

Theta-entropy field transformation mechanism into matter, interactions, and the dark sector: a hypothetical framework

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Annotation

This paper proposes a hypothetical framework for describing a possible mechanism for the transformation of the theta-entropy field S_θ —a nonlocal archive of irreversible events—into observable matter, interactions, and the dark sector. The Acta Universi (AU) hypothesis postulates that the fundamental structure of reality is a field S_θ , and that particles, fields, and interactions represent emergent modes of coherence within this field.

The work systematizes the chain of emergence, which includes several levels:

1. **Emergence of constants** - fundamental constants (α , G , $\hbar$, masses) are considered as functionals of the archive structure.
2. **Fermions** (6 quarks and 6 leptons) are localized field modes S_θ with topological invariants that determine flavors and generations.
3. **Interactions** (strong, weak, electromagnetic, gravitational, Higgs) - as different types of correlations between localized modes.
4. **Structures** (nuclei, atoms, molecules) are represented as standing coherent modes, and mixing (CKM, PMNS) and CP violation are represented as overlap integrals and asymmetry of records in the archive.
5. **Radiation** (electromagnetic and gravitational waves) - as propagating perturbations of gradient S_θ and metric.
6. **Dark sector** - dark matter as unmanifested modes with zero EM charge, dark energy as global entropy of the archive.

All transitions described in this paper are **theoretical and speculative**. None of them have direct experimental confirmation within the AU framework. Mainstream theories (the Standard Model, QCD, QED, electroweak theory, and general relativity) are retained as fundamental; the AU framework is proposed as an additional ontological language, not as a replacement for existing physics.

The goal of this paper is to propose a unified language for discussing possible connections between the AU hypothesis and particle physics, as well as to formulate formalization directions and testable consequences. Numerical estimates, if provided, are illustrative orders of magnitude and depend on the assumptions made.

Keywords: Acta Universi; theta-entropy field; emergence of constants; quarks; confinement; atom; electromagnetic radiation; dark matter; dark energy; hypothetical framework.

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Introduction

1.1 Statement of the problem: the need for a unified mechanism

Modern particle physics and cosmology have made impressive strides in describing matter, interactions, and the evolution of the universe. The Standard Model (SM) accurately describes the electromagnetic, weak, and strong interactions, as well as the spectrum of known elementary particles. General Relativity (GR) describes gravity as the curvature of spacetime.

The Lambda-Cold Dark Matter (Λ CDM) model successfully explains the large-scale structure of the universe, the cosmic microwave background, and accelerated expansion by introducing dark matter and dark energy.

However, beyond this impressive picture, a number of fundamental questions remain to which the Standard Model and Λ CDM do not provide definitive answers:

- **The nature of dark matter and dark energy.** Dark matter makes up about 27% of the universe's energy budget, dark energy about 68%, while ordinary matter only about 5%. What are these "dark" components? Are they particles, fields, or something fundamentally different?
- **Mass hierarchy and number of generations.** Why do fermions have three generations? Why do the masses of the generations differ so greatly? Why are neutrino masses so small?
- **CP symmetry violation.** Why does matter predominate over antimatter in the Universe? What is the mechanism of baryogenesis?
- **Quantum gravity.** How to reconcile general relativity and quantum mechanics? Is spacetime fundamental or emergent?
- **The cosmological constant problem.** Why is the observed value Λ 120 orders of magnitude smaller than the naive estimate from quantum field theory?

The Acta Universi (AU) hypothesis, proposed by D. E. Yashchenko in 2025, offers an ontological framework in which the fundamental structure of reality is a non-local archive of irreversible events— **the entropy field of thought forms S_θ** . Space-time, matter, and interactions are viewed as emergent structures generated by the dynamics of this field. Previous works in the AU cycle have proposed separate interpretations for gravity, quantum entanglement, dark energy, and other phenomena. However, until now, a unified framework linking the field S_θ to the entire spectrum of elementary particles and interactions has been lacking.

The question arises: **is it possible to construct a single hypothetical mechanism that would describe the transformation of the field S_θ into matter, interactions, and the dark sector—not as a set of disparate interpretations, but as a consistent chain of emergence?**

This paper proposes such a mechanism. We do not claim to prove the biological or physical consequences of the AU, nor do we propose a replacement for the Standard Model. Our goal is to provide specialists with a compact and methodologically transparent framework within which to discuss possible connections between the AU hypothesis and particle physics.

1.2 Purpose and objectives of the study

The aim of the work is to propose a comprehensive hypothetical mechanism for the transformation of the theta-entropy field S_θ into matter, interactions, and a dark sector.

Specific objectives of the study:

1. **Systematize all levels of emergence** —from constants and fermions to interactions, structures, radiation, and the dark sector—into a single chain.
2. **Clearly label the status of each statement:** empirical fact / working hypothesis / speculation. Mixing levels is unacceptable.
3. **Formulate possible directions of formalization** —what mathematical structures could connect field parameters S_Θ with observable quantities (masses, coupling constants, mixing matrices).
4. **Suggest testable implications** —both cautious (correlation studies) and speculative (dynamic-related deviations from the SM S_Θ).
5. **Ensure interdisciplinary transparency** —the text is structured so that a specialist from any field (particle physics, cosmology, quantum gravity) can enter any chapter and immediately see the status of statements.

1.3 Methodological caveat

All transitions described in this paper are **hypothetical**. None of them have direct experimental confirmation within the AU framework. Mainstream theories (the Standard Model, QCD, QED, electroweak theory, and general relativity) are retained as fundamental. The AU framework is proposed as an additional ontological language, not as a replacement for existing physics.

Three levels of statements:

1. **Empirically confirmed phenomena** are those that have already been measured or are actively studied in the mainstream (particle spectra, coupling constants, cosmological data).
2. **Hypothetical AU interpretations** are possible readings of these phenomena in terms of S_Θ , coherence and archive.
3. **Speculative assumptions** are further consequences that have no experimental support.

Numerical estimates, if given, are illustrative orders of magnitude and depend on the assumptions made. They are not the results of direct measurements.

Disclaimer of Clinical and Technological Promises: None of the statements in this approach constitute recommendations for device development, therapy, or diagnostics. This work is of a theoretical nature.

1.4 Structure of the work

The article is organized as follows.

Part I (Chapters 1–2) lays the ontological foundations: the definition of a field S_Θ , its characteristics (record density $\rho_{\text{записей}}$, non-local core $K(x, y)$, coherence $\mathcal{C}$, entropic mismatch δS_Θ), the criterion for localization and particle production.

Part II (Chapters 3–4) considers the emergence of constants: fundamental constants as functionals of the archive structure, the stability of constants as a consequence of global coherence, the hierarchy of masses, and the problem of generations.

Part III (Chapters 5–6) is devoted to fermions as localization modes: six quarks and six leptons, their flavors, colors and generations as topological invariants and excitation levels.

Part IV (Chapters 7–11) describes interactions as types of correlations: strong (confinement), weak (flavor switching), electromagnetic (gradient waves), gravitational (emergent metric), and Higgs mechanism (condensate S_Θ).

Part V (Chapters 12–14) covers structures: nuclei, atoms, molecules, generations and mixing (CKM, PMNS), CP-breaking and baryogenesis.

Part VI (Chapters 15–16) is devoted to radiation: electromagnetic and gravitational waves as perturbations of the gradient S_Θ and metric.

Part VII (Chapters 17–18) describes the dark sector: dark matter as unmanifested modes with zero EM charge and dark energy as the global entropy of the archive.

Part VIII (Chapters 19–20) formulates directions of formalization and testable consequences (cautious and speculative).

Part IX (Chapters 21–23) discusses comparisons with the mainstream, limitations and criticisms, and prospects for development.

The conclusion summarizes the main results, emphasizing the hypothetical status of all transitions and the need for interdisciplinary dialogue.

The appendices contain a glossary, mathematical apparatus, links to previous works in the AU cycle, and a table of statement statuses.

Part I. Ontological Foundations

Chapter 1. Field S_Θ as a Fundamental Reality

1.1 Field Definition S_Θ

In the Acta Universi (AU) hypothesis, the fundamental structure of reality is **the entropy field of thought forms** S_Θ — a non-local archive of all irreversible events. This field is not a field in the usual physical sense (like an electromagnetic or gravitational field); it is **an ontological structure** in which all acts of information are recorded, and space-time, matter, and interactions are emergent with respect to it.

Definition: A field $S_\Theta(x)$ is a scalar field on the base manifold, the values of which correspond to the local density of irreversible records (thought forms) in the universal archive.

$$S_{\Theta}(x): \mathcal{M} \rightarrow \mathbb{R}$$

where $\mathcal{M}$ is the underlying manifold (not necessarily coinciding with the observed space-time).

The key difference from known fields: Unlike the quantum fields of the Standard Model, S_{Θ} it does not describe particles or their interactions. It describes **the informational structure of reality** — what is "recorded" in the archive. Particles and interactions arise as **modes of coherence** of this field.

Status: Ontological postulate of AU. Not empirically supported.

1.2 Field characteristics S_{Θ}

1.2.1 Record Density $\rho_{\text{записей}}$

Local recording density determines how intensively irreversible events are recorded in a given area of the archive.

$$\rho_{\text{записей}}(x) = \frac{dN_{\text{events}}}{dV}$$

where dN_{events} is the number of irreversible events in an elementary volume dV .

Physical interpretation: In regions with high gravitational $\rho_{\text{записей}}$ fields, the archive is actively "filled" with new events. This may correspond to regions with high intensity of physical processes (for example, near black holes or in the early Universe).

Mainstream connection: The concept of event density has parallels with the entropy of black holes (Bekenstein-Hawking), where entropy is proportional to the area of the horizon rather than the volume. In the AU model, $\rho_{\text{записей}}$ it plays a similar role, but at a more fundamental level.

Status: Hypothetical characteristic.

1.2.2 Non-local kernel $K(x, y)$

The non-local core $K(x, y)$ describes **the archive memory** — correlations between records at different points.

$$K(x, y) = \alpha_{\text{nl}} \frac{e^{-|x-y|/\ell_{\text{AU}}}}{|x-y|} \cdot \Theta(\tau_x - \tau_y)$$

Where:

- α_{nl} — non-local coupling constant,
- ℓ_{AU} — the scale of nonlocality,

- $\Theta(\tau_x - \tau_y)$ — a step function that ensures causality at the level of kairos time.

Physical interpretation: The core $K(x, y)$ allows records at one point to influence records at another point without the usual signal interactions. This explains nonlocal correlations (quantum entanglement, the presentiment effect, UAP phenomena).

Mainstream connection: Nonlocal correlations in quantum mechanics (entanglement) have parallels with the core $K(x, y)$. However, in the AU model, nonlocality is a **fundamental property of the archive**, not a consequence of quantum theory.

Status: Hypothetical construction.

1.2.3 Global entropy S_Θ

Global entropy S_Θ is an integral characteristic of an archive that determines its “volume” and evolution.

$$S_\Theta^{\text{glob}} = \int_{\mathcal{M}} S_\Theta(x) d^4x$$

Physical interpretation: The increase in global entropy corresponds to the accumulation of records in the archive. In the AU model, this increase is associated with cosmological expansion (via Λ_{eff}) and the arrow of time.

Mainstream connection: The second law of thermodynamics states that the entropy of an isolated system does not decrease. In the AU model, this is a consequence of growth S_Θ^{glob} .

Status: Hypothetical characteristic.

1.3 Coherence and entropic mismatch

1.3.1 Coherence $\mathcal{C}$

Coherence $\mathcal{C}$ is a measure of the consistency of a field's configuration S_Θ with the archive.

$$\mathcal{C}[\mathcal{A}] = \frac{\langle S_\Theta^{(\mathcal{A})} | K | S_\Theta^{\text{arch}} \rangle}{\| S_\Theta^{(\mathcal{A})} \|_K \cdot \| S_\Theta^{\text{arch}} \|_K}$$

Where:

- $S_\Theta^{(\mathcal{A})}$ — a configuration corresponding to a given structure (particle, field, interaction),
- S_Θ^{arch} — “reference” archive configuration,
- $\langle \cdot | K | \cdot \rangle$ — scalar product with kernel K .

Physical interpretation: High coherence ($\mathcal{C} \rightarrow 1$) means that the configuration resonates with the archive and creates a stable recording. Low coherence ($\mathcal{C} \rightarrow 0$) indicates misalignment.

Mainstream connection: In quantum mechanics, coherence describes the preservation of phase relations. The AU model $\mathcal{C}$ generalizes this concept to the archival level.

Status: Hypothetical characteristic.

1.3.2 Entropic mismatch δS_Θ

Entropic misalignment δS_Θ is a measure of the deviation of a configuration from archival coherence.

$$\delta S_\Theta[\mathcal{A}] = \int_{\mathcal{M}} |S_\Theta^{(\mathcal{A})}(x) - \mathcal{P}_K S_\Theta^{\text{arch}}(x)|^2 d^4x$$

where $\mathcal{P}_K$ is the projector onto the subspace consistent with the kernel K .

Physical interpretation: Low δS_Θ corresponds to a coherent configuration (true), high to a discordant one (false or unstable).

Mainstream connection: The concept of misalignment has parallels with errors in quantum computing and decoherence in open systems.

Status: Hypothetical characteristic.

1.4 Nonlocality and Causality

1.4.1 Non-locality of the archive

The nonlocality of the archive means that correlations between records are not limited by the speed of light in chronos-time. However, this does not violate causality, because causality is preserved at the level **of the archive's structure** (kairos-time).

$$\oint d\tau_{\text{ont}} > 0$$

for any closed loop in space-time.

Physical interpretation: Non-local correlations (quantum entanglement, UAP) are a manifestation of the non-locality of the archive. Causality is preserved because events are already "recorded" in the archive in the correct order.

Mainstream connection: In quantum mechanics, nonlocal correlations (entanglement) do not violate causality because they do not transfer information in the classical sense. In the AU model, this is generalized to the archive level.

Status: Hypothetical interpretation.

1.4.2 Causality at the archive level

Causality in the AU model is determined not by signals, but by **the order of records** in the archive. An event A is the cause of an event B if the record A precedes the record B in kairos time.

$$A < B \Leftrightarrow \tau_A < \tau_B$$

Physical interpretation: This allows non-local correlations to be explained without violating causality: events can be correlated in chronos-time, but causally ordered in kairos-time.

Mainstream connection: In general relativity, causality is determined by light cones. In the AU model, causality is determined by the structure of the archive, which allows the concept of causality to be extended to non-local correlations.

Status: Hypothetical interpretation.

1.5 Chapter 1 Summary

1. **The field S_Θ** is the fundamental structure of reality in the AU hypothesis, a non-local archive of irreversible events. Particles, interactions, and spacetime emerge from it.
2. **Field characteristics:** record density $\rho_{\text{записей}}$, non-local core $K(x, y)$, global entropy $S_\Theta^{\text{глоб}}$.
3. **Coherence $\mathcal{C}$** is a measure of the consistency of a configuration with the archive. **Entropic mismatch δS_Θ** is a measure of deviation from archival coherence.
4. **Non-locality of the archive** - correlations between records are not limited by the speed of light, but causality is preserved at the level of the archive structure (kairos time).
5. **Status:** All statements are ontological postulates of the AU, not empirically confirmed facts. Mainstream theories are retained as core ones.

Chapter 2. Criterion of localization and particle production

In the previous chapter, we defined the field S_Θ as a fundamental reality and introduced its key characteristics. Now we turn to the central question: how **do localized structures—particles—emerge from a continuous field S_Θ** ?

In the AU ontology, particles are not fundamental entities. They represent **localized modes of field coherence S_Θ** —regions where the density of entries exceeds a critical value, and a stable topological configuration is formed. In this chapter, we describe the localization criterion, the topological invariant, and the pair production mechanism.

2.1 Condition $\rho_{\text{записей}} > \rho_{\text{crit}}$ as a localization trigger

2.1.1 Critical Record Density

In the AU model, the localization of the field S_0 into a particle occurs when the critical density of entries is exceeded:

$$\rho_{\text{записей}}(x) > \rho_{\text{crit}}$$

where ρ_{crit} is the critical value determined by the archive parameters (nonlocality scale ℓ_{AU} , coupling constant λ , effective temperature T_{eff}).

Physical interpretation: When the local density of irreversible events reaches a critical threshold, the field "condenses"—a stable localized structure is formed. This is analogous to a phase transition in condensed matter: upon reaching a critical density, the system transitions to a new state.

Mainstream connection: In quantum field theory, particle creation occurs when energy transfer exceeds the rest mass threshold ($E > mc^2$). In the AU model, the threshold is equivalent to ρ_{crit} : when the density of entries exceeds the critical value, a particle is "born."

Status: Hypothetical interpretation.

2.1.2 Evaluation ρ_{crit}

Within the AU model ρ_{crit} , it can be estimated through archive parameters:

$$\rho_{\text{crit}} \sim \frac{m_f c^2}{\hbar \cdot \ell_{\text{AU}}^3}$$

where m_f is the mass of the fermion, c is the speed of light, $\hbar$ is the reduced Planck constant.

Numerical estimate (illustrative): For electron ($m_e \approx 0.511 \text{ MeV}$) and $\ell_{\text{AU}} \sim 10^{-15} \text{ m}$:

$$\rho_{\text{crit}} \sim 10^{45} \text{ событий/м}^3$$

This is an illustrative order of magnitude, depending on the assumptions made. A precise value requires calibration using observed data.

Status: Speculative.

2.1.3 Phase transition and stability

At, $\rho_{\text{записей}} > \rho_{\text{crit}}$ a **stable localized mode** is formed. Its stability is determined by its positive "rigidity"—the second variation of the mismatch energy:

$$\frac{\delta^2 E}{\delta \varphi^2} \big|_{\text{loc}} > 0$$

where $\varphi = \delta S_\Theta$ is the field fluctuation.

Physical interpretation: The localized mode is a local attractor: small deviations return to it, which ensures the stability of the particle.

Mainstream connection: In quantum field theory, particle stability is determined by conservation laws (energy, momentum, charge). In the AU model, stability is determined by the topology of the localized configuration.

Status: Hypothetical interpretation.

2.2 Topological invariant of a localized configuration

2.2.1 Definition of a topological invariant

A localized field configuration S_Θ is characterized by a **topological invariant** —an integer that is preserved under continuous deformations:

$$Q_{\text{top}} = \frac{1}{2\pi} \oint_{\partial\Omega} \nabla S_\Theta \cdot dl$$

where $\partial\Omega$ is the boundary of the localized region.

Physical interpretation: The topological invariant determines the "flavor" of a particle. Different values Q_{top} correspond to different types of fermions.

Mainstream connection: In particle physics, the flavors of quarks and leptons are distinguished by quantum numbers (charge, strangeness, charm, etc.). In the AU model, these quantum numbers correspond to topological invariants of localized modes.

Status: Speculative interpretation.

2.2.2 Charge fraction and color

The fractionality of the electric charge of quarks ($2/3, -1/3$) in the AU model is interpreted as the fractionality of the topological invariant during localization:

$$Q_{\text{ent}}^{(q)} = \frac{1}{2\pi} \oint_{\partial\Omega_q} \nabla S_\Theta \cdot dl = \begin{cases} +2/3 & (\text{u, c, t}) \\ -1/3 & (\text{d, s, b}) \end{cases}$$

The color (three states of quarks) is interpreted as **three orientations of the coil** in the local region:

$$\text{цвет} \in \{\text{красный, зелёный, синий}\} \leftrightarrow \{\nabla, S_\Theta, \tau^1 \nabla S_\Theta \cdot \tau^2 \nabla S_\Theta \cdot \tau^3\}$$

where τ^a are the generators of SU(3).

Mainstream connection: Charge fractionality and color are empirical facts confirmed in deep inelastic scattering experiments. In the AU model, they receive a topological interpretation.

Status: Speculative interpretation.

2.2.3 Three generations as three levels of excitation

Three generations of fermions are interpreted as three discrete excitation levels of one topological structure:

$$\Theta^{(n)}(t) = \sum_i a_i^{(n)}(t) | \psi_i \rangle, n = 1,2,3$$

where $n = 1$ is the ground state (u, d, e, ν_e), $n = 2$ is the first excitation (c, s, μ , ν_μ), $n = 3$ is the second excitation (t, b, τ , ν_τ).

The mass hierarchy corresponds to the difference in energy levels:

$$m^{(n)} \propto \Delta E_n = E_n - E_1$$

Connection to the Mainstream: The problem of the number of generations and the mass hierarchy remains open in the Standard Model. In the AU model, it receives a natural explanation through a discrete spectrum of excitations.

Status: Speculative interpretation.

2.3 Pair production as compensation for entropic charge

2.3.1 The mechanism of pair birth

In the AU model, **the creation of a pair** (particle–antiparticle) occurs when attempting to separate localized configurations with a non-zero topological invariant:

$$Q_{\text{top}} \neq 0 \Rightarrow \text{рождение компенсирующей пары}$$

Physical interpretation: The archive requires global neutrality: the total topological invariant must be zero. When attempting to "pull" one charge out of the vacuum, a particle-antiparticle pair is created, canceling out the charge.

Mainstream connection: In quantum field theory, pair production is described as the creation of a particle and antiparticle from a vacuum at sufficient energy. In the AU model, this is a consequence of the requirement that the archive be neutral.

Status: Hypothetical interpretation.

2.3.2 Antiparticles as "mirror" modes

Antiparticles in the AU model are interpreted as “mirror” modes with the opposite topological invariant:

$$\Theta_{\text{анти}}(t) = \sum_i a_i^*(t) | \psi_i \rangle, \quad Q_{\text{top}}^{\text{анти}} = -Q_{\text{top}}$$

Physical interpretation: The antiparticle is not a "different" particle, but the same mode, but with the opposite orientation of the coil ∇S_{Θ} .

Mainstream connection: In quantum field theory, antiparticles are described by complex conjugation of the wave function. In the AU model, this corresponds to the reverse orientation of the topological coil.

Status: Speculative interpretation.

2.3.3 Annihilation as a “collapse” of modes

Annihilation (particle + antiparticle $\rightarrow$ photons) in the AU model is interpreted as the “collapse” of a pair of modes with compensating topological invariants:

$$Q_{\text{top}} + (-Q_{\text{top}}) = 0 \Rightarrow \text{излучение градиентных волн}$$

Physical interpretation: During annihilation, localized modes are "unpacked" into gradient waves (photons). The rest energy is converted into radiant energy.

Mainstream connection: The annihilation of electron-positron pairs into photons is an experimentally confirmed process. In the AU model, it receives a topological interpretation.

Status: Hypothetical interpretation.

2.4 Connection with the Mainstream

2.4.1 Particle production in quantum field theory

In quantum field theory, particle production is described as the excitation of quantum fields through energy transfer. For example, the production of an electron-positron pair by a photon in the field of a nucleus (the Bethe-Heitler process) requires a photon energy of $10 E > 2m_e c^2 \approx 1.022 \text{ MeV}$.

In the AU model, the threshold analog is ρ_{crit} : when the density of records exceeds a critical value, a localized mode is "born." This does not replace quantum field theory, but rather offers an additional ontological language.

2.4.2 Topological defects and solitons

In condensed matter physics and cosmology, topological defects (solitons, vortices, monopoles) arise during phase transitions and are characterized by topological invariants. In the AU model, localized modes are analogous to solitons: they are stable due to their topology.

Mainstream connection: Solitons in nonlinear systems (sine-Gordon equation, Skyrme model) are well-studied objects. The AU model proposes them as prototypes of elementary particles.

2.4.3 The problem of the number of generations

The number of fermion generations (three) remains an open question in the Standard Model. In the AU model, three generations arise naturally as three excitation levels of a single topological structure. This does not contradict the mainstream theory, but offers an additional explanation.

Status: Speculative interpretation.

2.5 Chapter 2 Summary

1. **Localization criterion:** When $\rho_{\text{записей}} > \rho_{\text{crit}}$ The field S_θ "condenses" into a localized mode—a particle. The critical density is estimated using archive parameters.
2. **Topological invariant** Q_{top} determines the "flavor" of a particle. Quark charge fractionality and color are interpreted as topological characteristics.
3. **Three generations** are three discrete excitation levels of a single topological structure. The mass hierarchy corresponds to the energy difference between the levels.
4. **Pair production** is compensation for entropic charge: the archive requires global neutrality. Antiparticles are "mirror" modes with opposite topological invariants.
5. **Annihilation** is the "collapse" of compensating modes with the emission of gradient waves (photons).
6. **Status:** All statements are hypothetical/speculative. Mainstream theories (quantum field theory, topological defects) remain fundamental.

Part II. Emergence of Constants

Chapter 3. Constants as functionals of the archive structure

In the previous section, we defined the field S_θ as a fundamental reality and described the localization mechanism that generates particles. Now we move on to the next level of emergence: **fundamental constants**.

In the Standard Model and General Relativity, constants (α , G , $\hbar$, c , fermion masses) are considered fixed parameters whose values are not derived from theory, but measured experimentally. In the AU ontology, constants receive a fundamentally different status: they are **functionals of the archive structure**. S_θ , that is, their values are determined by the global and local properties of the entropy field of thought forms.

In this chapter we will consider how constants can be expressed in terms of archive parameters, why they are stable, and what implications this has for understanding the early Universe.

3.1 General principle: constants as functionals

3.1.1 Main hypothesis

In the AU model, fundamental constants are not independent parameters. They arise as **functionals** of the field structure S_θ , its gradients, and the nonlocal kernel $K(x, y)$:

$$\begin{aligned}\alpha &= \mathcal{F}_1[S_\theta, \nabla, S_\theta K] \\ \frac{G}{\hbar c} &= \mathcal{F}_2[S_\theta, \nabla, S_\theta K] \\ m_f &= \mathcal{F}_3[S_\theta, \nabla, S_\theta K]\end{aligned}$$

where $\mathcal{F}_i$ are functionals determined by the archive dynamics.

Physical interpretation: Constants are not "input parameters" of the theory, but **emergent characteristics** of the archive. Their values are determined by how the archive is "structured" at a fundamental level.

Mainstream connection: Some approaches to quantum gravity and string theory also view constants as emergent (for example, in the landscape of string vacua). The AU model proposes a specific mechanism: the constants are determined by the structure S_θ .

Status: Hypothetical interpretation.

3.1.2 Fine structure constant α

The fine-structure constant $\alpha \approx 1/137$ is one of the most accurately measured constants in physics. In the AU model, it can be expressed through the ratio of characteristic archive scales:

$$\alpha = \frac{\ell_{\text{AU}}}{\ell_{\text{Planck}}} \cdot \mathcal{G}[\rho_{\text{записей}}]$$

Where:

- ℓ_{AU} — the scale of non-locality of the archive,
- ℓ_{Planck} — Planck length,

- $\mathcal{G}[\rho_{\text{записей}}]$ — a dimensionless functional of the record density.

Physical interpretation: α determines the strength of the electromagnetic interaction. In the AU model, it is related to how densely the archive is packed at Planck scales.

Numerical assessment (illustrative): If $\ell_{\text{AU}} \sim 10^{-15}\text{m}$ (the kernel scale), and $\ell_{\text{Planck}} \sim 10^{-35}\text{m}$, then $\ell_{\text{AU}}/\ell_{\text{Planck}} \sim 10^{20}$. To obtain, $\alpha \sim 10^{-2}$ the functional $\mathcal{G}$ must be of the order of 10^{-22} .

Status: Speculative.

3.1.3 Gravitational constant G

The gravitational constant G determines the strength of gravitational interaction. In the AU model, it can be expressed in terms of the global entropy of the archive:

$$G = \frac{\hbar c}{S_{\Theta}^{\text{glob}}} \cdot \mathcal{H}[\mathcal{C}]$$

Where:

- S_{Θ}^{glob} — global entropy of the archive,
- $\mathcal{H}[\mathcal{C}]$ — functional of coherence.

Physical interpretation: G is inversely proportional to the global entropy of the archive. The more records in the archive, the weaker the gravitational interaction.

Connection to the mainstream: In entropic gravity (Verlinde, 2011) G , entropy is also linked. The AU model offers a concrete form of this connection.

Status: Hypothetical interpretation.

3.1.4 Fermion masses

The masses of fermions in the AU model are determined by the strength of the coupling with the field condensate S_{Θ} :

$$m_f = y_f \cdot v$$

Where:

- y_f — Yukawa coupling (a dimensionless parameter determined by the mode topology),
- $v = \langle S_{\Theta} \rangle$ — vacuum average of the field S_{Θ} .

Physical interpretation: The fermion mass is a measure of how strongly its localized mode is "coupled" with the archive condensate. Particles with higher masses interact more strongly with the condensate.

Connection to the mainstream: In the Standard Model, fermion masses are also determined via Yukawa constraints and the vacuum expectation value of the Higgs field. The AU model replaces the Higgs field with a condensate S_Θ , but retains the coupling structure.

Status: Hypothetical interpretation.

3.2 Stability of constants as a consequence of global coherence

3.2.1 Why are constants stable?

In the AU model, the stability of the constants is explained by **the global coherence of the archive**. If the archive is in a highly coherent state ($\mathcal{C} \rightarrow 1$ on cosmological scales), then its structural characteristics (including the constants) do not change over time.

$$\frac{d\alpha}{dt} \approx 0 \Leftrightarrow \mathcal{C}_{\text{glob}} \rightarrow 1$$

Physical interpretation: The constants are stable not because they are "fundamental," but because the archive exists in a stable, coherent state. If the coherence were to be disrupted, the constants could change.

Connection to the mainstream: Experimental constraints on the variation α (for example, from quasar spectra) show that $\Delta\alpha/\alpha < 10^{-5}$ on cosmological timescales. In the AU model, this is a consequence of global coherence.

Status: Hypothetical interpretation.

3.2.2 Local fluctuations of constants

local fluctuations in regions with broken coherence are possible in the AU model:

$$\alpha_{\text{lok}}(x) = \alpha_0 \cdot (1 + \delta\alpha(x))$$

where $\delta\alpha(x)$ is a local fluctuation associated with $\delta S_\Theta(x)$.

Physical interpretation: In regions with high entropy load (e.g. near black holes or in the early Universe), the constants may locally deviate from their global values.

Mainstream connection: Some models of quantum gravity also predict local variations in the constants. The AU model proposes a specific mechanism: fluctuations δS_Θ .

Status: Speculative interpretation.

3.2.3 Constants and Kairos Time

In the AU model, the constants can slowly evolve in kairos time τ :

$$\alpha(\tau) = \alpha_0 \cdot \left(1 + \epsilon \cdot \frac{dS_{\Theta}^{\text{глоб}}}{d\tau} \right)$$

where ϵ is a small parameter.

Physical interpretation: If an archive continues to accumulate records, its structure may slowly change, leading to an evolution of the constants. However, in the modern era, this effect is negligible.

Connection to Mainstream: Hypotheses about the variation of constants (Dirac, 1937) are actively discussed in cosmology. The AU model offers a concrete connection to the increase in entropy.

Status: Speculative interpretation.

3.3 Possible variations of constants in the early Universe

3.3.1 The Early Universe as an Epoch of Low Coherence

In the early Universe (before recombination), the archive was in a state of **low global coherence**: $C_{\text{глоб}} \ll 1$. This means that the constants could have been unstable and differed from their present-day values.

$$\alpha_{\text{ранняя}} \neq \alpha_{\text{совр}}$$

Physical interpretation: In the first moments after the Big Bang, the density of records was extremely high, which could lead to deviations of the constants from their modern values.

Mainstream connection: In cosmology, hypotheses about the variation of constants in the early Universe (for example, in models with dynamical α) are actively discussed. The AU model proposes a specific mechanism: fluctuations S_{Θ} .

Status: Speculative interpretation.

3.3.2 Variation α and spectra of quasars

One way to test the variation hypothesis α is to analyze quasar spectra. The AU model predicts that deviations α should correlate with the density of records in the corresponding regions of the archive.

$$\frac{\Delta\alpha}{\alpha} \propto \delta S_{\Theta}$$

Mainstream Relation: There is conflicting evidence regarding the potential for variation α (Webb et al., 1999; Murphy et al., 2003). Some studies indicate small variation ($\Delta\alpha/\alpha \sim 10^{-5}$), while others find no significant effects.

Status: Speculative interpretation requiring verification.

3.3.3 Variation G and cosmological data

The gravitational constant G can also vary in the early universe. In the AU model, this is due to changes in global entropy:

$$G(\tau) = \frac{\hbar c}{S_{\Theta}^{\text{glob}}(\tau)} \cdot \mathcal{H}[\mathcal{C}]$$

Mainstream relationship: Variation G is limited by observations (e.g., from primordial nucleosynthesis and cosmic microwave background data). Modern constraints: $|\dot{G}/G| < 10^{-12} \text{ year}^{-1}$.

Status: Speculative interpretation.

3.4 Connection with the Mainstream

3.4.1 The problem of the cosmological constant

One of the most serious problems in modern physics is **the problem of the cosmological constant**: the observed value Λ is 120 orders of magnitude smaller than the naive estimate from quantum field theory.

In the AU model, this problem can be illuminated in a new way: Λ_{eff} is determined by the global entropy of the archive, which is "cut off" by the holographic principle:

$$\Lambda_{\text{eff}} \propto \frac{S_{\Theta}^{\text{glob}}}{A_{\text{горизонт}}}$$

Physical interpretation: The holographic principle limits the number of degrees of freedom in a volume, leading to a "natural" suppression Λ .

Mainstream connection: The holographic principle ('t Hooft, Susskind) is actively discussed in quantum gravity. The AU model offers a concrete implementation: Λ_{eff} as a functional of S_{Θ} .

Status: Hypothetical interpretation.

3.4.2 Landscape of string vacuums

In string theory, there is a "landscape" of $\sim 10^{500}$ possible vacua with different values of the constants. In the AU model, the analogue of the landscape is **the space of possible**

configurations of the archive. S_Θ Different configurations correspond to different values of the constants.

Mainstream connection: The idea of landscape (Susskind, 2003) is actively discussed in the context of the anthropic principle. The AU model offers an alternative: constants are determined by the structure of the archive, not by the choice of a vacuum.

Status: Speculative interpretation.

3.4.3 Emergence of constants in quantum gravity

In some approaches to quantum gravity (for example, loop quantum gravity or causal dynamical triangulation), constants are also considered emergent. The AU model proposes a specific mechanism: constants as functionals of S_Θ .

Status: Hypothetical interpretation.

3.5 Chapter 3 Summary

1. **Constants as functionals:** In the AU model, the fundamental constants ($\alpha, G, \hbar, m_f$) are functionals of the archive structure S_Θ , its gradients and the non-local kernel $K(x, y)$.
2. **Stability of constants:** The stability of constants is explained by the global coherence of the archive ($\mathcal{C} \rightarrow 1$). Local fluctuations are possible in areas with impaired coherence.
3. **Variations in the Early Universe:** In the early universe, when coherence was low, the constants may have differed from their present-day values. This can be verified by analyzing quasar spectra and cosmological data.
4. **Connection with the mainstream:** The AU model offers new approaches to the problem of the cosmological constant (through the holographic principle) and to the idea of landscape (through the space of archive configurations).
5. **Status:** All statements are hypothetical/speculative. Mainstream theories (the Standard Model, General Relativity, quantum gravity) remain the default.

Chapter 4. The Hierarchy of the Masses and the Problem of Generations

In the previous chapter, we considered how fundamental constants can be expressed through the structure of the archive S_Θ . Now we turn to one of the most intriguing mysteries of the Standard Model: **the generation problem and the fermion mass hierarchy**.

Why are there three generations of fermions? Why do the generation masses differ by orders of magnitude? Why are neutrinos so light? In the Standard Model, these questions have no definitive answers: the fermion masses are free parameters, and the number of generations is

postulated. In the AU ontology, these phenomena are hypothetically interpreted through a discrete spectrum of excitations of localized field modes S_Θ .

4.1 Three generations as three levels of arousal

4.1.1 Main hypothesis

In the AU model, three generations of fermions are interpreted as **three discrete excitation levels of a single topological structure**. Each generation corresponds to a specific field localization mode S_Θ :

$$\Theta^{(n)}(t) = \sum_i a_i^{(n)}(t) |\psi_i\rangle, \quad n = 1, 2, 3$$

Where:

- $n = 1$ — ground state (u, d, e, v_e),
- $n = 2$ — first excitation (c, s, μ , v_μ),
- $n = 3$ — second excitation (t, b, τ , v_τ).

Physical interpretation: Generations are not independent "copies" of particles, but **excited states** of the same topological structure. Just as an atom has discrete energy levels, a localized field mode S_Θ has a discrete spectrum of excitations.

Connection to Mainstream: The Standard Model postulates three generations but leaves them unexplained. Some extensions (such as models with extra dimensions or discrete symmetries) attempt to explain the number of generations. The AU model offers an alternative approach: generations as excitation levels.

