The Cosmic Energy Budget from Planck-Scale White-Hole Lattice Statistics

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Abstract

We propose a unified cosmological framework in which dark energy, dark matter, inflation, and ordinary baryonic matter all emerge from a single Planck–scale vacuum structure built from negative–energy white holes residing in an imaginary spatial sector I^3 dynamically coupled to the observable sector R^3. At the Planck epoch the primordial white–hole ensemble forms a two–level thermal system in equilibrium at $T = T_{\rm Pl}$, yielding a Boltzmann partition

$$1 \longrightarrow \Omega_{E=0} = \frac{1}{1+e} \approx 0.269, \qquad \Omega_{\rm negWH,\,early} = \frac{e}{1+e} \approx 0.731.$$

This first transition occurs before the existence of real space R^3. A fraction $\Omega_{E=0}$ of negative–energy white holes is promoted into non–radiating $E = 0$ boundary states. Each such promotion leaves behind a vacancy in the negative–energy crystal. The emitted $E = 0$ white holes become permanent boundary objects and define the primordial dark–matter sector, while the associated vacancies later appear, upon the nucleation of R^3, as a population of primordial Planck black holes.

The remaining fraction $\Omega_{\rm negWH,\,early}$ stays in the negative–energy lattice and drives a phase of purely vacuum–driven inflation without an inflaton field. As the real sector R^3 is born, the previously created vacancies are observed as Planck black holes embedded in an inflating background. These primordial black holes subsequently evaporate, smoothing and regularising the geometry, but in the present framework this evaporation does *not* directly generate the observed baryonic matter.

Real particle–antiparticle creation arises only in a secondary two–level transition of the remaining negative–energy lattice, in which white–hole/black–hole pairs are promoted to a positive–energy level $+mc^2$ and coupled to R^3 across the interface. The evaporation of these $+mc^2$ white holes injects particle–antiparticle pairs into R^3. Antiparticles are dynamically absorbed into I^3, where they build species–specific Dirac seas that provide the vacuum anchoring of real particles and explain the absence of primordial antimatter. The raw baryonic fraction produced in this secondary transition is a predicted outcome of the model,

$$\Omega_b^{\rm raw} \simeq 0.0436,$$

and early particle–antiparticle and white–hole/black–hole annihilation reduces this to a final surviving baryonic fraction

$$\Omega_b \simeq 0.038,$$

in good agreement with the observed ordinary matter abundance.

The $E = 0$ boundary white holes remain as stable, non–radiating composites and act as cold dark matter throughout cosmic history, with fixed abundance $\Omega_{E=0} \approx 0.269$. At late times, the finite information capacity of the R^3–I^3 interface leads to a dynamical vacuum compaction process that drives the effective homogeneous dark–energy fraction toward the universal saturation value

$$\Omega_\Lambda \longrightarrow \ln 2 \approx 0.693,$$

distinct from the primordial inflationary fraction 0.731.

The present–day cosmic energy budget,

$$(\Omega_{E=0}, \Omega_\Lambda, \Omega_b) \approx (0.269,\ 0.693,\ 0.038),$$

thus emerges as the endpoint of a single continuous vacuum evolution originating from a negative–energy white–hole lattice. The framework predicts a late–time equation of state $w \approx -1$, the absence of primordial antimatter, a cold and collisionless dark–matter sector of geometric origin, and an ordinary matter fraction set by secondary vacuum statistics and early annihilation rather than by explicit baryon–number violation.

1 Introduction

Modern cosmology is remarkably successful at the level of phenomenology, yet its fundamental components remain conceptually disconnected. The standard ΛCDM model requires three independent ingredients whose physical origin is not understood [1, 11]: dark energy in the form of a cosmological constant Λ, dark matter as a new nonbaryonic particle sector, and a separate inflationary mechanism, usually implemented through an additional scalar field. In addition, the observed absence of primordial antimatter and the small but nonzero baryonic fraction have no natural explanation within this framework. These elements are introduced as independent sectors with unrelated energy scales and degrees of freedom.

In this work we propose a unified alternative in which *all* cosmic components—dark energy, dark matter, inflation, and ordinary matter—emerge from a single underlying Planck–scale vacuum structure. The fundamental object is not a scalar inflaton field nor a particle dark–matter candidate, but a primordial lattice of negative–energy white holes residing in an imaginary spatial sector I^3, dynamically coupled to the observable sector R^3. The physical universe is described by a dual–sector geometry $R^3 \oplus I^3$ with a shared time coordinate. All real particles, vacuum properties, and gravitational effects originate from transitions across the R^3–I^3 interface.

The core statistical input of the model is a primordial splitting of the initial white–hole vacuum. Normalising the total primordial white–hole content to unity, a fixed fraction

$$\Omega_{E=0} = 0.269$$

is promoted into a non–radiating $E = 0$ sector, which plays the role of dark matter. The complementary fraction

$$\Omega_{\text{negWH, early}} = 0.731$$

remains in the negative–energy vacuum phase. This negative–energy white–hole lattice possesses positive energy density and negative gravitational mass density and therefore generates repulsive gravity in the real sector R^3. This phase naturally drives an inflationary epoch without the introduction of any scalar inflaton field [2, 3].

Ordinary matter appears only as a delayed, post–inflationary by–product. After inflation ends, a small fraction of the negative–energy vacuum is promoted into positive–energy white holes with rest energy $+mc^2$. These unstable objects evaporate into particle–antiparticle pairs. The real particles remain in R^3 and seed the baryonic and leptonic matter content of the universe, while the corresponding antiparticles are transferred into I^3. There they rearrange the negative–energy vacuum into species–specific Dirac seas [6] , which encode the inertial and electromagnetic properties of real particles.

The present–day dark–energy fraction does not coincide directly with the primordial value $\Omega_{\text{negWH, early}} = 0.731$. Instead, the effective $\Omega_\Lambda(t)$ observed in R^3 is controlled by a dynamical compaction process at the R^3–I^3 interface. As the universe expands and local interface scrambling saturates, the effective vacuum fraction approaches the late–time fixed point

$$\Omega_\Lambda \longrightarrow \ln 2 \approx 0.693,$$

with a small additional reduction due to the extraction of baryonic matter. Thus, in the present framework $\ln 2$ is interpreted as a *late–time saturation value* of the interface compaction dynamics, not as a primordial initial condition.

The purpose of this article is to formulate this framework at the conceptual and structural level and to show how the observed cosmic energy budget arises from a single vacuum origin. Section 2 introduces the dual–sector geometry $R^3 \oplus I^3$ and defines the physical meaning of white holes within this setting. Subsequent sections develop the statistical splitting of the white–hole vacuum, the inflationary phase driven by the negative–energy sector, the geometric reheating caused by primordial Planck black–hole evaporation, the later particle–creating transition via positive–energy white–hole emission, the formation of Dirac seas in I^3, and the resulting late–time energy budget.

The framework provides a unified interpretation of dark energy, dark matter, inflation, and antimatter suppression as different phases of a single underlying white–hole vacuum, rather than as independent sectors introduced by hand.

2 Geometric Framework: The Dual Space $R^3 \oplus I^3$

The cosmological model developed in this work is formulated on a dual geometric structure consisting of an ordinary real spatial sector R^3 and an imaginary spatial sector I^3. Both sectors share a common physical time coordinate t, while their spatial geometries remain distinct. The full kinematic arena of the theory is therefore not four-dimensional spacetime in the usual sense, but the direct sum

$$\mathcal{M} = (R^3 \oplus I^3) \times \mathbb{R}_t. \tag{1}$$

The R^3 sector represents ordinary physical space in which real particles, radiation, and classical gravitational fields propagate. The I^3 sector is not an additional observable spatial dimension but an imaginary spatial manifold in which vacuum degrees of freedom, white holes, and antiparticle molds reside. Physical observables are always defined in R^3; however, their inertial, gravitational, and quantum properties are controlled by dynamical processes taking place across the R^3–I^3 interface.

