Emergence of Real Space from Mold Oscillators in Imaginary Quaternion Geometry

Ivars Fabriciuss

June 29, 2025

Abstract

We propose a physical framework in which real space $\mathbb{R}^3$, time $\mathbb{R}_t$, and an unobservable imaginary mold space $\mathbb{I}^3$ form a unified 7-dimensional structure. This model interprets imaginary spatial coordinates as physically meaningful directions orthogonal to real space, in which mold-like structures with positive mass but negative energy reside. By allowing quantized oscillations along imaginary directions, we derive a spectrum of negative-energy mold states that are electromagnetically inert and geometrically confined. These mold oscillators possess negative volume, imaginary displacements, and imaginary forces, but are thermally active at the Planck scale. Crucially, the zero-point energy of the mold vacuum cancels exactly with that of real space due to frequency reflection symmetry ($\omega \leftrightarrow -\omega$), resolving the cosmological constant discrepancy. A weak coupling at the boundary between spaces gives rise to a small residual vacuum energy consistent with observed dark energy. The resulting ontology, based solely on geometric and thermodynamic principles, establishes a rigorous physical basis for the existence of an unobservable but physically active imaginary space underlying the real universe.

1 Geometry of Imaginary Quaternion Space

We begin by formalizing the structure of space in this framework, which extends standard 3-dimensional real space into a 7-dimensional hybrid: three real spatial coordinates $x, y, z \in \mathbb{R}^3$, one shared time coordinate $t \in \mathbb{R}$, and three imaginary spatial coordinates $i, j, k \in \mathbb{I}^3$. This defines a 7-dimensional geometric structure composed of three real spatial axes, three imaginary spatial axes corresponding to the mold space, and one shared time axis."

$$\mathbb{R}^3 \oplus \mathbb{I}^3 \oplus \mathbb{R}_t$$

This structure is inspired by Hamilton's quaternion algebra:

$$q = t + ix + jy + kz,$$

where $i^2 = j^2 = k^2 = ijk = -1$, but we reinterpret i, j, k as physical imaginary spatial directions rather than algebraic symbols.

1.1 Volume and Orientation

The triple product in quaternion space gives the volume:

$$V = (ia) \cdot (jb) \times (kc) = -abc$$

This implies that any volume spanned by orthogonal imaginary basis vectors has negative real value:

$$V_{\text{imaginary}} = -abc < 0$$

Thus, negative volume is a built-in geometric feature of quaternionic imaginary space, and not merely a convention. This naturally represents negative energy negative volume structure as a "mold" of particle in the imaginary space, so this space is called a "mold space" in the article. Paticle molds does not have charge so are invisible to EM detection, as is the whole imaginary mold space. It coexists with real space in real time.

1.2 Displacements and Velocities

A particle-like structure (mold) residing in imaginary space is displaced along an imaginary vector:

$$\vec{u}(t) = iu_x(t) + ju_y(t) + ku_z(t)$$

Its velocity is:

$$\vec{v}(t) = \frac{d\vec{u}}{dt} \in \mathbb{I}^3, \quad \text{with } t \in \mathbb{R}$$

Since time remains real, acceleration is also imaginary:

$$\vec{a}(t) = \frac{d^2\vec{u}}{dt^2} \in \mathbb{I}^3$$

1.3 Force and Mass Density

Assuming each mold has positive mass $m > 0$ but is embedded in negative volume $V < 0$, the resulting mass density becomes:

$$\rho = \frac{m}{V} < 0$$

The inertial force acting on the mold obeys Newton's second law, generalized into imaginary space:

$$\vec{F} = m\vec{a}, \quad \vec{a} \in \mathbb{I}^3$$

Hence, forces and responses are purely imaginary vector quantities.

1.4 Oscillatory Behavior

We now consider oscillatory solutions along each imaginary axis, of the form:

$$u_i(t) = A_i \cos(\omega t + \phi_i), \quad A_i \in \mathbb{R}, \quad \omega \in \mathbb{R}$$

Despite occurring along imaginary axes, the oscillations have real frequencies. Therefore, energy associated with these oscillators can be formally defined by:

$$E = \frac{1}{2}m\left|\frac{d\vec{u}}{dt}\right|^2 + \frac{1}{2}K\left|\vec{u}\right|^2$$

Since the displacement $\vec{u}$ lies along imaginary directions, the square magnitude yields a real and positive scalar. However, the oscillator is understood to contribute negative energy within the physical context:

$$E_{\text{mold}} = -\frac{1}{2}KA^2 < 0$$

The total energy of a mold oscillator confined to imaginary space is given by:

$$E_{\text{mold}} = -\frac{1}{2}KA^2$$

Here, K is the real and positive spring constant (or restoring stiffness), and A is the amplitude of oscillation along the imaginary axes i, j, k. The negative sign reflects the fact that mold oscillators reside in a space of negative volume and are governed by inverted restoring forces. These oscillators, while possessing real-valued amplitudes and frequencies, contribute negative energy to the vacuum. This is not merely a mathematical artifact: the negative energy of mold oscillators plays a crucial role in stabilizing the vacuum and ensuring that the total zero-point energy of the combined system (real + imaginary spaces) cancels to zero. This cancellation mechanism underlies the resolution of the cosmological constant problem in the present model.

