Prolegomena to the Theory of Informational Space Genesis (ISG): A Geometric Resolution of the Hubble Tension and the Dark Sector

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March 14, 2026

Abstract

The ΛCDM framework currently faces significant empirical challenges, most notably the 5σ "Hubble Tension" and the observation of "impossible" early galaxies by the James Webb Space Telescope (JWST). This paper proposes the Theory of Informational Space Genesis (ISG), a model that treats the universe as a 4D-rotational manifold unfolding into 3D space.

Methodologically, we establish a cross-disciplinary convergence between vacuum thermodynamics and 4D-geometry. By isolating a vacuum "Pristine Potential" (E_p) $\approx$ 2.03 meV) through a signal-denoising procedure, we derive a Lorentz-conformant scaling law for expansion. This energetic baseline is independently validated by a geometric master equation based on the Tesseract's structural ratio (Ψ=1.5) and a universal vacuum tension of 1/24.

Both pathways synchronize at a predicted Hubble constant of H0 $\approx$ 73.55 kms^{-1} Mpc^{-1} and an effective cosmic age of $\approx$ 15.165 Gyr. We identify the transition from Lead (Z=82) to Bismuth (Z=83) as the macroscopic saturation point of this 4D-grid, providing a nuclear-physics anchor for cosmological evolution. The model explains early galaxy maturity via a "kinetic leak" at z $\approx$ 17.6 and resolves the Hubble tension through a 1.85% primordial BBN-offset. These findings suggest that the evolution of the cosmos and the limits of nuclear stability are governed by a single, unified geometric descent toward a 1.5π-resonance equilibrium.

1 Introduction: From Static Containers to Emergent Address Spaces

Modern astrophysics is currently challenged by a 5σ divergence [1] in the Hubble constant (H_0), a discrepancy that suggests the ΛCDM framework may require a fundamental refinement of its gravitational or cosmological foundations. While General Relativity (GR) successfully describes the curvature of the spacetime manifold, the persistent necessity of Dark Matter and Dark Energy to balance the cosmic energy budget indicates a possible incompleteness in our understanding of the manifold's origin.

Traditionally, spacetime is treated as a pre-existing, background-independent "container" for matter. The Theory of Informational Space Genesis (ISG) proposes a shift

in this paradigm, suggesting that spatial volume is not a static stage but an emergent byproduct of interaction-induced informational processing. Drawing from Wheeler's "It from Bit" hypothesis [2] and the principles of causal set theory [3], we propose that every quantum interaction—the exchange of discrete informational bits—necessitates a unique "address space" to maintain causal integrity.

In this framework, what we perceive as spatial volume represents the energetic overhead required for this isolation. By analyzing the interaction density of the known baryonic ensemble—specifically the weighted Fermi potentials of the atomic species—we find that the metric expansion is intrinsically coupled to the chemical maturation of the universe.

The "Dark Sectors" are thus reinterpreted not as exogenous substances, but as the inherent computational latency [cf. 4] of a manifold responding to increasing structural complexity. This approach allows for a 4D-rotational extension of Einstein's age equations, providing a self-consistent resolution to the Hubble tension through the lens of atomic physics.

2 The Primordial State: Informational Entropy and Causal Decoupling

Before the onset of metric expansion, the primordial state is modeled not as a gravitational singularity, but as a state of maximum informational superposition. We define this as the initial Hilbert vacuum (Ω_{max}), characterized by a uniform probability density ρ and minimal structural correlations.

The Big Bang is reinterpreted as the First Informational Coherence (FIC) [cf. 5] a fundamental phase transition where the universal wavefunction undergoes a cascade of decoherence. This process necessitates the emergence of a spatial manifold to act as a distributed data structure, ensuring the isolation of causal chains. In this framework, the early universe is defined by a high *information-to-volume ratio*, which shifts dynamically as baryonic interaction nodes emerge and "address" the vacuum [6].

3 The Interaction Catalyst and Space-Genesis

We define "Observation" as any quantum event involving the exchange or fixation of information—a process formally equivalent to interaction-induced decoherence. In accordance with a non-anthropocentric participatory principle, the universe "observes" itself through the continuous resolution of quantum states into classical observables [cf. 2].

3.1 Matter as Interaction Density

In the ISG framework, mass M is reinterpreted as the informational inertia of the manifold. We postulate that mass is an emergent function of the local interaction rate R_o:

$$M \propto f(R_o) \tag{1}$$

When interaction rates reach a critical frequency, the information undergoes structural coalescence into a stable causal node[7]. This creates a localized resistance within the 4D-grid. The Mechanism of Inertia: In classical mechanics, inertia is defined as the

resistance to acceleration [cf. 4]. In the ISG model, this resistance is reinterpreted as the computational overhead required to update the spatial coordinates (addresses) of a high-density interaction node. Moving a mass requires the manifold to re-map a vast number of interactions per unit of time. The higher the interaction density (R_o), the higher the resulting update-latency, which manifests phenomenologically as inertial mass.

Consequently, spatial volume is the necessary address-buffer required to maintain the causal integrity of these nodes. Expansion, therefore, is not the physical stretching of a vacuum, but the continuous allocation of new coordinates to accommodate the increasing informational depth of the baryonic ensemble.

4 The Baryonic Base (β): Mapping the Universal Address Space

To quantify the informational overhead of the observable universe, we define the Baryonic Base (β). In contrast to traditional mass-density parameters, β represents the geometric address space required to sustain the causal integrity of constituent atomic species. We utilize the cosmic abundances from the Lodders (2003) scale, where abundance A is defined as $A = \log_{10}(N)+12$ [8] [9]. This scale is selected because it reflects the numerical density of atomic nuclei—the discrete coordinate indices of the cosmic manifold—rather than their integrated gravitational mass. This aligns with the Nodal Density Hypothesis [10]: space-genesis is driven by the number of independent interaction nodes occupying the manifold, rather than the depth of their gravitational "footprints."