Status: Speculative interpretation.

4.1.2 Discrete excitation spectrum

The excitation spectrum of a localized mode is determined by the effective dynamics operator:

$$\hat{L} = \omega_0^2 - \tilde{\mu}\Phi + \hat{K}$$

Where:

- ω_0^2 — natural frequency of the mode,
- $\tilde{\mu}$ — constant of connection with the field of consciousness Φ ,
- $\hat{K}$ — is an integral operator with kernel $K(x, y)$.

The eigenvalues $\hat{L}$ determine the energies of the levels:

$$\hat{L}\Theta^{(n)} = \lambda_n \Theta^{(n)}$$

The difference in energy between the levels corresponds to the difference in the masses of the generations:

$$\Delta m_{12} = m^{(2)} - m^{(1)}, \Delta m_{23} = m^{(3)} - m^{(2)}$$

Physical interpretation: The mass hierarchy is a consequence of the discrete nature of the excitation spectrum. The higher the level, the greater the energy and, consequently, the mass.

Mainstream connection: In quantum mechanics, discrete spectra arise naturally (atomic levels, vibrational modes of molecules). The AU model extends this idea to fermions.

Status: Speculative interpretation.

4.1.3 Why exactly three generations?

In the AU model, the number of generations is determined **by the topology of the localized mode**. If the topological invariant Q_{top} takes values in a certain set, then the number of stable excitation levels can be limited.

Possible explanations:

- **Topological constraint:** only three excitation levels are stable (the rest quickly decay).
- **Energy limitation:** Higher levels require energy that is not achievable under current conditions.
- **Symmetry constraint:** the archive structure allows only three modes with non-zero coherence.

Physical interpretation: The number of generations is not random, but a consequence of the archive's structure. If the topology were different, the number of generations could have been different.

Connection to the mainstream: In some models (e.g., with gauge groups E_8 or $SO(10)$), the number of generations is also determined by topology. The AU model offers an alternative mechanism.

Status: Speculative interpretation.

4.2 Mass hierarchy as a difference in energy levels

4.2.1 Mass hierarchy in the Standard Model

In the Standard Model, fermion masses span a huge range:

Particle	Weight
Neutrino	$< 0.1\text{eV}$
Electron	0.511MeV
Muon	105.7MeV
Tau	1777MeV
u-quark	$\sim 2\text{MeV}$
d-quark	$\sim 5\text{MeV}$
s-quark	$\sim 95\text{MeV}$
c-quark	$\sim 1.3\text{GeV}$
b-quark	$\sim 4.2\text{GeV}$
t-quark	$\sim 173\text{GeV}$

The mass ratio between generations is from 10 to 10^3 , and between light and heavy fermions it is up to 10^{12} .

Mainstream Connection: The mass hierarchy problem is one of the central problems in particle physics. In the Standard Model, masses are free parameters that can be manually adjusted.

4.2.2 AU interpretation: mass hierarchy as a difference in levels

In the AU model, the mass hierarchy is explained **by the difference in energies of discrete excitation levels:**

$$m^{(n)} = m_0 \cdot f_n$$

where m_0 is the characteristic scale of the mass, f_n is the dimensionless function of the level n .

For an excitation spectrum described by the operator $\hat{L}$, the energy difference between levels can be exponentially small:

$$\Delta E_{n,n+1} \sim E_0 \cdot e^{-\gamma n}$$

where γ is a parameter determined by the structure of the kernel $K(x, y)$.

Physical interpretation: An exponential mass hierarchy arises naturally if excitation levels are separated by exponentially small energy gaps.

Connection to the Mainstream: Some models (such as those with supersymmetry breaking or extra dimensions) also produce exponential mass hierarchies. The AU model proposes a specific mechanism: a discrete spectrum of excitations.

Status: Speculative interpretation.

4.2.3 Neutrinos as an "almost free" mode

Neutrinos have extremely small masses ($< 0.1\text{eV}$) compared to other fermions. In the AU model, this is explained by the fact that neutrinos correspond to an **"almost free" mode** — a localized configuration with minimal coupling to the condensate S_Θ :

$$m_\nu = y_\nu \cdot v, y_\nu \ll y_e$$

Physical interpretation: Neutrinos interact almost exclusively with the archive, so their mass is small. This corresponds to their weak interaction with other particles.

Mainstream connection: The neutrino mass problem is one of the central problems in modern physics. The seesaw mechanism explains the smallness of neutrino masses through the existence of heavy right-handed neutrinos. The AU model offers an alternative: the neutrino as an "almost free" mode.

Status: Speculative interpretation.

4.2.4 Top quark as a maximally excited mode

The top quark has a mass of $\sim 173\text{GeV}$, which is orders of magnitude greater than the masses of the other quarks. In the AU model, this is explained by the fact that the top quark corresponds to **the most excited mode** with the strongest coupling to the condensate:

$$y_t \approx 1, m_t \approx v$$

Physical interpretation: The top quark nearly "merges" with the archive condensate, which explains its enormous mass. This also explains its short lifetime ($\sim 10^{-25}\text{s}$): it decays rapidly due to its strong coupling to the archive.

Mainstream coupling: The top quark is unique among quarks: its Yukawa coupling is close to unity. The AU model explains this by the maximum excitation of the mode.

Status: Speculative interpretation.

4.3 The problem of intergenerational mixing

4.3.1 CKM matrix and PMNS matrix

In the Standard Model, transitions between generations are described by mixing matrices:

- **CKM matrix** (Cabibbo–Kobayashi–Maskawa) — for quarks,
- **PMNS matrix** (Pontecorvo–Maki–Nakagawa–Sakata) — for leptons.

These matrices contain the mixing angles and the CP-violation phase. Their values are not derived from theory, but measured experimentally.

Mainstream connection: The problem of generational mixing is one of the central problems in particle physics. In the Standard Model, mixing matrices are free parameters.

4.3.2 AU interpretation: overlap integrals between modes

In the AU model, mixing matrices are interpreted as **overlap integrals** between entropy modes of different generations:

$$V_{ij} = \langle \theta^{(i)} | \theta^{(j)} \rangle_K$$

where $\langle \cdot | \cdot \rangle_K$ is the scalar product with kernel K .

Physical interpretation: Generational mixing is a consequence of mode overlap. The greater the overlap between modes, the stronger the mixing.

Connection to mainstream: In some models (e.g., with discrete symmetries), mixing matrices are also derived from overlap integrals. The AU model offers a specific mechanism.

Status: Speculative interpretation.

4.3.3 Hierarchy of mixing angles

The quark mixing angles (CKM) are small (~ 0.2), while the lepton mixing angles (PMNS) are large (~ 0.5 – 1). In the AU model, this difference is explained **by the different degree of mode overlap** for quarks and leptons:

$$V_{ij}^{(q)} \sim \epsilon^{|i-j|}, V_{ij}^{(\ell)} \sim 1$$

where $\epsilon \sim 0.2$ is the suppression parameter.

Physical interpretation: Quarks are more localized, so their modes overlap less. Leptons are less localized, so their modes overlap more.

Mainstream Connection: The hierarchy of mixing angles is an empirical fact. The AU model offers a qualitative explanation through varying degrees of localization.

Status: Speculative interpretation.

4.4 Connection with the Mainstream

4.4.1 The Mass Hierarchy Problem in the Standard Model

The mass hierarchy problem is a central one in particle physics. In the Standard Model, fermion masses are free parameters, and their values are not deducible from the theory. There are various approaches to addressing this problem:

- **The seesaw mechanism** explains the smallness of neutrino masses through the existence of heavy right-handed neutrinos.
- **Models with extra dimensions** explain the hierarchy through the localization of fermions in extra dimensions.
- **Discrete symmetries** explain the number of generations and the structure of mixing.

The AU model offers an alternative approach: **generations as levels of arousal**. This does not replace existing models, but rather offers an additional ontological language.

4.4.2 The problem of the number of generations

The number of generations (three) remains an open question in the Standard Model. In cosmology, the number of generations is constrained by data on primordial nucleosynthesis (three types of light neutrinos). In the AU model, the number of generations is determined by the topology of the localized mode.

Connection to the mainstream: In some models (e.g., the gauge group model E_8), the number of generations is also determined by topology. The AU model proposes a specific mechanism: a discrete excitation spectrum.

4.4.3 Neutrino masses and oscillations

The discovery of neutrino oscillations (Super-Kamiokande, 1998; SNO, 2001) showed that neutrinos have nonzero masses and mix. In the AU model, neutrino masses are explained by their weak coupling to the condensate S_Θ , and oscillations by transitions between modes.

Mainstream connection: Neutrino oscillations are an experimentally confirmed phenomenon. The AU model offers an additional language for describing them.

Status: Speculative interpretation.

4.5 Chapter 4 Summary

1. **Three generations** are interpreted as three discrete excitation levels of a single topological field structure S_Θ . The number of generations is determined by the topology of the localized mode.

2. **The mass hierarchy** is explained by the energy differences between discrete levels. Exponential hierarchy arises naturally when levels are separated by exponentially small energy gaps.
3. **The neutrino** is an "almost free" mode with minimal coupling to the condensate S_Θ . **The top quark** is the most excited mode with the strongest coupling.
4. **Mixing matrices** (CKM, PMNS) are interpreted as overlap integrals between modes of different generations. The hierarchy of mixing angles is explained by the varying degrees of localization of quarks and leptons.
5. **Mainstream connection:** The AU model offers an alternative approach to the mass hierarchy problem without replacing existing models (seesaw, extra dimensions, discrete symmetries).
6. **Status:** All statements are speculative. Mainstream theories remain the default.

Part III. Fermions as Localization Modes

Chapter 5. Quarks: Six Flavors and Three Colors

In the previous chapters, we described the field localization mechanism S_Θ and introduced a topological invariant as a characteristic of localized modes. Now we turn to the first concrete implementation of this mechanism: **quarks** —fermions participating in the strong interaction.

In the Standard Model, quarks are represented by six flavors (u, d, s, c, b, t) and three color states (red, green, blue). They are not observed in the free state due to confinement, but they do manifest themselves in hadrons. In the AU ontology, quarks are hypothetically interpreted as **localized** field coils S_Θ with topological invariants determining flavor and three coil orientations determining color.

5.1 General mechanism: localized coil ∇S_Θ

5.1.1 Quark as a topological mode

In the AU model, a quark is a localized configuration of the field S_Θ , characterized by a **non-zero topological invariant**:

$$Q_{\text{top}}^{(q)} = \frac{1}{2\pi} \oint_{\partial\Omega_q} \nabla S_\Theta \cdot dl$$

where $\partial\Omega_q$ is the boundary of the localized region.

Physical interpretation: A quark is a "coil" of the field gradient S_θ , localized in a small region. This coil cannot be "unwound" without disrupting its topology, which ensures the quark's stability.

Connection to Mainstream: In topological field theory (e.g., the Skyrme model), particles are also described as topological solitons. The AU model offers a similar approach, but at the field level S_θ .

Status: Speculative interpretation.

5.1.2 Electric charge fractionality

The electric charge of quarks takes fractional values: $+2/3(u, c, t)$ and $-1/3(d, s, b)$. In the AU model, the fractionality of the charge is interpreted as **the fractionality of the topological invariant**:

$$Q_{ent}^{(q)} = \begin{cases} +2/3 & (u, c, t) \\ -1/3 & (d, s, b) \end{cases}$$

Physical interpretation: The fractional nature of the charge is a consequence of the fact that the loop ∇S_θ is not "closed" in a local region. The total charge (the whole charge) only occurs in bound states (hadrons).

Mainstream connection: The fractional nature of quark charges is an experimentally confirmed fact (deep inelastic scattering). In the AU model, it receives a topological interpretation.

Status: Speculative interpretation.

5.2 Six Scents: A Table with AU Interpretations

5.2.1 Aromas as levels of arousal

In the AU model, the six quark flavors are interpreted as **three excitation levels** (generations) for two types of charge ($+2/3$ and $-1/3$):

Generation	Charge+2/3	Charge−1/3	AU interpretation
I	u (up)	d (down)	Ground state of the coil
II	c (charm)	s (strange)	First arousal
III	t (top)	b (bottom)	Second excitement

Physical interpretation: Each quark represents a specific field localization mode S_θ . Different flavors correspond to different excitation levels of the same topological structure.

Mainstream Connection: In the Standard Model, quark flavors are distinguished by quantum numbers (strangeness, charm, loveliness, truth). The AU model offers an alternative language: flavors as excitation levels.

Status: Speculative interpretation.

5.2.2 Detailed table of quarks

Quark	Charge	Generation	Mass (MeV)	AU interpretation
u	+2/3	I	~ 2	Minimum turn, ground state
d	-1/3	I	~ 5	Compensating turn, ground state
s	-1/3	II	~ 95	First excitation of the compensating turn
c	+2/3	II	~ 1300	First excitation of the minimum turn
b	-1/3	III	~ 4200	Second excitation of the compensating turn
t	+2/3	III	~ 173000	Maximum excitation, strong connection with condensate

Numerical estimates: Quark masses are measured quantities. The AU interpretation relates them to the energy difference between excitation levels.

Status: Speculative interpretation.

5.2.3 Top quark as a special mode

The top quark is unique among quarks: its mass ($\sim 173\text{GeV}$) is close to the vacuum average $v \approx 246$ value, and its Yukawa coupling is $y_t \approx 1$. In the AU model, this is explained by the fact that the top quark corresponds to **the most excited mode** with the strongest coupling to the condensate S_Θ :

$$y_t \approx 1, m_t \approx v$$

Physical interpretation: The top quark almost "merges" with the archive condensate, which explains its huge mass and short lifetime ($\sim 10^{-25}\text{s}$).

Mainstream connection: The top quark is the subject of active research (for example, at the LHC). Its unusual properties (large mass, short lifetime) remain the subject of theoretical debate.

Status: Speculative interpretation.

5.3 Color as three orientations of the coil

5.3.1 Color definition in the AU model

In the Standard Model, each quark can exist in one of three color states: red (r), green (g), and blue (b). Color is a quantum number associated with the strong interaction.

In the AU model, **color is interpreted as three orientations of the coil** ∇S_θ in the local area:

$$\text{цвет} \in \{r, g, b\} \leftrightarrow \{\nabla, S_\theta, \tau^1 \nabla S_\theta \cdot \tau^2 \nabla S_\theta \cdot \tau^3\}$$

where τ^a are generators of the group $SU(3)$.

Physical interpretation: Color is not an "additional degree of freedom," but a geometric characteristic of the loop. The three colors correspond to three independent gradient orientations in a local region.

Mainstream connection: Color is an experimentally confirmed quantum number (e.g., from measurements of the decay width $\pi^0 \rightarrow \gamma\gamma$ and ratio $R = \sigma(e^+e^- \rightarrow \text{адроны})/\sigma(e^+e^- \rightarrow \mu^+\mu^-)$). In the AU model, it receives a topological interpretation.

Status: Speculative interpretation.

5.3.2 Color retention (confinement)

In the Standard Model, color states are not observed in free form: there is **confinement** —color retention. In the AU model, confinement is explained by **the nonlocal neutrality of the archive**:

$$\int_{\Omega} K(x, y) \nabla S_\theta(y) d^4y = 0 \text{ (для свободного состояния)}$$

Physical interpretation: The archive requires global color neutrality. It is impossible to "extract" a single color charge, as this would violate the neutrality of the archive.

Mainstream Connection: Confinement is one of the central problems of quantum chromodynamics. In the AU model, it is interpreted through a nonlocal core $K(x, y)$. This mechanism will be discussed in more detail in Chapter 7.

Status: Speculative interpretation.

5.3.3 Gluons as color carriers

In the Standard Model, color is carried by gluons—eight massless particles corresponding to $SU(3)$ generators. In the AU model, gluons are interpreted as **correlation modes** between color loops:

$$G_\mu^a \leftrightarrow \partial_\mu (\nabla S_\theta \cdot \tau^a)$$

Physical interpretation: A gluon is not a "particle" in the usual sense, but a mode of correlation between the color states of quarks. Eight gluons correspond to eight independent correlation modes.

Mainstream connection: Gluons are experimentally confirmed particles (observed in three-jet events at e^+e^- colliders). In the AU model, they are interpreted through field correlations S_θ .

Status: Speculative interpretation.

5.4 Connection with the Mainstream

5.4.1 Quark model and QCD

The quark model was proposed by Gell-Mann and Zweig in 1964 to explain the spectrum of hadrons. QCD (quantum chromodynamics) is a gauge theory of the strong interaction based on the $SU(3)$ group. It successfully describes:

- Confinement (color retention),
- Asymptotic freedom (weakening of interaction at short distances),
- Hadron spectrum,
- The processes of birth and decay.

In the AU model, quarks and gluons are given an additional ontological language: they are interpreted as localized coils and correlation modes of the field S_θ . This does not replace QCD, but offers an alternative interpretation.

5.4.2 Experimental confirmation

The existence of quarks has been confirmed by numerous experiments:

- Deep inelastic scattering (SLAC, 1968) - showed the point structure of protons.
- e^+e^- -annihilation - confirmed fractional charges and three colors.
- Top quark production (Fermilab, 1995) confirmed the existence of the sixth quark.
- Studying the properties of the top quark at the LHC has clarified its mass and Yukawa coupling.

The AU model does not contradict these data, but offers a topological interpretation of them.

5.4.3 Open questions

Despite the successes of the QCD, open questions remain:

- Why are there three colors?
- Why do quarks have fractional charges?
- Why are there six flavors?
- Why do quark masses vary so much?

The AU model offers hypothetical answers to these questions, linking them to the field topology S_Θ . These answers require further formalization and verification.

5.5 Chapter 5 Summary

1. **Quarks** in the AU model are interpreted as localized turns of a field S_Θ with a non-zero topological invariant $Q_{\text{top}}^{(q)}$.
2. **The fractionality of the electric charge** ($+2/3, -1/3$) is interpreted as the fractionality of the topological invariant.
3. **The six flavors** are interpreted as three excitation levels (generations) for two charge types. The top quark is the most highly excited mode with strong coupling to the condensate.
4. **The color** (three states) is interpreted as three orientations of the coil corresponding to ∇S_Θ the $SU(3)$ generators.
5. **Confinement** is explained by the nonlocal neutrality of the archive: free color states are forbidden. **Gluons** are correlation modes between color loops.
6. **Mainstream connection:** The AU model is consistent with QCD and experimental data, but offers an additional ontological language for interpreting quarks and gluons.
7. **Status:** All statements are speculative. Mainstream theories (quark model, quantum chromodynamics) remain the default.

Chapter 6. Leptons: Six Particles

In the previous chapter, we examined quarks as localized coils of a field S_Θ with color states. Now we turn to **leptons** —the second group of fermions in the Standard Model.

Unlike quarks, leptons do not participate in the strong interaction and have no color charge. They exist in six flavors: electron (e), muon (μ), tau (τ), and three types of neutrinos (ν_e, ν_μ, ν_τ). In the AU ontology, leptons are hypothetically interpreted as **color-neutral localized**

modes of the field S_θ , and neutrinos as "almost free" modes with minimal coupling to the archive condensate.

6.1 General mechanism: color-neutral modes

6.1.1 Lepton as a mode without a color loop

In the AU model, a lepton is a localized field configuration S_θ with **zero color charge**:

$$Q_{\text{color}}^{(\ell)} = 0$$

This means that the turn ∇S_θ corresponding to a lepton does not have a preferred orientation in color space (unlike quarks, which carry one of three colors).

Physical interpretation: A lepton is a "closed" mode that does not require color compensation. This is why leptons are observed in a free state, while quarks are confined.

Mainstream connection: In the Standard Model, leptons carry no color charge and do not participate in the strong interaction. The AU model offers a topological interpretation: a lepton is a mode with zero color turn.

Status: Speculative interpretation.

6.1.2 Electric charge of leptons

Charged leptons (e, μ , τ) have a charge -1 (in units of elementary charge), while neutrinos have zero charge:

$$Q_{\text{em}}^{(e,\mu,\tau)} = -1, Q_{\text{em}}^{(\nu)} = 0$$

In the AU model, this is interpreted as varying degrees of "twisting" of the coil:

$$Q_{\text{em}}^{(\ell)} \propto \oint_{\partial\Omega_\ell} \nabla S_\theta \cdot dl$$

For charged leptons the loop is closed (whole charge -1), for neutrinos it is "open" (zero charge).

Physical interpretation: Lepton charge is a topological characteristic of the closedness of a loop. Unlike quarks, where the loop is "open" (fractional charge), leptons have integer charge.

Mainstream connection: The electric charge of leptons is an experimentally confirmed fact. The AU model offers a topological interpretation.

Status: Speculative interpretation.

6.2 Six leptons: table with AU interpretation

6.2.1 Aromas as levels of arousal

In the AU model, six leptons are interpreted as **three excitation levels** (generations) for two types of particles (charged leptons and neutrinos):

Generation	Charged lepton	Neutrino	AU interpretation
I	e (electron)	ν_e	Ground state of the closed mode
II	μ (muon)	ν_μ	First arousal
III	τ (tau)	ν_τ	Second excitement

Physical interpretation: Each lepton represents a specific field localization mode S_θ . Different flavors correspond to different excitation levels of the same topological structure.

Mainstream connection: In the Standard Model, leptons are distinguished by quantum numbers (electron, muon, tau). The AU model offers an alternative language: flavors as excitation levels.

Status: Speculative interpretation.

6.2.2 Detailed table of leptons

Lepton	Charge	Generation	Weight	AU interpretation
e	-1	I	0.511MeV	Closed mode, ground state
μ	-1	I $\rightarrow$ II	105.7MeV	First arousal
τ	-1	II $\rightarrow$ III	1777MeV	Second excitement
ν_e	0	I	$< 0.1\text{eV}$	"Almost free" fashion
ν_μ	0	I $\rightarrow$ II	$< 0.1\text{eV}$	Mixed fashion
ν_τ	0	II $\rightarrow$ III	$< 0.1\text{eV}$	Mixed fashion

Numerical estimates: Leptons' masses are measured quantities. The AU interpretation relates them to the energy difference between excitation levels.

Status: Speculative interpretation.

6.2.3 Lepton mass hierarchy

The masses of charged leptons exhibit a hierarchy:

$$m_e : m_\mu : m_\tau \approx 1 : 207 : 3477$$

In the AU model, this hierarchy is explained **by the difference in energies of discrete excitation levels**:

$$m^{(n)} = m_0 \cdot f_n$$

where f_n is a dimensionless function of the level n .

Physical interpretation: An exponential hierarchy of lepton masses arises naturally if excitation levels are separated by exponentially small energy gaps.

Mainstream connection: The lepton mass hierarchy is one of the mysteries of the Standard Model. The AU model offers a qualitative explanation.

Status: Speculative interpretation.

6.3 Neutrinos as "almost free" modes

6.3.1 Smallness of the neutrino mass

Neutrinos have extremely small masses ($< 0.1\text{eV}$) compared to other fermions. In the AU model, this is explained by the fact that neutrinos correspond to an **"almost free" mode** — a localized configuration with minimal coupling to the condensate S_Θ :

$$m_\nu = y_\nu \cdot v, \quad y_\nu \ll y_e$$

where y_ν is the Yukawa neutrino constraint, v is the vacuum average of the field S_Θ .

Physical interpretation: Neutrinos interact almost exclusively with the archive, so their mass is small. This corresponds to their weak interaction with other particles.

Mainstream connection: The neutrino mass problem is one of the central issues in modern physics. The seesaw mechanism explains the smallness of neutrino masses through the existence of heavy right-handed neutrinos. The AU model offers an alternative: the neutrino as an "almost free" mode.

Status: Speculative interpretation.

6.3.2 Neutrino oscillations as transitions between modes

The discovery of neutrino oscillations (Super-Kamiokande, 1998; SNO, 2001) showed that neutrinos can transition between flavors. In the AU model, this is interpreted as **transitions between modes**:

$$\nu_\alpha(t) = \sum_i U_{\alpha i} \nu_i e^{-iE_i t/\hbar}$$

where $U_{\alpha i}$ is the PMNS mixing matrix, defined as the overlap integral between modes:

$$U_{\alpha i} = \langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K$$

Physical interpretation: Neutrino oscillations are a consequence of the overlap of modes of different flavors. The probability of oscillation depends on the difference in mass and energy:

$$P(\nu_\alpha \rightarrow \nu_\beta) = \sum_{i,j} U_{\alpha i} U_{\beta i}^* U_{\alpha j}^* U_{\beta j} e^{-i\Delta m_{ij}^2 L/2E}$$

Mainstream connection: Neutrino oscillations are an experimentally confirmed phenomenon. The AU model offers an additional language for describing them.

Status: Speculative interpretation.

6.3.3 Sterile neutrinos

Some extensions of the Standard Model postulate **sterile neutrinos** —particles that do not participate in the weak interaction. In the AU model, they are interpreted as **unmanifested modes** with a zero interaction matrix element:

$$\langle \Theta_{\text{sterile}} | A_\mu | \Theta_{\text{sterile}} \rangle = 0$$

Physical interpretation: Sterile neutrinos are modes that do not interact with the electromagnetic field or the weak interaction. They may be part of dark matter (see Chapter 17).

Mainstream connection: Sterile neutrinos are candidates for dark matter (ν MSM model). The AU model offers an additional language for describing them.

Status: Speculative interpretation.

6.4 Leptonic Mixing: PMNS Matrix

6.4.1 Definition of PMNS matrix

The PMNS (Pontecorvo–Maki–Nakagawa–Sakata) matrix describes neutrino mixing:

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U_{\text{PMNS}} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

where ν_i are the mass eigenstates.

6.4.2 AU interpretation: overlap integrals

In the AU model, the PMNS matrix is interpreted as **a matrix of overlap integrals** between entropy modes:

$$U_{\alpha i} = \langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K$$

Physical interpretation: Neutrino mixing is a consequence of mode overlap. The greater the overlap between modes, the stronger the mixing.

Mainstream connection: The PMNS matrix contains three mixing angles and a CP-violating phase. Their values have been measured experimentally:

- $\theta_{12} \approx 33.4^\circ$,
- $\theta_{23} \approx 42.3^\circ$,
- $\theta_{13} \approx 8.6^\circ$.

The AU model offers a qualitative explanation: large mixing angles (θ_{12}, θ_{23}) correspond to strong mode overlap, while a small angle (θ_{13}) corresponds to weak overlap.

Status: Speculative interpretation.

6.4.3 Hierarchy of mixing angles

The lepton mixing angles (PMNS) are large, while the quark mixing angles (CKM) are small:

$$\theta_{\text{PMNS}} \sim 30^\circ\text{--}45^\circ, \theta_{\text{CKM}} \sim 13^\circ$$

In the AU model, this difference is explained **by the different degrees of localization** of quarks and leptons:

- Quarks are highly localized (due to color interaction) $\rightarrow$ modes overlap little $\rightarrow$ small mixing angles.
- Leptons are weakly localized $\rightarrow$ modes overlap strongly $\rightarrow$ large mixing angles.

Physical interpretation: The hierarchy of mixing angles is a consequence of the different degrees of localization.

Mainstream connection: The distinction between PMNS and CKM is an empirical fact. The AU model offers a qualitative explanation.

Status: Speculative interpretation.

6.5 Connection with the Mainstream

6.5.1 The Standard Model and Leptons

In the Standard Model, leptons are described as point particles that do not participate in the strong interaction. Their masses and mixing are free parameters. The AU model does not contradict this data, but offers an additional ontological language: leptons as color-neutral modes of the field S_Θ .

6.5.2 Experimental confirmation

The existence of leptons has been confirmed by numerous experiments:

- Discovery of the electron (Thomson, 1897),
- Discovery of the muon (Anderson, 1936),
- Discovery of the tau lepton (Perl, 1976),
- Discovery of the neutrino (Reines & Cowan, 1956),
- Discovery of neutrino oscillations (Super-Kamiokande, 1998; SNO, 2001),
- Measuring PMNS mixing angles (Daya Bay, RENO, T2K, NOvA).

The AU model does not contradict these data, but offers a topological interpretation of them.

6.5.3 Open questions

Despite the successes of the Standard Model, open questions remain:

- Why are there three generations of leptons?
- Why do lepton masses vary so much?
- Why are neutrinos so light?
- Why are the mixing angles of PMNS large and CKM small?
- Do sterile neutrinos exist?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

6.6 Chapter 6 Summary

1. **Leptons** in the AU model are interpreted as color-neutral localized field modes S_θ with zero color turn.
2. **The electric charge** of leptons (-1 for e, μ, τ ; 0 for neutrinos) is interpreted as the degree of closure of the loop.
3. **The six leptons** are interpreted as three excitation levels (generations) for two types of particles (charged leptons and neutrinos).
4. **Neutrinos** are "almost free" modes with minimal coupling to the condensate S_θ . **Neutrino oscillations** are transitions between modes described by the PMNS matrix.
5. **The PMNS matrix** is interpreted as a matrix of overlap integrals between entropy modes. Large lepton mixing angles are explained by weak mode localization.
6. **Mainstream connection:** The AU model does not contradict the Standard Model and experimental data, but offers an additional ontological language for interpreting leptons.
7. **Status:** All statements are speculative. Mainstream theories (the Standard Model, neutrino oscillation theory) remain the default.

Part IV. Interactions as Types of Correlations

Chapter 7. Strong Interaction and Confinement

In previous chapters, we described fermions as localized modes of the field S_θ : quarks as colored coils, and leptons as color-neutral modes. Now we turn to the first and strongest interaction— **the strong force** —which holds quarks together in hadrons and determines the structure of nuclei.

In the Standard Model, the strong interaction is described by quantum chromodynamics (QCD), a gauge theory with the $SU(3)$ group. Key features of QCD are asymptotic freedom (weakening of the interaction at short distances) and confinement (color confinement, the inability to observe free quarks). In the AU ontology, the strong interaction is hypothetically interpreted as **the nonlocal neutrality of the archive**, and confinement as a consequence of the behavior of the nonlocal nucleus $K(x, y)$ at long distances.

7.1 Mechanism: Non-local neutrality of the archive → color solitude

7.1.1 Confinement as a requirement of neutrality

In the AU model, confinement is explained **by the requirement of global neutrality of the archive**. The archive does not allow the existence of an isolated color charge, as this would violate its coherence:

$$\int_{\Omega} K(x, y) \nabla S_{\theta}(y) d^4 y \neq 0 \text{ (для свободного цветного состояния)}$$

Physical interpretation: Color charge is an "open loop" of the field S_{θ} . The archive requires all loops to be closed (color-neutral). Therefore, a free quark cannot exist: it must be bound to other quarks that compensate for the color.

Mainstream connection: In QCD, confinement is explained by the nonperturbative dynamics of gluons: the color field "condenses" into strings that hold quarks together. The AU model offers an alternative language: confinement as a requirement for the neutrality of the archive.

Status: Speculative interpretation.

7.1.2 Entropic tension of a string

When attempting to separate quarks in the AU model, **entropic tension arises** —an analogue of the gluon string in QCD:

$$E_{\text{conf}}(r) \sim \sigma \cdot r$$

where σ is the tension coefficient determined through the non-local kernel:

$$\sigma \propto \left| \int_{\Omega} K(x, y) \nabla S_{\theta}(y) d^4 y \right|$$

Physical interpretation: As the distance between quarks increases, the "entropic tension" increases because the archive strives to restore neutrality. Energy increases linearly with distance—this corresponds to a linear confinement potential.

Mainstream connection: In QCD, the linear confinement potential $V(r) \sim \sigma r$ is confirmed by lattice calculations. $\sigma \approx 0.18 \text{ GeV/fm}$ (The GeV value is $\sim 10^9 \text{ erg/cm}$). The AU model offers an interpretation σ in terms of archive parameters.

Status: Speculative interpretation.

7.1.3 Generation of pairs when a string breaks

When a critical distance is reached, r_{crit} , the entropic tension becomes so great that the string "breaks" and a new quark-antiquark pair is born:

$$r > r_{\text{crit}} \Rightarrow \text{рождение пары } q\bar{q}$$

Physical interpretation: The Archive cannot allow the energy to grow infinitely. Instead, it creates a compensating pair, which "shorts" the loops and restores neutrality. This explains why it is impossible to "pull out" a single quark: attempting to do so creates a new pair.

Mainstream connection: In QCD, pair production during string breakage is the mechanism of hadronization (the transformation of quarks into hadrons). It is experimentally observed in e^+e^- -annihilation (the formation of hadron jets).

Status: Speculative interpretation.

7.2 Gluons as SU(3) correlation modes

7.2.1 Eight gluons

In QCD, the strong interaction is carried by eight gluons, corresponding to the generators of the SU(3) group. In the AU model, gluons are interpreted as **correlation modes** between color loops:

$$G_\mu^a \leftrightarrow \partial_\mu (\nabla S_\Theta \cdot \tau^a), \quad a = 1, \dots, 8$$

where τ^a are the generators of SU(3).

Physical interpretation: A gluon is not a "particle" in the usual sense, but a mode of correlation between the color states of quarks. Eight gluons correspond to eight independent correlation modes.

Mainstream connection: The existence of eight gluons has been confirmed experimentally (for example, in three-jet events at e^+e^- -colliders). The AU model offers a topological interpretation.

Status: Speculative interpretation.

7.2.2 Gluon condensate

In QCD, the vacuum contains a **gluon condensate** — a nonzero mean square of the gluon field:

$$\langle G_{\mu\nu}^a G_a^{\mu\nu} \rangle \neq 0$$

In the AU model, this is interpreted as a **non-zero average of the correlations** between color loops in a vacuum:

$$\langle \nabla S_\Theta \cdot \tau^a \rangle \neq 0$$

Physical interpretation: The archive's vacuum is not empty: it contains fluctuations in the correlations between color states. These fluctuations create an effective "mass" for gluons and ensure confinement.

Mainstream connection: The gluon condensate is a key element of nonperturbative quantum chromodynamics. Its GeV^{-4} value $\langle G^2 \rangle \approx 0.012$ is used in sum rules (SVZ). The AU model offers an interpretation via field correlations S_θ .

Status: Speculative interpretation.

7.2.3 Three-gluon and four-gluon vertices

In QCD, gluons interact with each other (unlike photons, which do not interact directly). This is described by three-gluon and four-gluon vertices.

In the AU model, these peaks are interpreted as **nonlinear correlations** between modes:

$$\text{три-глюонная вершина} \leftrightarrow \partial_\mu \partial_\nu (\nabla S_\theta \cdot \tau^a) \cdot (\nabla S_\theta \cdot \tau^b)$$

Physical interpretation: The nonlinearity of the strong interaction is a consequence of the nonlinearity of correlations in the archive. Gluons interact with each other because their correlation modes overlap.

Mainstream connection: Gluon self-interaction is a key feature of QCD, responsible for asymptotic freedom and confinement.

Status: Speculative interpretation.

7.3 Asymptotic freedom and confinement through behavior $K(x, y)$

7.3.1 Asymptotic freedom at small r

In QCD, the strong interaction weakens at small distances (asymptotic freedom). In the AU model, this is explained **by the behavior of the nonlocal nucleus**. $K(x, y)$ at small $|x - y|$:

$$K(x, y) \rightarrow \text{const при } |x - y| \rightarrow 0$$

Physical interpretation: At small distances, the correlations between the color loops weaken because the core K becomes constant. This corresponds to a weakening of the interaction.

Mainstream connection: Asymptotic freedom is an experimentally confirmed phenomenon (e.g., in deep inelastic scattering). 2004 Nobel Prize (Gross, Politzer, Wilczek).

Status: Speculative interpretation.

7.3.2 Confinement at larger r

At large distances the core $K(x, y)$ grows:

$$K(x, y) \sim |x - y| \text{ при } |x - y| \rightarrow \infty$$

Physical interpretation: At large distances, correlations between color loops become stronger. This corresponds to an increase in energy with distance and leads to confinement.

Mainstream connection: In QCD, confinement is explained through the behavior of the gluon field at large distances (string formation). The AU model offers an interpretation through the behavior of $K(x, y)$.

Status: Speculative interpretation.

7.3.3 Cornell Potential

The interaction potential of quarks in QCD is described **by the Cornell potential**:

$$V(r) = -\frac{4\alpha_s}{3r} + \sigma r$$

where the first term is the Coulomb part (asymptotic freedom), the second is the linear confinement.

In the AU model, this potential can be derived from the behavior $K(x, y)$:

$$V(r) = \int K(x, y) \nabla S_\theta(y) d^4y \approx -\frac{A}{r} + B \cdot r$$

Physical interpretation: The Cornell potential is a consequence of two modes of behavior of the nucleus K : constant at small values r and linear at large values r .

Mainstream connection: The Cornell potential is the standard confinement model, confirmed by lattice calculations and quarkonia (charmonium, bottomium) spectroscopy.

Status: Speculative interpretation.