2 Quantized Oscillators in Mold Space

We model mold structures as quantized harmonic oscillators within the imaginary space $\mathbb{I}^3$. Each oscillator has displacements aligned along i, j, k with quantized energy levels governed by:

$$E_n = -\hbar\omega\left(n + \frac{1}{2}\right), \quad n = 0, 1, 2, \ldots$$

The minus sign reflects that mold oscillators store negative energy relative to real space. Time evolution remains governed by real time t, so oscillations are stable and bounded.

2.1 Negative Temperature Formalism

We define the partition function for a single oscillator:

$$Z = \sum_{n=0}^{\infty} e^{-\beta E_n}$$

This converges only for $\beta < 0$ — i.e., the system must be at negative absolute temperature.

The average energy and entropy are:

$$\langle E \rangle = -\hbar\omega\left(\frac{1}{2} + \frac{1}{e^{-\beta\hbar\omega} - 1}\right)$$

$$S = k_B\left(\ln Z + \beta\langle E \rangle\right)$$

Molds are thus most stable in high negative-temperature phases and exhibit inverted population distributions — a necessary condition for energy transfer to real space.

Historical Context: Dirac's Sea

The concept of a negative-energy substrate has historical roots in the work of Paul Dirac, who postulated that the vacuum consists of an infinite sea of negative-energy electron states, later known as the Dirac sea. In our framework, this notion is reinterpreted geometrically: the mold lattice in imaginary quaternion space serves as a discrete, oscillator-based analog of Dirac's continuous sea. Mold excitations correspond to transitions within a structured, Planck-scale reservoir of negative energy. Unlike Dirac's model, our construction naturally resolves the zero-point energy problem and supports emergent particle behavior via quantized transitions between mold and real space.

3 Transition to Real Space: Negative Frequencies as Positive Energy

The oscillatory modes of the mold lattice, while entirely imaginary in spatial direction, possess real-valued frequencies ω. The solutions to the harmonic oscillator equation in this context are symmetric under time reversal, leading to both positive and negative frequency components:

$$u(t) = Ae^{i\omega t} + Be^{-i\omega t}$$

In standard quantum mechanics, negative frequency modes are often discarded or reinterpreted via creation operators. In this model, however, the negative frequency modes correspond to real-space phenomena.

3.1 Energy Reflection at the Mold-Real Boundary

Consider the total energy associated with each oscillation mode:

$$E = \pm \hbar \omega \left(n + \frac{1}{2} \right)$$

In mold space, these energies are negative due to the embedding in negative-volume geometry. When an oscillator mode transitions across the interface into real space, its energy flips sign:

$$E_{\text{real}} = -E_{\text{mold}} = +\hbar |\omega| \left(n + \frac{1}{2} \right)$$

This mechanism allows real particles to be interpreted as the projection of negative-energy mold excitations into the real $\mathbb{R}^3$ space.

3.2 Interpretation of Time Flow

Because $\omega < 0$ corresponds to modes with reversed time phase, the apparent time direction of the emerging real-space particle aligns with forward-time evolution, even though it originated from a backward-phase mode in mold space.

This duality resolves the apparent contradiction between energy positivity in real space and the bounded-from-below oscillator structure in the mold vacuum.

3.3 Real and Imaginary Energy Components

In our model, physical space is divided into two distinct domains: real space $\mathbb{R}^3$, where ordinary particles and fields reside, and imaginary space $\mathbb{I}^3$, where molds exist and oscillate. Although mold motion occurs entirely along imaginary spatial directions, time remains shared and real. This shared time allows imaginary oscillations to possess real frequencies — and therefore, real energies — even though their spatial displacements are unobservable in $\mathbb{R}^3$.

These oscillations in mold space store negative energy relative to the positive energy states of real particles. When a mold system undergoes a transition — for example, due to instability or external disturbance — part of its oscillatory energy can no longer remain confined within imaginary space. Instead, this energy is reconfigured and emitted as a real-space excitation: a particle, a photon, or another positive-energy manifestation.

Importantly, not all imaginary motion contributes to observable real outcomes. Only specific combinations of mold oscillations — such as those aligned with real time and associated with a loss of internal equilibrium — can project energy outward into the real domain. This transformation is not continuous; it happens in discrete events when energy stored in the mold becomes dynamically incompatible with purely imaginary confinement and is released into $\mathbb{R}^3$.

In this way, imaginary-space dynamics serve as a hidden reservoir of oscillatory energy. These oscillations are electromagnetically inert and gravitate repulsively due to their negative energy density, yet they underlie the emergence of real matter and interactions through selective transitions into real space.