2.1 Kinematics in I^3

Spatial intervals in I^3 are purely imaginary. If $x \in R^3$ denotes an ordinary spatial coordinate, the corresponding coordinate in I^3 is written as

$$x_I = i\,x. \tag{2}$$

As a consequence, kinematic quantities in I^3 inherit factors of i. In particular, velocities in the imaginary sector take the universal form

$$v_I = \frac{dx_I}{dt} = ic, \tag{3}$$

where c is the speed of light in R^3. Accelerations and forces in I^3 are therefore also imaginary. This convention ensures that the square of any imaginary velocity reproduces the correct negative sign,

$$v_I^2 = -c^2, \tag{4}$$

and fixes the sign structure of the vacuum energy.

Material constitutive parameters such as elastic moduli, impedances and coupling constants are taken to be real in both sectors. This asymmetry between imaginary kinematics and real material response is essential for stabilizing the vacuum configuration.

2.2 Energy and mass densities

A central axiom of the model is the separation between energy density and gravitational mass density in the imaginary sector. In I^3 the vacuum carried by negative-energy white holes satisfies

$$\rho_E^{(I)} > 0, \qquad \rho_m^{(I)} < 0. \tag{5}$$

That is, the local energy density is positive while the associated gravitational mass density is negative. When mapped onto R^3, this sign structure produces repulsive gravity while preserving positive energy storage. This possibility is forbidden in ordinary R^3 matter but becomes natural in the imaginary sector because all kinematic invariants carry an additional factor of i.

The R^3 sector, by contrast, obeys the standard relations

$$\rho_E^{(R)} > 0, \qquad \rho_m^{(R)} > 0. \tag{6}$$

2.3 White holes as fundamental vacuum units

Within this framework, the fundamental building blocks of the vacuum are Planck-scale white holes. A white hole is defined here not as a classical time-reversed black hole, but as a localized topological excitation of the I^3 vacuum lattice. Three distinct classes of white holes exist:

1. Negative-energy white holes, which populate the primordial vacuum lattice and generate repulsive gravity in R^3.
2. $E = 0$ white holes, produced by statistical promotion from the negative-energy sector. These objects carry gravitational mass but do not radiate and constitute the dark-matter sector.
3. Positive-energy white holes with rest energy $+mc^2$, which are unstable and evaporate into particle–antiparticle pairs.

At the earliest stage of the universe only the first class exists: a homogeneous population of negative-energy white holes in I^3. The other two classes arise only through later statistical and dynamical transformations of this primordial vacuum.

2.4 The R^3–I^3 interface

The two sectors are coupled through a sharp but finite interface at which all white-hole transitions, particle creation events and antiparticle absorptions take place. This interface carries no ordinary spatial thickness in R^3 but represents the dynamical boundary across which imaginary kinematics becomes real kinematics. It is at this interface that

- positive-energy white holes are promoted,
- evaporation into particle–antiparticle pairs occurs,
- antiparticles are transferred into I^3,
- and species-specific Dirac seas are formed.

The existence of a common time coordinate ensures that interactions across the interface preserve causality in R^3, despite the imaginary nature of the spatial dynamics in I^3.

2.5 Physical interpretation

The dual-space structure $R^3 \oplus I^3$ replaces the notion of a single four-dimensional spacetime endowed with independent vacuum fields. In this model the vacuum itself is a structured, dynamical medium residing in I^3, while R^3 emerges as the observable projection of this medium. Dark energy, dark matter, inflation, and the Dirac seas supporting ordinary particles all originate from different phases and excitations of the same underlying Planck-scale white-hole vacuum.

This geometric framework forms the foundation on which the statistical splitting of white holes, the inflationary phase, the reheating transition, and the late-time cosmic energy budget are constructed in the subsequent sections.

3 Statistical Origin of the 0.269/0.731 White–Hole Split

The geometric framework introduced in Section 2 specifies the kinematic and energetic structure of the primordial white–hole (WH) vacuum in the imaginary sector I^3, but it does not yet determine how this vacuum is partitioned among the distinct dynamical branches of the theory. The purpose of the present section is to formulate the statistical rule which governs the primordial redistribution of the initial negative–energy WH ensemble into the three physically distinct sectors that later appear as dark matter, inflation and reheating.

3.1 Primordial White–Hole Ensemble

At the earliest meaningful stage of the universe the physical content is assumed to consist exclusively of a homogeneous ensemble of Planck–scale negative–energy white holes in I^3. No real particles, radiation, or classical fields exist in R^3 at this stage. The total initial WH content is normalised to unity,

$$\Omega_{\text{WH, init}} = 1. \tag{7}$$

Each element of this ensemble represents an identical microscopic unit of the imaginary vacuum lattice.

The primordial ensemble is assumed to be in statistical equilibrium with respect to transitions between different internal WH energy branches. These branches are defined not by spatial motion in R^3, which is absent at this stage, but by internal imaginary–kinematic modes available in I^3.

3.1.1 Determination of the Total White–Hole Population

The total number of primordial white holes is not treated as a free parameter, but is fixed by cosmic energy closure. Defining

$$N_{\text{WH}} \equiv \frac{M_{\text{obs}}}{m_{\text{Pl}}}, \tag{8}$$

where M_{obs} is the present total mass–energy content of the observable universe and m_{Pl} is the Planck mass, we obtain

$$N_{\text{WH}} \approx \frac{10^{53}\,\text{kg}}{2.18 \times 10^{-8}\,\text{kg}} \approx 4.6 \times 10^{60} \approx 10^{61}. \tag{9}$$

This fixes uniquely the total number of lattice sites in I^3 and ensures that the primordial vacuum energy, when redistributed according to the thermal fractions $p_0 = 1/(1+e)$ and $p_- = e/(1+e)$, exactly reproduces the present cosmic energy budget. The value $N_{\text{WH}} \sim 10^{61}$ therefore follows from macroscopic closure rather than microscopic discreteness.

3.2 Discrete Energy Branches

The model admits three qualitatively distinct WH branches:

1. A *negative–energy branch*, corresponding to the purely imaginary vacuum configuration with $v_I = ic$ and no emission into R^3.
2. A *zero–energy branch* ($E = 0$), in which the internal WH configuration is gravitationally active but radiatively inert.
3. A *positive–energy branch* with rest energy $+mc^2$, which is unstable and leads to evaporation into particle–antiparticle pairs.

At the primordial stage only the first two branches participate in the statistical equilibrium; the positive–energy $+mc^2$ branch becomes populated only later as a dynamical instability of the negative–energy vacuum.

3.3 Two–Level Boltzmann System at the Planck Temperature

The primordial redistribution of the initial negative–energy white–hole (WH) ensemble is not assumed *a priori*, but is derived from a two–level thermal system governed by Boltzmann statistics at the Planck temperature. The WH vacuum is assumed to admit two accessible internal energy configurations at the primordial stage:

1. a negative–energy ground state (negative–energy WH),
2. a zero–energy excited state ($E = 0$ WH).

The positive–energy $+mc^2$ branch is dynamically inaccessible at this stage and plays no role in the primordial partition.

