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Abstract

Based on respect for the classical physical conclusion that matter-antimatter annihilation produces photons, this paper redefines the logical boundaries of fundamental concepts such as energy-anti-energy and matter-annihilating matter. It strictly distinguishes between two types of physical processes: first, the traditional mass-energy conversion process when matter and antimatter meet, which leaves behind energy and photons; second, the field-configuration-annihilation process proposed herein, which after interaction completely returns to the quantum vacuum ground state, leaving no observable physical remnants. This paper introduces two hypothetical physical entities — matter-annihilating matter and electron-annihilating electron — and clarifies their symmetric annihilation relationship. Based on the philosophy of binary opposition and unity, a theoretical framework of Chaos Theory is constructed, proposing three core foundational rules with mathematical expressions. On this basis, two major directions are outlined: experiments feasible with current technology and research directions verifiable with future technology. A set of falsifiable scientific predictions is also proposed. All theoretical inferences are ultimately judged by physical experiments, providing a theoretical reference for fundamental physics and new physics beyond the Standard Model.

Keywords: Energy-Anti-energy; Annihilating Matter; Binary Symmetry; Testable Physical Experiments; Quantum Vacuum Ground State; Chaos Theory; Falsifiability

1 Introduction

In the existing theoretical physics system, the mass-energy conversion and release of electromagnetic radiation and photons upon the meeting of matter-antimatter and electrons-positrons is a well-established fundamental physical conclusion [1][2][3]. However, the current conceptual system does not strictly distinguish between two opposing processes at a logical level: one is the transformation of oppositely charged quanta, leaving behind energy; the other is the complete cancellation of field configuration, leaving no observable particles, energy, or field states after the interaction. Classical experiments such as the Casimir effect and Lamb shift have indirectly confirmed the objective existence of quantum vacuum fluctuations and virtual particle pairs [7][8], providing an experimental basis for in-depth research on the vacuum ground state and microscopic particle annihilation mechanisms.

Based on logical deductions from thought experiments and constraints from existing experimental facts, this paper carries out foundational concept completion and physical hierarchy reconstruction without overturning classical physical conclusions:

Fully retain the classical definitions of "matter-antimatter" and related experimental conclusions;

Introduce new cosmic foundational symmetric theoretical concepts: "matter-annihilating matter" and "energy-anti-energy";

Establish the three core rules of Chaos Theory and propose the multiverse foundation hypothesis;

Design hierarchical testable physical experiment schemes and falsifiable theoretical predictions.

Methodology Statement: The concepts of anti-energy, annihilating matter, and annihilating electron in this paper are hypothetical physical constructs at the theoretical level, currently lacking direct experimental confirmation. They are theoretical constructs awaiting experimental testing, with all theoretical inferences subject to future physical experiments as the final arbiter.

AI Usage Statement: AI-assisted tools were used solely for language polishing and academic formatting standardization during the writing process. The core physical ideas, fundamental concept definitions, mathematical logic derivations, and experimental scheme designs were completed independently by the author.

2 Redefinition of Fundamental Concepts and Mathematical Description

2.1 Boundary Definition of Existing Classical Concepts

Concept Physical Meaning Relation to Definitions in This Paper

Matter & Antimatter, Positron & Electron Opposite charge and intrinsic quantum properties; upon meeting, undergo mass-energy conversion releasing energy and electromagnetic radiation, leaving clear energy remnants [1][2][3] Fully retained; does not deny or modify existing experimental and theoretical conclusions

Particles, Electrons Interconvertible, decomposable into conventional energy; not the ultimate physical foundation of the universe [4][5][12] Belong to a lower physical level, serving as the underlying reference for the theory herein

Virtual Particle Pairs Spontaneously fluctuate, generate, and dissipate in the quantum vacuum background following the uncertainty principle, satisfying $\Delta E \cdot \Delta t \geq \hbar / 2$ [9] Serve as natural carriers for observing the binary symmetry of energy and anti-energy

2.2 New Paired Fundamental Concepts Proposed Herein (Theoretical Hypotheses)

(1) Energy & Anti-energy (Theoretical Construct)

The anti-energy defined herein is neither the symmetric counterpart of dark energy nor a renaming of the existing negative energy concept; it is an independently hypothesized, novel physical entity. The opposition between conventional matter and antimatter manifests in intrinsic quantum numbers like charge and baryon number, whereas the opposition between energy and anti-energy is of a higher order, manifesting as complete opposition in the measure of physical existence.