This asymmetry is built into the cosmological evolution: only negative-frequency mold modes are allowed to become real particles, ensuring a net energy flux from imaginary to real space.

3.4 Relativistic Covariance in Hybrid Space

The hybrid manifold $\mathbb{R}^3 \oplus \mathbb{I}^3 \oplus \mathbb{R}_t$ naturally separates into a visible real sector and an invisible imaginary sector. Rotational symmetries in each 3-dimensional subspace form the groups $SO(3)_R$ and $SO(3)_I$, acting independently on the real and imaginary spatial coordinates, respectively:

$$\vec{x} \in \mathbb{R}^3 \Rightarrow SO(3)_R, \qquad \vec{u} \in \mathbb{I}^3 \Rightarrow SO(3)_I$$

To ensure relativistic consistency, we must understand how these rotational symmetries embed into the Lorentz group $SO(1,3)$, which preserves the Minkowski metric in real space:

$$ds^2 = -c^2dt^2 + dx^2 + dy^2 + dz^2$$

Within the real subspace $(\mathbb{R}^3, t)$, standard Lorentz transformations apply, preserving causality and the speed of light. However, since mold-space displacements occur along imaginary axes with velocities $\vec{v} \in \mathbb{I}^3$, the effective speed becomes ic, and Lorentz transformations must act independently on the real and imaginary parts.

We thus postulate a doubling of the local symmetry group:

$$SO(3,1)_R \times SO(3)_I$$

The group $SO(3,1)_R$ acts on real space-time $(\mathbb{R}^3, t)$, while $SO(3)_I$ preserves rotational invariance in the imaginary mold subspace. These two sectors are coupled only via scalar boundary interactions across defect sites, which are invariant under both subgroups.

In this formalism, the imaginary sector is not inertially accessible from the real sector — but real curvature and forces may emerge from torsional excitations in $SO(3)_I$. The embedding of $SO(3)_R \times SO(3)_I \subset SO(6)$ suggests that the full symmetry group is a 6D rotational group with shared real time:

$$\mathbb{R}^3 \oplus \mathbb{I}^3 \oplus \mathbb{R}_t \Rightarrow \text{Covariant under } SO(6) \times \mathbb{R}_t$$

This structure allows for rotational dynamics in both sectors, but preserves causality and relativistic structure in the observable space. All physical projections — including mass, charge, and gravity — must respect $SO(3,1)_R$ covariance and derive from scalar or vector invariants under this embedding.

4 Field Quantization and Boundary Interactions

The mold lattice, consisting of quantized oscillators in imaginary space, exhibits discrete excitation levels. These can be modeled analogously to phonon quantization in solid state physics.

The Hamiltonian for a single oscillator mode:

$$H = \frac{1}{2}m\dot{u}^2 + \frac{1}{2}Ku^2$$

yields eigenvalues:

$$E_n = -\hbar\omega\left(n + \frac{1}{2}\right), \quad n = 0, 1, 2, \ldots$$

The minus sign corresponds to negative energy of the mold space.

At the interface between mold and real space, energy can be exchanged through a coupling Hamiltonian:

$$H_{\text{int}} = \gamma\, \dot{u}_{\text{mold}} \cdot \dot{u}_{\text{real}}$$

Assuming Planck-scale displacements:

$$\dot{u} \sim \ell_{\text{Pl}}\omega_{\text{Pl}}, \quad \Rightarrow \quad \rho_\Lambda \sim \gamma\ell_{\text{Pl}}^2\omega_{\text{Pl}}^2$$

This gives:

$$\rho_\Lambda \sim \gamma \cdot \frac{c^5}{\hbar G}$$

To match observations:

$$\gamma \sim 10^{-122}$$

This small coupling explains the non-zero cosmological constant after vacuum energy cancellation and establishes a dynamical mechanism for real space emergence through oscillatory leakage.

5 Transition to Real Space

Mold oscillations evolve under imaginary-space dynamics with time $t \in \mathbb{R}$, and spatial displacements $\vec{u} \in \mathbb{I}^3$. The oscillator equation takes the familiar form:

$$m\frac{d^2\vec{u}}{dt^2} + K\vec{u} = 0$$

whose general solution involves frequencies ω satisfying:

$$\omega = \pm\sqrt{\frac{K}{m}}$$

This produces two roots — one positive and one negative — which reflect the two fundamental directions of temporal evolution allowed by the oscillator. In standard quantum mechanics, both roots are typically retained symmetrically; however, in our model, the distinction between them acquires ontological meaning.

The positive root $\omega > 0$ corresponds to a bound oscillation entirely confined within imaginary space. It defines the stable mold state, contributing negative vacuum energy while remaining electromagnetically inert and gravitationally repulsive. This is the default state of the gravitational vacuum lattice: a sea of Planck-scale molds oscillating with positive frequency.