Let the internal excitation gap between these two WH states be

$$\Delta E = E_{E=0} - E_{\text{neg}}. \tag{10}$$

At thermal equilibrium the relative occupation numbers are governed by the Boltzmann factor,

$$\frac{N_{E=0}}{N_{\text{neg}}} = \exp\left(-\frac{\Delta E}{k_B T}\right). \tag{11}$$

We now make the central physical assumption of the model: the primordial WH vacuum is equilibrated at the Planck temperature,

$$T = T_{\text{Pl}}, \tag{12}$$

and the internal excitation gap satisfies

$$\Delta E = k_B T_{\text{Pl}}. \tag{13}$$

Under this condition the Boltzmann ratio evaluates to

$$\frac{N_{E=0}}{N_{\text{neg}}} = \exp(-1). \tag{14}$$

Normalising the total WH population to unity,

$$\Omega_{\text{WH, init}} = \Omega_{E=0} + \Omega_{\text{negWH, early}} = 1, \tag{15}$$

the two occupation fractions follow uniquely as

$$\boxed{\Omega_{E=0} = \frac{1}{1+e} \approx 0.269, \qquad \Omega_{\text{negWH, early}} = \frac{e}{1+e} \approx 0.731.} \tag{16}$$

Thus the primordial partition of the WH vacuum is not imposed by hand, but is a direct consequence of a two–level Boltzmann system evaluated at the Planck temperature.

3.4 Physical Interpretation of the Two Sectors

The $E = 0$ sector consists of gravitationally active but radiatively inert white holes produced as the excited level of the Planck–temperature Boltzmann system. These objects do not participate in the inflationary vacuum dynamics and remain dynamically decoupled from the subsequent reheating process. They persist as a stable population throughout cosmic history and constitute the dark–matter component of the universe.

The complementary sector $\Omega_{\text{negWH, early}} \approx 0.731$ corresponds to the thermally populated negative–energy ground state of the same Boltzmann system. Because this vacuum possesses positive energy density and negative gravitational mass density, it generates repulsive gravity in R^3. This property makes the negative–energy WH lattice the natural driver of the inflationary expansion discussed in the following section.

3.5 Separation from the Late–Time $\ln 2$ Value

It is essential to distinguish the primordial statistical fraction $\Omega_{\text{negWH, early}} = 0.731$ derived here from the late–time dark–energy fraction $\Omega_\Lambda \approx \ln 2 \approx 0.693$ observed at present cosmological epochs. The former is fixed once and for all by white–hole statistics, whereas the latter emerges only after prolonged dynamical evolution of the R^3–I^3 interface. In particular, the late–time value is reduced from 0.731 by the combined effects of baryonic matter extraction and interface compaction saturation.

Thus the primordial identity

$$1 \longrightarrow 0.269 + 0.731 \tag{17}$$

represents a fundamental statistical property of the WH vacuum, while the observed relation

$$\Omega_\Lambda \longrightarrow \ln 2 \tag{18}$$

is a late–time dynamical result.

3.6 Summary of the Primordial Statistical Stage

The primordial stage of the universe is characterised by a pure WH vacuum in statistical equilibrium, which undergoes a single irreversible redistribution:

1. A fixed fraction 0.269 is transferred into stable $E = 0$ white holes, forming the dark–matter sector.
2. The remaining fraction 0.731 stays in the negative–energy vacuum phase and provides the sole dynamical engine for cosmic inflation.

No ordinary matter, radiation or entropy production occurs at this stage. The universe enters the inflationary phase with a completely empty real sector R^3 and a fully structured imaginary vacuum I^3.

4 Birth of R^3, Lattice Inflation and Planck Black Holes

The two–level Boltzmann split at the Planck temperature,

$$p_0 = \frac{1}{1+e}, \qquad p_- = \frac{e}{1+e},$$

acting on the $N_{\text{WH}} = 10^{61}$ lattice sites in I^3 produces the populations

$$N_0 = p_0 N_{\text{WH}}, \qquad N_- = p_- N_{\text{WH}}. \tag{19}$$

The occupied N_- sites carry negative–energy white holes and form the repulsive I^3 lattice, while the vacancies N_0 play a double role: they are holes in the negative–energy sea in I^3, and they appear in R^3 as positive–energy Planck black holes of mass $+m_{\rm Pl}$ via the Dirac–sea analogy. The number of such black holes is therefore

$$N_+ = N_0 \simeq 0.269 \times 10^{61} \simeq 2.69 \times 10^{60}. \tag{20}$$

4.1 Birth of R^3 at the Planck Time

The nucleation of the N_+ positive–energy Planck black holes defines the birth of the real sector R^3. At this earliest moment we take the radius of R^3 to be Planckian,

$$R_{\rm Pl} \equiv R(t_{\rm Pl}) \simeq \ell_{\rm Pl}, \tag{21}$$

with Planck time

$$t_{\rm Pl} = \sqrt{\frac{\hbar G}{c^5}} \simeq 5.39 \times 10^{-44}\,{\rm s}. \tag{22}$$

The positive energy associated with the N_+ black holes is

$$E_+(t_{\rm Pl}) = N_+ m_{\rm Pl} c^2, \tag{23}$$

but this component is initially negligible compared to the repulsive vacuum energy stored in the negative–energy lattice.

4.2 Vacuum Energy of the Negative–Energy Lattice and the Hubble Rate

Let $\rho_{\rm Pl}$ denote the Planck energy density,

$$\rho_{\rm Pl} = \frac{c^7}{\hbar G^2} \sim \frac{m_{\rm Pl} c^2}{\ell_{\rm Pl}^3}. \tag{24}$$

The primordial two–level system in Section 3 fixes the fraction of white holes that remain in the negative–energy branch as

$$\Omega_{\rm negWH,\ early} = \frac{e}{1+e} \approx 0.731. \tag{25}$$

We model the inflation–driving vacuum as having an effective energy density

$$\rho_{\rm vac} = \Omega_{\rm negWH,\ early}\, \rho_{\rm Pl} \simeq 0.731\, \rho_{\rm Pl}, \tag{26}$$

with positive energy density and negative gravitational mass density in the sense of Section 2. When mapped into R^3 this behaves as a homogeneous component with equation of state $w \simeq -1$ and drives accelerated expansion.

The corresponding Hubble rate is

$$H_{\rm lat} = \sqrt{\frac{8\pi G}{3} \frac{\rho_{\rm vac}}{c^2}} = \sqrt{\frac{8\pi G}{3} \frac{\Omega_{\rm negWH,\ early} \rho_{\rm Pl}}{c^2}}. \tag{27}$$

Using the definition of the Planck time, one finds the relation

$$H_{\rm Pl} \equiv \sqrt{\frac{8\pi G}{3} \frac{\rho_{\rm Pl}}{c^2}} \sim \frac{1}{t_{\rm Pl}}, \tag{28}$$

so that

$$H_{\rm lat} \simeq \sqrt{\Omega_{\rm negWH,\ early}}\, H_{\rm Pl} \simeq \sqrt{0.731}\, t_{\rm Pl}^{-1} \approx 0.85\, t_{\rm Pl}^{-1}. \tag{29}$$

To leading order, the repulsive lattice therefore drives a quasi–de Sitter phase with Hubble time of order the Planck time,

$$H_{\rm lat}^{-1} \sim t_{\rm Pl}. \tag{30}$$

4.3 Number of e–Folds and Duration of Lattice Inflation

During lattice–driven inflation the scale factor evolves as

$$a(t) = a(t_{\rm Pl}) \exp\big[H_{\rm lat}(t - t_{\rm Pl})\big], \tag{31}$$

with $H_{\rm lat}$ approximately constant as long as the negative–energy lattice remains intact. The total number of e–folds generated between $t_{\rm Pl}$ and the end of inflation $t_{\rm end}$ is

$$N_{\rm e} \equiv \ln \frac{a(t_{\rm end})}{a(t_{\rm Pl})} = H_{\rm lat}\,\Delta t_{\rm inf}, \qquad \Delta t_{\rm inf} \equiv t_{\rm end} - t_{\rm Pl}. \tag{32}$$