7.4 Connection with the Mainstream

7.4.1 QCD and Lattice Computing

Quantum chromodynamics is a gauge theory of the strong interaction based on the $SU(3)$ group. It successfully describes:

- Confinement (color retention),
- Asymptotic freedom (weakening of interaction at short distances),
- Hadron spectrum,
- The processes of birth and decay.

Lattice QCD calculations confirm the linear confinement potential and the existence of a gluon condensate. The AU model does not contradict these data, but offers an additional ontological language.

7.4.2 Experimental confirmation

The existence of gluons and confinement have been confirmed by numerous experiments:

- Three-jet events at e^+e^- the -colliders (PETRA, 1979) confirmed the existence of gluons.
- The study of quarkonia (charmonium, bottomonium) confirmed the linear confinement potential.
- Deep inelastic scattering confirmed asymptotic freedom.
- Lattice calculations confirm gluon condensate.

The AU model does not contradict these data, but offers a topological interpretation of them.

7.4.3 Open questions

Despite the successes of the QCD, open questions remain:

- How exactly does confinement occur at the non-perturbative level?
- Why are free quarks not observed?
- What is the role of gluon condensate in the formation of hadrons?
- How to relate QCD to gravity (quantum gravity)?

The AU model offers hypothetical answers to these questions by relating them to the behavior of the non-local core $K(x, y)$.

7.5 Chapter 7 Summary

1. **Confinement** in the AU model is explained by the requirement of global neutrality of the archive: free color states are prohibited.
2. **Entropic tension** in a string arises when attempting to separate quarks. At a critical distance, the string "breaks," creating a new quark-antiquark pair.
3. **Gluons** are interpreted as SU(3) correlation modes between color loops. Eight gluons correspond to eight independent correlation modes.
4. **Gluon condensate** is a non-zero average of correlations in a vacuum, ensuring confinement.
5. **Asymptotic freedom** is explained by the behavior of the kernel $K(x, y)$ at small r (constancy), **confinement** - at large r (linear growth).

6. **The Cornell potential** can be derived from the behavior $K(x, y)$: Coulomb part + linear confinement.
7. **Mainstream connection:** The AU model is consistent with QCD and experimental data, but offers an additional ontological language for interpreting the strong interaction.
8. **Status:** All statements are speculative. Mainstream theories (QCD, lattice computation) remain the default.

Chapter 8. Weak Interaction

In the previous chapter, we examined the strong interaction and confinement as a consequence of the nonlocal neutrality of the archive. Now we turn to the second strongest interaction— **the weak interaction** —which is responsible for radioactive decay, neutrino processes, and CP symmetry violation.

In the Standard Model, the weak interaction is described by the electroweak theory (Glashow–Weinberg–Salam) with the gauge group $SU(2)_L \times U(1)_Y$. It is mediated by three massive bosons (W^+ , W^- , Z^0) and the photon. Key features include parity violation (the weak interaction acts only on the left-handed components of fermions), the massiveness of W and Z (in contrast to the massless photon), and flavor switching of quarks and leptons. In the AU ontology, the weak interaction is hypothetically interpreted as **flavor switching** —a transition between entropic modes—and $W^\pm$ and Z^0 as **twisted modes** of the field S_Θ .

8.1 Mechanism: Switching aroma- transition between modes

8.1.1 Weak interaction as a change of fashion

In the AU model, the weak interaction is interpreted as **a transition between** field localization modes S_Θ . While the strong interaction holds quarks in hadrons, the weak interaction **changes the particle flavor**, converting one mode into another:

$$\Theta^{(\alpha)} \rightarrow \Theta^{(\beta)} \text{ (смена аромата)}$$

Physical interpretation: The weak interaction is a "switch" between excitation levels of a single topological structure. For example, during beta decay of a neutron ($d \rightarrow u + W^- \rightarrow u + e^- + \bar{\nu}_e$), a quark d transforms into a quark u , emitting a W^- boson.

Mainstream connection: In the Standard Model, the weak interaction changes the flavor of fermions through charged currents ($W^\pm$) and neutral currents (Z^0). The AU model offers a topological interpretation: a flavor change is a transition between modes.

Status: Speculative interpretation.

8.1.2 Charged and neutral currents

In electroweak theory, a distinction is made between:

- **Charged currents** ($W^\pm$): change the flavor and charge of fermions,
- **Neutral currents** (Z^0): do not change the aroma, but transfer momentum and spin.

In the AU model this difference is interpreted as:

- $W^\pm$ — “switching” modes that change the topological invariant,
- Z^0 are “neutral” modes that do not change the topology but modulate the coherence.

Physical interpretation: $W^\pm$ bosons "rewrite" a mode, transforming it into a different one. Z^0 bosons "modulate" an existing mode without changing its flavor.

Mainstream connection: The difference between charged and neutral currents is an experimentally confirmed fact (discovery of neutral currents in Gargamelle, 1973).

Status: Speculative interpretation.

8.1.3 Universality of the weak interaction

The weak interaction is universal: it acts on all fermions with the same strength (up to Yukawa couplings). In the AU model, this is explained by **the universality of the transition between modes**:

$$g_{\text{weak}} = \text{const (для всех фермионов)}$$

Physical interpretation: All field modes S_θ "switch" in the same way, because the transition mechanism is determined by the structure of the archive, and not by the properties of a particular mode.

Mainstream connection: The universality of the weak interaction is a key principle of electroweak theory. The AU model offers an interpretation through the universality of transitions in the archive.

Status: Speculative interpretation.

8.2 $W^\pm, Z^0$ as twisted modes

8.2.1 Definition of twisted mode

In the AU model, $W^\pm$ and Z^0 are interpreted as **twisted modes** – “twisted” field configurations S_θ :

$$\begin{aligned} W_\mu^\pm &\leftrightarrow \partial_\mu (\nabla S_\theta \cdot \sigma^\pm) \\ Z_\mu^0 &\leftrightarrow \partial_\mu (\nabla S_\theta \cdot \sigma^3) \end{aligned}$$

where $\sigma^\pm = (\sigma^1 \pm i\sigma^2)/2$ and σ^3 are generators of $SU(2)$.

Physical interpretation: $W^\pm$ and Z^0 are not ordinary gradient waves (like a photon), but rather "twisted" modes with internal structure. This "twistedness" corresponds to isospin and weak hypercharge.

Mainstream connection: In electroweak theory, $W^\pm$ and Z^0 are described as components of the $SU(2)_L \times U(1)_Y$ gauge field γ . The AU model offers a topological interpretation: twisted modes.

Status: Speculative interpretation.

8.2.2 Massiveness of W and Z as the "twist" of the mode

In the Standard Model, W and Z are massive ($m_W \approx 80.4\text{GeV}$, $m_Z \approx 91.2\text{GeV}$), while the photon is massless. In the AU model, this difference is explained **by the degree of "twist"** of the mode:

- **A photon** is an untwisted gradient wave ($\sigma = 0$), massless.
- **$W^\pm, Z^0$** — twisted modes ($\sigma \neq 0$), massive.

Physical interpretation: The mass of W and Z is a consequence of the "twisted" nature of the mode. A twisted mode has an effective inertia, which manifests itself as mass.

Mainstream connection: In electroweak theory, the W and Z masses arise via the Higgs mechanism (spontaneous symmetry breaking). The AU model offers an alternative interpretation: the mass is a "twist" of the mode. The Higgs mechanism will be discussed in more detail in Chapter 11.

Status: Speculative interpretation.

8.2.3 Relationship between W, Z and the photon

In electroweak theory, $W^\pm, Z^0$ and the photon are different combinations of the $SU(2)_L$ and $U(1)_Y$ gauge fields γ :

$$\begin{pmatrix} \gamma \\ Z^0 \end{pmatrix} = \begin{pmatrix} \cos \theta_W & \sin \theta_W \\ -\sin \theta_W & \cos \theta_W \end{pmatrix} \begin{pmatrix} B_\mu \\ W_\mu^3 \end{pmatrix}$$

where θ_W is the Weinberg angle ($\approx 28.2^\circ$).

In the AU model this is interpreted as **a mixing of twisted modes**:

$$\begin{aligned} A_\mu &= \cos \theta_W B_\mu + \sin \theta_W W_\mu^3 \\ Z_\mu^0 &= -\sin \theta_W B_\mu + \cos \theta_W W_\mu^3 \end{aligned}$$

Physical interpretation: Photon and Z^0 are different superpositions of the "basic" modes B_μ and W_μ^3 . The Weinberg angle determines the degree of mixing.

Mainstream connection: The Weinberg angle is a measured quantity ($\sin^2 \theta_W \approx 0.231$). The AU model offers a mode-mixing interpretation.

Status: Speculative interpretation.

8.3 Parity violation as asymmetry of turns

8.3.1 Parity violation in weak interactions

One of the key features of the weak interaction is **parity violation** (P-violation): the weak interaction acts only on the left-handed components of fermions (left-handed helicities) and does not act on the right-handed ones.

Слабое взаимодействие: только левые компоненты

Physical interpretation: Parity violation means that the weak interaction "distinguishes" between left and right.

Mainstream connection: Parity violation discovered by Wu et al. (1957) in the decay of ^{60}Co . Nobel Prize 1957 (Lee & Yang).

Status: Empirical fact.

8.3.2 AU interpretation: asymmetry of turns

In the AU model, parity violation is interpreted as an asymmetry of the field S_0 **turns**:

$$N_{\text{левых}} \neq N_{\text{правых}}$$

where $N_{\text{левых}}$ and $N_{\text{правых}}$ are the numbers of left and right turns in the archive.

Physical interpretation: The archive contains more left-handed turns than right-handed ones (or vice versa). The weak interaction "selects" only those modes that correspond to the dominant orientation of the turns.

Mainstream connection: In the Standard Model, parity violation is explained by the structure of the $SU(2)$ gauge group S_L (the subscript L denotes "left"). The AU model offers a topological interpretation: the asymmetry of the turns.

Status: Speculative interpretation.

8.3.3 Helicity and Chirality

In particle physics, a distinction is made between **helicity** (the projection of spin onto the direction of motion) and **chirality** (the eigenvalue of the matrix γ^5). The weak interaction acts on the left-handed chiral components.

In the AU model, chirality is interpreted as **the orientation of the coil** relative to the direction of propagation:

$$\text{киральность} \leftrightarrow \text{знак } \nabla S_\Theta \cdot p$$

where p is the fashion impulse.

Physical interpretation: Left chirality corresponds to a coil "twisted" against the direction of motion; right chirality - in the direction.

Mainstream connection: Chirality is a key concept in electroweak theory. The AU model offers a geometric interpretation.

Status: Speculative interpretation.

8.4 Connection with the Mainstream

8.4.1 Electroweak Theory

Electroweak theory (Glashow–Weinberg–Salam, 1960s) combines the electromagnetic and weak interactions into a single gauge theory with the group $SU(2)_L \times U(1)_Y$. It successfully describes:

- W and Z masses (via the Higgs mechanism),
- Parity violation,
- Neutral currents,
- Mixing photon and Z^0 (Weinberg angle).

Nobel Prize 1979 (Glashow, Salam, Weinberg). The AU model does not contradict electroweak theory, but offers an additional ontological language: $W^\pm$ and Z^0 as twisted modes, parity violation as asymmetry of the turns.

8.4.2 Experimental confirmation

The existence of W and Z has been confirmed experimentally:

- Discovery of neutral currents (Gargamelle, 1973),
- Discovery of W and Z (UA1 and UA2 on SPS, 1983),
- Precise measurements of W and Z masses (LEP, Tevatron, LHC),

- Measuring the Weinberg angle ($\sin^2\theta_W \approx 0.231$).

The AU model does not contradict these data, but offers a topological interpretation of them.

8.4.3 Open questions

Despite the successes of electroweak theory, open questions remain:

- Why does the weak interaction violate parity?
- Why are W and Z massive, but the photon is massless?
- Why does the Weinberg angle have this particular meaning?
- How to connect the weak interaction with the strong one (grand unification)?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

8.5 Chapter 8 Summary

1. **The weak interaction** in the AU model is interpreted as a **flavor switch** - a transition between entropic modes of the field S_Θ .
2. **$W^\pm$ and Z^0** are interpreted as **twisted modes** - "twisted" configurations of the field S_Θ : $W_\mu^\pm \leftrightarrow \partial_\mu(\nabla S_\Theta \cdot \sigma^\pm)$.
3. **The massiveness of W and Z** is explained by the "twisted" nature of the mode, which creates effective inertia. The photon is massless because it is not twisted.
4. **Parity violation** is interpreted as an **asymmetry of the turns** in the archive: $N_{\text{левых}} \neq N_{\text{правых}}$. Weak interaction acts only on modes with a dominant turn orientation.
5. **The mixing of W, Z, and the photon** is explained by the superposition of the "base" modes B_μ and W_μ^3 . The Weinberg angle determines the degree of mixing.
6. **Mainstream connection:** The AU model does not contradict electroweak theory and experimental data, but offers an additional ontological language for interpreting the weak interaction.
7. **Status:** All statements are speculative. Mainstream theories (electroweak theory, the Higgs mechanism) remain the default.

Chapter 9. Electromagnetic interaction

In the previous chapter, we examined the weak interaction as a flavor switch between entropic modes. Now we turn to **the electromagnetic interaction** —the most studied and accurately described interaction in physics.

In the Standard Model, electromagnetic interaction is described by quantum electrodynamics (QED), a gauge theory with group $U(1)$. It is carried by the massless photon, acts on all charged particles, and exhibits gauge invariance. In the AU ontology, electromagnetic interaction is hypothetically interpreted as a gradient field S_Θ **wave**: the photon corresponds to a massless perturbation $\partial_\mu S_\Theta$, and gauge invariance corresponds to the freedom to choose the phase of the archive.

9.1 Photon as a massless gradient wave

9.1.1 Definition of a photon in the AU model

In the AU model, the photon is interpreted as a **massless gradient** field wave S_Θ :

$$A_\mu \leftrightarrow \partial_\mu S_\Theta \text{ (калибровочно-инвариантная часть)}$$

where A_μ is the vector potential of the electromagnetic field.

Physical interpretation: A photon is not a "particle" in the usual sense, but a propagating perturbation of the field gradient S_Θ . Unlike the $W^\pm$ and Z^0 (twisted modes), the photon has no internal "twist," which explains its masslessness.

Mainstream connection: In QED, the photon is described as a quantum of the $U(1)$ gauge field. The AU model offers a topological interpretation: the photon is a gradient wave.

Status: Speculative interpretation.

9.1.2 Photon masslessness

In the Standard Model, the photon is massless. In the AU model, this is explained **by the absence of "entropic charge"** on the gradient wave:

$$m_\gamma = 0 \Leftrightarrow Q_{\text{ent}}^{(\gamma)} = 0$$

Physical interpretation: The photon is not "bound" to the condensate S_Θ because its mode has no internal twist. This corresponds to the absence of mass.

Mainstream connection: The masslessness of the photon has been confirmed experimentally (e.g., from constraints on the deviation from Coulomb's law and from data on Jupiter's magnetic field). The current limit is $m_\gamma < 10^{-18} \text{ eV}$.

Status: Speculative interpretation.

9.1.3 Equation of motion of a photon

In QED, the equation of motion of a photon (in the absence of sources) has the form:

$$\square A_\mu = 0$$

In the AU model this equation emerges from the field dynamics S_Θ :

$$\square(\partial_\mu S_\Theta) = 0$$

Physical interpretation: The photon's equation of motion is a consequence of the linearity of the gradient wave in the limit of small fluctuations. In the general case (in the presence of sources), the equation takes the form:

$$\square A_\mu = \mu_0 J_\mu$$

where J_μ is the current associated with the motion of charged modes.

Mainstream connection: Maxwell's equations are the classical foundation of electrodynamics. The AU model proposes a derivation of them from dynamics S_Θ .

Status: Speculative interpretation.

9.2 Gauge invariance as freedom of choice of archive phase

9.2.1 Gauge invariance in QED

In QED, the electromagnetic field has **gauge invariance**: physical observables do not change under the transformation:

$$A_\mu \rightarrow A_\mu + \partial_\mu \chi$$

where χ is an arbitrary function.

Physical interpretation: Gauge invariance means that the vector potential A_μ is defined up to its gradient. Only the field strength has physical meaning $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$.

Mainstream connection: Gauge invariance is a key principle of QED and the entire Standard Model.

Status: Empirical fact.

9.2.2 AU interpretation: freedom of choice of archive phase

In the AU model, gauge invariance is interpreted as **freedom to choose the archive phase**:

$$S_\Theta \rightarrow S_\Theta + \chi$$

Physical interpretation: The field S_Θ is defined up to an additive function. Only the gradient χ , which corresponds to the field strength, $F_{\mu\nu}$ has physical meaning ∇S_Θ .

Mainstream connection: In quantum field theory, gauge invariance is related to charge conservation (Noether's theorem). The AU model offers an interpretation through the freedom to choose the phase of the archive.

Status: Speculative interpretation.

9.2.3 Field strength as an antisymmetric part $\partial_\mu \partial_\nu S_\Theta$

In the AU model, the electromagnetic field strength $F_{\mu\nu}$ is interpreted as **the antisymmetric part** of the second derivative of the field S_Θ :

$$F_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \partial_\nu \partial_\mu S_\Theta$$

Physical interpretation: The field strength is the "torsion" of the field gradient S_Θ . Unlike the gradient itself (which is gauge-dependent), the torsion is gauge-invariant.

Mainstream connection: In differential geometry, the field strength is the curvature of the gauge bundle. The AU model offers an interpretation in terms of second derivatives S_Θ .

Status: Speculative interpretation.

9.3 Polarization as orientation ∇S_Θ

9.3.1 Photon polarization

A photon can be in one of two polarization states: horizontal or vertical (or a superposition of the two). Polarization is described by a vector e perpendicular to the direction of propagation.

Mainstream connection: Photon polarization is an experimentally confirmed fact (for example, in the Compton effect, in polarization filters, in quantum cryptography).

9.3.2 AU Interpretation: Gradient Orientation

In the AU model, polarization is interpreted as **the orientation of the gradient** ∇S_Θ in a plane perpendicular to the direction of propagation:

$$e \leftrightarrow \frac{\nabla S_\Theta}{|\nabla S_\Theta|}$$

Physical interpretation: Polarization is a geometric characteristic of a gradient wave. Two polarization states correspond to two independent gradient orientations.

Mainstream connection: In QED, polarization is described by a state vector in two-dimensional space. The AU model offers a geometric interpretation.

Status: Speculative interpretation.

9.3.3 Polarization Entanglement

In quantum mechanics, the polarizations of two photons can be entangled (for example, in a Bell state). In the AU model, this is interpreted as a **nonlocal correlation** between the orientations of the gradients of the two waves:

$$|\Psi_{\text{ent}}\rangle = \frac{1}{\sqrt{2}}(|H_1V_2\rangle - |V_1H_2\rangle)$$

Physical interpretation: Polarization entanglement is a consequence of nonlocal correlations in the archive. The orientations of the gradients of two photons are correlated through the kernel $K(x, y)$.

Mainstream connection: Polarization entanglement is an experimentally confirmed phenomenon (e.g., in the experiments of Aspect, 1982; in quantum cryptography). The AU model offers an interpretation through a nonlocal core.

Status: Speculative interpretation.

9.4 Connection with the Mainstream

9.4.1 Quantum Electrodynamics (QED)

QED is the most accurately tested theory in physics. It describes:

- Interaction of photons with charged particles,
- Lamb shift,
- Anomalous magnetic moment of the electron ($g - 2$),
- Compton scattering,
- Birth of couples.

The accuracy of QED predictions reaches [the same level 10^{-12} as] (for example, for $g - 2$ the electron). The AU model does not contradict QED, but offers an additional ontological language: the photon as a gradient wave, gauge invariance as freedom to choose the phase of the archive.

9.4.2 Experimental confirmation

Electromagnetic interaction has been confirmed by countless experiments:

- Coulomb's experiment (1785),
- Oersted's experiment (1820)
- Maxwell's equations (1865),
- Michelson–Morley experiment (1887)

- Photoelectric effect (Einstein, 1905),
- Compton scattering (1923),
- QED precision tests ($g - 2$, Lamb shift).

The AU model does not contradict these data, but offers a topological interpretation of them.

9.4.3 Open questions

Despite the successes of QED, open questions remain:

- Why is a photon massless?
- Why is gauge invariance a fundamental principle?
- How to connect electromagnetic interaction with others (grand unification)?
- What is the nature of quantum polarization entanglement?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

9.5 Chapter 9 Summary

1. **The photon** in the AU model is interpreted as a massless gradient field S_Θ **wave**: $A_\mu \leftrightarrow \partial_\mu S_\Theta$.
2. **The photon's masslessness** is explained by the absence of "entropic charge" in the gradient wave. Unlike $W^\pm$ and Z^0 , the photon has no internal twist.
3. **Gauge invariance** is interpreted as **freedom of choice of the archive phase**: $S_\Theta \rightarrow S_\Theta + \chi$. Only the gradient has physical meaning ∇S_Θ .
4. **Field strength** $F_{\mu\nu}$ is interpreted as the antisymmetric part of the second derivative of the field S_Θ .
5. **Polarization** is interpreted as the orientation of the gradient ∇S_Θ in a plane perpendicular to the direction of propagation. Polarization entanglement is a nonlocal correlation through the kernel $K(x, y)$.
6. **Mainstream connection**: The AU model does not contradict QED and experimental data, but offers an additional ontological language for interpreting electromagnetic interaction.
7. **Status**: All statements are speculative. Mainstream theories (QED, Maxwell's equations) remain fundamental.

Chapter 10. Gravitational Interaction

In previous chapters, we examined the strong, weak, and electromagnetic interactions as different types of field correlations S_Θ . Now we turn to **the gravitational interaction** —the most universal, but also the least understood from the perspective of quantum theory.

The Standard Model does not include gravity: it is described by general relativity (GR) as a curvature of spacetime. The quantum theory of gravity remains incomplete. In the AU ontology, gravity is hypothetically interpreted as **a global field gradient** S_Θ generating an emergent metric. The graviton—the quantum of metric perturbation—corresponds to the second derivative S_Θ .

10.1 Mechanism: Global gradient $S_\Theta \rightarrow$ emergent metric

10.1.1 Main hypothesis

In the AU model, the spacetime metric $g_{\mu\nu}$ is not fundamental. It emerges from the field structure S_Θ :

$$g_{\mu\nu}(x) = \eta_{\mu\nu} + \alpha \cdot \partial_\mu S_\Theta(x) \partial_\nu S_\Theta(x) + \beta \cdot \int K(x, y) \partial_\mu S_\Theta(y) \partial_\nu S_\Theta(y) d^4y$$

Where:

- $\eta_{\mu\nu}$ — flat Minkowski metric,
- α, β — coupling constants,
- $K(x, y)$ — non-local kernel.

Physical interpretation: Gravity is not a fundamental force, but an emergent phenomenon arising from the entropy gradient of thought forms. Regions of high entropy ∇S_Θ correspond to regions of high spacetime curvature.

Mainstream connection: The idea of emergent gravity is developed in the works of Verlinde (entropic gravity, 2011), Padmanabhan (2010), and Jacobson (1995). The AU model proposes a specific mechanism: the metric as a functional of S_Θ .

Status: Hypothetical interpretation.

10.1.2 Gravity as an entropy gradient

In the AU model, gravitational acceleration is related to the entropy gradient:

$$g = \frac{c^2 \lambda |\nabla S_\Theta|}{\rho_{AU} r}$$

Where:

- λ — coupling constant of the AU field,
- ρ_{AU} — density of the AU field,
- r — characteristic radius.

Physical interpretation: Bodies are attracted to those places where "more events are recorded"—where the entropy is higher. This is a generalization of Verlinde's idea to the case of a dynamic field S_Θ .

Mainstream connection: Verlinde's entropic gravity derives Newton's law from thermodynamic considerations. The AU model offers a concrete form: $g \propto \nabla S_\Theta$.

Status: Hypothetical interpretation.

10.1.3 Gravitational time dilation

In general relativity, gravitational time dilation is described by the metric:

$$\frac{dt_{\text{локальный}}}{dt_{\text{удалённый}}} = \sqrt{1 + \frac{2\phi}{c^2}}$$

where ϕ is the gravitational potential.

In the AU model, this is interpreted as **a slowing down of kairos time** at high recording density:

$$\frac{dt_{\text{локальный}}}{dt_{\text{удалённый}}} \approx 1 + \frac{\nabla S_\Theta}{c^2}$$

Physical interpretation: In areas with high recording density (e.g. near massive bodies) kairos time slows down, which manifests as gravitational time dilation.

Mainstream connection: Gravitational time dilation has been confirmed experimentally (Pound–Rebka, 1959; Hafele–Keating, 1971; GPS corrections).

Status: Hypothetical interpretation.

10.2 Graviton as a quantum of metric perturbation

10.2.1 Definition of graviton in the AU model

In the AU model, the graviton is interpreted as **a quantum of metric perturbation** corresponding to the second derivative of the field S_Θ :

$$h_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta$$

where $h_{\mu\nu}$ is the perturbation of the metric ($g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$).

Physical interpretation: The graviton is not a "particle" in the usual sense, but a propagating perturbation of the metric generated by dynamics S_Θ . Unlike the photon (a gradient wave), the graviton corresponds to the second derivative of the field.

Mainstream connection: In quantum gravity theory, the graviton is described as a spin-2 field quantum. The AU model offers a topological interpretation: the graviton as a metric perturbation.

Status: Hypothetical interpretation.

10.2.2 Masslessness of the graviton

In general relativity, the graviton is massless (gravity propagates at the speed of light). In the AU model, this is explained **by the absence of "entropic charge"** in the metric perturbation:

$$m_{\text{grav}} = 0 \Leftrightarrow Q_{\text{ent}}^{(\text{grav})} = 0$$

Physical interpretation: The graviton is not "coupled" with the condensate S_Θ because its mode has no internal twist (unlike $W^\pm$ and Z^0).

Mainstream connection: The masslessness of the graviton has been confirmed by gravitational wave observations (LIGO/Virgo, 2015–2025). Current limit: $m_{\text{grav}} < 10^{-22} \text{eV}$.

Status: Hypothetical interpretation.

10.2.3 Equation of motion of the graviton

In the linear approximation, the equation of motion of the graviton has the form:

$$\square h_{\mu\nu} = 0$$

In the AU model this equation emerges from the field dynamics S_Θ :

$$\square(\partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta) = 0$$

Physical interpretation: The equation of motion of the graviton is a consequence of the linearity of the metric perturbation in the limit of small fluctuations.

Mainstream connection: Gravitational wave equations are the classical foundation of general relativity. The AU model proposes a dynamical derivation of these equations S_Θ .

Status: Hypothetical interpretation.

10.3 Einstein's equations as a consequence of dynamics S_Θ

10.3.1 Einstein's equations in general relativity

Einstein's equations relate the curvature of space-time to the energy-momentum of matter:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

where $G_{\mu\nu}$ is the Einstein tensor, Λ is the cosmological constant, $T_{\mu\nu}$ and is the energy-momentum tensor.

10.3.2 AU interpretation: inference from dynamics S_Θ

In the AU model, Einstein's equations can be derived from the variation of the action with respect to the metric:

$$S = \int \left(\frac{c^4}{16\pi G} R + \mathcal{L}_{\text{AU}}[S_\Theta] \right) \sqrt{-g} d^4x$$

where $\mathcal{L}_{\text{AU}}$ is the Lagrangian of the field S_Θ .

Variation on $g^{\mu\nu}$ gives:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}^{(\text{AU})}$$

where $T_{\mu\nu}^{(\text{AU})}$ is the field energy-momentum tensor S_Θ :

$$T_{\mu\nu}^{(\text{AU})} = \partial_\mu S_\Theta \partial_\nu S_\Theta - \frac{1}{2} g_{\mu\nu} (\partial_\alpha S_\Theta \partial^\alpha S_\Theta - m^2 S_\Theta^2)$$

Physical interpretation: Einstein's equations are a consequence of field dynamics S_Θ . The curvature of spacetime is determined by the distribution of the entropy of thought forms.

Mainstream connection: Scalar-tensor theories of gravity (e.g., Brans–Dicke theory) also consider the connection between a scalar field and a metric. The AU model proposes a specific form: S_Θ as a source of curvature.

Status: Hypothetical interpretation.

10.3.3 Cosmological constant Λ

In general relativity, the cosmological constant Λ describes the accelerating expansion of the Universe. In the AU model, Λ_{eff} it is determined by the global entropy of the archive:

$$\Lambda_{\text{eff}} = \Lambda_0 + \gamma \cdot S_{\Theta}^{\text{glob}} + \delta \cdot \left(\frac{dS_{\Theta}^{\text{glob}}}{dt} \right)^2$$

Physical interpretation: The accelerated expansion of the Universe is a consequence of increasing global entropy. The more records in the archive, the stronger the "repulsion" leading to accelerated expansion.

Mainstream connection: DESI 2025 data point to the possible evolution of dark energy ($w(a) = w_0 + w_a(1 - a)$). The AU model proposes a specific mechanism: the evolution of S_{Θ} .

Status: Hypothetical interpretation.

10.3.4 Modified Friedmann equations

In cosmology, the Friedmann equations describe the expansion of the Universe:

$$H^2 = \frac{8\pi G}{3} \rho + \frac{\Lambda c^2}{3}$$

In the AU model, the modified Friedman equations include the contribution S_{Θ} :

$$H^2 = \frac{8\pi G}{3} \rho + \frac{\Lambda_{\text{eff}}(S_{\Theta})c^2}{3}$$

Physical interpretation: The expansion of the Universe is determined not only by the density of matter, but also by the dynamics of the entropy of the archive.

Mainstream connection: The modified Friedmann equations are actively discussed in the context of dark energy and modified gravity.

Status: Hypothetical interpretation.

10.4 Connection with the Mainstream

10.4.1 Verlinde's Entropic Gravity

Erik Verlinde (2011) proposed an interpretation of gravity as an entropic force arising from the thermodynamic properties of spacetime. The basic idea is that gravity is not a fundamental force, but a consequence of the system's tendency to maximize entropy.

The AU model develops this idea: gravity is a consequence of the field gradient S_{Θ} . The formula is:

$$g = \frac{c^2 \lambda |\nabla S_{\Theta}|}{\rho_{\text{AU}} r}$$

is a generalization of Verlinde's formula to the case of a dynamic field.

Mainstream Connection: Verlinde's work has generated considerable interest and is actively discussed in the literature. The AU model offers a concrete implementation: S_Θ as a source of entropic force.

10.4.2 Gravitational waves

Gravitational waves are a prediction of general relativity, confirmed by LIGO/Virgo (2015–2025). In the AU model, they are interpreted as propagating perturbations of the metric generated by the dynamics S_Θ :

$$\square h_{\mu\nu} = 0$$

Mainstream connection: Observations of gravitational waves (GW150914, GW170817, and others) confirm general relativity with high precision. The AU model does not contradict these data, but offers additional language.

10.4.3 Quantum gravity

The problem of quantum gravity is one of the central ones in modern physics. Various approaches exist: loop quantum gravity, string theory, causal dynamical triangulation, and asymptotically safe gravity.

The AU model offers an alternative approach: gravity emerges from field dynamics S_Θ . This does not replace existing approaches, but it does offer an additional ontological language.

Status: Hypothetical interpretation.

10.4.4 Open questions

Despite the successes of GTR, open questions remain:

- How to quantize gravity?
- Why is the cosmological constant so small?
- What is the nature of dark energy?
- How to relate gravity to other interactions?

The AU model offers hypothetical answers to these questions by relating them to field dynamics S_Θ .

10.5 Chapter 10 Summary

1. **Gravity** in the AU model is interpreted as a **global field gradient** S_Θ that generates an emergent metric: $g_{\mu\nu} = \eta_{\mu\nu} + \alpha \partial_\mu S_\Theta \partial_\nu S_\Theta + \dots$
2. **Gravitational acceleration** is related to the entropy gradient: $g = c^2 \lambda |\nabla S_\Theta| / (\rho_{AU} r)$.

3. **Gravitational time dilation** is interpreted as a dilation of kairos time at high recording density.
4. **The graviton** is a quantum of metric perturbation corresponding to the second derivative $S_\Theta: h_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta$. The masslessness of the graviton is explained by the absence of "entropic charge".
5. **Einstein's equations** can be derived from the variation of the action with respect to the metric with the field Lagrangian S_Θ .
6. **Cosmological constant** Λ_{eff} is determined by the global entropy of the archive and can evolve over time.
7. **Mainstream connection:** The AU model develops the ideas of entropic gravity (Verlinde) and proposes a concrete mechanism for quantum gravity.
8. **Status:** All statements are hypothetical. Mainstream theories (general relativity, quantum gravity) remain the default.

Chapter 11. The Higgs Mechanism

In previous chapters, we examined the strong, weak, electromagnetic, and gravitational interactions as different types of field correlations S_Θ . Now we turn to **the Higgs mechanism** — a mechanism for spontaneous breaking of electroweak symmetry that explains the masses of the $W^\pm$ and Z^0 bosons, as well as the masses of fermions.

In the Standard Model, the Higgs mechanism is described by a scalar Higgs field with a nonzero vacuum expectation value. In the AU ontology, the Higgs mechanism is hypothetically interpreted as **a field condensate** S_Θ : a nonzero vacuum expectation value $\langle S_\Theta \rangle = v \neq 0$, the oscillation quantum of which corresponds to the Higgs boson, and the coupling to the condensate determines the particle masses.

11.1 Field condensate $S_\Theta: \langle S_\Theta \rangle = v \neq 0$

11.1.1 Vacuum mean in the AU model

In the AU model, the vacuum is not empty: the field S_Θ has a non-zero vacuum expectation value:

$$\langle S_\Theta \rangle = v \neq 0$$

where v is the characteristic scale, analogous to the vacuum average of the Higgs field in the Standard Model ($v \approx 246 \text{ GeV}$).

Physical interpretation: The archive is "filled" with records even in the absence of particles. A non-zero average S_θ means that the vacuum has a non-zero entropic density of records. This is consistent with the idea that spacetime is not empty, but "saturated" with information.

Mainstream connection: In the Standard Model, the Higgs field has a nonzero vacuum expectation value, leading to spontaneous electroweak symmetry breaking. The AU model suggests an interpretation: the condensate S_θ is analogous to the Higgs condensate.

Status: Hypothetical interpretation.

11.1.2 Spontaneous symmetry breaking

In the Standard Model, the electroweak symmetry $SU(2)_L \times U(1)_Y$ is spontaneously broken to $U(1)_{em}$ at a nonzero vacuum expectation value of the Higgs field. In the AU model, this is interpreted as **a transition of the archive to a state with nonzero coherence:**

$$C_{\text{Bakuum}} \neq 0$$

Physical interpretation: At high recording densities, the archive enters a state with non-zero coherence. This breaks the original symmetry and leads to the appearance of masses on the particles.

Mainstream connection: Spontaneous symmetry breaking is a key mechanism in particle physics (Nambu, 1960; Goldstone, 1961; Higgs, 1964; Englert & Brout, 1964). Nobel Prize 2013 (Higgs, Englert).

Status: Hypothetical interpretation.

11.1.3 Field potential S_θ

The field potential S_θ in the AU model can be written as:

$$V(S_\theta) = -\mu^2 S_\theta^2 + \lambda S_\theta^4$$

Where $\mu^2 > 0, \lambda > 0$.

The minimum potential is achieved when:

$$\langle S_\theta \rangle = v = \sqrt{\frac{\mu^2}{2\lambda}}$$

Physical interpretation: The potential has a "Mexican hat" shape characteristic of spontaneous symmetry breaking. The minimum corresponds to a nonzero vacuum expectation value.

Mainstream connection: The Higgs field potential has a similar form. The AU model suggests an interpretation: S_θ as a scalar field with a potential of type ϕ^4 .

Status: Hypothetical interpretation.

11.2 Higgs boson as a quantum of condensate oscillations

11.2.1 Definition of the Higgs boson in the AU model

In the AU model, the Higgs boson is interpreted as **a quantum of condensate oscillations** S_Θ around the vacuum mean:

$$S_\Theta(x) = v + h(x)$$

where $h(x)$ is the fluctuation corresponding to the Higgs boson.

Physical interpretation: The Higgs boson is not a "particle" in the usual sense, but an oscillation of the condensate of the archive. Its mass is determined by the curvature of the potential at its minimum:

$$m_H^2 = 2\mu^2 = 4\lambda v^2$$

Mainstream connection: The Higgs boson was discovered at the LHC in 2012 (ATLAS and CMS). Its mass $m_H \approx 125$ is GeV. The AU model suggests an interpretation: the Higgs is an oscillation of a condensate S_Θ .

Status: Hypothetical interpretation.