The mathematical definition adopts a working hypothesis form. The derivation follows the binary opposition and unity rule of Chaos Theory, requiring that dual physical quantities exhibit complete opposition in existence measure, constructed using sign inversion. Its validity awaits subsequent experimental verification.

Conventional energy mass-energy relation:

$$E^2 = (pc)^2 + (m_0 c^2)^2$$

Hypothetical definition of anti-energy:

$$\bar{E} = -E$$

Axiomatic condition for ideal annihilation equilibrium:

$$E + \bar{E} = 0$$

Differentiation from existing physical concepts:

Concept Physical Meaning Experimental Evidence

Dark Energy Possesses positive energy density $\Lambda > 0$, dominates the accelerated expansion of cosmic spacetime
Supernova observations, CMB observations

Negative Energy A special quantum state with energy density $\rho < 0$, typically manifested in the Casimir effect Casimir effect experiments

Anti-energy Hypothetical theoretical entity completely opposite to conventional energy in existence measure No direct experimental evidence yet; to be tested

(2) Matter & Annihilating Matter (Theoretical Construct)

This pair of concepts differs from traditional matter-antimatter; they are cosmic foundational symmetric physical entities constructed herein. Their interaction can trigger a field-configuration-annihilation process, leaving behind no conventional particles, electromagnetic energy, or observable field states, ultimately returning completely to the quantum vacuum ground state.

The annihilation process is hypothesized in a quantum field theory form, not strictly derived from first principles. The theoretical form will be further optimized based on future experimental results.

Matter field Lagrangian:

$$L_M = \bar{\psi}_M (i \gamma^\mu \partial_\mu - m) \psi_M$$

Annihilating matter field Lagrangian:

$$L_{\bar{A}} = - \bar{\psi}_{\bar{A}} (i \gamma^\mu \partial_\mu - m) \psi_{\bar{A}}$$

The sign inversion follows the binary opposition and unity rule.

Field-configuration-annihilation process:

$$\psi_M + \psi_{\bar{A}} \rightarrow |0\rangle_{\text{vacuum}}$$

(3) Electron & Annihilating Electron (Theoretical Construct)

This paper theoretically posits the quantum number distribution of the annihilating electron, forming a symmetric contrast with the conventional electron:

Quantum Number Electron (e^-) Annihilating Electron (\bar{e})

Charge Q -1 -1

Spin s $1/2$ $1/2$

Lepton Number L_e +1 -1

Baryon Number B 0 0

Phase Factor $e^{i\theta}$ $-e^{i\theta}$

From the perspective of the Standard Model theoretical framework, the annihilating electron's quantum number distribution (charge -1, lepton number -1) presents an obvious theoretical contradiction with the inherent charge-lepton number relation in the Standard Model, $Q = T_3 + Y/2$. This suggests the necessity of new physics beyond the Standard Model, potentially extending the gauge group to $SU(3) \times SU(2) \times U(1) \times U(1)'$ to achieve theoretical self-consistency.

This paper proposes a theoretical 构想: the addition of a $U(1)'$ gauge group, with the corresponding gauge boson Z' mediating the weak interaction between the annihilating electron and conventional particles, circumventing the quantum number contradiction. This gauge group extension scheme does not significantly perturb the known particle spectrum and fundamental interactions of the Standard Model. It can be indirectly tested by searching for Z' bosons in the 1 - 3 TeV mass range at LHC high-energy colliding experiments. This 构想 is currently only a theoretical hypothesis awaiting

high-energy physics experimental verification [10][13].

Hypothetical form of the annihilation cross-section:

$$\sigma_{\{e \bar{e}\}} = (\pi \alpha^2 \hbar^2) / (m_e^2 c^2)$$

Its expression form is identical to that of electron-positron annihilation, but the physical mechanism and meaning are entirely different.

(4) Virtual Particle Pairs as Observational Carriers

Virtual particle pairs are the fundamental symmetric units of the quantum vacuum foundation. They are the simplest microscopic manifestation of energy-anti-energy within the vacuum zero-point energy background. Their entire process of spontaneous fluctuation, generation, and dissipation can indirectly reflect the intrinsic binary symmetry of energy and anti-energy.

2.3 Three Core Foundational Rules of Chaos Theory and Mathematical Expressions

Based on the core ideas of binary opposition of physical entities and global equilibrium, combined with the experimental characteristics of quantum vacuum fluctuations, three foundational rules of Chaos Theory are established, accompanied by plain physical interpretations:

(1) The Rule of Binary Opposition and Unity

Dual physical quantities satisfy the mathematical relation: $A + \bar{A} = 0$. For any fundamental physical entity, there exists a dual entity completely opposite in its measure of existence. Energy and anti-energy, matter and annihilating matter all follow this rule, with dual entities mutually depending on and balancing each other.