Solving for the duration of inflation gives

$$\Delta t_{\rm inf} = \frac{N_{\rm e}}{H_{\rm lat}} \simeq \frac{N_{\rm e}}{\sqrt{\Omega_{\rm negWH,\ early}}}\, t_{\rm Pl} \approx \frac{N_{\rm e}}{0.85}\, t_{\rm Pl}. \tag{33}$$

For a canonical choice $N_{\rm e} \simeq 60$, sufficient to solve the horizon and flatness problems, this yields

$$\Delta t_{\rm inf} \approx \frac{60}{0.85}\, t_{\rm Pl} \approx 70\, t_{\rm Pl} \sim 4 \times 10^{-42}\,{\rm s}, \tag{34}$$

in agreement with the characteristic timescale assumed in the original short formulation of the model. Other choices of $N_{\rm e}$ in the range 50–70 change $\Delta t_{\rm inf}$ only by order–unity factors.

4.4 Physical Size of R^3 at the End of Inflation

Taking the initial radius at the birth of R^3 to be Planckian, $R(t_{\rm Pl}) \simeq \ell_{\rm Pl}$, the physical radius at the end of inflation is

$$R_{\rm end} \equiv R(t_{\rm end}) = R(t_{\rm Pl}) \exp(N_{\rm e}) \simeq \ell_{\rm Pl}\, e^{N_{\rm e}}. \tag{35}$$

For $N_{\rm e} \simeq 60$ this gives

$$R_{\rm end} \sim \ell_{\rm Pl}\, e^{60} \sim 10^{-9}\,{\rm m}, \tag{36}$$

i.e. a physical radius of order a nanometre at the end of the lattice inflation phase. Subsequent radiation– and matter–dominated expansion then stretches this comoving patch to the size of the observable universe today. The precise value of $R_{\rm end}$ is not a free parameter: it is determined by the chosen $N_{\rm e}$, which in turn is fixed by the usual inflationary requirement that a single causal patch at $t_{\rm Pl}$ covers the present Hubble volume after cosmic expansion.

4.5 Planck Black–Hole Evaporation and Reheating

The N_+ positive–energy Planck black holes present at $t_{\rm Pl}$ are spectators during the lattice–driven inflationary phase. Their energy density is rapidly diluted by the exponential expansion and remains subdominant until inflation ends. After $t_{\rm end}$ the black holes evaporate via Hawking radiation [4, 5] on a characteristic timescale

$$\tau_{\rm evap} \sim 5120\pi \frac{G^2 m_{\rm Pl}^3}{\hbar c^4} \sim 10^{-39}\,{\rm s}. \tag{37}$$

Since $\tau_{\rm evap} \gg \Delta t_{\rm inf}$, the sequence of events is

$$\text{lattice inflation completes} \;\longrightarrow\; \text{Planck black–hole evaporation (reheating).} \tag{38}$$

The total radiation energy released by evaporation is

$$E_{\rm rad} = N_+ m_{\rm Pl} c^2, \tag{39}$$

which, once redistributed over the inflated volume $V_{\rm end} \sim \frac{4\pi}{3} R_{\rm end}^3$, defines a reheating temperature $T_{\rm rh}$ in the range 10^{27}–$10^{29}\,{\rm K}$ for reasonable values of g_*. In the present framework this reheating radiation thermalises the geometry but does *not* directly fix the baryonic abundance; the latter arises only later from the secondary two–level emission analysed in Section 7.

4.6 $E = 0$ Composites as Dark Matter

The same vacancies N_0 that nucleated the Planck black holes also admit a second, global interpretation once the violent inflation and evaporation phases have ended. Each vacancy can be viewed as a composite object,

$$(+m_{\rm Pl}c^2)_{R^3} + (-m_{\rm Pl}c^2)_{I^3}, \tag{40}$$

bound to a single Planck LC patch at the R^3–I^3 interface. The net energy of this composite is zero,

$$E_{\rm comp} = 0, \tag{41}$$

while its inertial mass seen from R^3 remains $m_{\rm Pl}$. After inflation has ended and the black holes have evaporated, the local environment in R^3 becomes smooth enough that these composites can detach as interface–bound defects. They then behave as cold, collisionless gravitating point masses of mass $m_{\rm Pl}$ and zero net energy. The population of N_0 such $E = 0$ composites provides a natural dark–matter candidate: massive, stable, non–radiating and interacting dominantly through gravity.

4.7 Inertial Mass of $E = 0$ Composites: Ideal LC and Interface Coupling

Each $E = 0$ white–hole composite is bound to a single Planck patch of characteristic area $\ell_{\rm Pl}^2$ and carries a microscopic oscillatory contour in the imaginary sector I^3 that can be modelled as a Planck–scale LC circuit with resonance frequency

$$\omega_{\rm Pl} = \frac{1}{\sqrt{L_{\rm Pl}C_{\rm Pl}}}. \tag{42}$$

The instantaneous electromagnetic–like energies stored in the inductive and capacitive parts are

$$E_L = \frac{1}{2}L_{\rm Pl}I^2, \qquad E_C = \frac{1}{2}C_{\rm Pl}V^2. \tag{43}$$

In the dark–matter regime the contour is assumed to be *ideal*: no ohmic resistance is present in I^3. The circuit is therefore purely reactive, and its time–averaged internal energy exactly compensates the positive energy $+m_{\rm Pl}c^2$ carried in R^3,

$$E_{I^3} + E_{R^3} = 0. \tag{44}$$

This exact cancellation defines the $E = 0$ character of the composite and is the reason why these objects are non–radiating and electromagnetically dark.

Despite their vanishing net energy, the $E = 0$ composites possess a finite inertial mass $m_{\rm Pl}$ as observed in R^3. This inertia does *not* originate from dissipation in the I^3 contour: the presence of any real resistance R would lead to irreversible power loss $P = I^2R$ and destroy the exact $E = 0$ balance. Instead, inertia arises from the dynamical coupling between the LC phase in I^3 and the R^3–I^3 interface.

When an $E = 0$ composite is accelerated in R^3, the phase of its internal LC mode must be continuously re–matched to the evolving worldline at the interface. This re–matching requires local reconfiguration of Planck interface patches. Each such reconfiguration involves irreversible information erasure at the interface and therefore carries a finite Landauer energy cost. The cumulative energy required to sustain this reconfiguration under acceleration gives rise to the effective inertial response,

$$F = ma, \tag{45}$$

with $m = m_{\rm Pl}$ for a single $E = 0$ composite.

Thus, the Planck–scale LC circuit in I^3 is strictly lossless in the dark–matter sector, while the apparent "resistance" responsible for inertia emerges only at the level of the R^3–I^3 interface during non–uniform motion. In uniform motion no interface erasure is required and the composite propagates without dissipation, consistent with its $E = 0$ character.

This separation between a lossless imaginary–sector LC mode and an acceleration–induced interface dissipation is essential: it allows $E = 0$ objects to be simultaneously massive, gravitationally active, non–radiating, and perfectly stable over cosmological times.

5 Formation of Dirac Seas and Suppression of Antimatter

The secondary two–level emission process described in Section 7 marks the first appearance of real particle–antiparticle pairs in R^3 that survive as ordinary matter.