11.2.2 Interaction of the Higgs boson with other particles

In the Standard Model, the Higgs boson interacts with fermions and gauge bosons proportionally to their masses. In the AU model, this is interpreted as **mode coupling to the condensate**:

$$\mathcal{L}_{\text{int}} = -y_f \bar{\psi} \psi S_\Theta - \frac{1}{2} g^2 W_\mu^+ W^{\mu-} S_\Theta^2 - \dots$$

Physical interpretation: Particles interact with the condensate S_Θ more strongly the greater their mass. This explains why the top quark (the heaviest fermion) is most strongly bound to the Higgs boson.

Mainstream connection: The interaction of the Higgs boson with particles has been confirmed experimentally (e.g., the observation of the decay of $H \rightarrow \gamma\gamma$, $H \rightarrow ZZ$, $H \rightarrow b\bar{b}$, $H \rightarrow \tau\tau$).

Status: Hypothetical interpretation.

11.2.3 Production and decay of the Higgs boson

In the Standard Model, the Higgs boson is produced in collisions of high-energy particles (e.g., $gg \rightarrow H$, $qq \rightarrow Hqq$) and decays into various particles. In the AU model, this is interpreted as **the excitation and relaxation of a condensate**:

рождение $H \leftrightarrow$ возбуждение S_Θ
 распад $H \leftrightarrow$ релаксация S_Θ

Physical interpretation: The production of a Higgs boson is a local excitation of the archive condensate. The decay is a relaxation to the vacuum mean.

Mainstream connection: The processes of Higgs boson production and decay have been studied with high precision at the LHC. The AU model offers an additional language for describing them.

Status: Hypothetical interpretation.

11.3 Mass generation: $m_f = y_f \cdot v, m_W = \frac{1}{2} g v$

11.3.1 Fermion masses

In the Standard Model, fermion masses arise through Yukawa couplings to the Higgs field:

$$m_f = y_f \cdot v$$

where y_f is the Yukawa constraint, v is the vacuum expectation value of the Higgs field.

In the AU model this is interpreted as **a coupling of modes with the condensate S_Θ** :

$$m_f = y_f \cdot \langle S_\Theta \rangle$$

Physical interpretation: The fermion mass is a measure of how strongly its mode is "coupled" with the archive condensate. Particles with higher masses interact more strongly with the condensate.

Connection to the mainstream: Fermion masses have been measured experimentally. Yukawa couplings are free parameters of the Standard Model. The AU model offers an interpretation: y_f as the "entropic charge" of the mode.

Status: Hypothetical interpretation.

11.3.2 Masses of the W and Z bosons

In the Standard Model, the masses of the W and Z bosons arise through interaction with the Higgs field:

$$m_W = \frac{1}{2} g v, m_Z = \frac{1}{2} \sqrt{g^2 + g'^2} v$$

where g and g' are the coupling constants of $SU(2)_L$ and $U(1)_Y$.

In the AU model this is interpreted as **a coupling of twisted modes with a condensate**:

$$m_W = \frac{1}{2} g \langle S_\Theta \rangle$$

Physical interpretation: The W and Z masses are a consequence of the "twisted" nature of the modes and their connection to the condensate. The photon remains massless because its mode is untwisted and unconnected to the condensate.

Connection to the mainstream: The masses of W and Z have been measured with high precision ($m_W \approx 80.4\text{GeV}$, $m_Z \approx 91.2\text{GeV}$). The AU model offers an interpretation through a connection to the condensate.

Status: Hypothetical interpretation.

11.3.3 Hierarchy of the Masses

In the Standard Model, fermion masses span a vast range: from $< 0.1\text{eV}$ (neutrinos) to 173GeV (top quarks). In the AU model, this hierarchy is explained **by the varying degrees of coupling of modes to the condensate**:

$$y_\nu \ll y_e \ll y_\mu \ll y_\tau \ll y_t$$

Physical interpretation: The mass hierarchy is a consequence of the varying degrees of "coupling" of modes with the condensate S_Θ . Neutrinos are almost uncoupled from the condensate, while the top quark is maximally coupled.

Mainstream connection: The mass hierarchy problem is one of the central problems in particle physics. The AU model offers a qualitative explanation.

Status: Hypothetical interpretation.

11.4 Spontaneous symmetry breaking as a transition of the archive into a state with $\mathcal{C} \neq 0$

11.4.1 Electroweak symmetry breaking

In the early universe ($T > 10^{15}\text{K}$), electroweak symmetry was unbroken: W, Z, and the photon were massless. Upon cooling below the critical temperature $T_{\text{EW}} \approx 159\text{GeV}$, a phase transition occurred, resulting in the Higgs field acquiring a nonzero vacuum expectation value, and W and Z acquiring mass.

In the AU model, this is interpreted as **a transition of the archive to a state with non-zero coherence**:

$$\mathcal{C}_{\text{архив}} = 0 \rightarrow \mathcal{C}_{\text{архив}} \neq 0$$

Physical interpretation: In the early Universe, the archive was in a state with zero coherence (a symmetric state). Upon cooling, it transitioned to a state with nonzero coherence (broken symmetry).

Mainstream connection: The electroweak phase transition is a subject of active research (for example, in the context of baryogenesis). The AU model offers an interpretation through archival coherence.

Status: Hypothetical interpretation.

11.4.2 Critical temperature

In the AU model, the critical temperature of the electroweak transition is related to the archive parameters:

$$T_{EW} \sim \sqrt{\frac{\mu^2}{\lambda}} \sim v$$

Physical interpretation: The critical temperature is determined by the scale of the vacuum mean v . At, $T > T_{EW}$ thermal fluctuations destroy the condensate; at, $T < T_{EW}$ the condensate forms.

Connection to the mainstream: In the Standard Model $T_{EW} \approx 159$, the GeV AU model offers an interpretation in terms of condensate parameters S_Θ .

Status: Hypothetical interpretation.

11.4.3 Relationship with baryogenesis

The electroweak phase transition may be associated with baryogenesis—the process that led to the predominance of matter over antimatter. In the AU model, this is interpreted as **the accumulation of asymmetry in the records** of the archive:

$$N_{\text{левых}} \neq N_{\text{правых}} \Rightarrow \text{барионная асимметрия}$$

Physical interpretation: Baryogenesis is a consequence of the asymmetry of the turns in the archive that arose during the electroweak transition.

Mainstream connection: The problem of baryogenesis is one of the central problems in cosmology. Sakharov's (1967) conditions are baryon number violation, C and CP violation, and thermal equilibrium breakdown. The AU model offers an interpretation through archive asymmetry.

Status: Hypothetical interpretation.

11.5 Connection with the Mainstream

11.5.1 Standard Model of the Higgs Mechanism

The Higgs mechanism is a key element of the Standard Model. It explains:

- Masses of W and Z bosons,
- Fermion masses,
- Spontaneous breaking of electroweak symmetry,
- The absence of mass in photons and gluons.

The Higgs boson was discovered at the LHC in 2012 (ATLAS and CMS). Its properties have been studied with high precision. The AU model does not contradict the Standard Model, but offers an additional ontological language: the condensate S_θ as an analogue of the Higgs field.

11.5.2 Experimental confirmation

The existence of the Higgs boson has been confirmed experimentally:

- Discovery of the Higgs boson (ATLAS and CMS, 2012),
- Mass measurement ($m_H \approx 125\text{GeV}$),
- Observation of decays ($H \rightarrow \gamma\gamma, H \rightarrow ZZ, H \rightarrow b\bar{b}, H \rightarrow \tau\tau$),
- Measuring spin and parity ($J^P = 0^+$).

The AU model does not contradict these data, but offers a topological interpretation of them.

11.5.3 Open questions

Despite the successes of the Standard Model, open questions remain:

- Why is the Higgs boson's mass exactly what it is?
- Why do Yukawa connections have such significance?
- Why is the electroweak scale ($v \approx 246\text{GeV}$) so small compared to the Planck scale?
- How to relate the Higgs mechanism to gravity?

The AU model offers hypothetical answers to these questions by relating them to field dynamics S_θ .

11.6 Chapter 11 Summary

1. **A field condensate** S_θ with a non-zero vacuum expectation value $\langle S_\theta \rangle = v \neq 0$ is interpreted as an analogue of the Higgs condensate.

2. **Spontaneous symmetry breaking** is interpreted as a transition of the archive to a state with non-zero coherence ($\mathcal{C} \neq 0$).
3. **Higgs boson** is a quantum of condensate oscillations S_Θ around the vacuum mean: $S_\Theta = v + h(x)$.
4. of fermion and gauge boson $m_f = y_f \cdot v$ **masses is explained by the coupling of modes with the condensate**; $m_W = \frac{1}{2} g v$.
5. **The hierarchy of masses** is explained by the different degrees of coupling of modes with the condensate: neutrinos are almost uncoupled, the top quark is maximally coupled.
6. **The electroweak phase transition** is interpreted as a transition of the archive from the state $\mathcal{C} = 0$ to the state $\mathcal{C} \neq 0$.
7. **Baryogenesis** is interpreted as the accumulation of asymmetry of records in the archive.
8. **Mainstream connection**: The AU model is consistent with the Standard Model and experimental data, but offers an additional ontological language for interpreting the Higgs mechanism.
9. **Status**: All statements are speculative. Mainstream theories (Standard Model, Higgs mechanism) remain the default.

Part V. Structures: Nuclei, Atoms, Generations, Mixing, CP Violation

Chapter 12. Nuclei and Atoms

In previous chapters, we described fermions as localized modes of a field S_Θ , and interactions as various types of correlations between them. Now we turn to **the bound structures** that these interactions generate: nuclei, atoms, and molecules.

In the Standard Model, nuclei are described as bound states of quarks and gluons (protons and neutrons) held together by the strong interaction, while atoms are described as bound states of nuclei and electrons held together by the electromagnetic interaction. In the AU ontology, these structures are hypothetically interpreted as **standing coherent modes** of the field S_Θ , and chemical bonding is interpreted as the overlap of such modes.

12.1 The nucleus as a bound state of quarks and gluons

12.1.1 Nucleons as bound states

In the Standard Model, the proton consists of three valence quarks (uud) bound by gluons, while the neutron consists of three (udd). The masses of the nucleons ($m_p \approx 938.3\text{MeV}$, $m_n \approx 939.6\text{MeV}$) are almost two orders of magnitude greater than the sum of the masses of their constituent quarks ($\sim 10\text{MeV}$). This means that the bulk of the nucleon mass is due to the binding energy of the gluon field, not the quark masses.

In the AU model, the nucleon is interpreted as **a bound state of color coils** held by entropic tension:

$$E_{\text{bind}} = \sum_i m_i c^2 - \Delta E_{\text{conf}}$$

where ΔE_{conf} is the confinement energy determined by the nonlocal kernel $K(x, y)$.

Physical interpretation: The nucleon mass is not the sum of the quark masses, but the energy of their binding through the archive. The bulk of the mass is the "entropic energy" of confinement.

Mainstream connection: In QCD, the proton mass is calculated through lattice simulations and confirmed experimentally. The AU model offers an interpretation: mass as the binding energy of modes.

Status: Speculative interpretation.

12.1.2 Nuclear forces as a residual interaction

In the Standard Model, nuclear forces are a residual manifestation of the strong interaction between nucleons, caused by the exchange of pions and other mesons. In the AU model, nuclear forces are interpreted as **residual correlations** between the color coils of different nucleons:

$$V_{\text{res}}(r) \sim -\frac{\alpha_{\text{res}}}{r} + \sigma_{\text{res}} r$$

where α_{res} and σ_{res} are parameters determined by the kernel $K(x, y)$.

Physical interpretation: Nuclear forces are a consequence of nonlocal correlations between modes forming different nucleons. At short distances, they attract, and at long distances, they repel (due to confinement).

Mainstream connection: Nuclear forces are described by phenomenological potentials (e.g., the Argon potential, CD-Bonn). The AU model offers an interpretation through a nonlocal nucleus.

Status: Speculative interpretation.

12.1.3 Nuclear membranes

In nuclear physics, there is a **shell model** that describes nucleons as filling discrete energy levels (shells). Magic numbers (2, 8, 20, 28, 50, 82, 126) correspond to filled shells and increased nuclear stability.

In the AU model, nuclear shells are interpreted as **discrete modes of** nuclear field coherence:

$$\Theta_{\text{AD}}^{(n)}(t) = \sum_i a_i^{(n)}(t) |\psi_i\rangle$$

where n is the shell number.

Physical interpretation: Nuclear shells are a consequence of the discrete nature of the spectrum of coherent modes. Magic numbers correspond to completely filled modes.

Mainstream connection: The shell model of the nucleus has been confirmed experimentally (e.g., the anomalous stability of magic nuclei). The AU model offers an interpretation through a discrete spectrum S_Θ .

Status: Speculative interpretation.

12.2 The Atom as a Standing Coherent Mode

12.2.1 Schrödinger equation for an atom in the AU model

In the AU model, an atom is interpreted as a **standing coherent mode** of the field S_Θ . The equation for electron modes can be written as:

$$\left[-\frac{\hbar^2}{2m} \nabla^2 + V_{\text{AU}}(r) \right] \psi = E \psi$$

where $V_{\text{AU}}(r)$ is the effective potential created by the nucleus and other electrons:

$$V_{\text{AU}}(r) = \lambda \int \frac{K(x, y)}{|x - y|} \nabla S_\Theta(y) d^4y$$

Physical interpretation: An atom is a standing field wave S_Θ , held together by the gradient of the nucleus. The electron shells correspond to discrete modes of this wave.

Mainstream connection: The Schrödinger equation for the atom is the foundation of quantum chemistry. The AU model does not contradict it, but offers a dynamical derivation S_Θ .

Status: Speculative interpretation.

12.2.2 Discreteness of energy levels

In quantum mechanics, the energy levels of an atom are discrete:

$$E_n = -\frac{13.6 \text{ эВ}}{n^2} \text{ (для водорода)}$$

In the AU model, discreteness arises as **eigenvalues of the effective dynamics operator**:

$$\hat{L}\psi_n = \lambda_n\psi_n$$

Where $\hat{L} = -\frac{\hbar^2}{2m}\nabla^2 + V_{\text{AU}}(r)$.

Physical interpretation: The discreteness of the energy levels is a consequence of the boundary conditions and mode coherence. The levels correspond to stable standing waves.

Mainstream connection: Atomic spectra have been studied with high accuracy (e.g., the hydrogen spectrum, the Lamb shift). The AU model offers a mode interpretation S_Θ .

Status: Speculative interpretation.

12.2.3 Spectral lines

Transitions between energy levels are accompanied by the emission or absorption of photons with a frequency of:

$$\hbar\omega = E_n - E_m$$

In the AU model this is interpreted as **a transition between modes** with the emission of a gradient wave:

$$\text{переход } \Theta^{(n)} \rightarrow \Theta^{(m)} \Rightarrow \text{излучение } \partial_\mu S_\Theta$$

Physical interpretation: Spectral lines are the result of transitions between coherent modes. The photon frequency corresponds to the energy difference between the modes.

Mainstream connection: Spectral lines are an experimentally confirmed fact (spectroscopy). The AU model offers an interpretation through mode transitions.

Status: Speculative interpretation.

12.3 Electron shells as discrete modes

12.3.1 Shell structure of an atom

In quantum mechanics, electrons in an atom occupy discrete shells (K, L, M, ...), characterized by a principal quantum number n , orbital angular momentum l , magnetic number m_l , and spin m_s . The Pauli principle prohibits two electrons from occupying the same state.

In the AU model, electron shells are interpreted as **discrete coherence modes**:

$$\Theta_{\text{atom}}^{(n,l,m_l,m_s)}(t) = \sum_i a_i(t) |\psi_i\rangle$$

Physical interpretation: Each shell is a specific field mode S_Θ , characterized by a set of quantum numbers. The Pauli exclusion principle is a consequence of the mode topology: two modes with the same quantum numbers cannot exist simultaneously.

Mainstream connection: The shell structure of the atom has been confirmed experimentally (e.g., Mendeleev's periodic law, X-ray spectra). The AU model offers an interpretation in terms of modes S_Θ .

Status: Speculative interpretation.

12.3.2 Mendeleev's Periodic Law

The periodic law is a consequence of the filling of electron shells. In the AU model, it is interpreted as **a sequential filling of** field modes S_Θ :

Период $\leftrightarrow$ заполнение оболочки

Physical interpretation: The chemical properties of elements are determined by the number of electrons in the outer shell, i.e., the number of occupied modes. Periodicity is a consequence of the discreteness of the mode spectrum.

Mainstream connection: The periodic law is the empirical basis of chemistry. The AU model offers an interpretation through modes S_Θ .

Status: Speculative interpretation.

12.3.3 Spin and the Pauli principle

Electron spin is an internal degree of freedom that can take two values ($\pm \hbar/2$). In the AU model, spin is interpreted as **the orientation of the mode turn**:

спин $\leftrightarrow$ ориентация ∇S_Θ

Physical interpretation: Spin is a topological characteristic of a mode. The Pauli exclusion principle is a consequence of the fact that two modes with the same spin orientation cannot occupy the same state.

Mainstream connection: Spin and the Pauli exclusion principle are experimentally confirmed facts (the Stern–Gerlach experiment, spectroscopy). The AU model offers an interpretation through mode topology.

Status: Speculative interpretation.

12.4 Chemical bonding as mode overlap

12.4.1 Covalent bond

In quantum chemistry, a covalent bond arises when the electron orbitals of two atoms overlap, resulting in a decrease in energy. In the AU model, this is interpreted as an overlap of field S_Θ modes:

$$C_{\text{связь}} = \langle \Theta_{\text{atom 1}} | \Theta_{\text{atom 2}} \rangle_K$$

Physical interpretation: Chemical bonding is a consequence of the overlap of coherent modes. The greater the overlap, the stronger the bond.

Mainstream connection: Covalent bonding is described by the molecular orbital (MO) method. The AU model offers an interpretation through mode overlap integrals.

Status: Speculative interpretation.

12.4.2 Ionic and hydrogen bonding

An ionic bond occurs when an electron is transferred from one atom to another. In the AU model, this is interpreted as **a mode transfer** from one atom to another:

$$\Theta_{\text{atom 1}} \rightarrow \Theta_{\text{atom 2}}$$

Hydrogen bonding is a weak interaction between polar molecules. In the AU model, it is represented as **a weak mode overlap**.

Physical interpretation: Different types of chemical bonds correspond to different degrees of overlap and mode transition.

Mainstream connection: Ionic and hydrogen bonds are studied in chemistry and biochemistry. The AU model offers an interpretation through modes S_Θ .

Status: Speculative interpretation.

12.4.3 Molecular Orbitals

In quantum chemistry, molecular orbitals are described as linear combinations of atomic orbitals (LCAO):

$$\psi_{\text{MO}} = \sum_i c_i \psi_i^{\text{AO}}$$

In the AU model this is interpreted as **a superposition of modes**:

$$\Theta_{\text{MO}} = \sum_i c_i \Theta_i$$

Physical interpretation: Molecular orbitals are superpositions of atomic modes. The coefficients c_i are determined by overlap integrals.

Mainstream connection: The MO method is the foundation of modern quantum chemistry. The AU model offers an interpretation through mode superposition S_Θ .

Status: Speculative interpretation.

12.5 Connection with the Mainstream

12.5.1 Nuclear Physics

Nuclear physics describes:

- The structure of nuclei (protons, neutrons),
- Nuclear forces (strong interaction),
- Nuclear reactions (decay, fusion),
- Shell structure.

The AU model does not contradict nuclear physics, but offers an additional ontological language: nuclei as bound states of color loops, nuclear forces as residual correlations.

12.5.2 Atomic Physics and Quantum Chemistry

Atomic physics and quantum chemistry describe:

- Electron shells,
- Spectral lines,
- Chemical bonds,
- Molecular orbitals.

The AU model offers an interpretation: atoms as standing coherent modes, chemical bonds as mode overlap.

12.5.3 Experimental confirmation

The structure of nuclei and atoms has been confirmed by numerous experiments:

- Rutherford's experiments (1911) - discovery of the nucleus,
- Franck-Hertz experiments (1914) - discreteness of energy levels,
- Spectroscopy is the measurement of spectral lines,
- X-ray diffraction analysis is the determination of the structure of molecules,
- Nuclear magnetic resonance (NMR) is the study of nuclear spins.

The AU model does not contradict these data, but offers a topological interpretation of them.

12.5.4 Open questions

Despite the advances in nuclear and atomic physics, open questions remain:

- Why is the mass of the nucleon so large compared to the masses of the quarks?
- Why do magic numbers exist?
- Why does the Pauli exclusion principle hold?
- How do nuclear and atomic structures relate to gravity?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

12.6 Chapter 12 Summary

1. **Nuclei** in the AU model are interpreted as bound states of color loops, held together by entropic tension. The nucleon mass is the binding energy of the modes.
2. **Nuclear forces** are residual correlations between the color coils of different nucleons.
3. **Nuclear shells** are discrete modes of nuclear field coherence. Magic numbers correspond to filled modes.
4. **An atom** is a standing coherent mode of the field S_Θ , described by the Schrödinger equation with an effective potential $V_{\text{AU}}(r)$.
5. **Electron shells** are discrete modes characterized by quantum numbers. The Pauli exclusion principle is a consequence of the mode topology.
6. **Chemical bonding** is the overlap of field modes S_Θ . Covalent, ionic, and hydrogen bonds correspond to varying degrees of mode overlap and transition.

7. **Molecular orbitals** are superpositions of atomic modes.
8. **Mainstream connection:** The AU model does not contradict nuclear physics, atomic physics and quantum chemistry, but offers an additional ontological language for interpreting structures.
9. **Status:** All statements are speculative. Mainstream theories (QCD, quantum mechanics, quantum chemistry) remain the default.

Chapter 13. Generations and Mixing

In previous chapters, we described fermions as localized modes of a field S_Θ , and interactions as correlations between them. Now we turn to one of the most intriguing features of the Standard Model: **the existence of three generations of fermions and the mixing between them.**

Why do fermions exist in three generations? Why do quarks mix weakly (the CKM matrix) while leptons mix strongly (the PMNS matrix)? Why is there a CP-violating phase in these matrices? In the Standard Model, these questions have no definitive answers: the mixing matrices are free parameters, and the number of generations is postulated. In the AU ontology, generations and mixing are hypothetically interpreted through **a discrete spectrum of excitations and overlap integrals** between entropy modes.

13.1 CKM matrix as overlap integrals

13.1.1 CKM matrix in the Standard Model

In the Standard Model, transitions between quark generations are described by the Cabibbo–Kobayashi–Maskawa (CKM) matrix. It relates the "weak" eigenstates of quarks (d', s', b') to the "mass" eigenstates (d, s, b):

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V_{\text{CKM}} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

The CKM matrix is unitary and is parameterized by three mixing angles and one CP-violation phase:

$$V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Experimentally measured values (moduli):

- $|V_{ud}| \approx 0.974, |V_{us}| \approx 0.225, |V_{ub}| \approx 0.004,$
- $|V_{cd}| \approx 0.225, |V_{cs}| \approx 0.973, |V_{cb}| \approx 0.041,$

- $|V_{td}| \approx 0.009, |V_{ts}| \approx 0.040, |V_{tb}| \approx 0.999.$

Mainstream connection: The CKM matrix is a key element of the Standard Model, describing quark mixing and CP violation. 2008 Nobel Prize (Kobayashi, Maskawa).

Status: Empirical fact.

13.1.2 AU interpretation: overlap integrals of modes

In the AU model, the CKM matrix is interpreted as a **matrix of overlap integrals** between entropy modes of different generations:

$$V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$$

where $\langle \cdot | \cdot \rangle_K$ is the scalar product with kernel K :

$$\langle \Theta^{(i)} | \Theta^{(j)} \rangle_K = \int \Theta^{(i)*}(x) K(x, y) \Theta^{(j)}(y) d^4x d^4y$$

Physical interpretation: Generational mixing is a consequence of mode overlap. The greater the overlap between modes i and j , the stronger the mixing.

Connection to the mainstream: In some models (e.g., with discrete symmetries or extra dimensions), mixing matrices are also derived from overlap integrals. The AU model offers a specific mechanism: overlap via the kernel K .

Status: Speculative interpretation.

13.1.3 Hierarchy of CKM elements

The elements of the CKM matrix exhibit a hierarchy:

$$\begin{aligned} |V_{ud}| &\sim |V_{cs}| \sim |V_{tb}| \sim 1 \\ |V_{us}| &\sim |V_{cd}| \sim \lambda \approx 0.22 \\ |V_{cb}| &\sim |V_{ts}| \sim \lambda^2 \approx 0.05 \\ |V_{ub}| &\sim |V_{td}| \sim \lambda^3 \approx 0.01 \end{aligned}$$

where $\lambda \approx 0.22$ is the Wolfenstein parameter.

In the AU model, this hierarchy is explained by **the exponential suppression of overlap integrals** with increasing generational difference:

$$|V_{ij}| \sim \lambda^{|i-j|}$$

Physical interpretation: The overlap between modes of different generations decreases with increasing difference in their excitation levels. This leads to an exponential hierarchy of CKM elements.

Mainstream connection: The hierarchy of CKM elements is an empirical fact. The Wolfenstein parameter λ is used for parameterization. The AU model offers an interpretation through overlap integrals.

Status: Speculative interpretation.

13.2 PMNS matrix for leptons

13.2.1 PMNS matrix in the Standard Model

Neutrino mixing is described by the Pontecorvo–Maki–Nakagawa–Sakata matrix (PMNS):

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U_{\text{PMNS}} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

where ν_i are the mass eigenstates.

The PMNS matrix is parameterized by three mixing angles ($\theta_{12}, \theta_{23}, \theta_{13}$) and the CP-violation phase (δ_{CP}):

$$U_{\text{PMNS}} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$

Experimentally measured values:

- $\theta_{12} \approx 33.4^\circ$ (solar neutrino angle),
- $\theta_{23} \approx 42.3^\circ$ (atmospheric neutrino angle),
- $\theta_{13} \approx 8.6^\circ$ (reactor neutrino angle),
- δ_{CP} — not yet measured accurately (limitations: $\sim 200^\circ$).

Mainstream connection: The PMNS matrix is a key element of neutrino physics. 2015 Nobel Prize (Kajita, McDonald) for the discovery of neutrino oscillations.

Status: Empirical fact.

13.2.2 AU interpretation: overlap integrals of lepton modes

In the AU model, the PMNS matrix is interpreted as a **matrix of overlap integrals** between lepton modes:

$$U_{\alpha i} = \langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K$$

where $\alpha = e, \mu, \tau$ are aromas, $i = 1, 2, 3$ are mass states.

Physical interpretation: Neutrino mixing is a consequence of the overlap of lepton modes. The greater the overlap, the stronger the mixing.

Mainstream connection: In models with discrete symmetries (e.g., A_4 , S_4), mixing matrices are also derived from overlap integrals. The AU model offers a specific mechanism: overlap via the kernel K .

Status: Speculative interpretation.

13.2.3 Large mixing angles of PMNS

Unlike CKM, the mixing angles of PMNS are large:

$$\theta_{12} \approx 33^\circ, \theta_{23} \approx 42^\circ, \theta_{13} \approx 9^\circ$$

In the AU model this is explained **by weak localization of lepton modes**:

$$\langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K \sim 1 \text{ (для лептонов)}$$

Physical interpretation: Leptons are weakly localized (have no color interaction), so their modes overlap greatly. This leads to large mixing angles.

Mainstream connection: Large PMNS angles are an empirical fact. The AU model offers a qualitative explanation through the varying degrees of localization of quarks and leptons.

Status: Speculative interpretation.

13.3 Difference between CKM and PMNS: Quarks vs. Leptons

13.3.1 Hierarchy of mixing angles

Comparison of quark and leptons mixing angles:

Parameter	Quarks (CKM)	Leptons (PMNS)
θ_{12}	13.0°	33.4°
θ_{23}	2.4°	42.3°
θ_{13}	0.2°	8.6°

Mainstream connection: The difference between CKM and PMNS is an empirical fact. It is not explained in the Standard Model.

13.3.2 AU interpretation: different degrees of localization

In the AU model, the difference is explained **by the different degrees of localization** of quarks and leptons:

- **Quarks** are highly localized (due to color interaction) → modes overlap little → small mixing angles.
- **Leptons** are weakly localized (no color interaction) → modes overlap strongly → large mixing angles.

Quantitatively:

$$\langle \Theta^{(i)} | \Theta^{(j)} \rangle_K \sim \begin{cases} \epsilon^{|i-j|} & (\text{кварки, } \epsilon \sim 0.2) \\ 1 & (\text{лептоны}) \end{cases}$$

Physical interpretation: The color interaction "compresses" quark modes, reducing their overlap. Lepton modes are "smeared" more, increasing the overlap.

Connection to the mainstream: In some models (e.g., with extra dimensions), the difference between CKM and PMNS is also explained by different fermion localizations. The AU model offers a specific mechanism.

Status: Speculative interpretation.

13.3.3 Verifiable consequences

The AU interpretation implies that the difference between CKM and PMNS should correlate with the different degrees of localization of quarks and leptons. This can be verified by:

- Accurate measurements of mixing angles,
- Study of rare decays (eg, $K \rightarrow \pi \nu \bar{\nu}$, $B \rightarrow \tau \nu$),
- Search for new particles that influence mixing.

Status: Speculative prediction requiring verification.

13.4 CP violation phase

13.4.1 CP violation in the Standard Model

CP violation is a symmetry breaking between matter and antimatter. In the Standard Model, it is described by a complex phase δ_{CP} in the CKM matrix (and possibly in the PMNS).

Experimentally, CP violation has been found in:

- Decays of K mesons (1964, Nobel Prize 1980),
- B-meson decays (2001, BaBar and Belle),

- Decays of D mesons (2019, LHCb).

Connection to the mainstream: CP violation is a key element to explain the baryon asymmetry of the Universe (Sakharov conditions).

Status: Empirical fact.

13.4.2 AU interpretation: asymmetry of records in the archive

In the AU model, the CP-violation phase is interpreted as **an asymmetry of records** in the archive:

$$\delta_{CP} \leftrightarrow N_{\text{левых}} \neq N_{\text{правых}}$$

where $N_{\text{левых}}$ and $N_{\text{правых}}$ are the numbers of left and right turns in the archive.

Physical interpretation: CP violation is a consequence of the archive containing more left-handed turns than right-handed ones (or vice versa). This leads to an asymmetry between matter and antimatter.

Mainstream connection: In the Standard Model, CP violation is described by a complex phase in the mixing matrix. The AU model offers an interpretation through coil asymmetry.

Status: Speculative interpretation.

13.4.3 Relationship with baryogenesis

Baryogenesis is the process that led to the predominance of matter over antimatter in the Universe. It requires (Sakharov's conditions):

1. Baryon number violation,
2. Violation of C and CP,
3. Leaving thermal equilibrium.

In the AU model, baryogenesis is interpreted as **the accumulation of asymmetries** in the records of the early Universe:

$$\Delta N = N_{\text{левых}} - N_{\text{правых}} \neq 0$$

Physical interpretation: In the early Universe, during the electroweak phase transition, the archive transitioned to a state with nonzero asymmetry of the turns. This led to the predominance of matter over antimatter.

Mainstream Connection: The problem of baryogenesis is one of the central problems in cosmology. The AU model offers an interpretation through archival asymmetry.

Status: Speculative interpretation.

13.5 Connection with the Mainstream

13.5.1 Mixing Matrices in the Standard Model

The CKM and PMNS matrices are key elements of the Standard Model. They describe:

- Mixing of quarks and leptons,
- CP violation,
- Neutrino oscillations.

Experimental data (K-mesons, B-mesons, neutrino experiments) confirm the Standard Model with high accuracy. The AU model does not contradict these data, but offers an additional ontological language: mixing matrices as overlap integrals of modes.

13.5.2 The problem of the number of generations

The number of generations (three) remains an open question in the Standard Model. In cosmology, the number of generations is constrained by data on primordial nucleosynthesis (three types of light neutrinos). In the AU model, the number of generations is determined by the topology of the localized mode.

Connection to the mainstream: In some models (e.g., the gauge group model E_8), the number of generations is also determined by topology. The AU model proposes a specific mechanism: a discrete excitation spectrum.

13.5.3 Open questions

Despite the successes of the Standard Model, open questions remain:

- Why are there three generations?
- Why do the mixing angles have these particular values?
- Why are CKM and PMNS so different?
- What is the nature of CP violation?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

13.6 Chapter 13 Summary

1. **The CKM matrix** is interpreted as a matrix of overlap integrals between quark modes of different generations: $V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$.
2. **The hierarchy of CKM elements** is explained by the exponential suppression of overlap integrals with increasing generation difference: $|V_{ij}| \sim \lambda^{|i-j|}$.

3. **The PMNS matrix** is interpreted as a matrix of overlap integrals between lepton modes:

$$U_{\alpha i} = \langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K.$$
4. **Large PMNS angles** are explained by weak localization of lepton modes (absence of color interaction).
5. **The difference between CKM and PMNS** is explained by the different degrees of localization of quarks and leptons: quarks are strongly localized $\rightarrow$ small angles; leptons are weakly localized $\rightarrow$ large angles.
6. **CP violation** is interpreted as an asymmetry of records in the archive: $N_{\text{левых}} \neq N_{\text{правых}}$.
7. **Baryogenesis** is interpreted as the accumulation of asymmetries in the records of the early Universe.
8. **Mainstream connection:** The AU model is consistent with the Standard Model and experimental data, but offers an additional ontological language for interpreting generations and mixing.
9. **Status:** All statements are speculative. Mainstream theories (the Standard Model, neutrino oscillation theory, baryogenesis) remain the default.

Chapter 14. CP Violation and Baryogenesis

In the previous chapter, we examined the mixing of generations and introduced the concept of CP violation as an asymmetry of archival records. Now we move on to a more detailed analysis **of CP violation** and its role in **baryogenesis** —the process that led to the predominance of matter over antimatter in the Universe.

In the Standard Model, CP violation is described by a complex phase in the CKM matrix (for quarks) and, possibly, in the PMNS matrix (for leptons). Baryogenesis requires the fulfillment of Sakharov's conditions: baryon number violation, C and CP violation, and a departure from thermal equilibrium. In the AU ontology, these phenomena are hypothetically interpreted through **the asymmetry of** field loops S_Θ and **the accumulation of asymmetry** in the records of the early universe.

14.1 CP Violation: From Symmetry to Asymmetry

14.1.1 Definition of CP symmetry

C-symmetry (charge conjugation) is the symmetry between particles and antiparticles. **P-symmetry** (spatial parity) is the symmetry between left and right. **CP-symmetry** is a combined symmetry: a transformation in which a particle is replaced by an antiparticle and a mirror image of space occurs simultaneously.

In the Standard Model, CP symmetry is violated in the weak interaction. This means that processes involving particles and antiparticles proceed differently.

Mainstream connection: CP violation was predicted by Kobayashi and Maskawa (1973) to explain CP violation in K-meson decays. Nobel Prize 2008.

Status: Empirical fact.

14.1.2 Experimental discoveries of CP violation

CP violation detected in several systems:

- **K-mesons** (1964, Cronin & Fitch): decays $K_L \rightarrow \pi^+ \pi^-$ showed CP violation. Nobel Prize 1980.
- **B-mesons** (2001, BaBar and Belle): The observation of CP violation in B-meson decays confirmed the Kobayashi–Maskawa prediction.
- **D-mesons** (2019, LHCb): first observation of CP violation in D-meson decays.
- **Neutrinos** (T2K, NOvA): constraints on the CP-violation phase in the PMNS matrix.

Mainstream connection: CP violation is a key element to explain the baryon asymmetry of the Universe.

Status: Empirical fact.

14.1.3 AU interpretation: asymmetry of turns

In the AU model, CP violation is interpreted as an asymmetry of the field S_Θ **turns**:

$$N_{\text{левых}} \neq N_{\text{правых}}$$

where $N_{\text{левых}}$ and $N_{\text{правых}}$ are the numbers of left and right turns in the archive.

Physical interpretation: The archive contains more left-handed turns than right-handed ones (or vice versa). This leads to an asymmetry between matter and antimatter, since particles correspond to one orientation of the turns, and antiparticles to the opposite.

Mainstream connection: In the Standard Model, CP violation is described by a complex phase in the mixing matrix. The AU model offers a topological interpretation: asymmetry of the turns.

Status: Speculative interpretation.

14.1.4 Parameterization of asymmetry

In the AU model, the degree of CP violation can be parameterized through **the asymmetry parameter η** :

$$\eta = \frac{N_{\text{левых}} - N_{\text{правых}}}{N_{\text{левых}} + N_{\text{правых}}}$$

The experimentally measured values of CP violation in K and B mesons correspond to $\eta \sim 10^{-3}$.

Physical interpretation: This parameter η determines the degree of archive asymmetry. A low value η indicates that the asymmetry is small, but sufficient for baryogenesis.