The negative root $\omega < 0$, however, signifies a loss of confinement. This mode cannot remain in imaginary space alone — instead, it initiates a transition into real space, manifesting as a particle or real-space excitation. Thus, the emergence of particles corresponds to the population of these negative-frequency solutions, which flip the energy sign and become physically observable as positive-energy states.

This mechanism connects the origin of real matter to the dynamics of imaginary-space molds. In particular, real particles originate not from vacuum instability, but from selective transitions between bound mold oscillations (positive ω) and emitted real-space excitations (negative ω). This frequency bifurcation is the mathematical basis of the real–imaginary boundary structure and gives rise to the coupling that defines physical particles.

5.1 Phonon Modes and Density of States

In 3D, assuming cubic symmetry and using $k_{\text{max}} \sim \pi/\ell_{\text{Pl}}$, the number of modes is:

$$N = \left(\frac{L}{\ell_{\text{Pl}}}\right)^3$$

We define a density of states $D(\omega)$ with cutoff at ω_{Pl}, but no longer need any regularization because positive and negative frequencies cancel in pairs:

$$\rho_{\text{vac}}^{\text{mold}} = -\frac{1}{2}\int d^3k\, \hbar\omega(k) \quad \text{(cancels with real space)}$$

6 Thermodynamics and Negative Temperature

Thermodynamic analysis of mold oscillators reveals a key insight: the negative energy structure requires negative temperature $T < 0$ for proper convergence of partition functions.

6.1 Partition Function and Energy Expectation

The partition function is defined by:

$$Z = \sum_{n=0}^{\infty} e^{-\beta E_n} = \sum_{n=0}^{\infty} \exp\left(\beta\hbar\omega\left(n + \frac{1}{2}\right)\right)$$

This series only converges when $\beta < 0$, which implies negative absolute temperature.

The mean energy is:

$$\langle E \rangle = -\frac{\partial \ln Z}{\partial \beta}, \quad \text{and entropy } S = k_B\left(\ln Z + \beta\langle E \rangle\right)$$

Entropy remains positive for $\beta < 0$, consistent with a well-defined statistical ensemble.

6.2 Transition from $E = -m_{\mathrm{Pl}}c^2$E = -mPl c² to $E = 0$E = 0

Let us now focus on a specific energy transition relevant to the early mold space configuration. Each mold begins in the lowest energy state $E = -m_{\mathrm{Pl}}c^2$, the most tightly bound oscillatory state within the imaginary vacuum. These molds are confined and contribute maximal negative energy density.

However, due to thermal agitation at the Planck temperature $T = T_{\mathrm{Pl}}$, a transition to a less bound but still non-interacting state $E = 0$ becomes statistically possible. This state corresponds to molds with no rest energy but finite positive mass and zero real-space interaction — making them excellent dark matter candidates. They still remain invisible to electromagnetism and do not radiate or decay.

The Boltzmann factor gives the probability $P(E)$ that a mold transitions to a higher energy level E from the ground state:

$$P(E) \propto e^{-\frac{E-E_0}{k_B T}} = e^{-\frac{\Delta E}{k_B T}}$$

With:

$$\Delta E = E_{\mathrm{final}} - E_{\mathrm{initial}} = 0 - (-m_{\mathrm{Pl}}c^2) = m_{\mathrm{Pl}}c^2$$

and $T = T_{\mathrm{Pl}}$, we have:

$$P_0 = \frac{e^{-\frac{m_{\mathrm{Pl}}c^2}{k_B T_{\mathrm{Pl}}}}}{Z} = \frac{1}{e+1}$$

This yields:

$$P_0 = \frac{1}{e+1} \approx \frac{1}{3.718} \approx 0.269$$

This is a finite and well-defined fraction: approximately 26.9% of all Planck molds undergo the transition to $E = 0$. Crucially, this value is independent of normalization and reflects a statistical equilibrium determined solely by the temperature and energy gap.

Thus, the total initial population of molds splits naturally: 26.9% become effectively massless and non-radiating, populating the real universe as dark matter, while the remaining 73.1% remain in the vacuum sea, contributing continued negative energy density. This explains both the finite mass content and the persistent gravitational background structure.

This result is central to the physical interpretation of mold space: only a well-defined, statistically calculable subset of molds become real-universe participants, and the process is governed purely by imaginary-space oscillator dynamics under Boltzmann statistics.

7 Vacuum Energy Cancellation and Cosmological Constant Resolution

In quantum field theory, each mode of a harmonic oscillator contributes a zero-point energy

$$E_{\text{ZP}} = \frac{1}{2}\hbar\omega$$

This leads to an infinite total vacuum energy density unless regulated. In our model, however, both the real and imaginary (mold) spaces host identical oscillator spectra, but with opposite sign contributions.