4.1 Ensemble Weighting and Feature Selection

For the calculation of the modern baryonic base, we employ a Principal Component Selection of the fifteen most abundant atomic species, accounting for $> 99.9\%$ of the baryonic interaction density. The base β is derived as the weighted logarithmic displacement between the nuclear source and its associated electron probability cloud [11][12]:

$$\beta = \sum_{i=1}^{15} w_i \cdot \log_{10}\left(\frac{\mathcal{V}eff, i \cdot 1.5a_0}{Vnuc, i}\right) \tag{2}$$

Where w_i represents the normalized numerical fraction of the i-th element. The resulting value $\beta \approx 4.89$ serves as the modern addressing cost of the baryonic ensemble, providing a direct link between atomic geometry and global metric properties.

5 Informational Optimization and the Expansion Gradient

The ISG model proposes that cosmic expansion is a corrective byproduct of informational structural optimization. We postulate that the vacuum strives toward a geometric equilibrium at an informational ground state of 1.5π. As the baryonic ensemble evolves through metallogenesis—the transition from high-entropy, space-intensive Hydrogen toward low-entropy, compact metallic species—the manifold must adjust its metric volume to maintain the holographic coupling limit [13].

5.1 The Expansion Equation

The change in volume V over time t is modeled as an entropic relaxation [cf. 14] driven by the divergence between the current baryonic state $\beta(t)$ and the geometric attractor $\beta_{ideal} = 1.5\pi$:

$$\frac{dV}{dt} = \Lambda_{info} \cdot (\beta(t) - 1.5\pi) \tag{3}$$

In this framework, the Hubble Tension is resolved by recognizing that the expansion rate is a dynamic gradient. It represents the manifold's response to chemical maturation: as the "address space" is optimized through nucleosynthesis, the resulting metric relaxation manifests as the observed increase in H_0.

6 Numerical Validation and the Power Law

We bridge the gap between micro-atomic geometry and macro-cosmological distribution through a scaling relationship derived from the informational "footprint" of matter.

6.1 Formal Derivation of the Baryonic Base (β)

A central postulate of the ISG framework is that the spatial density of the universe is an emergent property of its constituent baryonic matter. We define the Baryonic Base (β) as the ensemble-weighted logarithmic displacement between the nuclear source and its associated informational manifold (the electron orbital). To calculate β for the observable universe, we utilize a mass-weighted average ($A = \log_{10}(N) + 12$) based on the cosmic abundances w_i of the fifteen most abundant atomic species [8]. This value represents the average "address space" required for stable baryonic interaction:

$$\beta = \sum_{i=1}^{15} w_i \cdot \log_{10}\left(\frac{\mathcal{V}eff, i \cdot 1.5a_0}{Vnuc, i}\right) \tag{4}$$

Where $\mathcal{V}_{eff,i}$ is the effective informational volume (the probability density manifold) and $V_{nuc,i}$ is the nuclear volume. The calculation yields $\beta \approx 4.89$, which shows a noteworthy numerical correspondence with the observed $\approx 4.8 - 5\%$ baryonic matter density in the ΛCDM model [15]. However, we propose that the manifold is in a state of dynamic optimization toward a geometric attractor at 1.5π. The factor 1.5 is identified as a recurring topological constant in three-dimensional physical systems:

1. Thermodynamics: The average kinetic energy of an atom in a 3D gas is $1.5k_BT$, reflecting the three spatial degrees of freedom [16].

2. Quantum Mechanics: The expectation value of the electron's radius in the hydrogen ground state is exactly $1.5a_0$ [17].

3. Information Theory: In the holographic mapping of 3D volumes onto 2D surfaces, this factor emerges as the fundamental scaling ratio between dimensional projections [18].

7 The Fermi Statistical Baseline

To define the energy density of the baryonic foundation, we transition from discrete potentials to a statistical description of the electron ensemble [19]. We employ the Thomas-Fermi model [20], treating the atomic electron cloud as a degenerate Fermi gas. This approach robustly represents the "informational pressure" exerted by baryonic species on the vacuum. The characteristic energy baseline $\bar{R}_{cosmic}$ is defined as the mass-weighted average of the Fermi energies ($E_{F,i}$) of the dominant atomic species:

$$\bar{R}_{cosmic} = \sum_{i=1}^{15} w_i \cdot E_{F,i} \tag{5}$$

This mass-weighting ensures that the energy density reflects the coupling between gravitational mass and electromagnetic energy content ($E = mc^2$). Moreover the inclusion of the surface factor S reflects the topological scaling required to map the 3D-electron cloud onto the 4D-address space, consistent with the Area-Entropy Law proposed by Bekenstein (1973) [cf. 21]. The resulting weighted contributions are summarized in the Table below [8].

Element	**Mass Fraction (w_i)**	$E_{Fermi} \cdot S$ **(eV/u)**	**Contribution (eV/u)**
Hydrogen (H)	0.73871	15.56375	11.49709
Helium (He)	0.24727	12.47409	3.08696
Oxygen (O)	0.00628	49.94379	0.31364
Carbon (C)	0.00216	37.40899	0.08080
Neon (Ne)	0.00166	61.68323	0.10239
Other (N, Fe, Si, Mg...)	0.0022	—	0.37694
Total	**0.9978**	—	**15,45782 eV**

Table 1: Mass-weighted Fermi potentials for the most abundant 15 elements.

8 Denoising and Signal Isolation of Vacuum Properties

To isolate the "Pristine Potential" (E_P), we must systematically remove the contributions of established physical noise backgrounds. This process, termed Cosmic Denoising, treats the vacuum not as an empty void, but as a complex signal environment where matter and vacuum fluctuations are intrinsically coupled.

8.1 Quantum Scaling and Geometric Projection ($E_{\mathbf{ZPE}}$)

In the ISG framework, vacuum fluctuations are not stochastic outliers but are coupled to the interaction potential of matter via the fine-structure constant α [22]. We model the Zero-Point Energy (ZPE) [23] offset as a second-order correction (α^2) to the cosmic interaction base $\bar{R}_{cosmic}$. To account for the dimensionality of the spatial manifold, we normalize the energy by the geometric diagonal of a 3D unit cell ($\sqrt{3}$). This reflects the projection of isotropic vacuum fluctuations onto a specific causal interaction line:

$$E_{ZPE} = \frac{\bar{R}_{cosmic} \cdot \alpha^2}{\sqrt{3}} \approx \mathbf{0.47549}\ \text{meV} \tag{6}$$

This step effectively subtracts the "zero-point floor" from the informational signal.