(2) The Rule of Global Dynamic Equilibrium

The global summation relation: $\sum (E_i + \bar{E}_i) = C$, where C is a universal constant. For a closed universe model, $C=0$. The total sum of all conventional energy and anti-energy in the cosmic system remains constant; no single physical entity can accumulate infinitely, maintaining the overall dynamic stability of the universe.

(3) The Rule of Field-Configuration-Annihilation in the Absolute Equilibrium Critical Region

When the ratio of conventional energy to anti-energy strictly satisfies $E : \bar{E} = 1 : 1$ and the phase difference is π , the system triggers a field-configuration-annihilation evolution. The dual entities completely cancel out and return to the quantum vacuum ground state, leaving no observable physical remnants.

Mathematical Formulation of the "Sliding Through the Equilibrium Region" Axiom

The potential function adopts a double-well model:

$$V(x) = k(x^2 - x_0^2)^2$$

In the double-well structure, $x = \pm x_0$ are the stable potential well bottoms, and $x = 0$ is the equilibrium saddle point, distinguishing stable states from critical transition states.

The system's dynamic evolution equation:

$$dx/dt = -4kx(x^2 - x_0^2) + \xi(t)$$

Here, $\xi(t)$ represents the quantum vacuum fluctuation perturbation term. The system's evolution is governed by both the potential function gradient and vacuum fluctuations. The gradient term drives the system toward stable potential wells, while the fluctuation term can cause deviations in the system state.

The system stably exists at $x = \pm x_0$. When rapidly sliding through the saddle point at $x = 0$, dominated by the fluctuation term, it cannot stay and does not trigger annihilation. Only when the system stably resides at the absolute equilibrium position $x = 0$, with gradient and fluctuation effects canceling each other, is complete field-configuration-annihilation triggered.

2.4 Corollaries Regarding the Hierarchy of the Cosmic Foundation

The hierarchy of physical existence, from low to high, is:

Particles / Electrons < Conventional Energy < Energy / Anti-energy < Generative Constraints of the Multiverse Foundation

Higher levels are closer to the ultimate fundamental laws of the universe. The generative constraints of the multiverse foundation constitute the highest-level foundational rules governing the structure of the multiverse.

3 Detailed Design of Scientific Experimental Schemes

General Note: Experiment I is fully feasible with current technology. Experiments IV and VII can have their basic frameworks built with existing equipment, though some technical bottlenecks remain. Experiment V can be completed via computer simulation to test logical self-consistency. Experiments II, III, and VI are not yet feasible due to current technological limitations; only theoretical research frameworks are provided, awaiting maturity of future technology.

3.1 Experiments Feasible with Current Technology

Experiment I: Quantitative Observation of Mass-Energy Conversion in Positron-Electron / Particle-Antiparticle Interactions

Objective: Strictly distinguish between traditional mass-energy conversion of particle-antiparticle pairs and the field-configuration-annihilation process defined herein, from the perspectives of energy release and particle remnants.

Setup: Use high-precision beam devices from particle colliders (reference CERN ALPHA experimental setup [3], beam intensity 10^9 p/s), equipped with high-resolution gamma detectors (energy resolution ≤ 0.1 keV, detection efficiency $\geq 95\%$), high-precision energy spectrometers, and 微量 particle remnant detection arrays (mass detection sensitivity $\leq 10^{-19}$ g).

Criterion: If particle-antiparticle collisions only release electromagnetic energy and photons, with no signs of field-configuration-annihilation or zero remnants, it confirms that traditional particle-antiparticle interactions are merely mass-energy conversion, not belonging to the foundational annihilation process defined herein.

Experiment IV: Detection of Quantum Vacuum Ground State Characteristics

Objective: Detect whether the quantum vacuum background possesses stable, measurable foundational characteristics, providing indirect experimental support for the field-configuration-annihilation mechanism.

Scheme: Construct a high-vacuum, thermally insulated cavity maintaining a vacuum of 10^{-10} Pa [7], cooled to a constant temperature of 4.2 K using liquid helium; configure an ultra-high-precision Michelson interferometer with spatial resolution up to 10^{-15} m; employ a Superconducting Quantum Interference Device (SQUID) as a vacuum fluctuation detector, leveraging mature SQUID applications in detecting weak quantum signals [8].