7.1 Pairwise Cancellation of Zero-Point Energies

In mold space, the oscillator energies are:

$$E_n^{(\text{mold})} = -\hbar\omega\left(n + \frac{1}{2}\right)$$

while in real space they are:

$$E_n^{(\text{real})} = +\hbar\omega\left(n + \frac{1}{2}\right)$$

Thus, each positive-frequency real space mode is mirrored by a negative-frequency imaginary mode. The sum of vacuum energies is:

$$\rho_{\text{vac}}^{\text{total}} = \sum_{\vec{k}}\left(\frac{1}{2}\hbar\omega_{\vec{k}} - \frac{1}{2}\hbar\omega_{\vec{k}}\right) = 0$$

This symmetry removes the need for a Planck-scale cutoff and eliminates the 10^{122} discrepancy in vacuum energy predictions.

7.2 Residual Coupling and Small Cosmological Constant

Despite exact cancellation in the bulk, a weak interaction across the boundary can lead to a small residual energy density:

$$H_{\text{int}} \sim \gamma\,\dot{u}_{\text{real}}\,\dot{u}_{\text{mold}}$$

This term couples the time derivatives of displacement in both spaces. Assuming $\dot{u} \sim \ell_{\text{Pl}}\omega_{\text{Pl}}$, the residual energy density is:

$$\rho_\Lambda \sim \gamma\,\ell_{\text{Pl}}^2\omega_{\text{Pl}}^2$$

To match observed values of the cosmological constant, γ must be extremely small:

$$\gamma \sim 10^{-122}$$

This framework offers a natural mechanism to solve the cosmological constant problem without fine-tuning or cutoff regularization.

8 Thermodynamic Properties of the Mold Lattice

The mold lattice, composed of mold oscillators in imaginary space, exhibits thermodynamic behavior governed by negative energy states and, in many cases, negative temperature.

8.1 Partition Function and Energy Spectrum

Each oscillator contributes an energy spectrum quantized as:

$$E_n = -\hbar\omega \left(n + \frac{1}{2} \right)$$

Assuming independent oscillators, the canonical partition function at inverse temperature β is:

$$Z = \sum_{n=0}^{\infty} \exp\left(-\beta E_n\right) = \exp\left(\beta \frac{\hbar\omega}{2}\right) \sum_{n=0}^{\infty} \exp\left(\beta\hbar\omega n\right)$$

The sum converges only if $\beta < 0$, i.e., the system must have a negative absolute temperature. Evaluating the series:

$$Z = \frac{\exp\left(\beta \frac{\hbar\omega}{2}\right)}{1 - \exp\left(\beta\hbar\omega\right)}$$

8.2 Mean Energy and Entropy

The mean energy of an oscillator becomes:

$$\langle E \rangle = -\frac{\hbar\omega}{2} - \frac{\partial}{\partial\beta} \ln Z = -\frac{\hbar\omega}{2} - \frac{\hbar\omega \exp(\beta\hbar\omega)}{1 - \exp(\beta\hbar\omega)}$$

The entropy is given by:

$$S = k_B \left(\ln Z + \beta \langle E \rangle \right)$$

which is strictly positive as long as $\beta < 0$ and $\omega > 0$. Therefore, despite occupying negative energy levels, the system possesses thermodynamically meaningful properties.

8.3 Negative Temperature and the Dominance of the Zero-Energy State

In a negative-temperature mold vacuum, higher energy levels become more populated than lower ones. As a result, the zero-energy state $E = 0$ becomes the most probable configuration accessible to molds transitioning from the ground state $E = -m_{\mathrm{Pl}}c^2$. This leads to a well-defined fraction of molds occupying the zero-energy level, which, as derived earlier, constitutes approximately 26.9% of the total mold population.

9 Residual Interaction and Cosmological Constant

Despite the exact cancellation of zero-point vacuum energy between real space and mold space, a small coupling may exist at their interface, giving rise to the observed cosmological constant. We assume that oscillators on both sides interact weakly through a boundary Hamiltonian:

$$H_{\mathrm{int}} = \gamma\, \dot{u}_{\mathrm{real}} \cdot \dot{u}_{\mathrm{mold}},$$

where $\gamma \ll 1$ is a dimensionless coupling constant representing the stiffness of the interface.

Assuming characteristic displacements at the Planck scale:

$$\dot{u}_{\mathrm{real}} \sim \ell_{\mathrm{Pl}}\omega_{\mathrm{Pl}}, \quad \dot{u}_{\mathrm{mold}} \sim \ell_{\mathrm{Pl}}\omega_{\mathrm{Pl}},$$

we obtain an energy density associated with the residual interaction:

$$\rho_\Lambda \sim \gamma \ell_{\mathrm{Pl}}^2 \omega_{\mathrm{Pl}}^2.$$

Recalling that $\omega_{\text{Pl}} = c/\ell_{\text{Pl}}$, we find:

$$\rho_\Lambda \sim \gamma \frac{c^2}{\ell_{\text{Pl}}^2}.$$

This yields the observed cosmological vacuum energy density for:

$$\gamma \sim 10^{-122}.$$

Thus, the cosmological constant problem is solved not by suppressing vacuum energy in either domain, but by recognizing their perfect cancellation except for a minute boundary leakage, governed by the geometry and stiffness of the interface.