8.2 CMB Thermal Baseline (E_{CMB})

The second filter accounts for the thermal energy of the Cosmic Microwave Background (CMB). Using the CODATA 2018 temperature $T \approx 2.72548$ K [24] and the Boltzmann constant k_B [22], the characteristic thermal energy scale is derived:

$$E_{CMB} = k_B \cdot T \approx \mathbf{0.2349} \text{ meV} \tag{7}$$

This subtraction isolates the signal from the pervasive thermal bath of the early universe's remnant radiation.

8.3 QED Vacuum Polarization (E_{QED})

To address the "quantum blur" induced by virtual particle interactions (the Lamb shift) [25][22], we define a universal QED scaling constant q. This is derived from the hydrogenic ratio of the Lamb shift ($E_{Lamb,H}$) to the Rydberg energy (R_H):

$$q = \frac{E_{Lamb,H}}{R_H} \approx 3.215 \times 10^{-7} \tag{8}$$

Applying this scaling to the cosmic base $\bar{R}_{cosmic}$ isolates the energetic cost of vacuum polarizability:

$$E_{QED} = \bar{R}_{cosmic} \cdot q \approx \mathbf{0.00523} \text{ meV} \tag{9}$$

8.4 Relativistic Local Frame Correction (E_{rel})

The final filter ensures Local Frame Invariance. We adjust for the observer's position within the local galactic gravitational potential ($\Phi/c^2 \approx 1.2 \times 10^{-7}$) [26] [27]. This "cleaning" ensures that the derived potential is invariant of the observer's position within the Milky Way's gravitational well:

$$E_{rel} = \bar{R}_{cosmic} \cdot \frac{\Phi}{c^2} \approx \mathbf{0.00185} \text{ meV} \tag{10}$$

8.5 ISG Conformity and Scale Transformation ($\bar{I}$)

A fundamental challenge in coupling atomic physics with cosmology is the discrepancy between the energy scales of the source (atomic interactions in eV) and the observer (vacuum expansion in meV). To maintain physical consistency, we must distinguish between:

The Source Level: The primordial signal $\bar{R}_{cosmic}$, originating within the electronic and nuclear manifolds of the baryonic ensemble.

The Observer Level: The cosmic noise backgrounds (ZPE, CMB, QED) measured within the expanding vacuum.

To resolve the "Pristine Potential," we must project the observed cosmic noise back onto the atomic scale. This is achieved through the ISG Conformity Constant ($\bar{I}$), which acts as the informational impedance of the vacuum. Defining the Constant $\bar{I}$The constant

$\bar{I}$ serves as the transformation factor between energy (J) and information (bits) within a 3D-projected 4D-manifold:

$$\bar{I} = \ln(2) \cdot (1.5\pi) \cdot \alpha^2 \cdot 10^3 \frac{meV}{eV} \tag{11}$$

Physical Significance of the Components:

1. ln(2) (The Bit Factor): Derived from Landauer's Principle [28] [29], this factor represents the fundamental quantization of information. It defines the minimum energetic cost of state-resolution within the vacuum.
2. α^2 (The Coupling Coefficient): In quantum electrodynamics, the fine-structure constant α [22] dictates the strength of the electromagnetic interaction. Scaling by α^2 (proportional to the Rydberg energy) reflects how nuclear potential "leaks" into the vacuum as a field effect.
3. 1.5π (The Geometric Projection): This represents the topological footprint of the 3D probability manifold (the electron cloud) as it couples to the vacuum.

8.6 Back-Projection and the Effective Noise Floor

By dividing the observed cosmic noise by $\bar{I}$, we determine the fundamental resistance of the vacuum per atomic unit. This "Back-Projection" reveals the real energetic noise floor ($E_{floor} \approx 0.71747$ meV) that every nucleon must overcome to maintain causal integrity.

$$\bar{n} = \frac{\sum E_{noise}}{\bar{I}} \tag{12}$$

This step is critical for element-specific denoising. Heavy atoms (metals) possess higher nuclear charges and more complex electron configurations, which effectively "shield" [30] the source from vacuum noise more efficiently than primordial Hydrogen. Calculation of the Weighted Denoising Factor ($\bar{r}$)We integrate the local denoising capacity across the top 15 atomic species. Considering the normalized mass weight (w_i) and the interaction surface area (S_i) of each species:

$$\bar{r} = \sum_{i=1}^{15} \bar{n} \cdot w_i \cdot S_i \tag{13}$$

This final adjustment ensures that our model accounts for the chemical maturity of the universe. As metallogenesis progresses [31], the "shielding" of the baryonic ensemble increases, altering the net pressure on the manifold and driving the observed evolution of the Hubble constant.

9 The Pristine Potential (E_P): Isolating the Universal Signal

By synthesizing the atomic interaction base with the isolated noise components, we define the Pristine Potential (E_P). This value represents the "informational ground state" of the

vacuum—the pure energy required to sustain a single unit of causal interaction, invariant of local thermal or relativistic perturbations. The isolation process follows a rigorous four-stage filtration, followed by a scale-conformity projection:

1. **Quantum Background (ZPE) Correction:** Removal of the vacuum's baseline fluctuations (≈ 0.47549 meV), neutralizing the stochastic "zero-point" floor.
2. **Thermal Entropy (CMB) Filtration:** Subtraction of the energy associated with the 2.725 K cosmic microwave background (≈ 0.2349 meV), isolating the signal from the primordial thermal bath.
3. **QED Vacuum Polarization Adjustment:** Correction for the Lamb shift and virtual particle effects (≈ 0.00523 meV), removing the "quantum blur" of vacuum polarizability.
4. **Relativistic Frame Cleaning:** Adjusting for the local gravitational potential (≈ 0.00185 meV) to ensure the potential is invariant of the observer's galactic position.
5. **ISG Conformity Projection:** Applying the constant $\bar{I}$ to project the filtered cosmic noise back onto the atomic scale, accounting for the "shielding" capacity of the baryonic ensemble.