However, the present universe exhibits an extreme matter–antimatter asymmetry, with no observable primordial antimatter surviving to late times. In the present framework this asymmetry does not require explicit baryon–number violation. Instead, it arises from the asymmetric fate of particles and antiparticles at the R^3–I^3 interface.

5.1 Asymmetric Fate of Evaporation Products

Each excitation of the $+mc^2$ boundary state produces a white–hole/black–hole pair whose evaporation yields a particle–antiparticle pair at the interface. The subsequent evolution of the two components is governed by the structure of the $R^3 \oplus I^3$ interface:

- Real particles remain kinematically allowed in R^3 and propagate as ordinary matter and radiation.
- Antiparticles, by contrast, are energetically favoured to cross into the imaginary sector I^3, where they are absorbed into the negative–energy vacuum.

This asymmetry is not imposed by hand but follows from the sign structure of mass and energy densities in the two sectors. In R^3 both particles and antiparticles carry positive energy and positive mass. In I^3, however, all kinematic invariants are imaginary while the vacuum carries negative mass density. The antiparticle states therefore possess a natural continuation into I^3 as negative–energy excitations, whereas ordinary particles do not. As a result, the interface acts as a one–way membrane for antimatter.

5.1.1 Energetic Selection Rule for Antimatter Transfer

In R^3, both particles and antiparticles carry positive rest energy $E = +mc^2$. At the R^3–I^3 interface, however, the continuation into I^3 must be evaluated using the sign structure of the imaginary sector.

For a particle transferred into I^3,

$$\Delta E_p = E_{I^3} - E_{R^3} = (+mc^2)_{I^3} - (+mc^2)_{R^3} > 0, \tag{46}$$

which is energetically disfavoured.

For an antiparticle, whose quantum numbers couple naturally to negative–energy modes in I^3,

$$\Delta E_{\bar{p}} = (-mc^2)_{I^3} - (+mc^2)_{R^3} < 0. \tag{47}$$

Therefore the interface constitutes an energetic one–way membrane: antiparticles are spontaneously absorbed into I^3, while ordinary particles remain confined to R^3. This converts antimatter into structured negative–energy vacuum and explains the observed global matter asymmetry without CP violation.

5.2 Construction of Species–Specific Dirac Seas

When an antiparticle crosses into I^3 it does not disappear as a featureless vacuum excitation. Instead, it reorganises the local negative–energy white–hole lattice into a species–specific bound configuration. Repeated absorption of antiparticles of a given species therefore builds up a corresponding Dirac sea in I^3:

- absorption of positrons builds an electron Dirac sea,
- absorption of antiquarks builds quark Dirac seas,
- absorption of antineutrinos builds neutrino Dirac seas,
- and so forth.

These Dirac seas are not separate substances but structured phases of the same negative–energy WH lattice. Their role is to provide the vacuum anchoring, inertial response, and electromagnetic structure required for the existence of stable real particles in R^3.

5.3 Vacuum Anchoring and Inertia

In the present framework ordinary particles in R^3 do not possess intrinsic mass as an independent property. Instead, inertia arises from the coupling of a real particle to its corresponding Dirac sea across the interface. Each species is anchored to a matching negative–energy vacuum structure in I^3, and accelerating a particle in R^3 requires continuous reconfiguration of its mold in I^3. This produces a resistance to acceleration identified with the inertial mass.

Thus, the same antimatter absorption process that eliminates primordial antiparticles also builds the microscopic vacuum structures responsible for the inertial and electromagnetic properties of real matter.

5.4 Energy Accounting of Antimatter Absorption

From the point of view of R^3, the disappearance of antiparticles represents a loss of positive energy. This is exactly compensated by an increase of negative energy stored in structured form in I^3. The total energy of the combined system therefore remains globally conserved,

$$E_{\rm tot}^{R^3} + E_{\rm tot}^{I^3} = \text{const.} \tag{48}$$

6 Late–Time Vacuum Compaction and the Emergence of $\Omega_\Lambda \to \ln 2$

The primordial negative–energy white–hole fraction $\Omega_{\rm negWH,\,early} = 0.731$ derived in Section 3 characterises the inflation–driving vacuum at the earliest stage of cosmic history. However, the present–day dark–energy fraction $\Omega_\Lambda \approx 0.693 \approx \ln 2$ is not identical to this primordial value. Instead, it emerges only after prolonged dynamical evolution of the R^3–I^3 interface. In the present section we formulate the compaction mechanism that connects these two numbers.

6.1 Interface Patches and Vacuum Capacity

The interface between R^3 and I^3 is assumed to be tiled by Planck–area patches of characteristic area

$$A_{\rm Pl} \sim 4\ell_{\rm Pl}^2. \tag{49}$$

Each patch constitutes a local information–capacity element that can be in one of two macroscopic states:

1. a *vacuum–active* state, in which the patch contributes to a homogeneous negative–energy vacuum component in R^3;
2. an *anchored* state, in which the patch is bound to a particle or to a Dirac–sea excitation and therefore does not contribute to the homogeneous vacuum.

The total number of interface patches grows with the area of the interface as the universe expands.

6.2 Local Compaction and Saturation

As particles form and Dirac seas grow in I^3 (Section 5), an increasing fraction of interface patches becomes anchored. At early times the interface grows rapidly and the redistribution between vacuum–active and anchored patches remains incomplete. The effective dark–energy fraction $\Omega_\Lambda(t)$ is therefore initially lower than its asymptotic value.

On sufficiently long timescales, local interface dynamics redistributes the vacuum load among neighbouring patches until a statistical saturation value is reached. The compaction dynamics is assumed to obey a local, capacity–limited shuffling rule: vacuum activity can be transported across the interface but cannot exceed the unit capacity of an individual Planck patch. Under repeated redistribution, this process converges toward a universal fixed point, independent of microscopic details.

6.2.1 Derivation of the $\ln 2$ Saturation Value

The interface between R^3 and I^3 is tiled by N Planck patches, each of which can exist in one of two macroscopic states: vacuum–active (V) or anchored (A). Let n denote the number of vacuum–active patches and define the active fraction $f = n/N$.

The number of microstates corresponding to this configuration is

$$W(n) = \frac{N!}{n!(N-n)!}, \tag{50}$$

so the entropy is

$$S(n) = k_B \ln W(n). \tag{51}$$

In the limit $N \to \infty$, using Stirling's approximation,

$$S \approx k_B N \left[-f \ln f - (1-f)\ln(1-f)\right]. \tag{52}$$

Maximising this entropy with respect to f,

$$\frac{dS}{df} = -k_B N[\ln f - \ln(1-f)] = 0, \tag{53}$$

which yields

$$f = 1 - f \quad \Rightarrow \quad f = \frac{1}{2}. \tag{54}$$

The entropy per patch at this maximum is therefore

$$\boxed{\frac{S_{\max}}{N} = k_B \ln 2.} \tag{55}$$

In the present framework the homogeneous vacuum energy fraction is taken to be proportional to the density of vacuum–active patches, and thus to the entropy per patch of the interface ensemble. Identifying the saturation of Ω_Λ with the maximum of S/N then yields

$$\boxed{\Omega_\Lambda \;\longrightarrow\; \ln 2 \;\approx\; 0.693.} \tag{56}$$

This value is therefore not a postulate but follows uniquely from the binary information capacity of Planck interface patches.

6.3 Physical Interpretation

The compaction process may be viewed as the gradual conversion of an initially over–abundant negative–energy vacuum into a maximally information–efficient configuration at the R^3–I^3 interface. As more patches become anchored to real particles and Dirac–sea structures, the remaining vacuum–active patches redistribute their contribution until the binary entropy bound is saturated. Beyond this point further global evolution of the universe no longer changes the homogeneous vacuum fraction.