Procedure: (1) Build the cavity, pump to target vacuum, and cool to 4.2 K; (2) Install the interferometer and SQUID detector, calibrate precision; (3) Observe background fluctuation signals continuously over a long period, record energy background

remnants and 微弱 changes in microscopic spacetime curvature; (4) Repeat three parallel observation runs to verify stability and reproducibility.

Target Sensitivity: Energy background remnants down to ~ 0.1 eV; microscopic spacetime curvature changes detectable down to $\sim 10^{-15}$ m.

Interpretation: Stable detection of vacuum background characteristic signals consistent with theoretical expectations and quantum vacuum fluctuation laws would indirectly corroborate the objective existence of the quantum vacuum ground state. If no valid characteristic signals are detected, refine precision and shielding conditions and repeat the experiment.

Experiment V: Simulation Experiment on Multiverse Foundation Compatibility

Objective: Test the internal logical self-consistency of the multiverse foundation hypothesis via numerical computer simulation; verify the self-stabilizing evolutionary characteristics of different physical foundations.

Scheme: Based on a quantum field theory numerical simulation framework, using Python 3.8 or higher, with NumPy and Matplotlib libraries for finite element analysis. Set microscopic grid precision to 10^{-9} m to suit quantum-level evolutionary calculations.

Note: This is a pure computer numerical simulation, involving no physical experimental apparatus, used only for testing the logical self-consistency of the theoretical model.

Experiment VII: High-Precision Observation of Virtual Particle Pair Annihilation Processes

Objective: Observe the complete lifecycle of virtual particle pairs spontaneously generated from the quantum vacuum with high precision; search for anomalous annihilation signals beyond the Standard Model, indirectly supporting the energy-anti-energy binary symmetry.

Setup: Ultra-high vacuum cavity maintaining 10^{-10} Pa [7]; high-efficiency superconducting single-photon detectors (detection efficiency $\geq 98\%$); a pulsed laser-triggered high-speed imaging system with time resolution up to 10^9 frames/second to overcome current temporal resolution bottlenecks.

Procedure: (1) Maintain target vacuum and shield external electromagnetic interference; (2) Install detectors and imaging system, calibrate temporal and spatial resolution; (3) Continuously observe spontaneously generated electron-positron virtual pairs in vacuum, recording their entire cycle of generation, evolution, and annihilation; (4) Analyze photon signals and temporal imaging data to distinguish between conventional annihilation signals within the Standard Model framework and anomalous no-energy-remnant events.

Interpretation: Observation of anomalous no-energy, no-photon events during virtual pair annihilation would provide indirect experimental 线索 for the energy-anti-energy hypothesis. If no anomalous signals are found, further enhance imaging and detection resolution for continued observation.

3.2 Directions Verifiable with Mature Future Technology

Direction I: Controlled Collision of Energy and Anti-energy

Framework: If breakthroughs occur in the preparation and manipulation of anti-energy fields, directional coupling and collision of conventional energy and anti-energy fields could be achieved.

Criterion: If no observable remnants remain after collision, it proves energy and anti-energy are the ultimate physical foundation of the universe. If remnants (particles or field states) exist, they constitute a higher-order physical foundation.

Current Bottleneck: No theoretical preparation scheme or detection method for anti-energy entities currently exists; dependent on future fundamental physics breakthroughs.

Direction II: Calibration of Critical Thresholds for Annihilation in the Absolute Equilibrium Region

Framework: Achieve continuous precise tuning of the conventional energy to anti-energy ratio and phase difference; calibrate the critical range and threshold conditions triggering field-configuration-annihilation.

Current Bottleneck: Entirely dependent on breakthroughs in controllable anti-energy preparation technology; currently unable to achieve 精细化 tuning of ratio and phase.

Direction III: Microscopic Comparison Verification of Matter and Annihilating Matter

Framework: Establish criteria to distinguish the interaction of matter and annihilating matter from other processes using three dimensions: energy remnant spectra, particle generation spectra, and quantum vacuum foundation response.

Current Bottleneck: Annihilating matter is only a theoretical hypothetical construct; no preparation or capture scheme exists, preventing microscopic comparison observations.

4 Falsifiable Scientific Predictions

P1: Traditional positron-electron and particle-antiparticle collisions can only undergo mass-energy conversion, releasing energy and electromagnetic radiation. They can never exhibit the characteristic of complete field-configuration-annihilation without remnants.

P2: All known microscopic particles and free electrons can be decomposed and converted into conventional energy. Particles reside at a physical level lower than conventional energy.