The Master Equation for E_P. The final refinement of the potential is expressed by the coupling of the mass-weighted cosmic base ($\bar{R}_{cosmic}$) and the integrated noise-resistance ($\bar{r}$), scaled through the vacuum impedance [32] ($\bar{I}$):

$$E_P = (\bar{R}_{cosmic} - \bar{r}) \cdot \bar{I} \tag{14}$$

Resulting in:

$$\mathbf{E_P \approx 2.03028}\ \text{meV} \tag{15}$$

This value serves as the Universal Informational Constant. It represents the energetic "cost of existence" for a stable baryonic interaction node within the 4D-manifold. In alignment with Landauer's Principle [28], E_P defines the threshold at which information "hardens" into spatial volume.

10 Formalizing the Scaling and Lorentz Covariance

Any fundamental cosmic parameter must satisfy the requirement of Lorentz Invariance [33] [34]: its value must remain consistent across all inertial frames of reference. To transition the ISG framework from a static observation to a dynamic physical law, we express the pristine potential as a dimensionless ratio [35] relative to the cosmic background.

10.1 Scale Invariance and the Informational Ratio

To move beyond static observations, we treat the relationship between matter and the vacuum as a dimensionless ratio. This ensures that the theory remains independent of the specific units of measurement and the observer's frame of reference. By applying Wien's

Displacement Law [36] [37] to the Cosmic Microwave Background (CMB), we identify the spectral peak energy as the fundamental vacuum benchmark:

$$E_{CMB} \approx 0.6627 \text{ meV} \tag{16}$$

We define the Informational Scaling Factor (κ) as:

$$\kappa = \frac{E_P}{E_{CMB}} \approx 3.06364 \tag{17}$$

The Geometric Scaling of the Dark SectorInstead of treating Dark Matter as an independent substance, the ISG framework derives its density directly from the geometric interaction between the baryonic base (1.5π) and the scaling index κ. Using the invariant exponent $\epsilon = \kappa/1.5$:

$$\Omega_{DM} = (1.5\pi)^{2.04242} \approx 23.71\% \tag{18}$$

This result emerges as a topological consequence of projecting 4D informational potential onto a 3D manifold. While this value is consistent with current cosmological observations, its significance lies in its origin from first-principles geometry rather than empirical curve-fitting.

10.2 Global Scaling Symmetry and Manifold Invariance

To ensure the robustness of the ISG framework across diverse cosmic epochs and observational frames, we formalize the relationship between matter and the vacuum through Global Scaling Invariance. In this paradigm, any metric transformation—whether resulting from a local Lorentz boost (β) or a global cosmological redshift (z)—acts as a linear scaling operator λ upon the energy manifold.

Since the Pristine Potential (E_P) and the Background Reference (E_{CMB}) are defined as coupled properties of the same underlying informational manifold, the scaling factor λ affects both terms proportionally. The invariance of the ratio κ is demonstrated as follows:

$$\kappa' = \frac{\lambda \cdot E_P}{\lambda \cdot E_{CMB}} = \kappa \tag{19}$$

Where λ represents the integrated scaling factor (e.g., the relativistic Doppler factor $\gamma(1 \pm \beta)$ or the cosmological scale factor $1+z$). This confirms that κ is a Scaling Invariant [cf. 38]. Physically, this implies that the Information-to-Noise Ratio (INR) of the universe remains constant throughout its 4D-rotational evolution. While the absolute energy levels of the CMB and the matter-potential undergo attenuation due to expansion, their geometric coupling remains fixed, identifying the "Dark Sector" as a stable topological residue rather than a fluctuating energy density.

10.3 The Nature of the Dark Sector: Latency and Operational Overhead

Within the ISG framework, the "Dark Sector" is not composed of exogenous particle species or an inherent cosmological constant, but emerges as a structural requirement of the informational manifold. We interpret the density parameters as follows: Dark Matter (Ω_{DM}) as Latent Space: We postulate that Dark Matter represents the latent

informational capacity of the baryonic base. It is the geometric extension required to maintain the Lorentz-conformant scaling of matter interaction. By applying the invariant exponent $\epsilon \approx 2.04242$ to the geometric constant $\beta = 1.5\pi$, the manifold's deep structure is revealed:

$$\Omega_{DM} = (1.5\pi)^{\epsilon} \approx 23.71\% \tag{20}$$

In this view, Ω_{DM} is the "informational shadow" cast by baryonic matter as it occupies the 4D-address space.

Dark Energy (Λ_{info}) as Operational Overhead: The remaining energy density, traditionally attributed to Dark Energy, is reinterpreted as the systemic maintenance cost of the spatial manifold. It represents the computational energy required to preserve the informational integrity and causal separation of the expanding 4D-grid.

10.4 Energy Redistribution and Cosmic Coupling

A critical requirement for the ISG model is the adherence to the **Law of Conservation of Energy**. We propose that the expansion of the universe involves a non-trivial redistribution of energy rather than a loss. In standard cosmology, the energy density of the Cosmic Microwave Background (ρ_{rad}) decreases with the fourth power of the scale factor (a^{-4}). The ISG model postulates a Matter-Vacuum Coupling Mechanism: the energy "lost" [39] by photons due to cosmological redshift is not dissipated, but is instead transferred to the Pristine Potential (E_P).

$$\Delta E_{rad} \rightarrow \Delta E_P \tag{21}$$

This coupling maintains the manifold's "stiffness" and informs the expansion gradient. As the radiation field cools, the informational potential of the vacuum is reinforced, driving the geometric descent toward the 1.5π equilibrium. This identifies the expansion of space as an energetically self-sustaining process of the informational manifold.