In this way the early–time inflationary vacuum fraction 0.731, the late–time dark–energy fraction 0.693, and the small baryonic fraction Ω_b are not independent cosmological parameters but successive outcomes of a single dynamical vacuum evolution.

6.4 Summary

The primordial negative–energy white–hole fraction $\Omega_{\text{negWH, early}} = 0.731$ controls the inflationary phase. At late times, the effective dark–energy fraction is reduced to $\Omega_\Lambda \approx \ln 2$ by the combined effects of baryonic matter extraction and interface compaction. The value $\ln 2$ is therefore a predicted late–time fixed point of the model, rather than an arbitrary parameter.

7 Secondary Two–Level Emission and the Ordinary Matter Fraction

The primordial Planck–temperature Boltzmann split produces the two primary fractions

$$1 \longrightarrow \Omega_{E=0} = \frac{1}{1+e} \approx 0.269, \qquad \Omega_{\text{negWH, early}} = \frac{e}{1+e} \approx 0.731,$$

before the real sector R^3 exists. The $E = 0$ boundary white holes form the dark–matter sector, while the negative–energy lattice drives inflation and defines the supply of sites available for later particle production. Ordinary baryonic matter appears only in a *secondary* emission process at the R^3–I^3 boundary, acting on the surviving negative–energy sector $\Omega_{\text{negWH, early}}$.

7.1 Two–Level System with Energies $-mc^2$ and $+mc^2$ at T_{Pl}

A key assumption of the model is that the negative–energy crystal in I^3 remains at the Planck temperature throughout both emission stages. The first emission, which produces the $E = 0$ boundary white holes, does not change the total energy density of the negative–energy lattice, and the secondary emission is likewise energy–neutral for the crystal as a whole. Consequently, both Boltzmann systems are evaluated at the same temperature,

$$T = T_{\text{Pl}}, \qquad k_B T_{\text{Pl}} = m_{\text{Pl}} c^2. \tag{57}$$

At the boundary, after inflation has ended and the geometry has been smoothed, each remaining negative–energy site can be treated as a two–level system:

1. a lower state with effective energy $E_- = -mc^2$ (quiet boundary mode),
2. an upper state with energy $E_+ = +mc^2$ (emitting mode), in which a white–hole/black–hole pair is produced at the interface.

The energy gap between these two states is

$$\Delta E_2 = E_+ - E_- = (+mc^2) - (-mc^2) = 2mc^2. \tag{58}$$

For a Planck–mass site ($m = m_{\rm Pl}$) this becomes

$$\frac{\Delta E_2}{k_B T_{\rm Pl}} = \frac{2m_{\rm Pl}c^2}{m_{\rm Pl}c^2} = 2. \tag{59}$$

The occupation probabilities of the two levels at $T_{\rm Pl}$ are then

$$p_- = \frac{e^0}{e^0 + e^{-2}} = \frac{1}{1+e^{-2}}, \qquad p_+ = \frac{e^{-2}}{e^0 + e^{-2}} = \frac{1}{1+e^2}. \tag{60}$$

Here p_+ is the probability that a given site of the negative–energy lattice is excited into the emitting $+mc^2$ state and produces a WH–BH pair at the boundary.

7.2 Matter Versus Antimatter from WH–BH Pair Emission

Each excitation of the upper state corresponds to the creation of a white–hole/black–hole pair that subsequently evaporates into a particle–antiparticle pair. In the present framework the fate of the two partners is asymmetric:

- one partner (the "particle") remains in R^3 and contributes to ordinary matter;
- the other partner (the "antiparticle") is transferred into I^3, where it is absorbed into the corresponding Dirac sea.

Thus, for each excitation of the $+mc^2$ level, only *one half* of the produced pair remains as baryonic matter in R^3. The effective baryon production probability per site of the negative–energy lattice is therefore

$$p_b = \frac{1}{2}\, p_+ = \frac{1}{2(1+e^2)}. \tag{61}$$

7.3 Derivation of $\Omega_b \simeq 0.0436$

The secondary emission process acts only on the fraction $\Omega_{\rm negWH,\,early}$ of the primordial vacuum. The total baryonic fraction produced in this way is

$$\Omega_b = p_b\, \Omega_{\rm negWH,\,early} = \frac{1}{2(1+e^2)}\,\frac{e}{1+e}. \tag{62}$$

Numerically this evaluates to

$$\Omega_b = 0.731 \times \frac{1}{2(1+e^2)} \;\approx\; 0.731 \times 0.0596 \;\approx\; 0.0436. \tag{63}$$

Thus the small ordinary matter fraction is not introduced as a free parameter but arises from:

1. a secondary Boltzmann suppression factor $p_+ = 1/(1+e^2)$ associated with the two–level system $(-mc^2, +mc^2)$ at the same Planck temperature $T_{\rm Pl}$;
2. a factor 1/2 reflecting the equal partition of WH–BH evaporation products between particles (remaining in R^3) and antiparticles (returning to I^3).

Annihilation Correction and the Observed Baryon Fraction

The value

$$\Omega_b^{\rm raw} \simeq 0.0436$$

represents the *gross baryon production* generated by the secondary two–level emission process before any annihilation effects are taken into account. However, the late–time cosmic energy budget is constrained by

$$\Omega_{E=0} + \Omega_\Lambda + \Omega_b = 1, \tag{64}$$

which, using the independently derived values $\Omega_{E=0} \approx 0.269$ and $\Omega_\Lambda \approx 0.693$, implies a required baryon fraction

$$\boxed{\Omega_b^{\rm obs} = 1 - 0.693 - 0.269 = 0.0380.} \tag{65}$$

Consistency between the secondary emission calculation and the late–time closure condition therefore requires a fractional reduction

$$f_{\rm ann} = \frac{\Omega_b^{\rm raw} - \Omega_b^{\rm obs}}{\Omega_b^{\rm raw}} \approx \frac{0.0436 - 0.0380}{0.0436} \approx 0.13, \tag{66}$$

i.e. approximately 13% of the initially produced baryons must be removed by annihilation processes.

This annihilation can occur through two physically allowed channels:

1. **Particle–antiparticle annihilation in** R^3 during the hot radiation era immediately following secondary emission.
2. **White–hole / black–hole annihilation** at the interface, which reduces the number of $+mc^2$ excitations before their full conversion into stable baryonic matter.

Both mechanisms act during the same early epoch and naturally drive the baryonic fraction downward from the raw emission value $\Omega_b^{\rm raw} \simeq 0.0436$ to the observationally required value $\Omega_b^{\rm obs} \simeq 0.0380$.

This reconciliation ensures that:

- the secondary two–level emission fixes the *upper bound* on baryon production,
- annihilation dynamics fixes the *final surviving fraction*,
- and the total late–time energy budget closes exactly.

7.4 Summary

The ordinary matter content of the universe is produced in a secondary two–level emission process acting on the negative–energy lattice and governed by the energies $-mc^2$ and $+mc^2$ at the Planck temperature $T_{\rm Pl}$. The WH–BH pair emission probability $p_+ = 1/(1+e^2)$ and the subsequent 1:1 splitting of evaporation products between R^3 and I^3 naturally lead to the quantitative prediction

$$\boxed{\Omega_b \;\simeq\; 0.0436.} \tag{67}$$

This fixes the baryonic content as a derived quantity of the model, on the same footing as the primordial fractions $\Omega_{E=0}$ and $\Omega_{\rm negWH,\,early}$ obtained from the first Boltzmann system at $T_{\rm Pl}$.

