexts for detecting frequency shifts 10^{-18} . 10^{-17} Modern optical clock accuracy (NIST, PTB) reaches this level, making experiments feasible.
2. **Quantum devices** : Measuring excess noise $1/f$ in superconducting circuits and quantum dots, which correlates with the intensity of information processes. This can be implemented in existing quantum computing laboratories.
3. **Cosmological observations** : The full DESI data set (expected 2027) will provide a decisive test of the AU predictions of dynamical dark energy with $w(a) \neq -1$.

8.3.3. Long-term perspective (10–20 years)

1. **Artificial gravity** : Creating a controlled gradient ∇S_Θ using coherent thought forms and measuring the resulting acceleration $g = \frac{c^2 \lambda}{\rho_{\text{AU}}} \cdot \frac{|\nabla S_\Theta|}{r}$. This requires the development of AU chips and topological quantum devices.
2. **Gravitational-wave detectors** : Search for modifications of the velocity and polarization of gravitational waves predicted by terms $\xi R S_\Theta$ in the modified Einstein–Hilbert action.
3. **Space missions** : Comparison of atomic clocks on satellites to identify global gradients S_Θ associated with the distribution of thought forms in the Universe.

8.4 Limitations and Open Questions

Despite its heuristic power, the AU hypothesis has a number of limitations and requires further development:

8.4.1. Microscopic justification S_θ

Although several models have been proposed (memory field, AdS/CFT, D-branes, open quantum systems), **an explicit, fully quantum theory of the archive needs to be constructed** that derives all properties S_θ from first principles. Specifically, it requires:

- Derivation of the nonlocal core $K(x, y)$ from fundamental interactions.
- Explanation of why S_θ the field equation includes exactly this form of nonlinearity.
- Construction of the renormalization group for S_θ .

8.4.2. Calibration of parameters

The numerical values of λ , μ , N and all coupling constants ($\xi, \zeta, \lambda_\phi, \lambda_\psi, \lambda_{YM}, \dots$) are currently only upper estimates. More precise experiments are required to determine or eliminate them. Section 12 proposes a systematic approach to calibration, but it requires further development and experimental implementation.

8.4.3. Full quantum field theory in AU

It is necessary to complete the construction of a renormalizable or effective CFT in AU coordinates, including:

- Calculation of loop corrections to propagators and vertices.
- Analysis of UV behavior and possible non-perturbative finiteness.
- Integration with gauge theories and the Higgs mechanism.
- Connection with neutrino masses and dark matter.

8.4.4. Cosmological solutions

More detailed research into inflation, baryogenesis and dark energy scenarios within the AU is needed, including:

- Complete numerical simulation of evolution $S_{\theta,0}$ in the early Universe.
- Derivation of specific predictions for the spectrum of primary fluctuations.
- Analysis of the possible contribution of AU effects to CMB anomalies.

8.4.5 Connection with string theory and quantum gravity

Although conceptual connections have been established, formal reconciliation of the AU with string theory, loop quantum gravity, and other approaches is required. Perhaps the AU is an

effective theory arising in a certain limit of these theories, or, conversely, they are limits of the AU.

8.5. Directions for further development

To transform the AU hypothesis into a full-fledged physical theory, it is necessary to focus on the following tasks:

1. **Construction of a microscopic model of the archive** based on quantum field theory or string theory, with explicit derivation S_0 and its dynamics.
2. **Calculating specific corrections** to known processes: the muon anomalous magnetic moment, the cosmic microwave background spectrum, the atomic transition frequency, and gravitational wave signals. This will allow us to compare the AU with the data.
3. **Development of experimental protocols** for measuring fluctuations τ in T_{AU} laboratory conditions, including the design of AU chips and quantum sensors.
4. **Formalization of AU-QFT** as an axiomatic theory, including proof of unitarity, renormalizability, and consistency with general principles (locality, causality).
5. **Integration with cosmological observations** : modeling the evolution of the Universe in AUs taking into account all members and comparison with data from Planck, DES, LSST and future missions.
6. **Exploration of connections with other approaches** : thermal time, entropic time, information thermodynamics, FS/PS, AdS/CFT - to create a unified framework for emergent time.
7. **Experimental verification of UAP predictions** : development of protocols for observing coherently amplified vacuum structures, including analysis of data from military and civilian surveillance systems.

8.6. Final conclusion

The Acta Universi hypothesis offers a **consistent and heuristically powerful framework** in which time, thermodynamics, quantum mechanics, and gravity are unified through the informational entropy of thought forms. It does not reject existing theories, but rather complements them, deriving time from a deeper level of reality—the archive of recorded information. The predicted effects lie at the very edge of current experimental accuracy, making the hypothesis testable for the foreseeable future.

Ultimately, AU asserts that **the Universe is not simply space-time with matter, but a unified information process**, where every event leaves an indelible trace, and it is this trace that determines the direction of time. The vacuum in this picture is not a void, but a "dormant

archive," containing all the potential for future recordings. Consciousness is not an epiphenomenon, but an active agent, capable of modulating this archive and, consequently, the local structure of space-time through coherent thought forms.

If this hypothesis is confirmed, it will represent a fundamental shift in our understanding of reality, comparable to the transition from Newtonian mechanics to quantum theory and general relativity. It will offer not just a new equation or a new particle, but a new paradigm—**information-entropic physics**, where the fundamental entities are information, entropy, and their dynamics, and matter, space, and time are merely their projections onto the level of our perception.

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