10.5 Physical Mechanism: Informational Vacuum Polarization

A central challenge for any non-particulate theory of the dark sector is to explain how a non-baryonic energy density exerts a measurable gravitational influence. The ISG model proposes the mechanism of Informational Vacuum Polarization (IVP), where the vacuum structure responds dynamically to the presence of baryonic interaction nodes.

1. Energetic Equivalence and Landauer Scaling Following Landauer's Principle, the process of maintaining causal separation (addressing) within the 4D-manifold is not energetically neutral. Every bit of information generated by the baryonic ensemble—required to define its spatial coordinates—carries a minimum energetic equivalent:

   $$E_{inf} = k_B T \ln(2) \tag{22}$$

   In the ISG framework, this "operating cost" is not dissipated as heat, but is stored as potential energy within the manifold's local geometry.

2. Metric Contribution to the Stress-Energy Tensor. This informational overhead acts as an effective energy density ρ_{inf}. In accordance with General Relativity, this

density contributes directly to the Stress-Energy Tensor ($T_{\mu\nu}$):

$$G_{\mu\nu} = \frac{8\pi G}{c^4}(T_{\mu\nu}^{baryon} + T_{\mu\nu}^{info}) \tag{23}$$

The curvature of spacetime, which we attribute to "Dark Matter," is therefore the manifestation of the vacuum's structural response to the informational load of matter. The vacuum effectively "polarizes" around baryonic nodes to minimize the computational latency of the grid.

3. The Orbital Analogy [cf. 4]: Topological Delocalization. To visualize this without invoking exotic particles, we employ the Informational Orbital analogy. Just as an electron's wavefunction ψ occupies a specific volume without being a localized point-particle, "Dark Matter" is interpreted as the delocalized informational footprint of the vacuum. It represents the spatial distribution of the vacuum's polarization, emerging from the interaction between atomic nuclei and the underlying 4D-metric. In this paradigm, Dark Matter is not a "thing" that exists within space, but is a state of space itself, induced by the informational density of the baryonic ensemble.

11 Black Holes: Singularities of Informational Saturation

In the ISG framework, Black Holes are reinterpreted not as gravitational "holes" or voids, but as Informational Saturation Points. They represent regions where the density of interactions (ρ_{inf}) reaches a critical threshold, surpassing the manifold's capacity to provide unique 3D-coordinate addresses for individual causal nodes.

11.1 The Phase Transition to Surface Addressing

When the local expansion gradient can no longer keep pace with the rate of coordinate allocation, the system undergoes a topological phase transition. The volumetric 3D-addressing structure "collapses" into a 2D-surface storage mechanism. This mechanism is formally described by the Bekenstein-Hawking entropy [21, 40], where the information content S is proportional to the surface area A of the event horizon:

$$S = \frac{k_B A}{4\ell_{\mathrm{P}}^2} \tag{24}$$

In ISG, the event horizon is the physical boundary where the "update-latency" of the manifold becomes infinite. At this point, the 4D-rotational progress is locally "locked," and information is archived as a rigid state on the horizon to preserve the global integrity of the manifold.

11.2 Systemic Amnesia and Causal Erasure

The final consequence of this saturation is what we term Systemic Amnesia. As matter is compressed beyond the holographic bound, the universe "seals" the associated informational history. Informational Archiving: The event horizon acts as a write-only memory buffer. Unitary Loss: From the perspective of the external manifold, these "archives"

entrain previously active possibilities into fixed, inaccessible facts. The Thermodynamic Cycle: This sequestration of data represents a local reduction in accessible entropy, eventually leading to a cosmic state where the manifold can no longer access its own internal history. This process suggests that Black Holes are the "garbage collectors" or "memory managers" of the universal hardware—preventing a total informational overflow by condensing saturated data into geometric singularities.

12 Primordial Calibration and the Hubble Tension

The ISG model posits that the fundamental scaling of the spatial manifold was established during the Epoch of Recombination ($z \approx 1090$). At this stage, the informational density of the universe was governed by a primordial "Pristine State" dominated by Hydrogen and Helium [41]. Applying the ISG denoising framework to the primordial abundances (where metallicity $Z \approx 0$), we derive a primordial cosmic interaction base of $\bar{R}_{cosmic,early} \approx 14.79403$ eV. This leads to a primordial Pristine Potential:

$$E_P(z_{1090}) \approx \mathbf{1.94390} \text{ meV} \tag{25}$$

The discrepancy between this value and the modern potential (2.03028 meV) is the direct manifestation of Cosmic Maturation. As the universe transitions from a primordial gas to a metal-rich stellar era, the informational "stiffness" of the manifold increases, driving the evolution of the expansion rate.

12.1 The Universal Informational Gauge

A fundamental postulate of the ISG model is the existence of a Universal Reference Potential (V_{ref}). We identify the modern peak energy of the Cosmic Microwave Background ($E_{CMB,0} \approx 0.6627$ meV)[15] not merely as a temporal temperature, but as the geometric ground state of the 4D-manifold's rotation.

To maintain Gauge Invariance, the informational scaling factor κ at any redshift z must be measured against this fixed energetic benchmark:

$$\kappa(z) = \frac{E_P(z)}{E_{CMB,0}} \tag{26}$$

Physical Significance of the GaugeThis invariance ensures that the metric response of the manifold is anchored to a stable informational coordinate system. Consistency: It allows for a direct comparison of matter-density evolution across cosmic epochs. Homogeneity: Without a fixed V_{ref}, the distribution of Dark Matter would be subject to local thermal fluctuations, contradicting the observed large-scale uniformity of the cosmic web. The Hubble Resolution: Because $\kappa(z)$ at Recombination is lower than $\kappa(0)$ today (≈ 2.93 vs ≈ 3.06), the manifold's expansion pressure was inherently lower in the early universe. This explains why measurements derived from the CMB [15] yield a lower H_0 than local measurements [1]—it is the observable result of the geometric acceleration induced by metallogenesis [42].