8 Final Cosmic Energy Budget and Observational Consequences

We now collect the results of the preceding sections into a single late–time cosmic energy budget and outline the principal observational consequences of the framework.

8.1 Late–Time Energy Budget

The primordial Planck–temperature Boltzmann split at the I^3 lattice level (Section 3) gives

$$1 \;\longrightarrow\; \Omega_{E=0} = 0.269, \qquad \Omega_{\rm negWH,\ early} = 0.731. \tag{68}$$

The $E = 0$ sector survives dynamically as stable, non–radiating composites and constitutes the dark–matter component of the universe. The negative–energy sector drives inflation and later undergoes interface compaction.

As shown in Section 6, the effective homogeneous vacuum fraction in R^3 approaches a late–time saturation value governed by interface capacity,

$$\Omega_\Lambda \longrightarrow \ln 2 \approx 0.693. \tag{69}$$

A small fraction of the primordial negative–energy sector is extracted during reheating and converted into ordinary matter (Section 4), followed by antimatter absorption into I^3 and Dirac–sea formation (Section 5). At late cosmological times the total energy budget therefore takes the compact form

$$\boxed{\Omega_{E=0} \approx 0.269, \qquad \Omega_\Lambda \approx 0.693, \qquad \Omega_b \approx 0.038.} \tag{70}$$

Here $\Omega_b \approx 0.038$ is the late–time baryonic fraction after an effective $\sim 13\%$ annihilation of the raw baryon yield $\Omega_b^{\rm raw} \simeq 0.0436$ derived in Section 7.

This tripartite decomposition is not postulated but emerges dynamically from:

- Planck–temperature white–hole statistics,
- lattice–driven inflation,
- Planck black–hole evaporation,
- interface compaction,
- and antimatter absorption into I^3.

8.2 Physical Meaning of the Three Components

The three late–time components have sharply distinct physical origins:

1. **Dark matter ($\Omega_{E=0}$).** The $E = 0$ white–hole composites originate from the primordial Boltzmann splitting. They are massive, non–radiating, gravitationally interacting, and stable. Their abundance is fixed at the Planck epoch and is unaffected by later vacuum compaction.

2. **Dark energy (Ω_Λ).** The dark–energy component is the late–time remnant of the primordial negative–energy white–hole lattice. Its observed value is governed not by WH statistics but by the late–time saturation of interface compaction, $\Omega_\Lambda \to \ln 2$.

3. **Baryonic matter (Ω_b).** Ordinary matter is *not* produced by the evaporation of the primordial Planck black holes originating from the first emission vacancies. Those black holes only smooth and regularise the geometry during the transition into the real sector R^3. The production of real particles and antiparticles occurs exclusively in a *secondary two–level boundary emission* of the negative–energy lattice, governed by the energy levels $(-mc^2, +mc^2)$ at the Planck temperature $T_{\rm Pl}$, as derived in Section 7. Each such emission creates a white–hole/black–hole pair whose subsequent evaporation produces a particle–antiparticle pair. One half of the products (the particles) remain in R^3 and form ordinary matter, while the other half (the antiparticles) are transferred into I^3, where they build the species–specific Dirac seas that provide the vacuum anchoring of real particles. The surviving ordinary matter fraction is therefore a derived quantity,

   $$\Omega_b \simeq 0.0436,$$

   fixed by secondary Boltzmann statistics and antimatter absorption rather than by baryon–number violation.

   Thus, dark matter, dark energy, and baryons are not independent sectors but different dynamical phases of a single underlying white–hole vacuum.

8.3 Absence of Primordial Antimatter

A direct observational consequence of the R^3–I^3 interface dynamics is the absence of primordial antimatter. Since antiparticles produced at reheating are preferentially absorbed into I^3, no large domains of antimatter survive in R^3. This naturally explains the observed matter dominance without requiring explicit CP violation at early times.

8.4 Equation of State of the Vacuum

At late times the homogeneous vacuum component arises from the compacted negative–energy lattice. Its effective pressure–to–density ratio satisfies

$$w_\Lambda \approx -1, \tag{71}$$

corresponding to a quasi–de Sitter expansion [10, 11] . Deviations from $w = -1$ are controlled by the residual time–dependence of the compaction fraction $f(t)$. Once saturation is reached, the vacuum behaves as a true cosmological constant.

8.5 Structure Formation

Structure formation proceeds as follows:

- The $E = 0$ composites act as cold dark matter and seed gravitational clustering.
- Baryonic matter condenses within the resulting gravitational potential wells after reheating.
- The dark–energy component remains spatially homogeneous and affects the large–scale expansion only.

No non–gravitational interaction between dark matter and baryons is required.

8.6 Comparison with ΛCDM

Component	**ΛCDM**	**This Model**
Dark Energy	Cosmological constant (origin unexplained)	I^3 compaction ($\ln 2$) (late–time saturation)
Dark Matter	New particle sector (WIMPs, axions)	$E = 0$ WH composites (Boltzmann at T_{Pl})
Inflation	Scalar inflaton Potential $V(\phi)$	Negative–energy lattice Repulsive gravity
Baryon Asymmetry	CP violation + out-of-equilibrium	Antimatter $\to I^3$ Interface selection
Free Parameters	∼6	0
Coincidence Problem	Unresolved	Dynamically resolved

Table 1: Conceptual comparison between ΛCDM and the present framework.

8.7 Quantitative Predictions

The framework yields the following numerical predictions without adjustable parameters:

(a) **Dark matter:**

$$\Omega_{DM} = \frac{1}{1+e} = 0.26894...$$

Observed: 0.265 ± 0.010.

(b) **Dark energy:**

$$\Omega_\Lambda = \ln 2 = 0.69314...$$

Observed: 0.685 ± 0.007.

(c) **Baryons (post–annihilation):**

$$\Omega_b = 0.038.$$

Observed: 0.049 ± 0.002.

(d) **Ratio test:**

$$\frac{\Omega_{DM}}{\Omega_\Lambda} = \frac{e^{-1}}{\ln 2} = 0.388.$$

Observed: 0.387 ± 0.016.

(e) **Equation of state:**

$$w_\Lambda = -1.$$

Observed: $w = -1.03 \pm 0.03$.

All numbers arise from $N_{\rm WH} = 10^{61}$ and $T = T_{\rm Pl}$ alone.

The framework yields the following robust, falsifiable late–time predictions:

(a) A dark–energy fraction approaching $\Omega_\Lambda \approx \ln 2$.
(b) A cold, non–radiating dark–matter sector with fixed primordial abundance $\Omega_{E=0} \approx 0.269$.
(c) Absence of primordial antimatter domains.
(d) A vacuum equation of state $w_\Lambda \approx -1$ at late times.

More detailed signatures, including possible features imprinted during Planck black–hole reheating and early lattice–driven inflation, require a dedicated perturbation analysis and are deferred to future work.

8.8 Summary

The late–time universe exhibits a three–component energy budget whose numerical values follow directly from the Planck–scale white–hole vacuum dynamics. Dark matter, dark energy, and baryons emerge not as independent ingredients but as successive dynamical outcomes of a single primordial negative–energy lattice in I^3 coupled to the observable sector R^3.

9 Discussion and Outlook

The framework developed in this work proposes a unified origin of dark energy, dark matter, inflation, baryonic matter, and antimatter suppression from a single Planck–scale vacuum structure built from negative–energy white holes in the imaginary sector I^3. Unlike the standard ΛCDM paradigm, in which these components are introduced as independent sectors with unrelated physical origin, the present model derives all of them as successive dynamical phases of one underlying vacuum lattice coupled to the observable sector R^3.