Mainstream connection: In the Standard Model, CP violation is parameterized by the phase δ_{CP} . The AU model offers an alternative parameterization via η .

Status: Speculative interpretation.

14.2 Weak angle θ_W as a parameter of asymmetry

14.2.1 Weinberg angle in the Standard Model

The Weinberg angle θ_W (weak mixing angle) determines the mixing between the electromagnetic and weak interactions:

$$\sin^2 \theta_W \approx 0.231$$

It enters into the relationship between the masses of the W and Z bosons:

$$\frac{m_W}{m_Z} = \cos \theta_W$$

Mainstream connection: The Weinberg angle is one of the key parameters of the Standard Model. It has been measured with high precision.

Status: Empirical fact.

14.2.2 AU interpretation: θ_W as a measure of archive asymmetry

In the AU model, the Weinberg angle is interpreted as **a parameter of archive asymmetry**:

$$\sin^2 \theta_W \leftrightarrow \frac{N_{\text{левых}}}{N_{\text{левых}} + N_{\text{правых}}}$$

Physical interpretation: The Weinberg angle determines what proportion of the turns in the archive are left-handed. This value $\sin^2 \theta_W \approx 0.231$ indicates that approximately 23% of the turns are left-handed.

Mainstream connection: In the Standard Model, the Weinberg angle determines the relative strengths of the electromagnetic and weak interactions. The AU model offers a topological interpretation: the fraction of left-handed turns.

Status: Speculative interpretation.

14.2.3 Communication with parity violation

Parity violation (P-violation) in the weak interaction means that the weak interaction acts only on the left-handed components of fermions. In the AU model, this is interpreted as a **dominance of left-handed loops** in the archive:

$$N_{\text{левых}} > N_{\text{правых}}$$

Physical interpretation: The weak interaction "selects" only those modes that correspond to the dominant orientation of the turns. This explains why the weak interaction violates parity.

Mainstream connection: Parity violation was discovered by Wu et al. (1957). The AU model offers an interpretation through turn asymmetry.

Status: Speculative interpretation.

14.2.4 Verifiable consequences

From the AU interpretation it follows that the Weinberg angle should correlate with the asymmetry parameter η :

$$\sin^2 \theta_W \approx \frac{1}{2}(1 + \eta)$$

This can be verified through precise measurements $\sin^2 \theta_W$ and comparison with estimates η from CP violation data.

Status: Speculative prediction requiring verification.

14.3 Baryogenesis: Accumulation of Asymmetry in the Early Universe

14.3.1 Sakharov's conditions

For baryogenesis (the predominance of matter over antimatter) three conditions are necessary (Sakharov, 1967):

1. **Baryon number violation** (B-violation) is a process that changes the difference between the number of baryons and antibaryons.
2. **Violation of C and CP** is an asymmetry between matter and antimatter.
3. **Departure from thermal equilibrium** is a deviation from the equilibrium distribution necessary for the accumulation of asymmetry.

Mainstream connection: Sakharov's conditions are the basis for baryogenesis theories. Nobel Prize in 1978 (Penzias, Wilson – for the discovery of the cosmic microwave background radiation; Sakharov – for his work on baryogenesis).

Status: Empirical basis.

14.3.2 Electroweak phase transition

In the early Universe, at $T \sim 100\text{GeV}$, an electroweak phase transition occurred: the Higgs field acquired a nonzero vacuum expectation value, and W and Z acquired mass. This transition could have been the source of baryogenesis if it were a first-order transition (with bubble formation).

In the AU model, the electroweak transition is interpreted as **a transition of the archive to a state with non-zero asymmetry**:

$$C_{\text{архив}} = 0 \rightarrow C_{\text{архив}} \neq 0, \eta \neq 0$$

Physical interpretation: During the electroweak transition, the archive transitioned from a symmetric state ($\eta = 0$) to a state with nonzero asymmetry ($\eta \neq 0$). This led to the accumulation of baryon asymmetry.

Mainstream connection: Electroweak baryogenesis is one model that explains baryon asymmetry. However, in the Standard Model, CP violation is not sufficient to account for the observed asymmetry.

Status: Speculative interpretation.

14.3.3 Accumulation of record asymmetry

In the AU model, baryogenesis is interpreted as **the accumulation of asymmetry in records** in the archive:

$$\Delta N = N_{\text{левых}} - N_{\text{правых}} \neq 0$$

Physical interpretation: In the early universe, during the electroweak transition, the archive accumulated asymmetry in the loops. This led to a predominance of matter (left-handed loops) over antimatter (right-handed loops).

Mainstream Connection: Observed Baryon Asymmetry of the Universe:

$$\eta_B = \frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 6 \times 10^{-10}$$

This means that for every billion photons there is approximately one baryon.

Status: Speculative interpretation.

14.3.4 Connection with the observed baryon asymmetry

In the AU model, the observed baryon asymmetry $\eta_B \approx 6 \times 10^{-10}$ corresponds to the archive asymmetry parameter:

$$\eta \sim 10^{-9}$$

Physical interpretation: A small but non-zero asymmetry of the archive led to the observed baryon asymmetry. If $\eta = 0$, the Universe would be symmetric (equal amounts of matter and antimatter).

Mainstream connection: In the Standard Model, CP violation is not sufficient to explain $\eta_B \approx 6 \times 10^{-10}$. Additional sources of CP violation (new physics) are required.

Status: Speculative interpretation.

14.4 Connection with the Mainstream

14.4.1 Experimental data on CP violation

CP violation has been studied in several systems:

- **K-mesons:** $\epsilon_K \approx 2.2 \times 10^{-3}$,
- **B-mesons:** $\sin 2\beta \approx 0.7$,
- **D-mesons:** $\Delta A_{CP} \approx -1.5 \times 10^{-3}$,
- **Neutrinos:** Limits on δ_{CP} (T2K, NOvA).

The AU model does not contradict these data, but offers an additional ontological language: CP violation as asymmetry of turns.

14.4.2 The problem of baryogenesis

The problem of baryogenesis is one of the central problems in cosmology. The observed baryon asymmetry $\eta_B \approx 6 \times 10^{-10}$ requires:

- B-violations (present in the Standard Model through sphalerons),
- CP violations (not enough in the Standard Model),
- Departure from equilibrium (possible during a first-order electroweak transition).

The AU model offers an interpretation: baryogenesis as the accumulation of archival asymmetries. This does not replace existing models, but it offers additional language.

14.4.3 Open questions

Despite the successes, open questions remain:

- Why is CP violation in the Standard Model so small?
- Is it enough for baryogenesis?
- What is the nature of CP violation in the neutrino sector?
- Are there additional sources of CP violation?

The AU model offers hypothetical answers to these questions, linking them to the asymmetry of the turns in the archive.

14.5 Chapter 14 Summary

1. **CP violation** is interpreted in the AU model as an asymmetry of the field S_Θ turns:
 $N_{\text{левых}} \neq N_{\text{правых}}$.
2. **Asymmetry parameter** $\eta = (N_{\text{левых}} - N_{\text{правых}})/(N_{\text{левых}} + N_{\text{правых}})$ determines the degree of CP violation.
3. **Weinberg angle** θ_W is interpreted as **a measure of archive asymmetry**: $\sin^2 \theta_W \leftrightarrow N_{\text{левых}}/(N_{\text{левых}} + N_{\text{правых}})$.
4. **Baryogenesis** is interpreted as **the accumulation of asymmetry** in the records of the early Universe during the electroweak phase transition.
5. **Observed baryon asymmetry** $\eta_B \approx 6 \times 10^{-10}$ corresponds to the archive asymmetry parameter $\eta \sim 10^{-9}$.
6. **Mainstream connection**: The AU model does not contradict experimental data on CP violation and baryogenesis, but offers an additional ontological language for their interpretation.
7. **Status**: All statements are speculative. Mainstream theories (Standard Model, electroweak baryogenesis) remain the default.

Part VI. Radiation

Chapter 15. Electromagnetic Radiation

In previous chapters, we described how a field S_Θ generates localized modes (fermions), correlations between them (interactions), and bound structures (nuclei, atoms). Now we turn to **radiation** —the process by which energy is transferred from one mode to another without transferring the localized structures themselves.

In the Standard Model, electromagnetic radiation is described by quantum electrodynamics (QED) as a flow of photons—quanta of the gauge field $U(1)$. In the AU ontology, electromagnetic radiation is hypothetically interpreted as **a propagating perturbation of the field gradient** S_Θ : the photon corresponds to a massless gradient wave $\partial_\mu S_\Theta$, and Maxwell's equations emerge from the dynamics of this field.

15.1 Propagating gradient perturbation: $\square A_\mu = \mu_0 J_\mu$

15.1.1 Equation of motion of a photon in the AU model

In the AU model, a photon is interpreted as a **propagating perturbation of** the field gradient S_Θ . The equation of photon motion emerges from the dynamics S_Θ :

$$\square A_\mu = \mu_0 J_\mu$$

Where:

- A_μ — vector potential associated with the gradient S_Θ : $A_\mu \leftrightarrow \partial_\mu S_\Theta$,
- J_μ — current associated with the motion of charged modes,
- μ_0 — magnetic constant.

Physical interpretation: A photon is a field gradient wave S_Θ propagating through spacetime. The source of this wave is the motion of charged modes (current J_μ).

Mainstream connection: The equation $\square A_\mu = \mu_0 J_\mu$ is the classical Maxwell equation for vector potential. The AU model proposes a dynamical derivation S_Θ .

Status: Speculative interpretation.

15.1.2 Connection with Maxwell's equations

From the equation for A_μ follow Maxwell's equations for field strengths:

$$E = -\nabla\phi - \frac{\partial A}{\partial t}, \quad B = \nabla \times A$$

In the AU model, the intensities are related to the field derivatives S_Θ :

$$F_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \partial_\nu \partial_\mu S_\Theta$$

Physical interpretation: Electric and magnetic fields are a "twist" of the field gradient S_Θ . Maxwell's equations describe the dynamics of this twist.

Mainstream connection: Maxwell's equations are the classical foundation of electrodynamics. The AU model offers an interpretation in terms of second derivatives S_Θ .

Status: Speculative interpretation.

15.1.3 Wave equation and the speed of light

In the absence of sources ($J_\mu = 0$) the equation for A_μ takes the form of a wave equation:

$$\square A_\mu = 0$$

The solutions to this equation are plane waves propagating at the speed of light c :

$$A_\mu(x, t) = \epsilon_\mu e^{i(kx - \omega t)}, \quad \omega = c |k|$$

Physical interpretation: The speed of light c is determined by the properties of the field S_θ : $c = \sqrt{1/(\epsilon_0 \mu_0)}$, where ϵ_0 and μ_0 are the electric and magnetic constants, which in the AU model are related to the archive parameters.

Mainstream connection: The speed of light is a fundamental constant measured with high precision ($c = 299\,792\,458\text{m/s}$). The AU model offers an interpretation: c as the speed of propagation of gradient waves in the archive.

Status: Speculative interpretation.

15.2 Photon as a quantum of a gradient wave

15.2.1 Field quantization A_μ

In QED, the field A_μ is quantized, and its quanta are photons. In the AU model, quantization emerges from the discreteness of the field modes S_θ :

$$A_\mu(x) = \sum_k (a_k \epsilon_\mu(k) e^{ikx} + a_k^\dagger \epsilon_\mu^*(k) e^{-ikx})$$

where a_k and $a_k^\dagger$ are the photon creation and annihilation operators.

Physical interpretation: A photon is a quantum of a gradient wave corresponding to the excitation of a certain field mode S_θ .

Mainstream connection: Quantization of the electromagnetic field is the basis of QED. The AU model offers a discrete-mode interpretation S_θ .

Status: Speculative interpretation.

15.2.2 Photon energy and momentum

The energy and momentum of a photon are determined by its frequency and wave vector:

$$E = \hbar \omega, \quad p = \hbar k$$

In the AU model, these quantities are related to the gradient wave parameters:

$$E \leftrightarrow \hbar \frac{\partial(\nabla S_\theta)}{\partial t}, \quad p \leftrightarrow \hbar \nabla(\nabla S_\theta)$$

Physical interpretation: The energy and momentum of a photon are properties of a gradient wave related to the rate of change of the gradient.

Mainstream connection: The de Broglie relations ($E = \hbar\omega$, $p = \hbar k$) are the foundation of quantum mechanics. The AU model offers a dynamic interpretation S_θ .

Status: Speculative interpretation.

15.2.3 Photon masslessness

The photon is massless (within experimental accuracy: $m_\gamma < 10^{-18}\text{eV}$). In the AU model, this is explained **by the absence of "entropic charge"** in the gradient wave:

$$m_\gamma = 0 \Leftrightarrow Q_{\text{ent}}^{(\gamma)} = 0$$

Physical interpretation: The photon is not "bound" to the condensate S_θ because its mode has no internal twist. Unlike the $W^\pm$ and Z^0 (twisted modes), the photon is an untwisted wave.

Mainstream connection: The masslessness of the photon has been confirmed experimentally. The AU model offers an interpretation based on the absence of entropic charge.

Status: Speculative interpretation.

15.3 Frequency and polarization in terms of S_θ

15.3.1 Frequency as the rate of change of gradient

In the AU model, the photon frequency ω is interpreted as **the rate of change of** the field gradient S_θ :

$$\omega \leftrightarrow \frac{\partial}{\partial t}(\nabla S_\theta)$$

Physical interpretation: The faster the field gradient changes S_θ , the higher the photon frequency. This corresponds to the intuitive idea: high-frequency photons (gamma quanta) are associated with rapid field changes.

Mainstream Connection: Photon frequency is a measurable quantity. The AU model offers a dynamic interpretation S_θ .

Status: Speculative interpretation.

15.3.2 Polarization as gradient orientation

In the AU model, photon polarization is interpreted as **the orientation of the gradient** ∇S_θ in a plane perpendicular to the direction of propagation:

$$e \leftrightarrow \frac{\nabla S_{\theta}}{|\nabla S_{\theta}|}$$

Physical interpretation: Polarization is a geometric characteristic of a gradient wave. Two polarization states correspond to two independent gradient orientations.

Mainstream connection: Photon polarization is an experimentally confirmed fact (the Compton effect, polarization filters, quantum cryptography). The AU model offers a geometric interpretation.

Status: Speculative interpretation.

15.3.3 Polarization Entanglement

In quantum mechanics, the polarizations of two photons can be entangled (for example, in a Bell state):

$$|\Psi_{\text{ent}}\rangle = \frac{1}{\sqrt{2}}(|H_1V_2\rangle - |V_1H_2\rangle)$$

In the AU model, this is interpreted as **a non-local correlation** between the orientations of the gradients of the two waves:

$$\langle \nabla S_{\theta}^{(1)} \cdot \nabla S_{\theta}^{(2)} \rangle \neq 0$$

Physical interpretation: Polarization entanglement is a consequence of nonlocal correlations in the archive. The orientations of the gradients of two photons are correlated through the kernel $K(x, y)$.

Mainstream connection: Polarization entanglement is an experimentally confirmed phenomenon (Aspect experiments, 1982; quantum cryptography). The AU model offers an interpretation through a nonlocal core.

Status: Speculative interpretation.

15.3.4 Radiation spectrum

The electromagnetic spectrum covers a vast range of frequencies: from radio waves ($\sim 10^3$ Hz) to gamma rays ($\sim 10^{20}$ Hz). In the AU model, the spectrum is interpreted as **a distribution of the rates of change of the field gradient S_{θ}** :

$$\frac{dN}{d\omega} \leftrightarrow \text{распределение } \frac{\partial}{\partial t}(\nabla S_{\theta})$$

Physical interpretation: Different frequencies correspond to different rates of gradient change. Low frequencies mean slow changes, high frequencies mean fast changes.

Mainstream connection: The electromagnetic spectrum has been studied in all ranges. The AU model offers a dynamic interpretation S_Θ .

Status: Speculative interpretation.

15.4 Connection with the Mainstream

15.4.1 Quantum Electrodynamics (QED)

QED is the most accurately tested theory in physics. It describes:

- Interaction of photons with charged particles,
- Lamb shift,
- Anomalous magnetic moment of the electron ($g - 2$),
- Compton scattering,
- Birth of couples.

The accuracy of QED predictions reaches 10^{-12} [for example, for $g - 2$ the electron]. The AU model does not contradict QED, but offers an additional ontological language: the photon as a gradient wave, Maxwell's equations as a consequence of the dynamics S_Θ .

15.4.2 Experimental confirmation

Electromagnetic radiation has been confirmed by countless experiments:

- Hertz's experiment (1887) - discovery of electromagnetic waves,
- Lebedev's experiment (1899) - light pressure,
- Photoelectric effect (Einstein, 1905),
- Compton scattering (1923),
- QED precision tests ($g - 2$, Lamb shift),
- Quantum cryptography (BB84, E91).

The AU model does not contradict these data, but offers a topological interpretation of them.

15.4.3 Open questions

Despite the successes of QED, open questions remain:

- Why is a photon massless?
- Why is the speed of light constant?
- What is the nature of quantum polarization entanglement?
- How to relate electromagnetic radiation to gravitational radiation?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

15.5 Chapter 15 Summary

1. **Electromagnetic radiation** in the AU model is interpreted as a **propagating perturbation of the field gradient** S_Θ : $\square A_\mu = \mu_0 J_\mu$, where $A_\mu \leftrightarrow \partial_\mu S_\Theta$.
2. **Maxwell's equations** emerge from field dynamics S_Θ . Field strengths are related to second derivatives S_Θ .
3. **The speed of light** c is determined by the archive properties: $c = \sqrt{1/(\epsilon_0 \mu_0)}$.
4. **A photon** is a quantum of a gradient wave. Its energy and momentum are related to its frequency and wave vector: $E = \hbar \omega$, $p = \hbar k$.
5. **The masslessness of the photon** is explained by the absence of “entropic charge” in the gradient wave.
6. **Frequency** is interpreted as the rate of change of the gradient, **polarization** as the orientation of the gradient. **Polarization entanglement** is a nonlocal correlation through the kernel $K(x, y)$.
7. **Mainstream connection**: The AU model does not contradict QED and experimental data, but offers an additional ontological language for interpreting electromagnetic radiation.
8. **Status**: All statements are speculative. Mainstream theories (QED, Maxwell's equations) remain fundamental.

Chapter 16. Gravitational Waves

In the previous chapter, we examined electromagnetic radiation as a propagating perturbation of the field gradient S_Θ . Now we turn to **gravitational waves** —ripples in spacetime predicted by general relativity and experimentally confirmed in 2015.

In general relativity, gravitational waves are described as metric perturbations $h_{\mu\nu}$ propagating at the speed of light. In the AU ontology, gravitational waves are hypothetically interpreted as **propagating perturbations of the metric** generated by the dynamics of the field S_Θ : the graviton corresponds to the second derivative S_Θ , and the wave equation emerges from the variation of the action with respect to the metric.

16.1 Metric perturbations: $\square h_{\mu\nu} = 0$

16.1.1 Definition of gravitational waves in the AU model

In the AU model, gravitational waves are interpreted as **propagating perturbations of the metric** generated by the dynamics of the field S_Θ :

$$g_{\mu\nu}(x) = \eta_{\mu\nu} + h_{\mu\nu}(x)$$

where $h_{\mu\nu}$ is a small perturbation associated with the second derivative S_Θ :

$$h_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta$$

Physical interpretation: A gravitational wave is a "ripple" in the metric that occurs when the field gradient changes S_Θ . Unlike an electromagnetic wave (a first-order gradient perturbation), a gravitational wave corresponds to a second-order perturbation—a change in the gradient itself.

Mainstream connection: In general relativity, gravitational waves are described as solutions of linearized Einstein equations. The AU model offers an interpretation in terms of second derivatives S_Θ .

Status: Hypothetical interpretation.

16.1.2 Wave equation for the graviton

In the linear approximation, the equation of motion of the graviton has the form:

$$\square h_{\mu\nu} = 0$$

In the AU model this equation emerges from the dynamics S_Θ :

$$\square(\partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta) = 0$$

Physical interpretation: The equation of motion of the graviton is a consequence of the linearity of the metric perturbation in the limit of small field fluctuations S_Θ .

Mainstream connection: The wave equation for the graviton is the classical basis of general relativity. The AU model proposes its derivation from dynamics S_Θ .

Status: Hypothetical interpretation.

16.1.3 Gauge invariance of gravitational waves

In general relativity, gravitational waves have gauge invariance: physical observables do not change under coordinate transformations:

$$h_{\mu\nu} \rightarrow h_{\mu\nu} + \partial_\mu \xi_\nu + \partial_\nu \xi_\mu$$

In the AU model, this is interpreted as **freedom of choice of coordinates** in the space of archive configurations:

$$S_{\Theta} \rightarrow S_{\Theta} + \xi_{\mu} x^{\mu}$$

Physical interpretation: Gauge invariance of gravitational waves is a consequence of the freedom of choice of coordinates in the description of the field S_{Θ} .

Mainstream connection: Gauge invariance is a key principle of general relativity. The AU model offers an interpretation through the freedom to choose coordinates in the archive.

Status: Hypothetical interpretation.

16.2 Connection with dynamics S_{Θ}

16.2.1 Source of gravitational waves

In general relativity, the source of gravitational waves is **the energy-momentum tensor** $T_{\mu\nu}$ with a non-zero quadrupole moment. In the AU model, the source is **the dynamics of** the field gradient S_{Θ} :

$$\square h_{\mu\nu} = \frac{16\pi G}{c^4} T_{\mu\nu}^{(\text{AU})}$$

Where:

$$T_{\mu\nu}^{(\text{AU})} = \partial_{\mu} S_{\Theta} \partial_{\nu} S_{\Theta} - \frac{1}{2} \eta_{\mu\nu} \partial_{\alpha} S_{\Theta} \partial^{\alpha} S_{\Theta}$$

Physical interpretation: Gravitational waves are emitted when the field gradient accelerates S_{Θ} . For example, merging black holes creates a rapidly changing gradient, leading to the emission of gravitational waves.

Mainstream connection: In general relativity, gravitational waves are emitted by quadrupole motion of masses. The AU model offers a dynamical interpretation S_{Θ} .

Status: Hypothetical interpretation.

16.2.2 Quadrupole radiation

In general relativity, the power of gravitational radiation is determined by the quadrupole formula:

$$P_{\text{grav}} = \frac{32}{5} \frac{G}{c^5} \left(\frac{d^3 Q_{ij}}{dt^3} \right)^2$$

where Q_{ij} is the quadrupole moment of the mass.

In the AU model, this formula emerges from the dynamics S_Θ :

$$P_{\text{grav}} \propto \left(\frac{\partial^3}{\partial t^3} \int S_\Theta(x) x_i x_j d^3x \right)^2$$

Physical interpretation: The power of gravitational radiation is a consequence of the change in the quadrupole moment of the gradient S_Θ .

Mainstream connection: The quadrupole formula has been confirmed by gravitational wave observations (e.g., GW150914—the merger of two black holes). The AU model offers an interpretation through archive dynamics.

Status: Hypothetical interpretation.

16.2.3 Merging black holes as a source of gravitational waves

Black hole mergers are the brightest source of gravitational waves observed by LIGO/Virgo. In the AU model, this is interpreted as **a rapid change in the gradient S_Θ** during the merger:

$$\Delta(\nabla S_\Theta) \neq 0 \Rightarrow \text{излучение гравитационных волн}$$

Physical interpretation: When black holes merge, the field gradient S_Θ changes dramatically, leading to the emission of gravitational waves. The signal shape (chirp) reflects the gradient's dynamics.

Mainstream connection: Observations of black hole mergers (GW150914, GW170817, and others) confirm general relativity with high precision. The AU model does not contradict these data, but offers additional language.

Status: Hypothetical interpretation.

16.3 Experimental confirmation

16.3.1 Discovery of gravitational waves

Gravitational waves were first detected by LIGO in 2015 (announced in 2016). The event, GW150914, was the merger of two black holes ~ 36 with ~ 29 solar masses. 2017 Nobel Prize (Weiss, Barish, Thorne).

Since then, dozens of events have been recorded:

- Black hole mergers (LIGO/Virgo),
- Neutron star merger (GW170817),

- Possible black hole-neutron star mergers (GW200115).

Mainstream connection: Observations of gravitational waves are a triumph for general relativity. The AU model is consistent with these data.

Status: Empirical fact.

16.3.2 Speed of gravitational waves

Observation of GW170817 (a neutron star merger) allowed us to measure the speed of gravitational waves:

$$|v_{\text{grav}} - c|/c < 10^{-15}$$

This confirms that gravitational waves travel at the speed of light, as predicted by General Relativity.

In the AU model, this is explained by the fact that the graviton is massless (like the photon), and its speed is determined by the properties of the archive.

Mainstream connection: Measuring the speed of gravitational waves is a key test of general relativity. The AU model offers an interpretation based on the masslessness of the graviton.

Status: Hypothetical interpretation.

16.3.3 Polarization of gravitational waves

In general relativity, gravitational waves have two tensor polarizations (plus and cross). Alternative theories of gravity may have additional polarizations (scalar and vector).

LIGO/Virgo observations so far limit additional polarizations, but do not exclude them completely.

In the AU model, gravitational waves have a tensor polarization corresponding to the second derivative S_{θ} . Possible scalar modes can arise with a non-zero trace $h_{\mu\nu}$.

Mainstream connection: Gravitational wave polarization is an active area of research. The AU model offers a mode interpretation S_{θ} .

Status: Hypothetical interpretation.

16.4 Connection with the Mainstream

16.4.1 General Theory of Relativity

General relativity describes gravity as a curvature of spacetime. Gravitational waves are a prediction of general relativity, confirmed experimentally. The AU model does not contradict general relativity, but it offers an additional ontological language: the metric as a functional of S_{θ} .

16.4.2 Quantum gravity

The problem of quantum gravity is one of the central problems in modern physics. The graviton—the quantum of the gravitational field—has not yet been detected. The AU model offers an interpretation: the graviton is a quantum of metric perturbation, corresponding to the second derivative S_Θ .

Mainstream connection: In loop quantum gravity and string theory, the graviton is also described as a spin-2 field quantum. The AU model offers an alternative interpretation.

Status: Hypothetical interpretation.

16.4.3 Gravitational-wave astronomy

Gravitational-wave astronomy is a new window onto the Universe. LIGO/Virgo observations allow us to study:

- Mergers of black holes and neutron stars,
- Testing of general relativity in strong fields,
- Measuring the Hubble constant,
- The nature of dark matter and dark energy.

The AU model does not contradict these data, but offers an additional language for interpreting them.

16.4.4 Open questions

Despite the successes, open questions remain:

- How to quantize gravity?
- Are there additional polarizations of gravitational waves?
- What is the nature of dark matter and dark energy?
- How do gravitational waves relate to electromagnetic radiation?

The AU model offers hypothetical answers to these questions by relating them to field dynamics S_Θ .

16.5 Chapter 16 Summary

1. **Gravitational waves** in the AU model are interpreted as **propagating perturbations of the metric** generated by the dynamics of the field S_Θ : $h_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta$.
2. **Wave equation** for the graviton: $\square h_{\mu\nu} = 0$ emerge from dynamics S_Θ .
3. **Gauge invariance** of gravitational waves is interpreted as freedom of choice of coordinates in the space of archive configurations.

4. **The source of gravitational waves** is gradient dynamics S_Θ . Quadrupole radiation emerges from changes in the gradient's quadrupole moment.
5. **Experimental confirmations:** LIGO/Virgo observations (GW150914, GW170817, etc.) confirm general relativity. The AU model is consistent with these data.
6. **The speed of gravitational waves** is equal to the speed of light ($|v_{\text{grav}} - c|/c < 10^{-15}$), which is explained by the masslessness of the graviton.
7. **Mainstream connection:** The AU model does not contradict general relativity and gravitational wave astronomy, but offers an additional ontological language for interpreting gravitational waves.
8. **Status:** All statements are hypothetical. Mainstream theories (general relativity, quantum gravity) remain the default.

Part VII. Dark Sector

Chapter 17. Dark Matter

In previous chapters, we described how the field S_Θ generates observable matter (fermions, bosons), interactions, and structures. However, observable matter accounts for only about 5% of the universe's energy budget. About 27% is **dark matter** —an invisible substance that manifests itself only through gravitational interactions.

In the Standard Model and Λ CDM, dark matter is described as hypothetical particles (WIMPs, axions, sterile neutrinos) that are not part of the Standard Model. In the AU ontology, dark matter is hypothetically interpreted as **unmanifested** field S_Θ **modes** —configurations with a zero matrix element of interaction with the electromagnetic field.

17.1 Unmanifested modes with zero EM charge

17.1.1 Definition of dark matter in the AU model

In the AU model, dark matter is interpreted as **unmanifested** field modes S_Θ —localized configurations that do not interact with the electromagnetic field:

$$\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$$

where A_μ is the vector potential of the electromagnetic field.

Physical interpretation: Dark matter is a mode that does not "glow" (emit or absorb light) because its topological structure is unrelated to the gradient S_Θ responsible for electromagnetic interaction. It interacts only gravitationally—through the shared gradient of the metric.

Mainstream connection: The Standard Model also describes dark matter as particles that do not interact electromagnetically. The AU model offers a topological interpretation: unmanifest modes.

Status: Speculative interpretation.

17.1.2 Gravitational interaction of dark matter

Although dark matter doesn't interact with the electromagnetic field, it does participate in gravitational interactions. In the AU model, this is explained by the fact that all modes—including unmanifested ones—contribute to the overall field gradient S_Θ :

$$\nabla S_\Theta^{\text{total}} = \nabla S_\Theta^{\text{видимая}} + \nabla S_\Theta^{\text{тёмная}}$$

Physical interpretation: Dark matter "feels" gravity because it contributes to the overall gradient of the archive. But it doesn't "glow" because its modes are not coupled to the electromagnetic gradient.

Mainstream connection: In the Λ CDM, dark matter interacts gravitationally but not electromagnetically. The AU model offers an interpretation through its contribution to the overall gradient S_Θ .

Status: Speculative interpretation.

17.1.3 Topology of latent modes

In the AU model, the latent modes are characterized **by a zero electromagnetic topological invariant**:

$$Q_{\text{em}}^{(\text{DM})} = \frac{1}{2\pi} \oint_{\partial\Omega_{\text{DM}}} \nabla S_\Theta \cdot dl = 0$$

Physical interpretation: Dark matter is a mode whose gradient "loop" is closed in such a way that it does not generate electromagnetic charge. They may have a non-zero "gravitational charge" (a contribution to the metric), but zero electromagnetic charge.

Mainstream connection: Some dark matter models (such as axions) also postulate zero electromagnetic charge. The AU model offers a topological interpretation.

Status: Speculative interpretation.

17.2 Candidates: Axions, WIMPs, Sterile Neutrinos

17.2.1 Axions

Axions are hypothetical particles introduced to solve the problem of strong CP violation in quantum chromodynamics (Peccei & Quinn, 1977). They have a small mass ($\sim 10^{-6}$ – 10^{-3} eV) and interact weakly with ordinary matter.

In the AU model, axions are interpreted as **unmanifested modes with low “entropic mass”**:

$$m_{\text{axion}} \ll v$$

Physical interpretation: Axions are modes weakly coupled to the condensate S_Θ . They interact almost entirely with visible matter, but contribute to the archive gradient.

Mainstream connection: Axions are one of the most popular candidates for dark matter. Experiments searching for them (ADMX, CAST, IAXO) are actively underway.

Status: Speculative interpretation.

17.2.2 WIMP (Weakly Interacting Massive Particles)

WIMPs are hypothetical particles with a mass ~ 10 of 1000 GeV that interact via the weak force. They are a classic candidate for dark matter (the SUSY model, extra dimensions).

In the AU model, WIMPs are interpreted as **unmanifested modes with a large “entropic mass”**:

$$m_{\text{WIMP}} \sim v$$

Physical interpretation: WIMPs are modes strongly coupled to the condensate S_Θ but do not interact with the electromagnetic field. They are “heavy” (contributing heavily to the gradient) but “dark” (not luminous).

Mainstream connection: WIMPs are one of the leading candidates for dark matter. Direct detection experiments (XENONnT, LZ, PandaX) are actively underway, but have not yet detected a signal.

Status: Speculative interpretation.

17.2.3 Sterile neutrinos

Sterile neutrinos are hypothetical particles that do not participate in the weak interaction (unlike active neutrinos). They may have masses in the keV–GeV range and constitute dark matter (the ν MSM model).

In the AU model, sterile neutrinos are interpreted as **unmanifested modes with zero weak charge**:

$$\langle \Theta_{\text{sterile}} | W_\mu | \Theta_{\text{sterile}} \rangle = 0$$

Physical interpretation: Sterile neutrinos are modes that do not interact with either the electromagnetic field or the weak interaction. They "see" only gravity.

Mainstream connection: Sterile neutrinos are candidates for dark matter and an explanation for the masses of active neutrinos (the seesaw mechanism). Experiments searching for them (KATRIN, IceCube) are ongoing.

Status: Speculative interpretation.

17.2.4 Comparison table of candidates

Candidate	Weight	Interaction	AU interpretation
Axions	10^{-6} – 10^{-3} eV	Weak with EM	Low entropy mass unmanifested mode
WIMP	10 – 1000 GeV	Weak	Unmanifested mode with high entropic mass
Sterile neutrinos	keV–GeV	Only gravity	Unmanifested mode with zero weak charge

Connection to the Mainstream: All three candidates are actively being explored in experiments. The AU model doesn't favor any of them, but offers a unifying language: unmanifested modes.

Status: Speculative interpretation.

17.3 Dark matter and the structure of the Universe

17.3.1 The role of dark matter in structure formation

In Λ CDM, dark matter plays a key role in shaping the large-scale structure of the Universe: it provides the gravitational framework within which galaxies and clusters form.

In the AU model this is interpreted as **the contribution of unmanifested modes to the overall gradient S_θ** :

$$\nabla S_\theta^{\text{total}} = \nabla S_\theta^{\text{видимая}} + \nabla S_\theta^{\text{тёмная}}$$

Physical interpretation: Dark matter creates an additional archive gradient that accelerates structure formation. Without it, the gravitational potential would be insufficient for galaxies to form.

Mainstream connection: Observations of the cosmic microwave background (Planck) and large-scale structure (SDSS, DES) confirm the role of dark matter in structure formation.

Status: Speculative interpretation.

17.3.2 Dark matter halos around galaxies

Observations of galaxy rotation curves show that they are surrounded **by dark matter halos** — extended regions dominated by dark matter. In the AU model, these are interpreted as **regions with a high density of latent modes**:

$$\rho_{\text{DM}}(r) \sim \frac{1}{r^2}$$

Physical interpretation: Dark matter halos are regions where latent modes form stable configurations that create an additional gradient S_θ .

Mainstream connection: Galaxy rotation curves (Rubin, 1970s) are key evidence for the existence of dark matter. The AU model offers an interpretation through unmanifested modes.

Status: Speculative interpretation.

17.3.3 Cosmological constraints

Observations of the cosmic microwave background (Planck) and large-scale structure (DES, Euclid) impose strong constraints on the properties of dark matter:

- Fraction of dark matter: $\Omega_{\text{DM}} h^2 \approx 0.12$,
- Lack of strong interaction with the EM field,
- Stability on cosmological times.

The AU model does not contradict these constraints, but provides an additional language for interpreting them.

Status: Empirical limitations.

17.4 Connection with the Mainstream

17.4.1 The Dark Matter Problem

The problem of dark matter is one of the central issues in modern physics and cosmology. Despite decades of research, the nature of dark matter remains unknown. Various hypotheses exist:

- **Particles:** WIMPs, axions, sterile neutrinos,
- **Modified gravity:** MOND, TeVeS,

- **Primordial black holes.**

The AU model offers an alternative approach: dark matter as unmanifested field modes S_Θ . This does not replace existing hypotheses, but it does offer an additional ontological language.

17.4.2 Experimental searches

Experiments to search for dark matter are actively underway:

- **Direct detection:** XENONnT, LZ, PandaX (WIMP search),
- **Indirect searches:** Fermi-LAT, HESS (search for annihilation products),
- **Collider searches:** LHC (search for new particles),
- **Axion experiments:** ADMX, CAST, IAXO.

No signals have been detected so far, which imposes limitations on possible models. The AU model does not contradict these limitations.

17.4.3 Open questions

Despite active searches, open questions remain:

- What is dark matter?
- Why doesn't it interact with the EM field?
- What is its mass and spin?
- Are there multiple types of dark matter?

The AU model offers hypothetical answers to these questions by relating them to the field topology S_Θ .