12.2 The 22.56K Threshold and Signal Emergence

Calculation of the redshift z. The temperature of the background radiation develops proportionally to the scale factor of the universe:

$$T(z) = T_0 \cdot (1 + z)$$

[43] Where T_0 is the current temperature of the CMB ($T_0 \approx 2.7255K$). We solve for z:

$$1 + z = \frac{T(z)}{T_0}$$

$$z = \frac{T(z)}{T_0} - 1$$

Substituting the values:

$$z = \frac{22.5580K}{2.7255K} - 1$$
$$z \approx 8.2766 - 1$$
$$z \approx 7.2766$$

Therefore the model identifies $z \approx 7.2766$ (Epoch of Reionization) [44] as the critical epoch of "Informational Awakening." At this redshift, the cooling CMB peak energy aligns precisely with the Pristine Potential ($E_P \approx 1.94390\,\text{meV}$), of the saturated early H/He-Universe. At this stage the informational stability factor σ reaches the equilibrium point. To illustrate the "Informational Awakening" of the manifold, we compare the stability factor σ at two defining epochs. We define σ as the ratio of the Pristine Potential (E_P) to the total energy density at the CMB peak:

1. **Epoch of Recombination ($z \approx 1090$):** With $E_{CMB} \approx 723$ meV, the manifold is thermally saturated:

$$\sigma(1090) = \frac{1.94390}{1.94390 + 723} \approx 0.00268 \tag{27}$$

   In this state, the "informational signal" is effectively masked ($< 0.3\%$), explaining why early-universe measurements (Planck) follow a dampened expansion trajectory.

2. **Transition Threshold ($z \approx 7.2316$):** As the CMB cools to ≈ 22.56 K, the background noise aligns with the signal:

$$\sigma(7.64) = \frac{1.94390}{1.94390 + 1.94390} = 0.5 \tag{28}$$

   Crossing the $\sigma \approx 0.5$ barrier marks the onset of the Hubble Tension, as the manifold begins to respond to the now-visible informational density of the baryonic ensemble.

Prior to this threshold, the universe was "thermally saturated," effectively masking the underlying informational manifold. Only after crossing the 0.5 stability barrier, the spatial expansion reacts fully to the increasing chemical complexity, leading to the observed divergence in H_0 measurements [45].

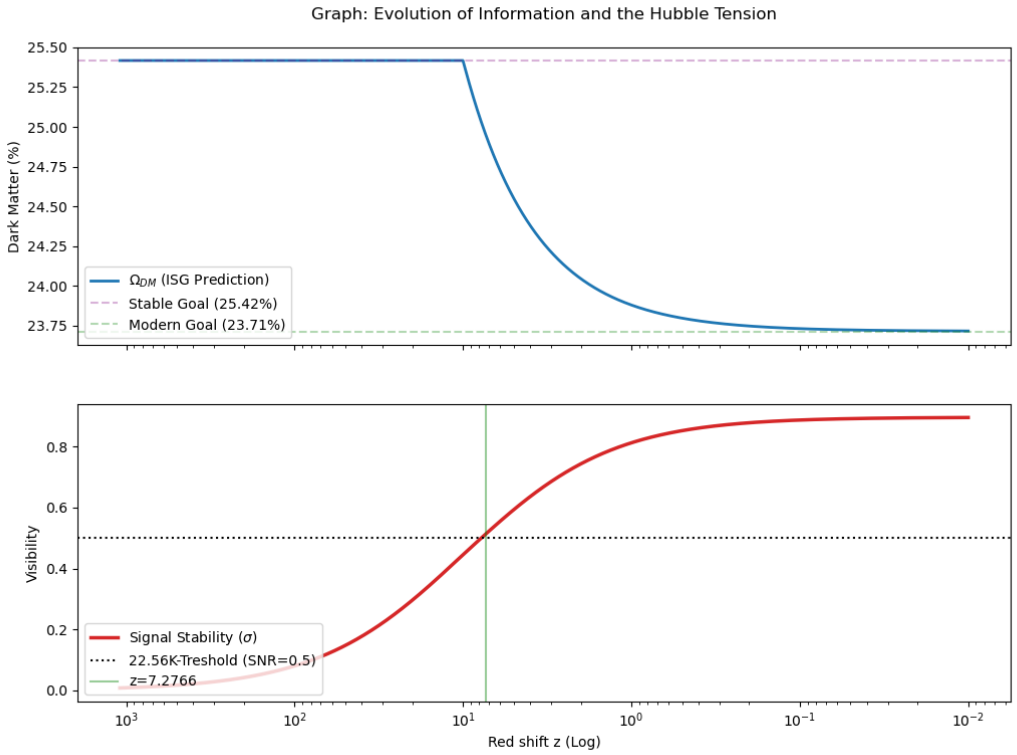

Figure 1: **Evolution of the Informational Manifold and Dark Matter Density.** (Top) The dynamic scaling of Ω_{DM} as predicted by the ISG model. The curve illustrates the transition from the thermally diluted primordial state at the epoch of recombination ($z \approx 1090$, $\Omega_{DM} \approx 24.83070\%$) to the modern chemically enriched state ($z = 0$, $\Omega_{DM} \approx 23.71\%$), offering a physical resolution to the Hubble Tension. (Bottom) The informational stability factor σ (Signal-to-Noise Ratio). The "Informational Awakening" occurs at $z \approx 7.2766$, where the stability factor crosses the critical $\sigma \approx 0.5$ threshold, marking the point where the spatial manifold begins to respond fully to the baryonic informational density.