10 Gravitational Projection and Curvature

In the hybrid framework combining real space $\mathbb{R}^3$, imaginary quaternionic space $\mathbb{I}^3$, and shared real time t, we consider how local asymmetries in the mold space manifest gravitational effects in observable real space.

The mold lattice consists of stable oscillator configurations characterized by negative energy and negative mass density, embedded in negative volume. Defects or transitions in this lattice produce local interruptions in the negative energy sea. These interruptions reduce the total negative energy density, producing a net positive energy contrast.

Let us denote this emergent energy density as

$$\rho_{\text{eff}} = \rho_{\text{mold, background}} - \rho_{\text{mold, perturbed}} > 0$$

Here, ρ_{eff} represents an emergent positive energy density due to asymmetry between mold and real space at the defect site. The resulting curvature in imaginary space becomes encoded in real space as gravitational attraction.

Since real space emerges from projection of the mold oscillator solutions with $\omega < 0$, the geometric deformation (curvature) of the mold background appears in the real projection as a distortion of the real metric, with geodesics bending toward the site of reduced negative energy.

This provides a natural geometric origin of gravity: it is not an intrinsic property of real space, but rather a projection of mold-space curvature due to oscillator defects and mass-energy asymmetries. Such projection gives rise to the classical gravitational potential in the low-energy limit:

$$\nabla^2 \Phi = 4\pi G \rho_{\text{eff}}$$

without requiring real-space mass to be the primary source.

Remark: Distinction Between G and γ

It is important to clarify that the gravitational constant G appearing in Eq. (10.2) is distinct from the coupling constant γ introduced earlier in the interaction Hamiltonian between mold and real space. The constant G is an experimentally determined quantity defining the strength of gravitational attraction in real space. In contrast, γ quantifies the amplitude of tunneling or overlap between mold-space modes and real-space fields, typically assumed to be extremely small, on the order of $\gamma \sim 10^{-122}$, to account for the observed vacuum energy scale.

While the two constants serve different roles, they may ultimately derive from the same underlying geometrical or topological structure of the mold lattice. For instance, both gravitational curvature and weak field coupling could emerge from distortions in the mold space or from quantized transitions between its oscillator modes. This suggests a deeper link between geometry and interaction that remains to be explored in detail.

This approach connects the Einstein field equations to boundary and defect dynamics of the imaginary oscillator lattice, yielding a fundamentally emergent view of gravitation.

11 Gravitational Effect as Mold-Space Curvature

Gravitation in this model is not a fundamental force, but a consequence of local distortions in the mold space geometry. When a mold is displaced or transitions to a different energy state—such as from $E = -mc^2$ to $E = 0$ or higher—the surrounding imaginary space experiences curvature. This curvature, characterized by a localized change in negative mass density, becomes encoded in real space as gravitational attraction.

In this picture, what appears as mass in real space is actually a projection of a defect or excitation in the mold lattice. The curvature or "strain" around such a defect affects the motion of nearby molds, which translates into the familiar force of gravity in real space. The gravitational constant G reflects this projection effect, while the extremely small coupling constant $\gamma \sim 10^{-122}$ governs the weak boundary interaction between the mold and real spaces. Though distinct, both constants may originate from the same underlying lattice structure and its response to topological excitations.

12 Toward a Unified Framework of Quantum and Classical Realities

The hybrid 7-dimensional structure we propose—comprising real space $\mathbb{R}^3$, imaginary quaternionic space $\mathbb{I}^3$, and shared real time t—provides a foundation not only for vacuum structure and cosmological energy balance, but also for bridging the quantum-classical divide.

12.1 Quantum Mechanics in Mold Space

By treating mold-space oscillators as harmonic fields in imaginary directions, we introduce a new framework for field quantization:

$$\hat{u}_i(t) = \sum_k \left(a_k e^{-i\omega_k t} + a_k^\dagger e^{i\omega_k t} \right) i_k$$

The raising and lowering operators act on mold oscillator states, and the corresponding field quantization carries over into the real space by projection of negative-frequency components.

12.2 Emergence of Classical Particles

Real space excitations appear as classical or quantum particles depending on coherence of the projection:

- Coherent oscillations yield persistent particle-like excitations.
- Decoherent transitions in mold space correspond to thermal radiation or quantum noise.

This offers a physical origin for wave-particle duality: the mold retains a wavelike phase structure, but real space sees only discrete projections, localized in energy and time.

12.3 Boundary Geometry and Temporal Directionality

Due to the symmetry of solutions $\pm\omega$, we ensure conservation laws and time-orientable causality. However, the asymmetry in projections ($\omega < 0$) explains the arrow of time in real space as a consequence of selecting one branch of the full wave solution. Mold space itself remains symmetric in time, thus preserving fundamental reversibility.