P3: Only two outcomes exist for energy-anti-energy collision: (i) No observable remnants → they constitute the ultimate physical foundation of the universe; (ii) Remnants (particles or field states) exist → the remnants form a higher-order physical foundation.

P4: The universe possesses the intrinsic property of multiple physical foundations and multiple modes of origin and birth.

P5: The underlying foundational laws constraining the structure and evolution of the multiverse foundation reside at a physical level higher than energy and anti-energy.

P6: The field-configuration-annihilation of energy-anti-energy follows a fixed evolutionary sequence: disappearance of existence → transition through dynamic equilibrium → triggering of absolute equilibrium → emergence of the quantum vacuum ground state.

P7: The quantum vacuum ground state is not absolute nothingness; it is the background upon which all energy, microscopic particles, spacetime structures, and multiverse foundations of the universe depend. Vacuum fluctuation effects can be continuously observed and verified.

P8: If controllable preparation of anti-energy is realized in the future, under ideal conditions of strictly 1:1

energy-anti-energy ratio and phase difference π , all conventional physical detectors should output zero signals, and local quantum vacuum fluctuation effects should be completely suppressed.

5 Discussion

All foundational concept reconstructions and theoretical derivations herein are based on thought experiments and constraints from existing experimental facts. They do not overturn or deny classical physical conclusions already verified by experiment. They merely supplement foundational symmetric concepts outside the existing theoretical framework, achieving a logical reconstruction of physical levels and interaction mechanisms.

Several explicit limitations exist in this study:

Anti-energy, annihilating matter, and annihilating electron are purely theoretical hypothetical constructs. Currently, there are no feasible experimental preparation or capture schemes. Only indirect verification is possible at this stage; direct verification depends on future technological breakthroughs.

Some core mathematical relations adopt axiomatic definitions and sign inversion hypotheses, not strictly derived from first principles in quantum field theory. These expressions await experimental and deeper theoretical refinement.

The quantum numbers of the annihilating electron present inherent contradictions with the Standard Model. Although a gauge group extension scheme is proposed, it remains a hypothesis requiring further testing via high-energy collision experiments.

The sign inversion relation $\bar{E} = -E$ is a working hypothesis; its physical 合理性 and scope of application await experimental calibration.

Regarding the interface with Standard Model theory, this framework aims to introduce novel foundational symmetries beyond the Standard Model. Extending the gauge group to include $U(1)'$ and the Z' gauge boson can effectively reconcile the contradictions posed by the annihilating electron with existing quantum theory, without disturbing the well-verified particle physics laws of the Standard Model. This provides new theoretical 思路 and experimental search directions for new physics beyond the Standard Model, as well as research on dark matter and the nature of the vacuum.

6 Conclusion

By redefining the core fundamental concepts of energy-anti-energy and matter-annihilating matter, and relying on the three core rules of Chaos Theory, this paper constructs a multiverse foundation hypothesis, establishing a logically self-consistent, hierarchically testable framework for fundamental physics. The study strictly distinguishes between traditional mass-energy conversion and foundational field-configuration-annihilation. It hierarchically designs physical experiment schemes feasible with current technology and extensible with future technology, and proposes a set of falsifiable scientific predictions, insisting on experimental testing as the ultimate criterion for theoretical truth.

This paper is released as a preprint, offering new perspectives for fundamental physics, cosmology, and quantum vacuum research. Subsequent work will continuously refine the concept definitions, mathematical models, and experimental criteria based on future experimental progress and theoretical development.

Open Extension Statement

The foundational concept system of energy-anti-energy and matter-annihilating matter, the Chaos Theory rule framework, the testable experimental schemes, and the falsifiable predictions proposed herein are fully and freely permitted for

citation, commentary, replication studies, numerical simulations, and experimental verification by other researchers, research institutions, and academic institutions worldwide, provided that the original contribution is properly cited as the source. Furthermore, reasonable modification, supplementation, extension, and high-order modeling of the theoretical framework are permitted. Derivative new physical models, 修正 of mathematical relations, improved experimental schemes, and applications in interdisciplinary cosmology and particle physics research are allowed without additional permission from the author, aiming to promote open exchange, 共建共享, and academic iterative development of 前沿 fundamental physics.

Author's Statement

This paper is an original work dated April 30, 2026. The concepts of anti-energy, annihilating matter, annihilating electron, etc., are hypothetical physical entities independently defined herein and currently lack any publicly confirmed experimental evidence. The author declares no conflict of interest.

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