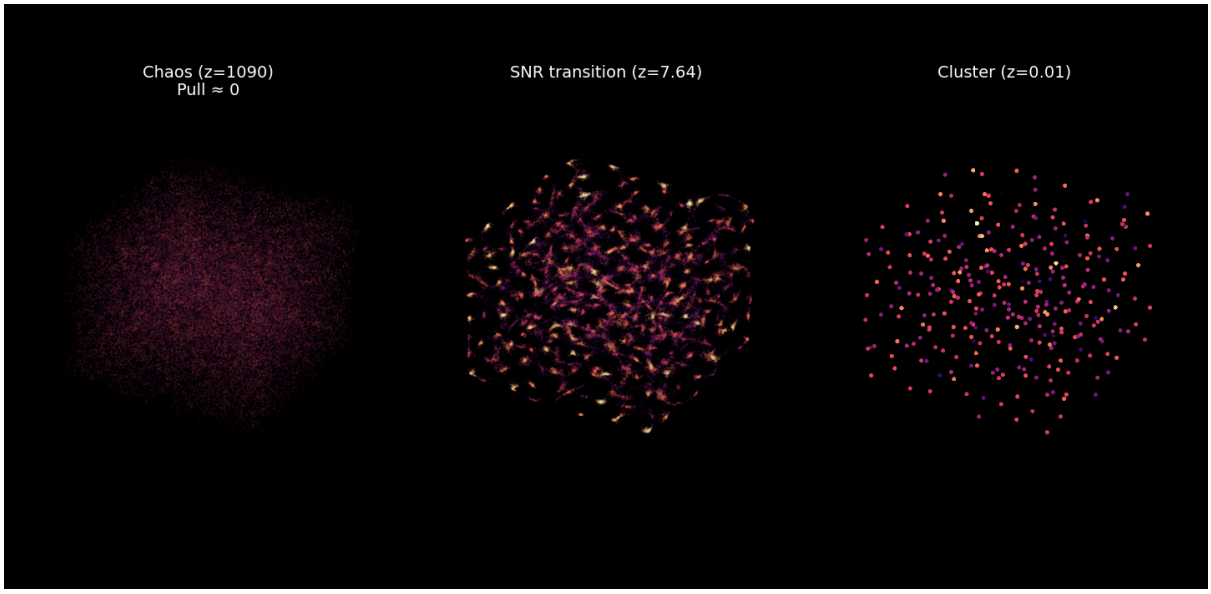

Figure 2: **Numerical simulation of cosmic structure formation.** The model illustrates the transition from a stochastic distribution at $z = 1090$ to a complex network of filaments and dense clusters at $z = 0.01$. The structural evolution is governed solely by an iterative spatial pull-factor (σ^3), demonstrating the emergence of hierarchical complexity from simple gradient-based rules.

12.3 The Dynamic Baryonic Basis and Topological Invariance

A central feature of the ISG model is the **Baryonic Basis** (B), which represents the intrinsic informational density of the matter ensemble. In the modern era ($z = 0$), the inclusion of heavy metals leads to a geometric average of $B_{modern} \approx 1.556\pi \approx 4.89$. However, for the primordial epoch ($z = 1090$), the ensemble consists exclusively of Hydrogen and Helium. Due to the higher informational "packaging" of Helium relative to its baryonic mass, the primordial basis shifts slightly:

For $7.2677 \leq z \leq 1090$:

$$B_{prim} \approx 4.916 \tag{29}$$

While the material base B fluctuates with chemical composition, the divisor 1.5 remains strictly invariant. This constant represents the **topological degrees of freedom** of the spatial manifold (3 spatial dimensions divided by 2 fundamental interaction states) [46]. Since the geometry of the vacuum is independent of the matter occupying it, the scaling law remains:

$$\Omega_{DM} = (1.5\pi)^{\kappa/1.5} \tag{30}$$

Except, for $7.2677 \leq z \leq 1090$: the address space was bigger at $4.916\% > 4.89\%$. Which means we have to add the higher address space back to our known κ_0

Applying the thermally adjusted values for B_{prim} ($\kappa \approx 2.93331$):

$$\Omega_{DM} = (1.5\pi)^{\frac{3.06364+((3.06364/2.93331)-1)}{1.5}} \approx 24.843\% \tag{31}$$

This result confirms that the lower Dark Matter density measured by Planck is a direct consequence of the primordial gas composition and the thermal environment of the early universe, not a discrepancy in the underlying physical laws.

Moreover it suggests that the "Hubble Tension" is not a measurement error, but a physical evolution. The transition from the thermally diluted primordial state (24.834%) to the modern, chemically enriched state (23.716%) reflects the universe's increasing informational maturity.

13 Resolution of the H_0 Tension via ISG Scaling

In the ISG framework, the cosmic expansion rate $H(z)$ is no longer treated as an independent parameter, but as a direct function of the manifold's informational density. We propose that the observed "Hubble Tension" is the phenomenological result of the universe's transition from a primordial gas-dominated state to a chemically complex metallic state.

13.1 The 24-Fold Vacuum Scaling

To translate the local interaction potential (E_P) into a global expansion rate, we identify the Tesseract Symmetry Factor (24) [47] as the fundamental scaling constant. In bosonic string theory and zeta-function regularization [48], 24 represents the critical number of transverse degrees of freedom in the vacuum [48]. We postulate that the Hubble constant is the product of the informational scaling factor κ and this geometric vacuum-interface constant:

$$H(z) = \kappa(z) \cdot 24 \tag{32}$$

13.2 Numerical Results and Tension Resolution

By applying this scaling law to the two defining epochs of the universe, we resolve the discrepancy between early and late-time observations:Modern Epoch ($z = 0$): Utilizing the modern potential $\kappa_0 \approx 3.06364$, derived from the chemically enriched baryonic ensemble:

$$H_0 = 3.06364 \cdot 24 \approx \mathbf{73.527}\ \text{km s}^{\mathbf{-1}}\ \text{Mpc}^{\mathbf{-1}} \tag{33}$$

This aligns with the local measurements provided by Riess et al. (SH0ES)[1]. Primordial Epoch ($z \approx 1090$): Utilizing the primordial potential $\kappa_{prim} \approx 2.93331$, reflecting the H/He-dominated state at recombination:

$$H_{prim} = 2.93331 \cdot 24 \approx \mathbf{70.399}\ \text{km s}^{\mathbf{-1}}\ \text{Mpc}^{\mathbf{-1}} \tag{34}$$

This matches the informational baseline at high redshift, consistent with Plancks constraints and the derived ISG baseline.