12.4 Residual Dark Energy from Mold–Real Coupling

Despite exact cancellation of zero-point energies in the combined imaginary and real spaces, a residual energy density appears due to weak coupling at the boundary. This energy arises not from incomplete cancellation, but from the finite probability that mold oscillators project a tiny amount of their energy into real space.

We define the energy leakage per oscillator as:

$$\delta E = \gamma_E E_{\text{Pl}}, \quad \text{with} \quad \gamma_E \sim 10^{-122}$$

Given the Planck energy $E_{\text{Pl}} = \sqrt{\frac{\hbar c^5}{G}}$, the resulting energy density projected into real space is:

$$\rho_{\text{vac}} = \gamma_E \cdot \rho_{\text{Pl}} = \gamma_E \cdot \frac{c^5}{\hbar G^2}$$

This value is consistent with the observed cosmological constant. The coupling constant γ_E is extremely small, reflecting the insulation of mold space from real space except at specific topological defects.

This leakage mechanism resolves the long-standing discrepancy between theoretical vacuum energy and observed dark energy without requiring arbitrary cutoffs or renormalization.

13 Gravitational Interaction Across Spaces

In this model, gravitation emerges not as a field confined to either the real or imaginary domain, but as a **coupled deformation mode** involving both the real space and the mold lattice. The fundamental idea is that mass-energy present in real space affects the underlying mold structure via boundary interaction, and vice versa.

13.1 Stress-Energy Feedback from Mold to Real Space

Molds are massive entities embedded in negative volume. While their internal energy is negative, they can **mediate curvature** of real space by adjusting the local density and topology of the underlying imaginary lattice. These adjustments propagate into real space as curvature effects, captured effectively by a modified Einstein equation:

$$G_{\mu\nu}^{\text{real}} + G_{\mu\nu}^{\text{mold}} = \frac{8\pi G}{c^4}\left(T_{\mu\nu}^{\text{real}} + T_{\mu\nu}^{\text{mold}}\right)$$

Here, $G_{\mu\nu}^{\text{mold}}$ is the curvature arising from distortions in mold space, while $T_{\mu\nu}^{\text{mold}}$ includes contributions from the imaginary-space oscillations and negative volume densities.

13.2 Geometric Potential of Mold Defects

Localized deformations in the mold lattice — such as **defects**, missing mold units, or excessive excitation — create discontinuities in the imaginary-space stress field. These project onto real space as **gravitational potentials**. We propose an effective scalar potential Φ in real space, sourced by imaginary mass density ρ_{mold}, defined as:

$$\nabla^2 \Phi = 4\pi G \rho_{\text{eff}}, \quad \rho_{\text{eff}} = \rho_{\text{real}} + \alpha \rho_{\text{mold}}$$

Here, α is a geometric projection factor coupling imaginary-space mass density to the real-space Poisson equation. This mechanism allows **mold-space defects** (such as missing or excited white hole molds) to appear as attractive or repulsive gravitational sources in the real universe.

13.3 Gravity as Mold-Mediated Elastic Force

At the microscopic level, gravitational interaction can be interpreted as an **elastic response** of the mold lattice to the presence of real matter. The torsional and longitudinal stiffness of the mold lattice define the gravitational constant G via:

$$G \sim \frac{\ell_{\rm Pl}^2 c^3}{\hbar} \sim \frac{c^2}{K_{\rm mold}}$$

This suggests that gravitational force is not fundamental but **emergent**, arising from elastic propagation through the negative-energy mold vacuum. The absence of gravitons in this framework is not a deficiency but a consequence of the elastic medium's continuous structure.

13.4 Gravitational Waves as Coupled Oscillations

Fluctuations in spacetime geometry — gravitational waves — can be reinterpreted here as **coherent oscillations** of mold and real space in phase. A passing gravitational wave corresponds to a coupled standing wave across both spaces:

$$u_{\rm real}(x,t) = A\cos(kx - \omega t), \quad u_{\rm mold}(x,t) = A\cos(kx + \omega t)$$

The counter-propagating time evolution (due to opposite frequency signs) enforces phase coherence, maintaining total energy conservation. Detection of such waves is thus interpreted as the real-space projection of mold-lattice resonances. We now propose a unifying interpretation: **real space arises entirely as a boundary projection** of dynamic events in the imaginary quaternionic mold space. All observed particles, fields, and their interactions can be recast as energetic reflections of phase transitions and oscillatory emissions originating from mold configurations.

13.5 Ontological Status of Real and Mold Space

Mold space is structurally primary: it hosts the fundamental degrees of freedom (rotor modes, bosonic condensates, fermionic molds) within a negative volume lattice framework. Real space is a derived space: it exists only where and when there is a projection of negative-energy mold transitions into positive-energy excitations.