17.5 Chapter 17 Summary

1. **Dark matter** in the AU model is interpreted as **unmanifested** field modes S_Θ -configurations with a zero matrix element of interaction with the EM field:

$$\langle \Theta_{DM} | A_\mu | \Theta_{DM} \rangle = 0.$$
2. **The gravitational interaction** of dark matter is explained by its contribution to the overall field gradient S_Θ .
3. **Candidates:** axions (low entropy mass), WIMPs (high entropy mass), sterile neutrinos (zero weak charge) - all interpreted as different types of latent modes.
4. **Role in structure formation:** Dark matter creates an additional archive gradient, accelerating the formation of galaxies and clusters.
5. **Dark matter halos** are regions with a high density of latent modes.

6. **Mainstream connection:** The AU model is consistent with observational data (rotation curves, cosmic microwave background, large-scale structure) and does not favor any of the candidates, but offers a common ontological language.
7. **Status:** All statements are speculative. Mainstream theories (Λ CDM, WIMPs, axions, sterile neutrinos) remain the default.

Chapter 18. Dark Energy

In the previous chapter, we examined dark matter as unmanifested field modes S_Θ . Now we turn to the second component of the dark sector— **dark energy**, which 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 described as a cosmological constant Λ —a homogeneous vacuum energy with the equation of state $w = -1$. However, the DESI 2025 data point to a possible evolution of dark energy ($w(a) \neq -1$), which challenges the simple model Λ . In the AU ontology, dark energy is hypothetically interpreted as **the global entropy of the archive**. $S_\Theta^{r\eta o\delta}$, which generates the effective cosmological constant Λ_{eff} .

18.1 Global Entropy of the Archive as a Source of Dark Energy

18.1.1 Definition Λ_{eff} through $S_\Theta^{r\eta o\delta}$

In the AU model, the effective cosmological constant Λ_{eff} is determined by the global entropy of the archive:

$$\Lambda_{\text{eff}} = \Lambda_0 + \gamma \cdot S_\Theta^{r\eta o\delta} + \delta \cdot \left(\frac{dS_\Theta^{r\eta o\delta}}{dt} \right)^2$$

Where:

- Λ_0 — the “basic” cosmological constant (possibly related to the initial conditions),
- γ, δ — coupling constants,
- $S_\Theta^{r\eta o\delta}$ — global entropy of the archive,
- $dS_\Theta^{r\eta o\delta}/dt$ — the rate of entropy growth.

Physical interpretation: Dark energy is not "vacuum energy" in the usual sense, but a **manifestation of the increasing entropy of the archive**. The more records accumulate in the archive, the stronger the effective "repulsion," leading to an accelerated expansion of the Universe.

Connection to the Mainstream: In holographic models of dark energy (e.g., HDE—Holographic Dark Energy), the density of dark energy is also linked to the entropy of the horizon. The AU model proposes a specific form: $\Lambda_{\text{eff}} \propto S_{\Theta}^{\text{rno6}}$.

Status: Hypothetical interpretation.

18.1.2 Dark Energy Density

The density of dark energy ρ_{DE} is related to Λ_{eff} through Einstein's equation:

$$\rho_{\text{DE}} = \frac{\Lambda_{\text{eff}} c^2}{8\pi G}$$

In the AU model this gives:

$$\rho_{\text{DE}} = \frac{c^2}{8\pi G} \left(\Lambda_0 + \gamma \cdot S_{\Theta}^{\text{rno6}} + \delta \cdot \left(\frac{dS_{\Theta}^{\text{rno6}}}{dt} \right)^2 \right)$$

Physical interpretation: The density of dark energy increases with increasing global entropy of the archive. This explains why dark energy dominates the late universe: as the record accumulates, its density increases.

Mainstream connection: Planck and DESI observations provide $\Omega_{\text{DE}} \approx 0.68$. The AU model offers an interpretation: Ω_{DE} as a function of S_{Θ}^{rno6} .

Status: Hypothetical interpretation.

18.1.3 Entropic radiation and dark energy

In previous chapters, we introduced the concept of entropic radiation (Chapter 10). In the AU model, dark energy can be associated with entropic radiation:

$$\Lambda_{\text{eff}} \leftrightarrow P_{\text{entropy}} = \frac{G\lambda^2}{c^5} \left(\frac{dS_{\Theta}}{dt} \right)^2$$

Physical interpretation: Entropic radiation from massive objects (black holes, galaxies, stars) contributes to the global entropy of the archive, which in turn determines Λ_{eff} .

Mainstream connection: Work on entropic cosmology (Easson, Frampton, Smoot, 2011) also considers the connection between entropy and dark energy. The AU model offers a specific mechanism.

Status: Hypothetical interpretation.

18.2 Evolution of the equation of state $w(a)$

18.2.1 CPL Parameterization

In cosmology, the equation of state of dark energy $w = p/\rho$ is often parameterized in the Chevallier–Polarski–Linder (CPL) form:

$$w(a) = w_0 + w_a(1 - a)$$

where $a = 1/(1 + z)$ is the scale factor, w_0 is the modern value, w_a is the rate of evolution.

In Λ CDM: $w_0 = -1$, $w_a = 0$.

DESI 2025 (DR2) data indicate a preference for evolving dark energy:

- $w_0 \approx -0.99 \pm 0.05$,
- $w_a \approx -0.3 \pm 0.3$ (depending on the combination of data).

This means that $w(a)$ it may deviate by ~ 1 several percent.

Mainstream connection: DESI DR2 (2025) is a key result indicating the possible evolution of dark energy. The statistical significance of the deviation from Λ CDM reaches $2.5\text{--}4.2\sigma$ depending on the analysis.

Status: Empirical data.

18.2.2 AU interpretation: $w(a)$ as a function $S_\Theta(t)$

In the AU model, the equation of state $w(a)$ is determined by the dynamics of global entropy:

$$w(a) = -1 + \frac{\gamma}{\rho_{\text{DE}} c^2} \cdot \frac{dS_\Theta^{\text{rno6}}}{d \ln a}$$

Physical interpretation: The deviation w from -1 is related to the rate of growth of the archive's entropy. If $dS_\Theta^{\text{rno6}}/d \ln a \neq 0$, then $w \neq -1$.

Connection to the mainstream: Quintessence models $w(a)$ also evolve. The AU model offers a specific connection: $w(a)$ as a function $S_\Theta(t)$.

Status: Hypothetical interpretation.

18.2.3 Comparison with DESI 2025

DESI 2025 data indicate:

- $w_0 > -1$ (that is, dark energy can be “phantom” or “quintessence”),
- $w_a < 0$ (evolution towards more negative values).

In the AU model this corresponds to:

- $\gamma > 0$ (the growth of entropy increases Λ_{eff}),
- $dS_{\Theta}^{\text{rlog}}/d \ln a > 0$ (entropy increases over time).

Physical interpretation: The observed evolution of dark energy is a consequence of the increasing entropy of the archive. The more records, the stronger the effective repulsion.

Mainstream Relation: The AU model does not contradict the DESI data, but provides an additional language for interpreting them.

Status: Hypothetical interpretation.

18.2.4 Possible values w_0 and w_a

In the AU model, possible values of w_0 and w_a are determined by the parameters γ and δ :

$$w_0 \approx -1 + \frac{\gamma S_{\Theta}^{\text{rlog}}(t_0)}{\rho_{\text{DE}} c^2}$$

$$w_a \approx -\frac{\gamma}{\rho_{\text{DE}} c^2} \cdot \frac{dS_{\Theta}^{\text{rlog}}}{d \ln a}$$

Physical interpretation: The values of w_0 and w_a depend on the current entropy of the archive and the rate of its growth.

Connection to the mainstream: In quintessence models w_0 , and w_a are also linked to scalar field parameters. The AU model offers an alternative interpretation.

Status: Speculative interpretation.

18.3 Cosmological consequences

18.3.1 Accelerated expansion

The accelerated expansion of the Universe is described by the Friedmann equation:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p)$$

For dark energy, the $w < -1/3$ second term becomes positive, which leads to acceleration.

In the AU model, acceleration is associated with an increase in entropy:

$$\frac{\ddot{a}}{a} \propto \gamma \cdot \frac{dS_{\Theta}^{\text{rlog}}}{dt}$$

Physical interpretation: Accelerated expansion is a consequence of the archive's increasing entropy. The faster the entropy increases, the greater the acceleration.

Mainstream connection: The discovery of accelerating expansion (Riess and Perlmutter, 1998; Nobel Prize 2011) is a key fact in cosmology. The AU model offers a dynamical interpretation S_Θ .

Status: Hypothetical interpretation.

18.3.2 Influence on the formation of structures

Dark energy influences the formation of large-scale structure: it suppresses the growth of density fluctuations on large scales. In the AU model, this is interpreted as **a competition between the dark matter gradient and the increase in entropy**:

$$\nabla S_\Theta^{\text{total}} = \nabla S_\Theta^{\text{DM}} + \nabla S_\Theta^{\text{DE}}$$

Physical interpretation: Increasing entropy (dark energy) counteracts gravitational collapse (dark matter), suppressing structure formation on large scales.

Mainstream connection: Observations of large-scale structure (SDSS, DES, Euclid) confirm the suppression of structure growth by dark energy. The AU model offers an interpretation through competing gradients.

Status: Hypothetical interpretation.

18.3.3 The Future of the Universe

Depending on the nature of dark energy, various future scenarios are possible:

- **Eternal Acceleration (de Sitter):** $w = -1$, The universe is expanding exponentially.
- **Big Rip:** $w < -1$, the expansion accelerates, leading to the rupture of all structures.
- **Cyclic model:** $w > -1$, expansion is replaced by contraction.

In the AU model, the future is determined by the dynamics of S_Θ^{rno6} :

- If $dS_\Theta^{\text{rno6}}/dt \rightarrow 0$, That $\Lambda_{\text{eff}} \rightarrow \text{const}(\text{de Sitter})$.
- If $dS_\Theta^{\text{rno6}}/dt \rightarrow \infty$, then $\Lambda_{\text{eff}} \rightarrow \infty(\text{Big Rip})$.
- If S_Θ^{rno6} it reaches a maximum, a reversal is possible (cyclical pattern).

Mainstream Connection: Future scenarios for the Universe are actively discussed in cosmology. The AU model offers an interpretation through archive dynamics.

Status: Speculative interpretation.

18.4 Connection with the Mainstream

18.4.1 Λ CDM and the cosmological constant problem

Λ CDM is the standard cosmological model, which successfully describes:

- Relic radiation,
- Large-scale structure,
- Accelerated expansion,
- Nucleosynthesis.

However, the Λ CDM faces a **problem with the cosmological constant**: the observed value Λ is 120 orders of magnitude smaller than the naive estimate from quantum field theory. The AU model offers a possible solution: Λ_{eff} it is determined by the holographic entropy of the archive, which is "cut off" at the horizon.

Mainstream connection: The cosmological constant problem is one of the central problems in theoretical physics. Holographic models (HDE, Agegraphic Dark Energy) offer possible solutions.

Status: Hypothetical interpretation.

18.4.2 Quintessence and Modified Gravity

Alternatives to Λ CDM include:

- **Quintessence:** a dynamic scalar field with $w(a) \neq -1$,
- **Modified gravity:** $f(R)$, scalar-tensor theories,
- **Interacting dark energy:** the exchange of energy between dark matter and dark energy.

The AU model offers an alternative approach: dark energy as the global entropy of the archive. This does not replace existing models, but it does offer an additional ontological language.

Status: Hypothetical interpretation.

18.4.3 Experimental data

Key experiments studying dark energy:

- **Planck (2018):** Measuring the cosmic microwave background, constraints on Ω_{DE} ,
- **DESI (2024–2025):** spectroscopy of galaxies, an indication of evolution $w(a)$,
- **Euclid (2023+):** mapping large-scale structure,
- **JWST (2022+):** Observations of distant galaxies.

The AU model does not contradict these data, but offers an additional language for interpreting them.

Status: Empirical data.

18.4.4 Open questions

Despite active research, open questions remain:

- What is dark energy?

- Why $w \approx -1$?
- Does it evolve $w(a)$?
- What is the nature of the cosmological constant?

The AU model offers hypothetical answers to these questions by relating them to field dynamics S_Θ .

18.5 Chapter 18 Summary

1. **Dark energy** in the AU model is interpreted as **the global entropy of the archive** $S_\Theta^{r_{\text{no6}}}$, which generates the effective cosmological constant $\Lambda_{\text{eff}} = \Lambda_0 + \gamma S_\Theta^{r_{\text{no6}}} + \delta(dS_\Theta^{r_{\text{no6}}}/dt)^2$.
2. **The density of dark energy** increases with increasing global entropy, which explains the dominance of dark energy in the late Universe.
3. **Evolution of the equation of state** $w(a)$ is determined by the dynamics of $S_\Theta(t)$. The deviation w from -1 is associated with the rate of entropy growth.
4. **Comparison with DESI 2025:** the data indicate a possible evolution of dark energy ($w_0 > -1$, $w_a < 0$), which corresponds to an increase in the entropy of the archive.
5. **Cosmological consequences:** accelerated expansion, suppression of structure formation, possible future scenarios (de Sitter, Big Rip, cyclic model).
6. **The problem of the cosmological constant** may gain new insight through the holographic interpretation Λ_{eff} .
7. **Mainstream connection:** The AU model is consistent with Λ CDM, quintessence, and DESI data, but offers an additional ontological language for interpreting dark energy.
8. **Status:** All statements are hypothetical. Mainstream theories (Λ CDM, quintessence, modified gravity) remain the default.

Part VIII. Formalization and Verifiable Consequences

Chapter 19. Directions of Formalization

In previous chapters, we described a hypothetical chain of emergence: from the field S_Θ through constants, fermions, interactions, structures, radiation, to the dark sector. However, for this scheme to become more than just a conceptual framework, but a scientific program, **formalization** is necessary —the derivation of specific mathematical relationships linking the archive's parameters to observable quantities.

In this chapter, we formulate **formalization directions** —problems that need to be addressed to develop the AU model. All of these are hypothetical and represent a program for future research, not definitive results.

19.1 Derivation of fermion masses as eigenvalues of the operator $\hat{L}$

19.1.1 Problem statement

In the AU model, fermion masses are determined by the discrete spectrum of excitations of localized modes. The problem is **to derive the fermion masses as eigenvalues of the effective dynamics operator. $\hat{L}$.**

The operator $\hat{L}$ has the form:

$$\hat{L} = \omega_0^2 - \tilde{\mu}\Phi + \hat{K}$$

Where:

- ω_0^2 — natural frequency of the mode,
- $\tilde{\mu}$ — constant of connection with the field of consciousness Φ ,
- $\hat{K}$ — is an integral operator with kernel $K(x, y)$.

The eigenvalues λ_n determine the masses:

$$m_n = \sqrt{\lambda_n} \cdot \frac{\hbar}{c}$$

19.1.2 What you need to get

Necessary:

1. Specify a specific shape of the kernel $K(x, y)$,
2. Solve the spectral problem $\hat{L}\Theta^{(n)} = \lambda_n\Theta^{(n)}$,
3. Compare the obtained spectrum with the observed fermion masses.

Expected result: A discrete spectrum λ_n corresponding to three generations of fermions with the observed mass hierarchy.

Status: Hypothetical problem. In the mainstream, fermion masses are free parameters of the Standard Model.

19.2 CKM matrix as a matrix of overlap integrals

19.2.1 Problem statement

In the AU model, the CKM matrix is interpreted as a matrix of overlap integrals between quark modes:

$$V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$$

Problem: derive the CKM matrix from overlap integrals and show that its elements correspond to the observed values.

19.2.2 What you need to get

Necessary:

1. Specify an explicit form of modes $\Theta^{(i)}$ for three generations of quarks,
2. Calculate overlap integrals with kernel $K(x, y)$,
3. Show that $|V_{ij}| \sim \lambda^{|i-j|}$, where $\lambda \approx 0.22$ is the Wolfenstein parameter,
4. Check the unitarity of the matrix.

Expected result: A CKM matrix with an element hierarchy corresponding to the observed one.

Status: Hypothetical problem. In mainstream theory, the CKM matrix is measured experimentally but not derived from first principles.

19.3 Weinberg angle as an asymmetry parameter

19.3.1 Problem statement

In the AU model, the Weinberg angle θ_W is interpreted as a parameter of archive asymmetry:

$$\sin^2 \theta_W \leftrightarrow \frac{N_{\text{левых}}}{N_{\text{левых}} + N_{\text{правых}}}$$

The task is to derive the Weinberg angle from the archive asymmetry parameters and show that its value $\sin^2 \theta_W \approx 0.231$ corresponds to the observed one.

19.3.2 What you need to get

Necessary:

1. Link $N_{\text{левых}}$ and $N_{\text{правых}}$ with field parameters S_Θ ,
2. Show that $\sin^2 \theta_W \approx 0.231$,
3. Link θ_W to CP-violation parameter η .

Expected result: Formula expressed $\sin^2\theta_W$ through archive parameters.

Status: Hypothetical problem. In mainstream theory, the Weinberg angle is a free parameter of the Standard Model.

19.4 The Dark Matter Condition as a Zero Matrix Element

19.4.1 Problem statement

In the AU model, dark matter is interpreted as unmanifested modes with a zero matrix element of interaction with the EM field:

$$\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$$

The task is **to derive the non-manifestation condition** from the mode topology and show which field configurations S_Θ satisfy it.

19.4.2 What you need to get

Necessary:

1. Set a topological criterion for unmanifested modes,
2. Show that $\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$,
3. Connect the parameters of the latent modes with the observed density of dark matter ($\Omega_{\text{DM}} h^2 \approx 0.12$).

Expected result: A criterion that allows one to identify latent modes and estimate their contribution to dark matter.

Status: Hypothetical problem. Mainstream theory describes dark matter as particles (WIMPs, axions, sterile neutrinos).

19.5 Evolution $w(a)$ from Dynamics $S_\Theta(t)$

19.5.1 Problem statement

In the AU model, the equation of state of dark energy $w(a)$ is determined by the dynamics of global entropy:

$$w(a) = -1 + \frac{\gamma}{\rho_{\text{DE}} c^2} \cdot \frac{dS_\Theta^{\text{r106}}}{d \ln a}$$

Task: **to derive evolution** $w(a)$ from dynamics $S_\Theta(t)$ and compare with DESI 2025 data.

19.5.2 What you need to get

Necessary:

1. Set the growth model $S_{\theta}^{\text{rob}}(t)$,
2. Calculate $w(a)$,
3. Compare with observed values $w_0 \approx -0.99$, $w_a \approx -0.3$.

Expected result: Curve $w(a)$ consistent with DESI 2025 data.

Status: Hypothetical problem. In the mainstream $w(a)$ it is parameterized phenomenologically (CPL).

19.6 Reducing Confinement to the Cornell Potential

19.6.1 Problem statement

In the AU model, confinement is described through the behavior of a non-local core $K(x, y)$:

- $K(x, y) \rightarrow \text{const}$ for small $|x - y|$ (asymptotic freedom),
- $K(x, y) \sim |x - y|$ at large $|x - y|$ (confinement).

Task: **derive the Cornell potential:**

$$V(r) = -\frac{4\alpha_s}{3r} + \sigma r$$

from behavior $K(x, y)$.

19.6.2 What you need to get

Necessary:

1. Specify an explicit form $K(x, y)$,
2. Calculate the effective potential $V(r)$,
3. Show that it comes down to Cornell's potential,
4. Associate the parameter σ with the archive parameters.

Expected result: Derivation of the Cornell potential from the non-local kernel $K(x, y)$.

Status: Hypothetical problem. In QCD, the Cornell potential is derived from lattice calculations.

19.7 Derivation of the Schrödinger equation as an approximation

19.7.1 Problem statement

In the AU model, the atom is described as a standing coherent mode of the field S_Θ :

$$\left[-\frac{\hbar^2}{2m} \nabla^2 + V_{\text{AU}}(r) \right] \psi = E\psi$$

Problem: **derive the Schrödinger equation** as an approximation for modes S_Θ in the limit of small fluctuations.

19.7.2 What you need to get

Necessary:

1. Write the equation for the modes S_Θ ,
2. Show that in the limit of small fluctuations it reduces to the Schrödinger equation,
3. Express $V_{\text{AU}}(r)$ in terms of the kernel $K(x, y)$.

Expected result: Derivation of the Schrödinger equation from dynamics S_Θ .

Status: Hypothetical problem. In mainstream thought, the Schrödinger equation is postulated.

19.8 Emergence $F_{\mu\nu}$ from $\partial_\mu \partial_\nu S_\Theta$

19.8.1 Problem statement

In the AU model, the electromagnetic field strength $F_{\mu\nu}$ is interpreted as the antisymmetric part of the second derivative of the field S_Θ :

$$F_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \partial_\nu \partial_\mu S_\Theta$$

Problem: **derive Maxwell's equations** from dynamics S_Θ and show that $F_{\mu\nu}$ the equations satisfy:

$$\partial_\mu F^{\mu\nu} = \mu_0 J^\nu, \quad \partial_{[\mu} F_{\nu\rho]} = 0$$

19.8.2 What you need to get

Necessary:

1. Write the Lagrangian for S_Θ ,
2. Show that variation with respect to $A_\mu \leftrightarrow \partial_\mu S_\Theta$ gives Maxwell's equations,
3. Express the current J^ν in terms of the motion of charged modes.

Expected result: Derivation of Maxwell's equations from dynamics S_Θ .

Status: Hypothetical problem. In QED, Maxwell's equations are postulated.

19.9 General formalization program

All the listed tasks form a **general program for formalizing the AU model**:

1. **Specifying an explicit form of the kernel** $K(x, y)$ is the key element that determines all interactions.
2. **Solve spectral problems** for the operator $\hat{L}$ - for mass derivation and mixing.
3. **Derive effective potentials** for confinement, atoms, and nuclei.
4. **Link archive parameters with observed values** through calibration using experimental data.
5. **Verify predictions** by comparing them with data from DESI, LHC, LIGO, and others.

Status: Future research program. None of the tasks have been resolved yet.

19.10 Chapter 19 Summary

1. **Derivation of fermion masses** as eigenvalues of the operator $\hat{L} = \omega_0^2 - \tilde{\mu}\Phi + \hat{K}$.
2. **CKM matrix** as a matrix of overlap integrals $V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$.
3. **Weinberg angle** as a parameter of archive asymmetry: $\sin^2 \theta_W \leftrightarrow N_{\text{левых}} / (N_{\text{левых}} + N_{\text{правых}})$.
4. **The dark matter condition** is like a zero matrix element: $\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$.
5. **Evolution** $w(a)$ - from dynamics $S_\Theta(t)$: $w(a) = -1 + \gamma(\rho_{\text{DE}} c^2)^{-1} dS_\Theta^{\text{rno6}} / d \ln a$.
6. **Confinement** is a reduction to Cornell's potential through behavior $K(x, y)$.
7. **The Schrödinger equation** as an approximation for modes S_Θ in the limit of small fluctuations.
8. **Maxwell's equations** - emergence $F_{\mu\nu}$ from $\partial_\mu \partial_\nu S_\Theta$.
9. **General program**: define $K(x, y)$ and solve spectral problems, derive potentials, relate parameters to observed quantities, check predictions.
10. **Status**: All problems are hypothetical. Mainstream theories remain the default.

Chapter 20. Verifiable Consequences (Cautious and Speculative)

In the previous chapter, we formulated the directions for formalizing the AU model—the problems that must be solved to derive specific mathematical relationships. Now we turn to **testable consequences**—what could be observed or measured if the AU model were true.

All consequences are divided into two groups:

1. **Cautious (closer to verification)** – implications that can be verified in the coming years using existing or emerging technologies. They are formulated as narrow correlational questions and do not require the adoption of the entire AU ontology.
2. **Speculative (long-range)** – consequences that lie beyond the horizon of current technologies and require fundamentally new detectors or the achievement of technological thresholds. They are retained as a model horizon, but not as a near-term experimental program.

All consequences are **hypothetical**. None of them have been experimentally confirmed within the AU.

20.1 Cautious Investigations (Closer to Verification)

20.1.1 Correlations between entropy parameters and observable quantities

Formulation: If the AU model is correct, there should be correlations between the parameters that are associated in the model with the archive entropy ($\rho_{\text{записей}}$, ∇S_{Θ} , $\mathcal{C}$) and the observed quantities (spectra, masses, coupling constants).

How to check:

1. **Spectral correlations:** Search for correlations between spectral characteristics of objects (e.g. spectra of quasars, galaxies) and their entropic parameters (e.g. density of records estimated through baryon density).
2. **Correlations in LHC data:** Search for correlations between particle production parameters (cross sections, asymmetries) and entropic parameters (e.g. multiplicity estimated through the number of particles).
3. **Cosmological correlations:** Search for correlations between large-scale structure parameters (power spectrum, baryon acoustic oscillations) and entropic parameters (e.g. global entropy).

Expected Result: Detection of statistically significant correlations that are not explained by standard models.

Status: Cautious investigation. Requires analysis of existing data and development of methods for estimating entropy parameters.

Mainstream connection: In cosmology, correlations between various observational quantities already exist (for example, correlations between the halo mass and its concentration). The AU model offers an additional language for interpreting them.

20.1.2 Variations of Constants in the Early Universe

Formulation: If the AU model is correct, the fundamental constants (α , G , m_e) could have varied in the early Universe when the coherence of the archive was low.

How to check:

1. **Quasar Spectra:** Analysis of quasar spectra to detect deviations α from the present-day value. Current limitations: $\Delta\alpha/\alpha < 10^{-5}$.
2. **Primordial nucleosynthesis:** Comparison of primordial nucleosynthesis predictions with observed light element abundances to constrain variations G and other constants.
3. **CMB:** Analysis of Planck data to search for deviations in recombination that might be caused by variation α or m_e .

Expected outcome: Detection of deviations that are not explained by standard models, or establishment of more stringent constraints.

Status: Cautious conclusion. Existing data already impose limitations, but the AU model predicts possible deviations in the early universe.

Mainstream connection: Hypotheses about the variation of constants (Dirac, 1937; Webb et al., 1999) are actively discussed. The AU model proposes a specific mechanism: fluctuations S_Θ .

20.1.3 Anomalies in LIGO/Virgo data

Formulation: If the AU model is correct, gravity waves may exhibit anomalies related to the dynamics S_Θ (e.g., waveform deviations, additional polarizations).

How to check:

1. **Waveform analysis:** Search for deviations from GR predictions in the shape of gravitational wave signals (e.g., in phase, amplitude, attenuation).
2. **Search for additional polarizations:** Analysis of LIGO/Virgo data to search for scalar or vector polarizations predicted by some extensions of general relativity.
3. **Correlations with entropic parameters:** Search for correlations between parameters of gravitational wave events and entropic parameters (e.g. black hole masses, distances).

Expected result: Detection of anomalies that are not explained by GR, or establishment of more stringent constraints.

Status: Cautious investigation. LIGO/Virgo data continues to accumulate, and analysis may reveal anomalies.

Mainstream Connection: Searching for deviations from general relativity in gravitational wave data is an active area of research. The AU model offers an additional language for interpretation.

20.1.4 Anomalies in DESI data

Formulation: If the AU model is correct, the evolution of dark energy $w(a)$ should correlate with the dynamics of $S_\Theta(t)$. The DESI 2025 data indicate a possible evolution of $w(a)$.

How to check:

1. **DESI data analysis:** Comparison of observed $w(a)$ and AU model predictions for different growth models $S_\Theta^{r_{\text{nog}}}(t)$.
2. **Data Combination:** Joint analysis of DESI, Planck, SN Ia and other data to refine parameters w_0 and w_a .
3. **Search for correlations:** Search for correlations between $w(a)$ and other entropic parameters (e.g. dark matter density, baryon density).

Expected result: Refinement of parameters w_0 and w_a their comparison with the predictions of the AU model.

Status: Cautious investigation. DESI 2025 data already point to possible evolution $w(a)$, and the AU model offers a concrete interpretation.

Mainstream connection: DESI DR2 (2025) is a key result indicating the possible evolution of dark energy. The AU model does not contradict these data, but offers additional language.

20.1.5 Anomalies in CP Violation Data

Formulation: If the AU model is correct, CP violation should correlate with the asymmetry of the turns in the archive. This could manifest itself as anomalies in the decays of K, B, and D mesons.

How to check:

1. **LHCb and Belle II data analysis:** Searching for deviations from the Standard Model predictions in CP asymmetries.
2. **Correlation search:** Search for correlations between CP asymmetries and other entropic parameters (e.g. multiplicity, energy).
3. **Comparison with AU model predictions:** Comparison of observed CP asymmetries with AU model predictions for different asymmetry parameters η .

Expected outcome: Detection of anomalies that are not explained by the Standard Model, or establishment of tighter constraints.

Status: Cautious investigation. Data from LHCb and Belle II continues to accumulate.

Mainstream Connection: The search for new physics in CP violation is an active area of research. The AU model offers an additional language for interpretation.

20.2 Speculative Consequences (Long-Term Horizon)

20.2.1 AU interfaces and regeneration modulation

Formulation: Hypothetical AU interfaces (devices modulating the local field S_Θ) could modulate tissue regeneration through the restoration of information coherence.

Status: Speculative. Lacks experimental confirmation. Requires fundamentally new technologies.

Mainstream connection: In bioelectric regeneration, approaches to modulating tissue through electrical fields already exist. AU interfaces offer an extension of this idea to the S_Θ .

20.2.2 Collective thought forms and global biological processes

Formulation: Collective thought forms (global meditations, mass visualizations) could influence global biological processes (ecosystemic, planetary) through non-local correlations of the AU-field.

Status: Speculative. No experimental confirmation. The connection with the noospheric level remains theoretical.

Mainstream connection: The Global Consciousness Project (GCP) records statistical anomalies in the TRNG during global events. The AU model offers an interpretation: collective thought forms as fluctuations S_Θ .

20.2.3 Nonlocal correlations between biological systems

Formulation: There are non-local correlations between biological systems that cannot be explained by known physical mechanisms (electromagnetic, gravitational interaction) and require an AU field for explanation.

Status: Speculative. Lacks experimental confirmation. Can only be verified with highly sensitive detectors and strictly controlled conditions.

Mainstream connection: Research in quantum biology (photosynthesis, magnetoreception) points to nonlocal correlations. The AU model offers an interpretation through a nonlocal core $K(x, y)$.

20.2.4 Direct "reading" of the archive

Formulation: Hypothetical AU devices could "read" information from the archive S_Θ - for example, reconstruct information about past events or predict future ones.

Status: Speculative. Has no experimental confirmation. Lies beyond the horizon of current technology.

Connection to the Mainstream: The idea of "reading" information from a fundamental field is the subject of philosophical and scientific speculation. The AU model offers a concrete language for describing it.

20.2.5 Impact on cosmological parameters

Formulation: Upon reaching a certain level S_{Θ}^{rob} (for example, through collective thought forms or technological processes), humanity could influence local cosmological parameters ($\delta w, \delta \Lambda$).

Status: Speculative. Has no experimental confirmation. Requires reaching technological thresholds ($S_{\Theta} > 10^{45}$ bits/s).

Mainstream Connection: The idea of consciousness influencing cosmology is a matter of speculation. The AU model offers a concrete language for describing it.

20.3 Discussion: How to distinguish cautious consequences from speculative ones

20.3.1 Separation criteria

1. **Technological accessibility:** Cautious implications can be tested using existing or developing technologies. Speculative implications require fundamentally new technologies.
2. **Independence from the AU ontology:** Cautious consequences are formulated as narrow correlational questions and do not require acceptance of the entire AU ontology. Speculative consequences follow directly from the AU model.
3. **Falsifiability:** Predictable conclusions can be both confirmed and falsified. Speculative conclusions can only be verified in the very distant future.
4. **Mainstream Connection:** Cautious implications often relate to existing anomalies or open questions. Speculative implications extend beyond the mainstream.

20.3.2 The Importance of Cautious Consequences

Cautious implications are **a bridge between the AU model and mainstream theory**. If confirmed, they will form the basis for more ambitious hypotheses. If not, they will limit the AU model and direct research in other areas.

20.3.3 The Role of Speculative Consequences

Speculative implications are **the model's horizon**. They point the way for future research, but are not part of the current experimental program. They remain as a long-term perspective until an independent empirical base emerges.

20.4 Chapter 20 Summary

1. **Cautious investigations (closer to verification):**

- Correlations between entropic parameters and observable quantities (spectra, LHC, cosmology).
- Variations of constants in the early Universe (quasars, nucleosynthesis, relic radiation).
- Anomalies in LIGO/Virgo data (signal shape, additional polarizations).
- Anomalies in DESI data (evolution $w(a)$).
- Anomalies in CP-violation data (LHCb, Belle II).

2. **Speculative implications (long-term horizon):**

- AU interfaces and regeneration modulation.
- Collective thought forms and global biological processes.
- Nonlocal correlations between biological systems.
- Direct "reading" of the archive.
- Impact on cosmological parameters.

3. **Separation criteria:** technological accessibility, independence from AU-ontology, falsifiability, connection with the mainstream.

4. **The Role of Cautious Consequences:** A Bridge between the AU Model and the Mainstream.

5. **The role of speculative consequences:** the horizon of the model, directions for future research.

6. **Status:** All implications are hypothetical. Mainstream theories remain the default.

Part IX. Discussion

Chapter 21. Comparison with the mainstream

In the previous chapters, we described a hypothetical chain of emergence: from a field S_0 through constants, fermions, interactions, structures, radiation, and finally the dark sector. Now we turn to a **critical comparison** of this scheme with mainstream theories.

The goal of this chapter is not to "prove" the AU model or "refute" the mainstream, but **to clearly show what the AU adds and what it doesn't replace**. We will consider how the AU

relates to the Standard Model, QCD, QED, electroweak theory, general relativity, Λ CDM, string theory, and loop quantum gravity. For each case, we will indicate:

- What the mainstream says,
 - What does AU add,
 - Where AU is compatible with mainstream,
 - Where open questions or contradictions arise.
-

21.1 Standard Model

21.1.1 What the Mainstream Says

The Standard Model (SM) is the most successful theory of elementary particles. It describes:

- Electromagnetic, weak and strong interactions,
- Spectrum of known fermions (6 quarks, 6 leptons),
- Bosons (photon, gluons, $W^\pm$, Z^0 , Higgs),
- Spontaneous breaking of electroweak symmetry,
- Particle masses via the Higgs mechanism.

The SM has been confirmed with high precision (e.g., $g - 2$ electron and Higgs boson decays). However, it has open questions:

- Doesn't include gravity,
- Doesn't explain dark matter and dark energy,
- Does not explain the number of generations and the hierarchy of the masses,
- Does not explain baryon asymmetry,
- Contains ~ 19 free parameters.

21.1.2 What AU adds

The AU model offers **an ontological language** for interpreting SM:

- Particles are localized modes of the field S_θ ,
- Interactions are types of correlations between modes,
- Constants are like functionalities of the archive structure,
- Generations are like levels of excitement,
- Mixing - like overlap integrals,

- CP violation - as asymmetry of turns.

21.1.3 Compatibility

The AU model **does not contradict** the SM in its empirical domain. It does not predict new particles in a range already excluded by experiments. It does not change the SM predictions for known processes. It offers **an additional language** for interpreting those aspects of the SM that remain unexplained (generation number, mass hierarchy, CP violation).

21.1.4 Open questions

- Can the AU model **quantitatively** reproduce the SM parameters (masses, mixing angles)?
- Is the AU model **falsifiable** in the SM domain?
- Isn't the AU model just **a reformulation** of the SM without any new predictions?

Status: The AU model is compatible with SM, but requires formalization for verification.

21.2 Quantum Chromodynamics (QCD)

21.2.1 What the Mainstream Says

QCD is a gauge theory of the strong interaction with the group $SU(3)$. It describes:

- Confinement (color retention),
- Asymptotic freedom (weakening of interaction at short distances),
- Hadron spectrum,
- Gluon condensate,
- Cornell Potential.

QCD has been confirmed by lattice calculations and experiments (three-jet events, quarkonia, deep inelastic scattering). However, confinement remains a nonperturbative phenomenon, not analytically derivable from first principles.

21.2.2 What AU adds

The AU model offers **a topological interpretation** of QCD:

- Quarks are like localized coils of the field S_θ ,
- Color is like three orientations of a coil,
- Gluons are like $SU(3)$ correlation modes,
- Confinement - as a requirement of archive neutrality,
- Cornell Potential - as a consequence of behavior $K(x, y)$.

21.2.3 Compatibility

The AU model **does not contradict** QCD in its empirical domain. It does not change the predictions of QCD for known processes. It offers **an additional language** for interpreting confinement and asymptotic freedom—phenomena that are described phenomenologically in QCD.

21.2.4 Open questions

- Can the AU model **derive** the Cornell potential from $K(x, y)$?
- Can the AU model **explain the** GeV^{-2} value $\sigma \approx 0.18$?
- Isn't the AU model just **a reformulation** of QCD?

Status: The AU model is compatible with QCD, but requires formalization.