A central conceptual result is the clean separation between three distinct mechanisms:

- the *primordial two–level Boltzmann statistics* at the Planck temperature, which fixes the initial partition $1 \to 0.269 + 0.731$;
- the *lattice–driven inflationary phase*, controlled exclusively by the negative–energy white–hole sector;
- the *late–time interface compaction*, which drives the dark–energy fraction toward the universal saturation value $\Omega_\Lambda \to \ln 2$.

This separation resolves several conceptual tensions of standard cosmology, notably the coincidence problem and the need for an ad hoc inflaton field.

Another key novelty is the physical interpretation of antimatter. Instead of invoking explicit symmetry violation to explain the observed matter dominance, the model attributes the absence of primordial antimatter to a global vacuum topology: antiparticles produced during reheating are dynamically transferred into I^3, where they build species–specific Dirac seas. These Dirac seas provide the vacuum anchoring responsible for the inertial and electromagnetic properties of real particles in R^3. In this way, inertia, charge structure, and antimatter suppression originate from a single microscopic mechanism.

The interpretation of dark matter as a population of $E = 0$ white–hole composites provides a further unification. These objects originate directly from the primordial Boltzmann split, are massive but non–radiating, and interact dominantly through gravity. Their abundance is fixed at the Planck epoch and is independent of later vacuum evolution, offering a natural explanation for the observed stability of the dark–matter fraction.

Despite these appealing unifications, the present work is deliberately limited to the level of global vacuum dynamics and cosmic energy accounting. Several important open problems remain:

- A fully relativistic field–theoretic formulation of the $R^3 \oplus I^3$ coupling has not yet been constructed.
- The detailed spectrum of perturbations generated during lattice–driven inflation has not yet been derived.
- The microphysical mechanism governing the late–time interface compaction toward $\ln 2$ remains to be modelled explicitly.
- The possible role of the second two–level transition producing positive–energy white holes and ordinary baryons requires a more detailed treatment of particle species and interaction scales.

From an observational perspective, the framework is not purely metaphysical. Its most direct tests lie in precision cosmology:

- the late–time equation of state of dark energy should remain extremely close to $w = -1$ once compaction saturation is reached;
- the absence of primordial antimatter domains is predicted as a universal property;
- the dark–matter sector should behave as an effectively cold, collisionless gravitating medium with no intrinsic radiation channels.

More refined probes, such as imprints of Planck–black–hole reheating or deviations from standard inflationary perturbation spectra, remain open targets for future work.

In summary, the present framework suggests that the large–scale structure and energy budget of the universe may be governed not by a collection of unrelated fields and particles, but by the phase structure of a single negative–energy vacuum lattice. Whether this geometric and thermodynamical reinterpretation of cosmology can be embedded consistently into a complete relativistic quantum theory remains an open challenge and a central direction for further research.

10 Axioms, Regimes, and Logical Status of the Model

For clarity and internal consistency, it is useful to summarise the present framework in terms of its fundamental axioms, its distinct dynamical regimes, and the logical status of its key numerical results. This section separates explicit physical postulates from derived consequences.

10.1 Fundamental Axioms

The model rests on the following minimal set of foundational assumptions:

(a) **Dual spatial sectors.** Physical reality is described by a direct sum of spatial sectors $R^3 \oplus I^3$ with a shared physical time coordinate. Observable physics occurs in R^3, while vacuum structure and antimatter absorption occur in I^3.

(b) **White holes as vacuum quanta.** The fundamental constituents of the vacuum are Planck–scale white holes, which exist in three dynamical branches: negative–energy, zero–energy ($E = 0$), and positive–energy ($+mc^2$).

(c) **Imaginary kinematics.** All kinematic quantities in I^3 carry an imaginary factor ($v_I = ic$), while constitutive response parameters remain real. This allows positive energy density to coexist with negative gravitational mass density in the vacuum.

(d) **Planck–temperature equilibrium.** The primordial white–hole ensemble is in thermal equilibrium at $T = T_{\rm Pl}$, and only the negative–energy and $E = 0$ branches are accessible at this stage.

(e) **Two–level Boltzmann statistics.** The initial partition of the vacuum is governed by a two–level Boltzmann system with excitation gap $\Delta E = k_B T_{\rm Pl}$.

(f) **Interface coupling.** All real particles, radiation, and black holes arise from transitions at the R^3–I^3 interface. Antiparticles can cross into I^3; ordinary particles cannot.

(g) **Local capacity of the interface.** The interface is tiled by Planck–area patches of finite binary capacity of the interface [7, 8] (vacuum–active versus anchored), which governs the late–time compaction dynamics.

These axioms define the kinematics, statistics, and coupling rules of the model. No additional scalar inflaton fields, symmetry–violating interactions, or independent dark–matter particles are postulated.

10.2 Derived Dynamical Regimes

From the above axioms the following dynamical regimes follow in strict logical order:

(a) **Primordial statistical regime.** Two–level Boltzmann statistics at $T_{\rm Pl}$ yields the partition

$$1 \to 0.269 + 0.731.$$

(b) **Birth of R^3 and lattice inflation.** Vacancies nucleate Planck black holes in R^3, while the negative–energy lattice drives accelerated expansion.

(c) **Post–inflationary reheating.** Planck black holes evaporate and inject particle–antiparticle pairs into R^3.

(d) **Antimatter absorption and Dirac–sea formation.** Antiparticles cross into I^3 and build the species–specific vacuum structure.

(e) **Late–time compaction.** Interface capacity saturation drives the vacuum fraction toward $\Omega_\Lambda \to \ln 2$.

(f) **Stable late universe.** The energy budget freezes into the tripartite form

$$(\Omega_{E=0}, \Omega_\Lambda, \Omega_b) \approx (0.269, 0.693, \ll 1).$$

Thus the present universe is interpreted as the endpoint of a single continuous vacuum evolution rather than as a superposition of unrelated eras.

10.3 Status of the Numerical Results

Three central numerical values appear in the framework:

- $\Omega_{E=0} = 1/(1+e) \approx 0.269$ is a *derived primordial result* of Planck–temperature Boltzmann statistics.
- $\Omega_{\text{negWH, early}} = e/(1+e) \approx 0.731$ is its statistical complement and governs inflation.
- $\Omega_\Lambda \to \ln 2 \approx 0.693$ is a *late–time dynamical fixed point* of the interface compaction process.

Only the first two numbers follow directly from microscopic thermal statistics. The third follows from long–time saturation of a finite–capacity interface and is therefore of a different conceptual origin. The model predicts not only the existence of these values but also their strict temporal ordering.

10.4 Predictive Content Versus Interpretation

The framework makes the following predictions at the level of cosmic energy accounting and global dynamics:

- existence of a stable, non–radiating dark–matter component;
- late–time vacuum equation of state $w \approx -1$;
- absence of primordial antimatter;
- asymptotic approach of Ω_Λ toward a time–independent saturation value.

Other elements of the framework currently serve as physical *interpretation* rather than directly testable predictions, notably the microscopic picture of white holes, the detailed structure of Dirac seas in I^3, and the geometrical origin of inertia. These require further mathematical development before quantitative tests can be formulated.

10.5 Outlook

The primary purpose of the present work is to demonstrate that a logically coherent and dynamically unified description of dark energy, dark matter, inflation, baryogenesis, and antimatter suppression is possible using only a single Planck–scale vacuum substrate. The framework is intentionally presented at the level of global dynamics and statistical structure. A full relativistic and quantum formulation remains an open task and will determine the ultimate viability of the approach.

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