13.6 Particle Creation and Causality

Each real particle corresponds to a discrete oscillation decay event in mold space. Since mold oscillators have real frequencies and imaginary spatial amplitudes, their negative-energy transitions at specific positions cause:

- Local energy transfer across the interface,
- Emergence of point-like particles or photons in real space,
- Causal structure determined by real time t, shared between both spaces.

13.7 Implications for Cosmology and Vacuum Energy

This view resolves long-standing cosmological tensions:

- The zero-point vacuum energy in real space is canceled by an equal and opposite contribution from mold oscillators.

- The residual cosmological constant arises solely from weak boundary coupling:

$$\rho_\Lambda \sim \gamma \ell_{\rm Pl}^2 \omega_{\rm Pl}^2 \sim 10^{-122} \rho_{\rm vac}^{\rm Plank}$$

- Dark matter emerges as a frozen zero-energy state of bosonic molds, while radiation and baryons arise from nonzero transitions.

Thus, the universe is not "from nothing"—it is from a silent mold sea that constantly decays and projects structured excitation into emergent reality.

Appendix A: Physical Properties of Mold Space

Appendix B: Experimental Predictions and Observational Consequences

The mold space framework predicts a series of distinctive physical phenomena rooted in the geometric duality between real and imaginary spatial domains. Most notably, it accounts for dark matter as a stable condensate of zero-energy molds, resolves the cosmological constant problem via exact vacuum energy cancellation, and introduces a natural mechanism for particle creation through mold excitation. Observable consequences include specific signatures in the CMB (such as the suppressed quadrupole), vacuum fluctuation anomalies, and possible deviations from Newtonian gravity in low-density regimes. These predictions provide avenues for indirect experimental validation using astrophysical, cosmological, and precision quantum systems.

Table 1: Summary of Physical Quantities in Mold Space (Planck-Scale)

Quantity	**Value (SI Units)**	**Sign**	**Imaginary/Real**	**Comments**
Time t	—	N/A	Real	Shared with real space
Displacement $\vec{u}$	$\sim \ell_{\mathrm{Pl}}$	—	Imaginary	Motion occurs in imaginary axes
Velocity $\vec{v}$	$\sim c$	—	Imaginary	Time derivative of imaginary displacement
Acceleration $\vec{a}$	$\sim c^2/\ell_{\mathrm{Pl}}$	—	Imaginary	Governs inertial behavior in mold
Mass m	m_{Pl}	Positive	Real	Mass of mold structure
Volume V	$\sim -\ell_{\mathrm{Pl}}^3$	Negative	Real	Negative from orientation of $\mathbb{I}^3$
Mass Density ρ	$m_{\mathrm{Pl}}/\ell_{\mathrm{Pl}}^3$	Negative	Real	Negative due to sign of volume
Spring Constant K	$\sim m_{\mathrm{Pl}}/\ell_{\mathrm{Pl}}^2$	Positive	Real	Governs oscillator restoring force
Torsional Stiffness τ	$\sim m_{\mathrm{Pl}}$	Positive	Real	Resistance to twist in rotor loops
Young's Modulus Y	$\sim c^2/\ell_{\mathrm{Pl}}^2$	Positive	Real	Elasticity of mold lattice
Energy Density ε	$\sim c^7/(\hbar G^2)$	Positive	Real	Energy stored in mold oscillator
Pressure P	$\sim -c^7/(\hbar G^2)$	Negative	Real	Negative pressure from bound modes
Speed of Sound v_s	$\sim ic$	—	Imaginary	Imaginary direction propagation
Frequency ω	$\sim 1/t_{\mathrm{Pl}}$	Positive	Real	Real-valued but interpreted in imaginary context
ZPE per oscillator	$-\frac{1}{2}\hbar\omega$	Negative	Real	Zero-point energy of mold mode
Total Mold Energy	$E = -\frac{1}{2}KA^2$	Negative	Real	From oscillator amplitude in imaginary space

Table 2: *

Table B.1: Observable Predictions from the Mold Space Framework

Prediction	**Description**
Dark Matter as Mold Condensate	Dark matter consists of zero-energy Planck-mass white hole molds; stable, non-interacting, bosonic in structure.
Exact Vacuum Energy Cancellation	Real and imaginary zero-point energies cancel exactly due to frequency pairing, solving the 10^{122} cosmological constant problem.
CMB Quadrupole Suppression	Thermal origin of real space from a mold lattice leads to suppressed long-wavelength modes, explaining observed low quadrupole amplitude.
Cosmological Dark Energy	Weak coupling at the mold–real boundary generates a small residual energy density consistent with observed dark energy.
Modified Gravity at Low Densities	Negative mass density of mold background implies repulsive effects that may appear as MOND-like behavior on galactic scales.
Thermal Spectrum Cutoff	Real particle creation is governed by mold oscillator transitions, producing natural high-energy cutoffs in primordial spectra.
Vacuum Fluctuation Anomalies	Oscillatory transitions between mold and real states may produce measurable deviations from standard QFT vacuum predictions.