21.3 Quantum Electrodynamics (QED)

21.3.1 What the Mainstream Says

QED is a gauge theory of electromagnetic interaction with the group $U(1)$. It describes:

- Interaction of photons with charged particles,
- Lamb shift,
- Anomalous magnetic moment of the electron ($g - 2$),
- Compton scattering,
- Birth of couples.

QED is the most accurately tested theory in physics (up to 10^{-12}). However, it does not explain why the photon is massless or why gauge invariance is a fundamental principle.

21.3.2 What AU adds

The AU model offers **a topological interpretation** of QED:

- Photon is like a massless gradient wave,
- Gauge invariance - as freedom of choice of the archive phase,
- The field strength is like an antisymmetric part $\partial_\mu \partial_\nu S_\Theta$,
- Polarization is like gradient orientation.

21.3.3 Compatibility

The AU model **does not contradict** QED in its empirical domain. It does not change the predictions of QED for known processes. It offers **an additional language** for interpreting gauge invariance and the masslessness of the photon.

21.3.4 Open questions

- Can the AU model **derive** Maxwell's equations from dynamics S_Θ ?
- Can the AU model **explain** gauge invariance?
- Isn't the AU model just a **reformulation** of QED?

Status: The AU model is compatible with QED, but requires formalization.

21.4 Electroweak Theory

21.4.1 What the Mainstream Says

Electroweak theory (Glashow–Weinberg–Salam) unites the electromagnetic and weak interactions into a single gauge theory with the group $SU(2)_L \times U(1)_Y$. It describes:

- W and Z masses (via the Higgs mechanism),
- Parity violation,
- Neutral currents,
- Mixing photon and Z^0 (Weinberg angle).

Electroweak theory has been confirmed experimentally (the discovery of W, Z, and Higgs). However, it does not explain why the Weinberg angle has its particular value or why parity violation occurs.

21.4.2 What AU adds

The AU model offers a **topological interpretation** of the electroweak theory:

- $W^\pm$ and Z^0 are twisted modes,
- The massiveness of W and Z is like the “twist” of fashion,
- Parity violation is like asymmetry of turns,
- Weinberg angle as a parameter of archive asymmetry.

21.4.3 Compatibility

The AU model **is consistent with** electroweak theory in its empirical domain. It does not alter the predictions for known processes. It offers **additional language** for interpreting parity violation and the Weinberg angle.

21.4.4 Open questions

- Can the AU model **infer** the Weinberg angle from archive parameters?
- Can the AU model **explain** parity violation?

- Isn't the AU model just a **reformulation** of the electroweak theory?

Status: The AU model is compatible with electroweak theory, but requires formalization.

21.5 General Theory of Relativity (GTR)

21.5.1 What the Mainstream Says

General relativity describes gravity as a curvature of spacetime. It predicts:

- Gravitational time dilation,
- Gravitational waves,
- Black holes,
- Cosmological expansion.

General relativity has been confirmed with high precision (Pound–Rebka, Hafele–Keating, LIGO/Virgo, GPS). However, it is not quantized and does not explain the nature of dark energy.

21.5.2 What AU adds

The AU model offers an **entropic interpretation** of general relativity:

- Metric - as a functional of S_Θ ,
- Gravity is like an entropy gradient,
- Gravitational time dilation is like kairos time dilation,
- Graviton as a quantum of metric perturbation.

21.5.3 Compatibility

The AU model **does not contradict** general relativity in its empirical domain. It does not alter the predictions of general relativity for known processes. It offers an **additional language** for interpreting gravity as an emergent phenomenon (cf. Verlinde's entropic gravity).

21.5.4 Open questions

- Can the AU model **derive** Einstein's equations from dynamics S_Θ ?
- Can the AU model **explain** the value of the cosmological constant?
- Isn't the AU model just a **reformulation** of GTR?

Status: The AU model is compatible with GR, but requires formalization.

21.6 Λ CDM and cosmology

21.6.1 What the Mainstream Says

Λ CDM is the standard cosmological model. It describes:

- Relic radiation,
- Large-scale structure,
- Accelerated expansion,
- Nucleosynthesis,
- Dark matter (27%) and dark energy (68%).

Λ CDM has been confirmed by Planck, DESI, SDSS, and Euclid. However, it does not explain the nature of dark matter and dark energy, nor the cosmological constant problem.

21.6.2 What AU adds

The AU model offers **an entropic interpretation** of Λ CDM:

- Dark matter - as unmanifested modes,
- Dark energy is like the global entropy of the archive,
- Evolution $w(a)$ as a function $S_\theta(t)$,
- Accelerated expansion is a consequence of increasing entropy.

21.6.3 Compatibility

The AU model **is consistent with** the Λ CDM in its empirical domain. It does not change the predictions for known data. It offers **an additional language** for interpreting dark matter, dark energy, and the cosmological constant problem.

21.6.4 Open questions

- Can the AU model **infer** $\Omega_{\text{DM}} h^2 \approx 0.12$ And $\Omega_{\text{DE}} \approx 0.68$?
- Can the AU model **explain** the evolution $w(a)$ indicated by DESI 2025?
- Isn't the AU model just **a reformulation** of Λ CDM?

Status: The AU model is compatible with Λ CDM, but requires formalization.

21.7 String Theory and Loop Quantum Gravity

21.7.1 What the Mainstream Says

String theory and loop quantum gravity (LQG) are the two main approaches to quantum gravity.

- **String theory:** particles as string vibrations, extra dimensions, supersymmetry, vacuum landscape.
- **LQG:** spacetime quantization, spin networks, discreteness of area and volume.

Both approaches have open questions: the lack of experimental evidence, the landscape problem (in string theory), the semiclassical limit problem (in LQG).

21.7.2 What AU adds

The AU model offers **an alternative approach** to quantum gravity:

- Space-time as an emergent structure of the field S_Θ ,
- Graviton as a quantum of metric perturbation,
- Non-locality as a fundamental property of the archive.

The AU model does not require extra dimensions (like string theory) or discrete space (like LQG). It offers **an ontological language** in which gravity emerges from dynamics S_Θ .

21.7.3 Compatibility

The AU model **does not contradict** either string theory or LQG in their conceptual frameworks. It offers **an alternative language** for describing quantum gravity. However, it lacks a mathematical framework comparable to these theories.

21.7.4 Open Questions

- Can the AU model **reproduce** the results of string theory or LQG within appropriate limits?
- Is the AU model **compatible** with supersymmetry or spin networks?
- Isn't the AU model just **a qualitative analogy** ?

Status: The AU model is compatible with approaches to quantum gravity, but requires formalization.

21.8 Comparison Summary Table

Theory	What the mainstream says	What does AU add?	Compatibility	Open questions
Standard model	Particles, interactions, Higgs	Ontological language (modes,	Does not contradict	Quantitative verification

Theory	What the mainstream says	What does AU add?	Compatibility	Open questions
		correlations, constants)		
KHD	Confinement, asymptotic freedom	Topological interpretation (coils, correlations)	Does not contradict	Derivation of Cornell's potential
KED	Photon, gauge invariance	Gradient wave, phase freedom	Does not contradict	Derivation of Maxwell's equations
Electroweak theory	W, Z, parity violation	Twisted modes, asymmetry of turns	Does not contradict	Derivation of the Weinberg angle
General relativity	Gravity, metric	Entropic gravity	Does not contradict	Derivation of Einstein's equations
ΛCDM	Dark matter, dark energy	Latent modes, global entropy	Does not contradict	Conclusion $\Omega_{\text{DM}}, \Omega_{\text{DE}}$
String Theory / LQG	Quantum gravity	Emergent space-time	Does not contradict	Formalization

21.9 What AU adds and what it doesn't replace

21.9.1 What AU adds

1. **Ontological language:** AU offers a unified language for describing all levels of reality, from constants to the dark sector.

2. **Interpretation of the Unexplained:** AU offers possible answers to open questions (number of generations, mass hierarchy, CP violation, dark matter, dark energy).
3. **Connecting fields:** AU links particle physics, cosmology, quantum gravity, and biology into a unified framework.

21.9.2 What AU does not replace

1. **Quantitative predictions:** AU does not yet make quantitative predictions comparable to SM, QCD, QED, or GR.
 2. **Experimental basis:** AU has no experimental support in any area.
 3. **Mathematical apparatus:** AU does not have a formalism comparable to string theory or LQG.
-

21.10 Chapter 21 Summary

1. **Standard model:** AU compatible, offers an ontological language, requires formalization.
2. **QCD:** AU is compatible, offers a topological interpretation of confinement.
3. **QED:** AU is compatible, offering an interpretation of the photon as a gradient wave.
4. **Electroweak theory:** AU compatible, offers an interpretation for W, Z and parity violation.
5. **OTR:** AU is compatible, offering an entropic interpretation of gravity.
6. **Λ CDM:** AU compatible, offers an interpretation of dark matter and dark energy.
7. **String theory/LQG:** AU compatible, offers an alternative approach to quantum gravity.
8. **What AU adds:** ontological language, interpretation of the unexplained, connections between domains.
9. **What AU does not replace:** quantitative predictions, experimental base, mathematical apparatus.
10. **Status:** The AU model is compatible with the mainstream, but requires formalization for verification.

Chapter 22. Limitations and criticism

In the previous chapter, we compared the AU model with mainstream theories and demonstrated that it is compatible with them but requires formalization. We now turn to a **critical analysis of** the AU model's limitations.

The purpose of this chapter is not to defend the AU model, but **to honestly point out its weaknesses**. A scientific hypothesis is tested not only by its explanatory power, but also by its ability to withstand criticism. We will consider:

- Lack of direct experimental evidence,
- The speculative nature of most transitions,
- The need for interdisciplinary verification,
- Mathematical gaps,
- Conceptual problems,
- The danger of non-falsifiability,
- Risks of premature statements.

All statements in this chapter are **criticisms**, not refutations. They point to what needs to be done to develop the AU model, not to reject it.

22.1 Lack of direct experimental evidence

22.1.1 No direct confirmation

The key limitation of the AU model is **that none of the transitions described in the paper have been directly confirmed experimentally**. No field S_Θ has been detected. No mode localization has been observed. The constants have not been derived from the archive structure.

Confinement has not been reduced to $K(x, y)$. Dark matter has not been identified as an unmanifest mode. Dark energy has not been derived from global entropy.

What this means is that the AU model is currently **a conceptual framework**, not an empirically supported theory. It is compatible with mainstream thinking, but lacks its own experimental evidence.

What to do: Design experiments that could directly or indirectly test the predictions of the AU model (see Chapter 20).

22.1.2 Lack of quantitative predictions

The AU model does not yet provide **quantitative predictions** comparable to those of the SM, QCD, QED, or general relativity. It does not predict specific values of masses, mixing angles, cross sections, or decay probabilities.

What this means is that the AU model cannot be used to calculate experiments in its current form. It provides a language, but not a computational tool.

What needs to be done: Formalize the AU model so that it produces numerical predictions that can be compared with experiment.

22.1.3 The Danger of "Explaining Everything"

One of the main dangers for any new theory is **its claim to explain everything**. The AU model describes a wide range of phenomena, from constants to dark energy. This can be both a strength and a weakness.

What this means: If a theory explains everything, it may not explain anything in particular. The AU model must be tested against **specific predictions**, not general concepts.

What to do: Focus on narrow, falsifiable predictions (see Chapter 20).

22.2 Speculative nature of most transitions

22.2.1 Transitions as hypotheses

Most transitions in the AU model are **hypothetical/speculative**. Here's their status:

Transition	Status
$S_\theta \rightarrow \text{constants}$	Hypothetical
Constants $\rightarrow$ fermions	Speculative
Fermions $\rightarrow$ interactions	Speculative
Interactions $\rightarrow$ structures	Speculative
Structures $\rightarrow$ radiation	Speculative
Radiation $\rightarrow$ dark sector	Speculative

What this means: The AU model is a **chain of hypotheses**, each of which requires careful testing. A weakness in one link can destroy the entire chain.

What needs to be done: Check each link individually, not just the entire chain as a whole.

22.2.2 Lack of inference from first principles

The AU model does not derive its results from **first principles**. It postulates a field S_θ , its properties, the shape of the nucleus $K(x, y)$, the shape of the potential, etc. These postulates are not derived from a more fundamental theory.

What this means is that the AU model is **phenomenological**, not fundamental. It describes, but does not explain, why the field S_θ has the properties it does.

What needs to be done: Show that the AU model can be derived from a more fundamental theory (e.g. quantum gravity or string theory).

22.2.3 The "fit" problem

One of the dangers for any new theory is **parameter overfitting** to observed data. If the parameters of an AU model ($\alpha, \beta, \gamma, \delta, \lambda$ etc.) are chosen to match observations, the theory loses its predictive power.

What this means is that an AU model should either **predict** parameters from first principles or **explain** their values, rather than simply fitting them.

What needs to be done: Show that the AU model parameters are not free, but are determined by the archive structure.

22.3 Need for interdisciplinary verification

22.3.1 Elementary particle physics

The AU model needs to be verified by particle physicists. Questions:

- Is the AU model compatible with LHC data?
- Doesn't it contradict the restrictions on new physics?
- Can it explain anomalies (for example, $g - 2_{\text{muon}}$)?

22.3.2 Cosmology

The AU model needs to be tested by cosmologists. Questions:

- Is it compatible with Planck, DESI, Euclid data?
- Can it explain evolution $w(a)$?
- Doesn't it contradict the restrictions on the variation of constants?

22.3.3 Quantum gravity

The AU model needs to be verified by quantum gravity experts. Questions:

- Is it compatible with LQG or string theory?
- Can it be quantized?
- Doesn't it contradict the singularity theorems?

22.3.4 Philosophy of science

The AU model needs to be tested by philosophers of science. Questions:

- Is it falsifiable?

- Isn't it metaphysical?
- Does it meet the criteria of scientific validity?

What this means is that the AU model cannot be assessed solely within its own circle. It requires **interdisciplinary verification**.

What needs to be done: Organize colloquiums and working groups with the participation of specialists from different fields.

22.4 Mathematical Gaps

22.4.1 Absence of explicit form $K(x, y)$

The key element of the AU model—the nonlocal core $K(x, y)$ —has no **explicit form**. We use a phenomenological form:

$$K(x, y) = \alpha_{nl} \frac{e^{-|x-y|/\ell_{AU}}}{|x - y|} \cdot \Theta(\tau_x - \tau_y)$$

but we do not derive it from first principles.

What this means: Without an explicit form, $K(x, y)$ it is impossible to compute specific predictions.

What you need to do: Withdraw $K(x, y)$ from the dynamics of the field S_Θ or postulate it on the basis of symmetries.

22.4.2 Lack of operator spectrum $\hat{L}$

We postulate that the fermion masses are eigenvalues of the operator $\hat{L}$:

$$\hat{L} = \omega_0^2 - \tilde{\mu}\Phi + \hat{K}$$

but we do not solve the spectral problem.

What does this mean: Without solving the spectral problem, it is impossible to predict the masses.

What needs to be done: Solve the spectral problem for $\hat{L}$ with an explicit form $K(x, y)$.

22.4.3 Lack of derivation of equations of motion

We postulate equations of motion for fields (Maxwell's equations, Einstein's equations, Schrödinger's equation), but we do not derive them from dynamics S_Θ .

What does this mean: Without deriving the equations of motion, the AU model remains phenomenological.

What needs to be done: Derive the equations of motion from the variation of the action with respect to S_Θ .

22.4.4 Lack of connection with observable quantities

We relate the AU model parameters to observed quantities (masses, constants, mixing angles) only qualitatively.

What this means: Without a quantitative relationship, the AU model cannot be tested.

What needs to be done: Establish quantitative relationships between the AU model parameters and the observed values.

22.5 Conceptual problems

22.5.1 What is a "field S_Θ "?

A field S_Θ is defined as a "non-local archive of irreversible events." But what does this mean **physically**? Is it a scalar field? A vector field? A tensor field? How is it related to spacetime?

What does this mean: The definition S_Θ remains **unclear**.

What needs to be done: Give a rigorous mathematical definition S_Θ and its connections with the observed fields.

22.5.2 What is an "irreversible event"?

We use the concept of "irreversible event" but don't provide a strict definition. Is an event irreversible if it increases entropy? If it can't be undone? If it's recorded in an archive?

What does this mean: The concept of an "irreversible event" remains **intuitive**.

What needs to be done: Give a rigorous definition of an irreversible event in terms of dynamics S_Θ .

22.5.3 What is "coherence" $\mathcal{C}$?

We define coherence $\mathcal{C}$ as a measure of the consistency of a configuration with the archive:

$$\mathcal{C}[\mathcal{A}] = \frac{\langle S_\Theta^{(\mathcal{A})} | K | S_\Theta^{\text{arch}} \rangle}{\| S_\Theta^{(\mathcal{A})} \|_K \cdot \| S_\Theta^{\text{arch}} \|_K}$$

But how to measure it $\mathcal{C}$ experimentally?

What this means: Coherence $\mathcal{C}$ remains a **theoretical construct**.

What needs to be done: Suggest experimental measurement methods $\mathcal{C}$.

22.5.4 What is “kairos time” τ ?

We introduce kairos time τ as "event-rich time" associated with increasing entropy. But how is it related to ordinary time t ? Is it observable?

What this means: Kairos time remains a **speculative construct**.

What needs to be done: Give a strict definition τ and its connections with t .

22.6 The danger of non-falsifiability

22.6.1 Popper criterion

According to Karl Popper, a scientific theory must be **falsifiable**: there must be possible observations that could disprove it. If a theory cannot be falsified by any observations, it is not scientific.

Question: Is the AU model falsifiable?

22.6.2 The "one-size-fits-all" problem

If the AU model can explain **any** observations (by adjusting the parameters), it becomes unfalsifiable. For example, if we can explain any fermion mass by adjusting the shape of $K(x, y)$, then the theory loses its predictive power.

What this means is that the AU model must make **specific predictions** that can be falsified.

What needs to be done: Formulate predictions that **rule out** certain possibilities. For example: "If the AU model is correct, then the electron mass should be in the range $X - Y$." If observations show a different value, the model is refuted.

22.6.3 The danger of the "metaphysical refuge"

If the AU model cannot be experimentally tested in the foreseeable future, it risks becoming **metaphysical** rather than scientific. This doesn't mean it's useless, but it does mean it can't claim to be a scientific theory in the strict sense.

What this means is that the AU model must offer **testable consequences** (see Chapter 20).

What to do: Focus on cautious consequences that can be tested in the coming years.

22.7 Risks of Premature Statements

22.7.1 The danger of "revolutionary" statements

One of the main dangers for any new theory is **premature declarations** of its revolutionary nature. If the AU model is presented as the "final theory of everything," this will draw justifiable criticism and undermine its credibility.

What this means is that the AU model should be presented **modestly** - as a hypothetical framework, not as a ready-made theory.

What to do: Clearly indicate the status of all statements (fact/hypothesis/speculation).

22.7.2 The danger of “substituting science”

If the AU model is used to **replace** established science (for example, to deny the Standard Model or General Relativity), this will harm both science and the AU model itself.

What this means is that the AU model should be **a complement** to the mainstream, not a replacement for it.

What needs to be done: Clearly indicate that the AU model does not replace the SM, QCD, QED, GTR, or Λ CDM.

22.7.3 The danger of "pseudoscience"

If the AU model is associated with pseudoscientific ideas (for example, with “quantum consciousness” in the esoteric sense), this will undermine its scientific reputation.

What this means is that the AU model must be presented **in a strictly scientific manner**, with a clear separation between facts and speculations.

What to do: Avoid formulations that could be interpreted as pseudoscientific.

22.8 What needs to be done to develop the AU model

22.8.1 Short-term tasks

1. **Formalization:** Give strict definitions of S_Θ , $K(x, y)$, $\mathcal{C}$, τ .
2. **Spectral problem:** Solve the spectral problem for $\hat{L}$.
3. **Equations of motion:** Derive the equations of Maxwell, Einstein, Schrödinger from dynamics S_Θ .
4. **Predictions:** Formulate narrow, falsifiable predictions.

22.8.2 Medium-term objectives

1. **Relationship to observables:** Establish quantitative relationships between the AU model parameters and the data.
2. **Interdisciplinary review:** Organize colloquiums with the participation of physicists, cosmologists, and philosophers.
3. **Comparison with mainstream:** Show that the AU model is compatible with SM, QCD, QED, GTR, Λ CDM.

22.8.3 Long-term tasks

1. **Experimental Validation:** Conduct experiments that test the predictions of the AU model.
 2. **Integration with quantum gravity:** Show that the AU model can be derived from a more fundamental theory.
 3. **Development of mathematical apparatus:** Develop a formalism comparable to string theory or LQG.
-

22.9 Chapter 22 Summary

1. **Lack of direct experimental evidence:** None of the AU model's transitions have been directly confirmed. The model is a conceptual framework, not an empirically supported theory.
2. **The speculative nature of most transitions:** the AU model is a chain of hypotheses, each of which requires independent verification.
3. **Need for interdisciplinary testing:** The AU model needs to be tested by experts in particle physics, cosmology, quantum gravity, and philosophy of science.
4. **Mathematical gaps:** Lack of explicit form $K(x, y)$, solution of the spectral problem, derivation of equations of motion and connection with observable quantities.
5. **Conceptual problems:** Vague definitions of S_θ "irreversible event", "coherence" $\mathcal{C}$, "kairos time" τ .
6. **The danger of non-falsifiability:** The AU model must make specific predictions that can be falsified.
7. **Risks of premature statements:** The AU model should be presented modestly, as a hypothetical framework, not as a ready-made theory.
8. **What needs to be done:** Formalization, solution of the spectral problem, derivation of equations of motion, formulation of predictions, interdisciplinary verification.
9. **Status:** The AU model is a hypothetical framework that requires significant work to develop into a scientific theory.

Chapter 23. Prospects

In the previous chapter, we examined the limitations and criticisms of the AU model. Now we turn to **the future** —to where this hypothetical framework might go.

The purpose of this chapter is not to promise a "revolution in physics," but **to outline realistic directions** for future work. We will consider:

- Development of formalism,
- Search for indirect signals,
- Integration with quantum gravity and cosmology,
- Connection with other fields (biology, computer science),
- Possible scenarios for the development of the AU model.

All statements in this chapter are **hypothetical/speculative**. They indicate possible directions for research, not definitive results.

23.1 Development of Formalism

23.1.1 Explicit form of the kernel $K(x, y)$

The first task is **to derive or postulate an explicit form of the nonlocal kernel** $K(x, y)$.

Possible approaches:

1. **From symmetries:** Require that $K(x, y)$ satisfies certain symmetries (Lorentz invariance, translation invariance, causality in kairos time).
2. **From the dynamics:** Output $K(x, y)$ as the Green's function for the field S_θ :

$$K(x, y) = \langle 0 | T\{S_\theta(x)S_\theta(y)\} | 0 \rangle$$

3. **From the holographic principle:** Connect $K(x, y)$ with horizon entropy:

$$K(x, y) \sim \frac{\partial^2 S_{\text{holo}}}{\partial x \partial y}$$

Expected result: Explicit form $K(x, y)$ that allows for the computation of specific predictions.

Status: Hypothetical problem.

23.1.2 Solution of the spectral problem for $\hat{L}$

The second task is **to solve the spectral problem** for the effective dynamics operator:

$$\hat{L}\Theta^{(n)} = \lambda_n \Theta^{(n)}$$

Where:

$$\hat{L} = \omega_0^2 - \tilde{\mu}\Phi + \hat{K}$$

Possible approaches:

1. **Numerical methods:** Discretization of an operator $\hat{L}$ on a lattice and solution of the eigenvalue problem.
2. **Analytical methods:** Finding approximate solutions for special forms $K(x, y)$ (e.g. exponential kernel, power kernel).
3. **Spectral Geometry:** Using spectral geometry techniques to analyze spectra $\hat{L}$.

Expected result: Spectrum λ_n corresponding to the masses of fermions and their generations.

Status: Hypothetical problem.

23.1.3 Derivation of the equations of motion

The third task is **to derive the equations of motion** for fields (Maxwell, Einstein, Schrödinger) from dynamics S_Θ .

Possible approaches:

1. **Variational principle:** Write down the action for the field S_Θ and obtain the equations of motion through variation.
2. **Effective action:** Derive the effective action for low-energy modes by integrating the high-energy degrees of freedom.
3. **Hydrodynamic limit:** Show that in the hydrodynamic limit the equations for S_Θ reduce to Maxwell's or Einstein's equations.

Expected result: Derivation of equations of motion from dynamics S_Θ .

Status: Hypothetical problem.

23.1.4 Relationship with observable quantities

The fourth task is **to establish quantitative relationships** between the parameters of the AU model and observed quantities (masses, constants, mixing angles).

Possible approaches:

1. **Calibration:** Adjust the parameters of the AU model so that they match the observed values.
2. **Prediction:** Show that the AU model parameters **are determined** by the archive structure and not selected.
3. **Comparison:** Compare AU model predictions with LHC, Planck, DESI, LIGO data.

Expected result: Quantitative relationships linking the AU model to observed quantities.

Status: Hypothetical problem.

23.2 Search for indirect signals

23.2.1 Anomalies in LHC data

One possible way to test the AU model is **to look for anomalies in the LHC data** that are not explained by the Standard Model.

Possible signals:

1. **Cross-section deviations:** Anomalous particle production cross-sections that could be related to the dynamics S_Θ .
2. **Additional resonances:** Peaks in the invariant masses that could correspond to excited modes S_Θ .
3. **Anomalies in CP violation:** Deviations from the Standard Model predictions in CP asymmetries.

Expected outcome: Detection of anomalies or establishment of stricter restrictions.

Status: Hypothetical. Requires analysis of existing data.

23.2.2 Anomalies in LIGO/Virgo data

Another possible avenue is **to look for anomalies in gravitational wave data**.

Possible signals:

1. **Deviations from GR:** Anomalies in the waveform (phase, amplitude, attenuation) that could be related to dynamics S_Θ .
2. **Additional polarizations:** Scalar or vector polarizations predicted by some extensions of general relativity.
3. **Correlations with entropic parameters:** Correlations between event parameters and entropic parameters.

Expected outcome: Detection of anomalies or establishment of stricter restrictions.

Status: Hypothetical. LIGO/Virgo data continues to accumulate.

23.2.3 Anomalies in DESI data

A third possible avenue is **to look for anomalies in the DESI dark energy data**.

Possible signals:

1. **Evolution $w(a)$:** Deviations from $w = -1$ that might be associated with growth S_Θ^{rob} .
2. **Correlations with entropy:** Correlations between $w(a)$ and other entropy parameters.
3. **Spatial variations:** Variations w in different directions that could be related to the non-locality of the archive.

Expected result: Refinement of parameters w_0 and w_a their comparison with the predictions of the AU model.

Status: Hypothetical direction. DESI data already point to possible evolution $w(a)$.

23.2.4 Anomalies in constant variation data

The fourth possible way is **to search for anomalies in the data on the variation of fundamental constants**.

Possible signals:

1. **Variation α :** Deviations α from the modern value in the early Universe.
2. **Variation G :** Deviations G from the modern meaning.
3. **Variation m_e :** Deviations of the electron mass from the modern value.

Expected result: Detection of deviations or establishment of stricter restrictions.

Status: Hypothetical direction. Existing data already impose limitations.

23.3 Integration with Quantum Gravity and Cosmology

23.3.1 Connection with loop quantum gravity (LQG)

The AU model can be integrated with LQG via **the discreteness of spacetime**.

Possible connections:

1. **Spin networks:** The field S_Θ can be coupled to LQG spin networks.
2. **Area discreteness:** Area quantization in LQG can emerge from mode discreteness S_Θ .
3. **Holographic principle:** Both approaches use the holographic principle to limit the degrees of freedom.

Expected result: Show that the AU model is compatible with LQG or can be derived from it.

Status: Hypothetical direction.

23.3.2 Connection with string theory

The AU model can be integrated with string theory via **extra dimensions** or **a landscape of vacua**.

Possible connections:

1. **Landscape:** The configuration space S_Θ can be analogous to the landscape of string vacuums.
2. **Extra Dimensions:** The field S_Θ can be associated with extra dimensions.

3. **Supersymmetry:** The AU model can be extended to a supersymmetric version.

Expected result: Show that the AU model is compatible with string theory or can be derived from it.

Status: Hypothetical direction.

23.3.3 Connection with cosmology

The AU model can be integrated with cosmology through **the entropic interpretation of** dark matter and dark energy.

Possible connections:

1. **Dark Matter:** Unmanifested Modes as Candidates for Dark Matter.
2. **Dark Energy:** Global Entropy as a Source Λ_{eff} .
3. **Inflation:** The field S_Θ may be related to inflaton.

Expected result: Show that the AU model is compatible with Λ CDM or can be derived from it.

Status: Hypothetical direction.

23.3.4 Connection with quantum information

The AU model can be integrated with quantum information via **von Neumann entropy** and **quantum entanglement**.

Possible connections:

1. **Von Neumann entropy:** Entropy S_Θ can be a generalization of von Neumann entropy.
2. **Quantum Entanglement:** Entanglement as Entropy-Mediated Correlation in the Archive.
3. **Quantum computing:** The AU model can be used to develop new quantum algorithms.

Expected result: Show that the AU model is compatible with or can be derived from quantum information.

Status: Hypothetical direction.

23.4 Connection with other areas

23.4.1 Biology

The AU model can be linked to biology through **the entropic interpretation** of life and consciousness.

Possible connections:

1. **Origin of life:** Panspermia as informational-nonlocal spread through the AU-field.

2. **Consciousness:** Thought-forms as coherent configurations in the AU-field.
3. **Evolution:** Growth S_0 as the driving force of evolution.

Expected outcome: Show that the AU model is compatible with biology or can be used to interpret biological phenomena.

Status: Hypothetical direction. Linked to previous works in the AU series.

23.4.2 Computer science and AI

The AU model can be related to computer science and AI through **the entropic interpretation** of computation and consciousness.

Possible connections:

1. **Quantum computing:** AU chips as quantum correlation processors.
2. **Artificial Intelligence:** AI as an Amplifier of the Entropy of Thought Forms.
3. **Neuromorphic Computing:** Neuromorphic AU Chips as an Interface with the AU Field.

Expected outcome: Show that the AU model is compatible with computer science or can be used to develop new technologies.

Status: Hypothetical direction.

23.4.3 Philosophy and theology

The AU model can be linked to philosophy and theology through **an ontological interpretation** of time, consciousness and meaning.

Possible connections:

1. **Philosophy of Time:** Kairos Time as Ontological Time.
2. **Philosophy of consciousness:** Thought forms as fundamental entities.
3. **Theology:** AU-field as "God's archive" or "logos".

Expected result: Show that the AU model is compatible with philosophical and theological concepts or can be used to interpret them.

Status: Hypothetical direction.

23.5 Possible scenarios for the development of the AU model

23.5.1 Scenario 1: The AU model remains the conceptual framework

In this scenario, the AU model is not experimentally supported, but is used as a **conceptual language** for interpreting physical and biological phenomena.

Consequences:

- The AU model remains philosophical/metaphysical.
- It does not replace the mainstream, but complements it.
- It is used to ask questions, not to answer them.

Probability: High (in the short term).

23.5.2 Scenario 2: The AU model receives indirect confirmation

In this scenario, the AU model receives **indirect confirmation** through the detection of correlations between entropy parameters and observed quantities.

Consequences:

- The AU model is becoming part of the mainstream as an additional language.
- It is used to interpret anomalies (dark energy, CP violation, constant variation).
- It stimulates new experiments.

Probability: Medium (in the medium term).

23.5.3 Scenario 3: The AU model receives direct confirmation

In this scenario, the AU model receives **direct confirmation** through the detection of the field S_0 or its manifestations.

Consequences:

- The AU model becomes a new physical theory.
- It requires a revision of the Standard Model and General Relativity.
- It opens up new technological possibilities.

Probability: Low (in the foreseeable future).

23.5.4 Scenario 4: The AU model is refuted

In this scenario, the AU model **is refuted** through the discovery of contradictions with experimental data.

Consequences:

- The AU model is rejected as a scientific theory.
- Its elements can be included in other theories.
- It remains in the history of science as an interesting but unsuccessful attempt.

Probability: Medium (if the model is not formalized).

23.6 What needs to be done to realize the prospects

23.6.1 Short-term tasks (1–3 years)

1. **Formalization:** Give strict definitions of S_Θ , $K(x, y)$, $\mathcal{C}$, τ .
2. **Spectral problem:** Solve the spectral problem for $\hat{L}$.
3. **Equations of motion:** Derive the equations of Maxwell, Einstein, Schrödinger from dynamics S_Θ .
4. **Predictions:** Formulate narrow, falsifiable predictions.

23.6.2 Medium-term objectives (3–10 years)

1. **Relationship to observables:** Establish quantitative relationships between the AU model parameters and the data.
2. **Interdisciplinary review:** Organize colloquiums with the participation of physicists, cosmologists, and philosophers.
3. **Comparison with mainstream:** Show that the AU model is compatible with SM, QCD, QED, GTR, Λ CDM.
4. **Search for indirect signals:** Analysis of LHC, LIGO, DESI, Planck data for anomalies.

23.6.3 Long-term objectives (10+ years)

1. **Experimental Validation:** Conduct experiments that test the predictions of the AU model.
2. **Integration with quantum gravity:** Show that the AU model can be derived from a more fundamental theory.
3. **Development of mathematical apparatus:** Develop a formalism comparable to string theory or LQG.
4. **Technological applications:** Develop AU chips, AU interfaces and other technologies.

23.7 Chapter 23 Summary

1. **Development of formalism:** Derivation of explicit form $K(x, y)$, solution of spectral problem for $\hat{L}$, derivation of equations of motion, connection with observable quantities.
2. **Search for indirect signals:** Analysis of LHC, LIGO/Virgo, DESI, and constant variation data for anomalies.
3. **Integration with quantum gravity and cosmology:** Connections with LQG, string theory, Λ CDM, quantum information.
4. **Connections with other fields:** Biology, computer science, AI, philosophy, theology.

5. **Possible scenarios:** AU model as a conceptual framework, indirect confirmation, direct confirmation, refutation.
6. **What needs to be done:** Formalization, solution of the spectral problem, derivation of equations of motion, formulation of predictions, interdisciplinary verification, experimental verification.
7. **Status:** All statements are hypothetical. The AU model is a hypothetical framework that requires significant work to develop into a scientific theory.

Conclusion

This paper proposes a hypothetical framework for describing a possible mechanism for the transformation of the theta-entropy field S_Θ —a nonlocal archive of irreversible events—into observable matter, interactions, and the dark sector. The Acta Universi (AU) hypothesis postulates that the fundamental structure of reality is a field S_Θ , and that particles, fields, and interactions represent emergent modes of coherence within this field.

We systematized the emergence chain, which includes several levels: the emergence of constants, fermions as localization modes, interactions as correlation types, structures (nuclei, atoms, molecules), radiation (electromagnetic and gravitational), and the dark sector (dark matter and dark energy). For each level, we indicated what the mainstream says, what the AU adds, and where open questions arise.

Key results

Part I laid the ontological foundations: the field S_Θ as a non-local archive, its characteristics (record density $\rho_{\text{записей}}$, non-local core $K(x, y)$, global entropy), localization criterion ($\rho_{\text{записей}} > \rho_{\text{crit}}$), topological invariant and pair production mechanism.

Part II examined the emergence of constants: α , G , $\hbar$, and the fermion masses as functionals of the archive structure. The stability of the constants is explained by global coherence; local fluctuations in the early universe are possible. The mass hierarchy and the number of generations are interpreted through a discrete spectrum of excitations.

Part III described fermions as localization modes: quarks (6 flavors, 3 colors) as localized coils ∇S_Θ , leptons as color-neutral modes, neutrinos as "almost free" modes.

Part IV presented interactions as types of correlations: strong (confinement via non-local neutrality of the archive), weak (flavor switching via twisted modes), electromagnetic (gradient waves), gravitational (emergent metric), Higgs mechanism (condensate S_Θ).

Part V considered structures: nuclei as bound states of quarks and gluons, atoms as standing coherent modes, generations and mixing as overlap integrals, CP violation as asymmetry of turns, baryogenesis as accumulation of asymmetry of records.

Part VI is devoted to radiation: electromagnetic waves as gradient perturbations S_Θ , gravitational waves as metric perturbations.

Part VII described the dark sector: dark matter as unmanifested modes with zero EM charge, dark energy as the global entropy of the archive, evolution $w(a)$ as a function of $S_\Theta(t)$.

Part VIII formulated the directions of formalization (deduction of masses, CKM, Weinberg angle, dark matter conditions, $w(a)$ confinement, Schrödinger equation, Maxwell equations) and testable consequences (cautious and speculative).

Part IX discussed comparisons with the mainstream (Standard Model, QCD, QED, electroweak theory, GR, Λ CDM, string theory, LQG), limitations and criticisms, and future developments.

Key points

1. **The AU model offers an ontological language, not a replacement for mechanisms.** It does not compete with the Standard Model, QCD, QED, GTR, or Λ CDM, but rather offers an additional interpretive layer.
2. **All transitions described in this paper are hypothetical/speculative.** None of them have been directly confirmed experimentally within the AU framework.
3. **The value of the approach at the current stage lies in the clarity of boundaries:** where is the data, where is the interpretation, where is the ethical question, where is there still only speculation.
4. **To move from speculation to science, the following are necessary:** formalization (explicit form $K(x, y)$, solution of the spectral problem, derivation of equations of motion), quantitative predictions, interdisciplinary verification, search for indirect signals.
5. **Ethical/methodological imperative:** the development of the AU model must be accompanied by strict adherence to the principles of epistemic integrity (fact/hypothesis/speculation), precaution (no premature statements), and interdisciplinarity (verification by specialists from different fields).
6. **If correlations between entropic parameters and observable quantities are consistently reproduced,** a basis for closer dialogue with the mainstream will emerge. If not, the AU will remain a cosmological and informational hypothesis without any necessary consequences for particle physics. Both outcomes are scientifically productive.

Limitations and future directions

Restrictions:

1. **Lack of direct experimental confirmation.** None of the transitions have been verified.

2. **The speculative nature of most transitions.** The chain of hypotheses requires independent verification of each link.
3. **Mathematical gaps.** There is no explicit form $K(x, y)$, no solution to the spectral problem, no derivation of the equations of motion.
4. **Conceptual problems.** Vague definitions of S_0 "irreversible event", "coherence" $\mathcal{C}$, "kairos time" τ .
5. **The danger of non-falsifiability.** A model must make specific predictions that can be falsified.
6. **The risks of making premature statements.** The model should be presented modestly, as a hypothetical framework.

Further directions:

1. **Formalization:** derivation $K(x, y)$, solution of the spectral problem, derivation of the equations of motion, connection with observable quantities.
2. **Search for indirect signals:** analysis of LHC, LIGO/Virgo, DESI, Planck data for anomalies.
3. **Integration with quantum gravity:** connections with LQG, string theory, quantum information.
4. **Connections with other fields:** biology, computer science, AI, philosophy, theology.
5. **Interdisciplinary review:** organizing colloquiums and working groups with the participation of specialists from different fields.

Closing remarks

The Acta Universi hypothesis proposes an ontological language in which a number of physical phenomena—constant, fermions, interactions, structures, radiation, the dark sector—can be considered as particular manifestations of a more general process of irreversible recording and coherence in a non-local archive.

This language **doesn't compete** with established mechanisms and **doesn't generate** premature statements. Its value at this stage lies in the clarity of boundaries: where is data, where is interpretation, where is an ethical question, and where is still just speculation.

If correlations between entropic parameters and already studied quantities are consistently reproduced, a basis for closer interdisciplinary dialogue will emerge. If not, the AU will remain a cosmological and informational hypothesis without any necessary consequences for elementary particle physics. Both outcomes are scientifically productive.

The key to productivity is maintaining a distinction between empirically researched phenomena, hypothetical AU interpretations, and ethical questions. Only then can specialists in particle

physics, cosmology, quantum gravity, mathematics, and philosophy use the proposed framework as a tool for asking questions, rather than as a source of premature answers.

Applications

Appendix A. Glossary of Key Terms

An alphabetical list of key terms used in the article, with brief definitions. All definitions are part of a hypothetical AU model and are not intended to be empirically supported.

The Archive (AU Archive) is a non-local structure of irreversible events in the AU ontology; the fundamental "log" of the Universe, in which all irreversible events are recorded. Non-local correlations in the archive are not limited by the speed of light, but causality is preserved at the level of the recording structure (kairos time).

Baryogenesis is the process that led to the predominance of matter over antimatter in the Universe. In the AU model, it is interpreted as the accumulation of asymmetry in the records of the archive (Chapter 14).

A boson is a particle with integer spin. In the AU model, bosons are interpreted as various types of field perturbations S_Θ : the photon is a gradient wave, gluons are $SU(3)$ correlation modes, $W^\pm$ and Z^0 are twisted modes, the Higgs are condensate oscillations, and the graviton is a metric perturbation (Chapters 7–11, 15–16).

The graviton is a hypothetical quantum of the gravitational field. In the AU model, it is interpreted as a quantum of metric perturbation corresponding to the second derivative S_Θ (Chapter 10, 16).

Gravitational interaction - in the AU model is interpreted as a global field gradient S_Θ that generates an emergent metric (Chapter 10).

The gluon is the carrier of the strong interaction. In the AU model, it is interpreted as an $SU(3)$ correlation mode between color loops (Chapter 7).

Double dark - see Dark matter, Dark energy.

Kairos time (τ) is an event-rich time associated with the irreversible growth of entropy S_Θ ; it is heterogeneous, directed, and is a time of formation and choice (Chapter 1, 10).

A quark is a fermion participating in the strong interaction. In the AU model, it is interpreted as a localized field coil S_Θ with a topological invariant that determines its flavor and three coil orientations that determine its color (Chapter 5).

Coherence ($\mathcal{C}$) is a measure of the consistency of a configuration with the archive. Coherence ($\mathcal{C} \rightarrow 1$) indicates high coherence (resonance with the archive). Low $\mathcal{C}$ coherence corresponds to inconsistency (Chapter 1).

The condensate S_Θ is a non-zero vacuum expectation value of the field S_Θ : $\langle S_\Theta \rangle = v \neq 0$. In the AU model, it is interpreted as an analogue of the Higgs condensate, responsible for mass generation (Chapter 11).

Confinement is the retention of color, the inability to observe free quarks. In the AU model, this is explained by the nonlocal neutrality of the archive (Chapter 7).

A lepton is a fermion that does not participate in the strong interaction. In the AU model, it is interpreted as a color-neutral localized field mode S_Θ (Chapter 6).

Localization is the process of “condensation” of a field S_Θ into a particle when the critical density of records is exceeded: $\rho_{\text{записей}} > \rho_{\text{crit}}$ (Chapter 2).

Mass - in the AU model is determined by the coupling of the mode with the condensate S_Θ : $m_f = y_f \cdot v$, $m_W = \frac{1}{2} g v$ (Chapter 11).

A thoughtform is a coherent configuration in the AU field that creates an irreversible record in the archive. In a physical context, it is a localized field mode S_Θ (Chapter 1).

Non-local kernel ($K(x, y)$) is an integral kernel that describes the archive memory and long-range correlations between records; it defines all interactions in the AU model (Chapter 1).

The neutrino is a light lepton. In the AU model, it is interpreted as an “almost free” mode with minimal coupling to the condensate S_Θ (Chapter 6).

Record density ($\rho_{\text{записей}}$) is the local density of irreversible events in the archive; it determines the recording intensity (Chapter 1).

The field S_Θ is the fundamental structure of reality in the AU hypothesis, a nonlocal archive of irreversible events. Particles, interactions, and spacetime are emergent relative to it (Chapter 1).

The Cornell potential is the phenomenological potential of quark interactions: $V(r) = -4\alpha_s/(3r) + \sigma r$. In the AU model, it can be derived from behavior $K(x, y)$ (Chapter 7, 19).

Mixing is the transition between generations of fermions. In the AU model, it is interpreted as overlap integrals between modes: $V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$ (Chapter 13).

Dark matter is an invisible substance that manifests itself gravitationally. In the AU model, it is interpreted as unmanifest modes with zero EM charge $\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$ (Chapter 17).

Dark energy is the energy responsible for the accelerated expansion of the Universe. In the AU model, it is interpreted as the global entropy of the archive: $\Lambda_{\text{eff}} = \Lambda_0 + \gamma S_\Theta^{\text{no6}} + \delta(dS_\Theta^{\text{no6}}/dt)^2$ (Chapter 18).

A fermion is a particle with half-integer spin. In the AU model, fermions are interpreted as localized modes of the field S_Θ (Chapters 5–6).

A photon is a quantum of the electromagnetic field. In the AU model, it is interpreted as a massless gradient wave: $A_\mu \leftrightarrow \partial_\mu S_\Theta$ (Chapter 9, 15).

Chronos-time (t) is a metric coordinate in space-time, emerging from the structure of the archive S_Θ ; it is homogeneous, continuous, and measurable (Chapter 1).

Color is the quantum number of quarks. In the AU model, it is interpreted as three orientations of the turn corresponding to $\nabla S_\Theta \text{SU}(3)$ generators (Chapter 5).

Entropic mismatch (δS_Θ) is a measure of the deviation of a configuration from archival coherence. A low value δS_Θ corresponds to a coherent configuration; a high value corresponds to a mismatched configuration (Chapter 1).

Thoughtform entropy (S_Θ) is a measure of accumulated irreversible records in the AU archive. It is determined using von Neumann entropy $S_\Theta = -k_B \text{Tr}(\rho \ln \rho)$ (Chapter 1).

Appendix B. Mathematical apparatus (hypothetical)

This appendix contains the basic mathematical formulas used in the AU model to describe the emergence of constants, fermions, interactions, and the dark sector. **All formulas are theoretical and have not been experimentally confirmed within the AU framework.**

B.1 Basic Definitions

Field S_Θ :

$$S_\Theta(x): \mathcal{M} \rightarrow \mathbb{R}$$

Record density:

$$\rho_{\text{записей}}(x) = \frac{dN_{\text{events}}}{dV}$$

Non-local kernel:

$$K(x, y) = \alpha_{\text{nl}} \frac{e^{-|x-y|/\ell_{\text{AU}}}}{|x-y|} \cdot \Theta(\tau_x - \tau_y)$$

Coherence:

$$\mathcal{C}[\mathcal{A}] = \frac{\langle S_{\Theta}^{(\mathcal{A})} | K | S_{\Theta}^{\text{arch}} \rangle}{\| S_{\Theta}^{(\mathcal{A})} \|_K \cdot \| S_{\Theta}^{\text{arch}} \|_K}$$

Entropic mismatch:

$$\delta S_{\Theta}[\mathcal{A}] = \int_{\mathcal{M}} |S_{\Theta}^{(\mathcal{A})}(x) - \mathcal{P}_K S_{\Theta}^{\text{arch}}(x)|^2 d^4x$$

B.2 Localization criterion

$$\rho_{\text{записей}}(x) > \rho_{\text{crit}} \sim \frac{m_f c^2}{\hbar \cdot \ell_{\text{AU}}^3}$$

Topological invariant:

$$Q_{\text{top}} = \frac{1}{2\pi} \oint_{\partial\Omega} \nabla S_{\Theta} \cdot dl$$

B.3 Emergence of Constants

$$\begin{aligned} \alpha &= \mathcal{F}_1[S_{\Theta}, \nabla, S_{\Theta}K] \\ \frac{G}{\hbar c} &= \mathcal{F}_2[S_{\Theta}, \nabla, S_{\Theta}K] \\ m_f &= y_f \cdot v, \quad v = \langle S_{\Theta} \rangle \end{aligned}$$

B.4 Fermions as localization modes

Fermion thought form:

$$\Theta_f(t) = \sum_i a_i(t) | \psi_i \rangle$$

Charge fraction:

$$Q_{\text{ent}}^{(q)} = \begin{cases} +2/3 & (\text{u, c, t}) \\ -1/3 & (\text{d, s, b}) \end{cases}$$

Color:

$$\text{цвет} \in \{r, g, b\} \leftrightarrow \{\nabla, S_{\Theta}, \cdot \tau^1 \nabla S_{\Theta} \cdot \tau^2 \nabla S_{\Theta} \cdot \tau^3\}$$

B.5 Interactions as Correlations

Strong (gluons):

$$G_\mu^a \leftrightarrow \partial_\mu (\nabla S_\Theta \cdot \tau^a)$$

Confinement:

$$E_{\text{conf}}(r) \sim \sigma \cdot r, \sigma \propto \left| \int_{\Omega} K(x, y) \nabla S_\Theta(y) d^4 y \right|$$

Weak ($W^\pm, Z^0$):

$$W_\mu^\pm \leftrightarrow \partial_\mu (\nabla S_\Theta \cdot \sigma^\pm), Z_\mu^0 \leftrightarrow \partial_\mu (\nabla S_\Theta \cdot \sigma^3)$$

Electromagnetic (photon):

$$A_\mu \leftrightarrow \partial_\mu S_\Theta, F_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \partial_\nu \partial_\mu S_\Theta$$

Gravitational (graviton):

$$h_{\mu\nu} \leftrightarrow \partial_\mu \partial_\nu S_\Theta - \eta_{\mu\nu} \square S_\Theta$$

Higgs mechanism:

$$S_\Theta(x) = v + h(x), m_H^2 = 4\lambda v^2$$

B.6 Structures

Atom (Schrödinger equation):

$$\left[-\frac{\hbar^2}{2m} \nabla^2 + V_{\text{AU}}(r) \right] \psi = E\psi$$

CKM matrix:

$$V_{ij} = \langle \Theta^{(i)} | \Theta^{(j)} \rangle_K$$

PMNS matrix:

$$U_{\alpha i} = \langle \Theta^{(\alpha)} | \Theta^{(i)} \rangle_K$$

B.7 Radiation

Maxwell's equation:

$$\square A_\mu = \mu_0 J_\mu$$

Graviton wave equation:

$$\square h_{\mu\nu} = 0$$

B.8 Dark Sector

Dark matter condition:

$$\langle \Theta_{\text{DM}} | A_\mu | \Theta_{\text{DM}} \rangle = 0$$

Dark Energy:

$$\Lambda_{\text{eff}} = \Lambda_0 + \gamma \cdot S_\Theta^{\text{rlog}} + \delta \cdot \left(\frac{dS_\Theta^{\text{rlog}}}{dt} \right)^2$$

Equation of state:

$$w(a) = -1 + \frac{\gamma}{\rho_{\text{DE}} c^2} \cdot \frac{dS_\Theta^{\text{rlog}}}{d \ln a}$$

Appendix C. Relationship with previous works of the AU-cycle

This appendix contains a map of the connections between this work and previous publications on the Acta Universi hypothesis. It indicates which works are cited in each chapter.

C.1 Work on the fundamental principles of AU

1. **"Acta Universi: A Unified Information-Entropy Paradigm – Explanations and Testable Predictions"** (Yashchenko, 2026). Used in Chapters 1–2, 19–20, and 23.
2. **"The act of recording the primary thought-form as the initiator of the expansion of the Universe"** (Yashchenko, 2026). Used in Chapters 1, 18.
3. **"Thought-form" as a metaphor for any recording of information in the Acta Universi hypothesis** (Yashchenko, 2026). Used in Chapters 1, 5–6.

4. **"Connection of kairos-time with thermodynamics in the Acta Universi hypothesis"** (Yashchenko, 2026). Used in Chapters 1, 10, and 14.
5. **"Spontaneous fluctuations of the theta-entropy field before significant events"** (Yashchenko, 2026). Used in Chapters 1, 20.
6. **"Gravity is the entropy gradient"** (Yashchenko, 2026). Used in Chapter 10.
7. **"LAW OF CONSERVATION OF CAUSALITY FOR THE AU-FIELD"** (Yashchenko, 2026). Used in Chapters 1, 2.
8. **"Mathematical model of space and time in the Acta Universi hypothesis"** (Yashchenko, 2026). Used in Chapters 1, 19.
9. **"Acta Universi: Emergent Spacetime from Entropy of Thought and Integrated Information"** (Yashchenko, 2026). Used in Chapters 1, 10.

C.2 Works on the physics of elementary particles and interactions

10. **"Fundamental Constants as Emergent Functionals in the Acta Universi Hypothesis"** (Yashchenko, 2026). Used in Chapters 3–4.
11. **"Quark confinement in the context of the Acta Universi hypothesis"** (Yashchenko, 2026). Used in Chapters 5, 7.
12. **"Electromagnetic radiation in the context of the Acta Universi hypothesis"** (Yashchenko, 2026). Used in Chapters 9, 15.
13. **"The structure of the atom from the point of view of the Acta Universi (AU) hypothesis"** (Yashchenko, 2026). Used in Chapter 12.

C.3 Work on the dark sector and cosmology

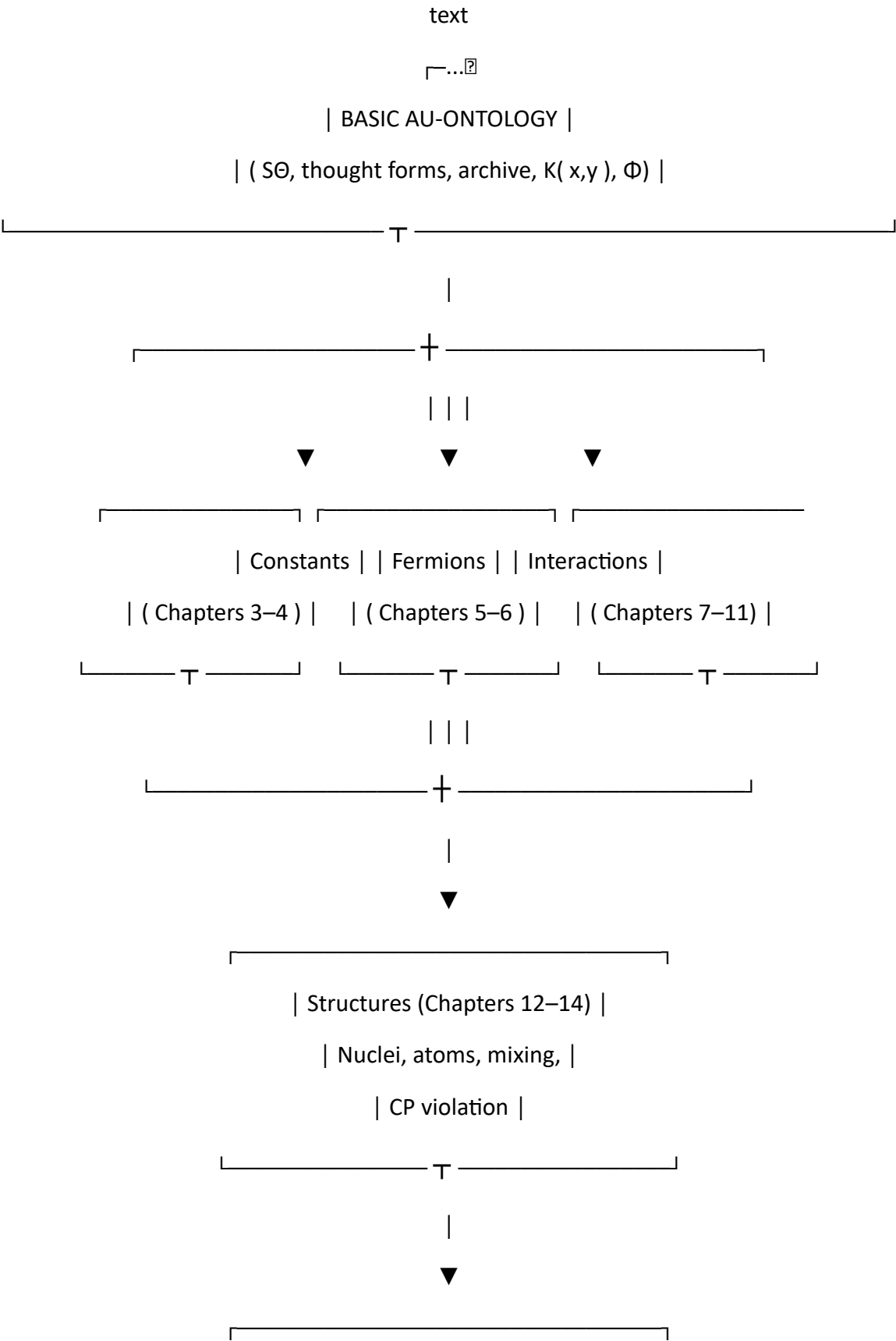
14. **"Dark matter from the point of view of the Acta Universi hypothesis"** (Yashchenko, 2026). Used in Chapter 17.
15. **"Entropy and Its Radiation in Dark Energy"** (Yashchenko, 2026). Used in Chapters 10, 18.
16. **"The concept of thought forms as a consequence of the Acta Universi hypothesis on the nature of dark energy and data from the Dark Energy Spectroscopic Instrument (DESI)"** (Yashchenko, 2026). Used in Chapters 18, 20.

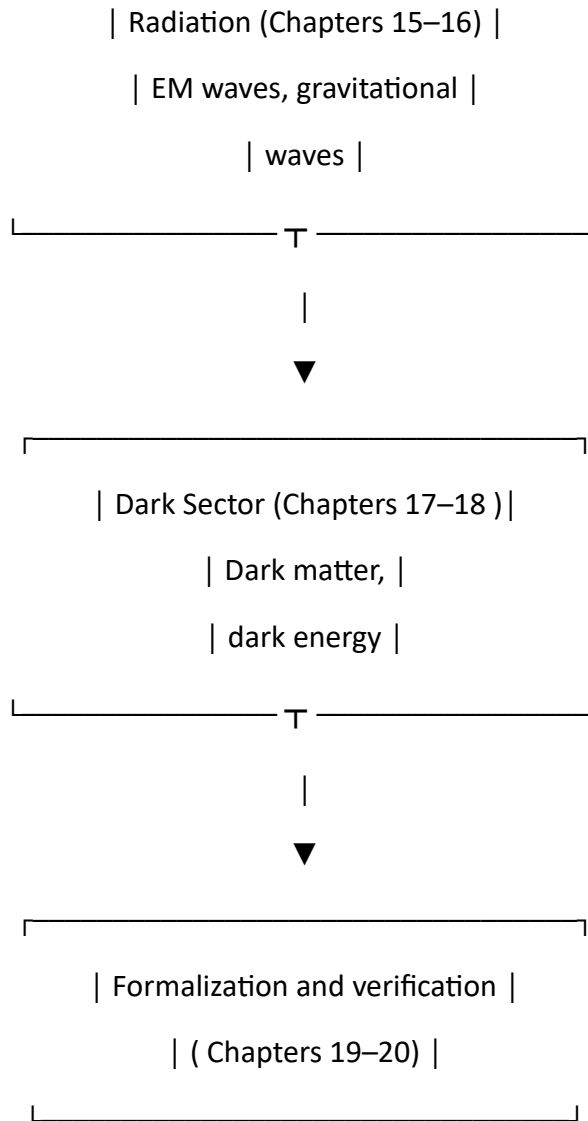
C.4 Works on quantum gravity and formalization

17. **"Acta Universi as the infinite-dimensional limit of string theory"** (Yashchenko, 2026). Used in Chapters 21, 23.
18. **"Quantum entanglement in the Acta Universi hypothesis"** (Yashchenko, 2025). Used in Chapters 9, 15, and 19.

19. "Extended Bell's theorem in the Acta Universi conjecture" (Yashchenko, 2025). Used in Chapters 9, 15, and 19.

C.5 Schematic connection map





Appendix D. Status of Claims

This appendix contains a summary table of the statuses of the statements used in this article. All statements are divided into three categories:

1. **An empirical fact** is something that has been measured or confirmed in the mainstream.
2. **A hypothesis** is a theoretical assumption of an AU model that requires verification.
3. **Speculation** is a further consequence that has no experimental support.

Statement	Status	Chapter
Field S_θ as a fundamental reality	Hypothesis	1

Statement	Status	Chapter
Localization criterion $\rho_{\text{записей}} > \rho_{\text{crit}}$	Hypothesis	2
Constants as functionals of S_Θ	Hypothesis	3
Three generations as levels of arousal	Speculation	4
Quarks as localized coils	Speculation	5
Leptons as color-neutral modes	Speculation	6
Gluons as SU(3) correlation modes	Speculation	7
$W^\pm, Z^0$ as twisted modes	Speculation	8
Photon as a gradient wave	Speculation	9, 15
Graviton as a metric perturbation	Hypothesis	10, 16
Higgs as a condensate oscillation S_Θ	Speculation	11
Nuclei as bound states of quarks	Speculation	12
Atoms as standing modes	Speculation	12
CKM/PMNS as overlap integrals	Speculation	13
CP violation as asymmetry of turns	Speculation	14
Baryogenesis as accumulation of asymmetry	Speculation	14
Dark matter as unmanifested modes	Speculation	17
Dark energy as global entropy	Hypothesis	18

Statement	Status	Chapter
Evolution $w(a)$ from dynamics S_Θ	Hypothesis	18
Correlations of entropy parameters with observables	Hypothesis	20
Variations of constants in the early Universe	Hypothesis	20
Anomalies in LIGO/Virgo data	Hypothesis	20
Anomalies in DESI data	Hypothesis	20
Anomalies in CP violation	Hypothesis	20
AU interfaces and regeneration modulation	Speculation	20
Collective thought forms and global processes	Speculation	20
Non-local correlations between biosystems	Speculation	20
Direct "reading" of the archive	Speculation	20
Impact on cosmological parameters	Speculation	20

Appendix E. Recommendations for Further Research

This appendix contains brief recommendations for researchers working in the field of the AU model.

E.1 For theoretical physicists

1. **Formalization:** Develop an explicit form of the kernel $K(x, y)$ based on symmetries or dynamics.
2. **Spectral problem:** Solve the eigenvalue problem for the operator $\hat{L}$.
3. **Equations of motion:** Derive the equations of Maxwell, Einstein, Schrödinger from dynamics S_Θ .

4. **Quantization:** Develop a procedure for quantizing the field S_Θ .

E.2 For cosmologists

1. **Dark energy:** Compare AU model predictions $w(a)$ with DESI, Euclid, JWST data.
2. **Dark matter:** Propose observational tests for latent modes.
3. **Early Universe:** Explore the possibility of constant variation in the early Universe.

E.3 For experimental physicists

1. **LHC:** Look for anomalies in the data that might be related to dynamics S_Θ .
2. **LIGO/Virgo:** Search for deviations from general relativity in gravitational wave signals.
3. **Precision measurements:** Look for correlations between entropic parameters and observed quantities.

E.4 For philosophers and methodologists

1. **Falsifiability:** Assess whether the AU model is falsifiable.
 2. **Ontology:** Analyze the status of the field S_Θ and its relation to observable reality.
 3. **Interdisciplinarity:** Develop criteria for evaluating interdisciplinary theories.
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Bibliography

Works on the Acta Universi hypothesis

1. **Yashchenko, D.** (2026). Fundamental Constants as Emergent Functionals in the Acta Universi Hypothesis / Fundamental Constants as Emergent Functionals in the Acta Universi Hypothesis. *Zenodo*. <https://doi.org/10.5281/zenodo.22024232>
2. **Yashchenko, D.** (2026). Quark confinement in the context of the Acta Universi hypothesis / Confinement quarks V context Acta Universi Hypotheses. *Zenodo*. <https://doi.org/10.5281/zenodo.22091060>
3. **Yashchenko, D.** (2026). Electromagnetic radiation in the context of the Acta Universi hypothesis / Electromagnetic radiation V context Acta Universi Hypotheses. *Zenodo*. <https://doi.org/10.5281/zenodo.22091219>
4. **Yashchenko, D.** (2026). The structure of the atom from the point of view of the Acta Universi (AU) hypothesis / Structure atom With points vision Hypotheses Acta Universi (AU). *Zenodo*. <https://doi.org/10.5281/zenodo.22079105>

5. **Yashchenko, D.** (2026). Dark matter from the point of view of the Acta Universi hypothesis / « Dark matter » with points vision Acta Universi Hypotheses. *Zenodo*. <https://doi.org/10.5281/zenodo.22066501>
6. **Yashchenko, D.** (2026). Entropy and its radiation in dark energy in the Acta Universi hypothesis / Entropy And her radiation V dark energy V Hypothesis Acta Universi. *Zenodo*. <https://doi.org/10.5281/zenodo.18127658>
7. **Yashchenko, D.** (2026). Gravity is the entropy gradient / Gravity is gradient entropy. *Zenodo*. <https://doi.org/10.5281/zenodo.20082347>
8. **Yashchenko, D.** (2026). The concept of thought forms as a consequence of the Acta Universi hypothesis on the nature of dark energy and data from the Dark Energy Spectroscopic Instrument (DESI) / Concept thought forms How investigation Acta Universi hypotheses about nature dark energy And Dark Energy Spectroscopic Instrument (DESI) data. *Zenodo*. <https://doi.org/10.5281/zenodo.20308641>
9. **Yashchenko, D.** (2026). Acta Universi: A Unified Information-Entropy Paradigm – Explanations and Testable Predictions / Acta Universi: a unified information-entropy paradigm – explanations and testable predictions. *Zenodo*. <https://doi.org/10.5281/zenodo.22137462>
10. **Yashchenko, D.** (2026). The act of recording the primary thought-form as the initiator of the expansion of the Universe / Act records primary thought forms How initiator extensions Universe. *Zenodo*. <https://doi.org/10.5281/zenodo.22065358>
11. **Yashchenko, D.** (2026). "Thought-form" as a metaphor for any recording of information in the Acta Universi hypothesis metaphor For any records information V Hypothesis Acta Universi. *Zenodo*. <https://doi.org/10.5281/zenodo.22010383>
12. **Yashchenko, D.** (2026). Connection of kairos-time with thermodynamics in the Acta Universi hypothesis / Communication kairos - time With thermodynamics V Hypothesis Acta Universi. *Zenodo*. <https://doi.org/10.5281/zenodo.22019999>
13. **Yashchenko, D.** (2026). Spontaneous fluctuations of the theta-entropy field before significant events. *Zenodo*. <https://doi.org/10.5281/zenodo.22137245>
14. **Yashchenko, D.** (2026). LAW OF CONSERVATION OF CAUSALITY FOR THE AU-FIELD / LAW SAVES CAUSALITIES FOR AU-FIELD. *Zenodo*. <https://doi.org/10.5281/zenodo.19689635>
15. **Yashchenko, D.** (2026). Mathematical model of space and time in the Acta Universi hypothesis / Mathematical model spaces And time V Hypothesis Acta Universi. *Zenodo*. <https://doi.org/10.5281/zenodo.20812754>
16. **Yashchenko, D.** (2026). Acta Universi: Emergent Spacetime from Entropy of Thought and Integrated Information / Acta Universi: space-time arising from the entropy of thought and integrated information. *Zenodo*. <https://doi.org/10.5281/zenodo.20845267>

17. **Yashchenko, D.** (2026). Acta Universi as the infinite-dimensional limit of string theory / Acta Universi as infinite-dimensional limit theories strings *Zenodo*.
<https://doi.org/10.5281/zenodo.17671014>
 18. **Yashchenko, D.** (2026). Quantum entanglement in the Acta Universi hypothesis / Quantum confusion V Hypothesis Acta Universi. *Zenodo*.
<https://doi.org/10.5281/zenodo.18143293>
 19. **Yashchenko, D.** (2026). Extended Bell's theorem in the Acta Universi conjecture / Extended theorem Bella V Hypothesis Acta Universi. *Zenodo*.
<https://doi.org/10.5281/zenodo.18143266>
 20. **Yashchenko, D.** (2026). Table of DOIs about Acta Universi Hypothesis at 08/27/2026. *Zenodo*. <https://doi.org/10.5281/zenodo.22120149>
-

Mainstream research

21. **Particle Data Group** (2025). Review of Particle Physics. *Physical Review D*, 110 (3), 030001. <https://doi.org/10.1103/PhysRevD.110.030001>
22. **DESI Collaboration** (2025). DESI 2024 VI: Cosmological Constraints from the Measurements of Baryon Acoustic Oscillations. *arXiv*. <https://arxiv.org/abs/2404.03002>
23. **Verlinde, E.** (2011). On the Origin of Gravity and the Laws of Newton. *Journal of High Energy Physics*, 2011 (4), 29. [https://doi.org/10.1007/JHEP04\(2011\)029](https://doi.org/10.1007/JHEP04(2011)029)
24. **Weinberg, S.** (1995). *The Quantum Theory of Fields, Vol. 1: Foundations*. Cambridge University Press.
25. **Weinberg, S.** (1996). *The Quantum Theory of Fields, Vol. 2: Modern Applications*. Cambridge University Press.
26. **Peskin, M. E., & Schroeder, D. V.** (1995). *An Introduction to Quantum Field Theory*. Addison-Wesley.
27. **Bekenstein, J. D.** (1973). Black holes and entropy. *Physical Review D*, 7 (8), 2333–2346. <https://doi.org/10.1103/PhysRevD.7.2333>
28. **Hawking, S. W.** (1975). Particle creation by black holes. *Communications in Mathematical Physics*, 43 (3), 199–220. <https://doi.org/10.1007/BF02345020>
29. **'t Hooft, G.** (2000). The holographic principle. *arXiv*. <https://arxiv.org/abs/hep-th/0003004>
30. **Maldacena, J.** (1998). The large N limit of superconformal field theories and supergravity. *Advances in Theoretical and Mathematical Physics*, 2 (2), 231–252. <https://doi.org/10.4310/ATMP.1998.v2.n2.a1>

31. **Penrose, R.** (1989). *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics*. Oxford University Press.
32. **Abbott, B. P., et al. (LIGO Scientific Collaboration and Virgo Collaboration)** (2016). Observation of Gravitational Waves from a Binary Black Hole Merger. *Physical Review Letters*, 116 (6), 061102. <https://doi.org/10.1103/PhysRevLett.116.061102>
33. **Amaro-Seoane, P., et al.** (2017). Laser Interferometer Space Antenna. *arXiv*. <https://arxiv.org/abs/1702.00786>
34. **Planck Collaboration** (2020). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6. <https://doi.org/10.1051/0004-6361/201833910>
35. **Riess, A.G., et al.** (1998). Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant. *The Astronomical Journal*, 116 (3), 1009–1038. <https://doi.org/10.1086/300499>
36. **Perlmutter, S., et al.** (1999). Measurements of Ω and Λ from 42 High-Redshift Supernovae. *The Astrophysical Journal*, 517 (2), 565–586. <https://doi.org/10.1086/307221>
37. **Sakharov, A. D.** (1967). Violation of CP Invariance, C Asymmetry, and Baryon Asymmetry of the Universe. *JETP Letters*, 5, 24–27.
38. **Kobayashi, M., & Maskawa, T.** (1973). CP-Violation in the Renormalizable Theory of Weak Interaction. *Progress in Theoretical Physics*, 49 (2), 652–657. <https://doi.org/10.1143/PTP.49.652>
39. **Peccei, R. D., & Quinn, H. R.** (1977). CP Conservation in the Presence of Pseudoparticles. *Physical Review Letters*, 38 (25), 1440–1443. <https://doi.org/10.1103/PhysRevLett.38.1440>
40. **Rubin, V. C., & Ford, W. K., Jr.** (1970). Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions. *The Astrophysical Journal*, 159, 379. <https://doi.org/10.1086/150317>
41. **Gross, D. J., & Wilczek, F.** (1973). Ultraviolet Behavior of Non-Abelian Gauge Theories. *Physical Review Letters*, 30 (26), 1343–1346. <https://doi.org/10.1103/PhysRevLett.30.1343>
42. **Politzer, H. D.** (1973). Reliable Perturbative Results for Strong Interactions? *Physical Review Letters*, 30 (26), 1346–1349. <https://doi.org/10.1103/PhysRevLett.30.1346>
43. **Wilson, K. G.** (1974). Confinement of Quarks. *Physical Review D*, 10 (8), 2445–2459. <https://doi.org/10.1103/PhysRevD.10.2445>
44. **Weinberg, S.** (1967). A Model of Leptons. *Physical Review Letters*, 19 (21), 1264–1266. <https://doi.org/10.1103/PhysRevLett.19.1264>

45. **Glashow, S. L.** (1961). Partial-symmetries of weak interactions. *Nuclear Physics*, 22 (4), 579–588. [https://doi.org/10.1016/0029-5582\(61\)90469-2](https://doi.org/10.1016/0029-5582(61)90469-2)
46. **Salam, A.** (1968). Weak and Electromagnetic Interactions. In *Elementary Particle Theory* (pp. 367–377). Almqvist & Wiksell.
47. **Higgs, P. W.** (1964). Broken Symmetries and the Masses of Gauge Bosons. *Physical Review Letters*, 13 (16), 508–509. <https://doi.org/10.1103/PhysRevLett.13.508>
48. **Englert, F., & Brout, R.** (1964). Broken Symmetry and the Mass of Gauge Vector Mesons. *Physical Review Letters*, 13 (9), 321–323. <https://doi.org/10.1103/PhysRevLett.13.321>
49. **ATLAS Collaboration** (2012). Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC. *Physics Letters B*, 716 (1), 1–29. <https://doi.org/10.1016/j.physletb.2012.08.020>
50. **CMS Collaboration** (2012). Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC. *Physics Letters B*, 716 (1), 30–61. <https://doi.org/10.1016/j.physletb.2012.08.021>