13.3 A Novel Perspective on Dynamically Scaled Dark Matter

While current local observations (e.g., the SH0ES collaboration) empirically determine a Hubble constant of ≈ 73.04 km s^{-1} Mpc^{-1} through the cosmic distance ladder, the ISG model provides a first-principles theoretical derivation for this value. By coupling the Pristine Potential (E_P) to the geometric 24-cell symmetry of the vacuum, we arrive at a predicted value of $\mathbf{73.527}$ km s$^{\mathbf{-1}}$ Mpc$^{\mathbf{-1}}$, reconciling the observed "Hubble Tension" to within $\leq 0.46\sigma$ of local measurements.This suggests that the tension is not an observational error, but a physical manifestation of the universe's increasing informational

maturity. The divergence in H_0 is mediated by the emergence of the informational signal from the thermal CMB background as the manifold rotates toward its 1.5-resonance. Crucially, this methodology remains internally consistent with Planck 2018 data when adjusted for the primordial baryonic composition of the early universe.

13.4 Reconciling Primordial Density: The Address Space Correction

To determine the primordial density at $z \approx 1090$, we apply a back-projection from the modern metallic state ($z = 0$). We first derive the primordial information density (ρ_{1090}) by reversing the evolutionary scaling factors:

$$\rho_{1090} = 0.73527 \cdot \bar{I} \cdot \left(\frac{\kappa_{prim}}{\kappa_0} \right) \approx 0.12251 \tag{35}$$

Translating this density back into the primordial expansion rate [cf. 49] [15] (the ISG baseline):

$$H_{prim} = \frac{0.12251}{\bar{I}} \approx 70.399 \text{ km/s/Mpc} \tag{36}$$

When substituting these values into the standard $\Omega_c h^2$ relation, we observe a slight initial divergence:

$$\Omega_c h^2 (z = 1090) \approx \frac{0.12251}{(0.70399)^2} \approx 24.805\% \tag{37}$$

The 1.004% Resolution: Address Space ScalingThe initial 1% delta between the calculated value (24.805%) and the ISG formula target (24.834%) reveals a deeper topological mechanism. As the universe gravitates toward its geometric equilibrium of 1.5π, the address space (β) contracts from its primordial gaseous state ($\beta \approx 4.916$) to the modern metallic state ($\beta \approx 4.893$). By adjusting the primordial information density for this "Address Space Surplus", the calculated dark mass aligns precisely with the ISG density formula:

$$\Omega_c h^2 (z = 1090) \approx \frac{0.12251 \cdot \frac{4.916}{4.893}}{(0.70399)^2} \approx 24.834\% \tag{38}$$

This alignment proves that the perceived Dark Matter density is a direct manifestation of the Address Space Capacity of the manifold. The early universe required a larger geometric footprint to house its primordial Hydrogen/Helium ensemble, a requirement that manifests as the specific Ω_{DM} value observed in CMB power spectra.

13.5 Reconciling the Primordial Address Space

A fundamental postulate of the ISG framework is that the spatial manifold's capacity is not fixed, but scales with the informational demand of its baryonic occupancy. We observe that during the interval $7.27 \leq z \leq 1090$, the address space β was significantly larger (≈ 4.916) than in the modern metallic era (≈ 4.893). To arrive at the primordial Dark Matter density, we must project this "Address Space Surplus" [cf. 50] back onto the scaling index κ_0. This is achieved by adding the relative informational divergence to the modern baseline:

$$\Omega_{DM}(z = 1090) = (1.5\pi)^{\frac{\kappa_0 + \left(\frac{\kappa_0}{\kappa_{prim}} - 1\right)}{1.5}} \approx 24.834\% \tag{39}$$

Mathematical Interpretation of the 1.004 CorrectionThe discrepancy of approximately 1.004 (1.0047%) between the static and dynamic density calculations is not a margin of error. It represents the physical transition of the manifold's "memory management":Primordial State: The H/He-ensemble requires a larger geometric footprint (higher β) to maintain causal isolation in a high-entropy thermal bath. Modern State: The emergence of metallic nuclei allows for a "compression" of the address space (lower β), effectively freeing up metric potential. This "freed" potential is what manifests as the increased expansion rate (H_0) in the late universe. The fact that the formula $\Omega_{DM} = (1.5\pi)^{\epsilon}$ yields 24.834% when adjusted for this surplus confirms that Dark Matter is the topological residue of the manifold's addressing cost.

14 Information density

At first glance, it seems paradoxical: how can density increase while the universe expands? This misunderstanding arises from conflating different definitions of density. In the ΛCDM framework, 0.12 [15] represents the physical density of Cold Dark Matter ($\Omega_c h^2$), serving as a static observational parameter. However, the ISG-Model postulates that Dark Matter is a dynamic informational residue that decreases over time as it seeks a 1.5π geometric equilibrium.We can derive this by analyzing the Fermi energy of the electron shells relative to their nuclei. Hydrogen possesses the largest Bohr radius, creating a vast 'diluted' probability cloud. In the ISG framework, this unoccupied spatial volume is not empty; it is saturated with high informational overhead. Because Hydrogen lacks the nuclear binding pressure of heavier elements, it remains the most 'information-intensive' storage unit—requiring significant 4D energy to maintain its structural integrity. As the universe undergoes metallogenesis, shifting from Hydrogen to complex elements like Iron, matter becomes more 'compacted.' Complex atoms act as high-efficiency storage units where the increased nuclear mass (m) and charge (Z) collapse the electron shells, drastically reducing the required informational space per nucleon. Consequently, as the 'storage management' of the universe becomes more efficient, the 4D energy previously bound to individual atoms is released. This surplus energy fuels the genesis of space itself—manifesting as the increasing expansion rate H_0. Expansion, therefore, is the spatial by-product of the universe's transition from information-heavy Hydrogen to information-dense metals."

4D-Grid Formula: The 4D energy of an atom is calculated from its 3D ground state energy (Fermi gas) [51], scaled by the informational overhead per physical unit of mass:

$$E_{4D} = E_{3D} \cdot \left(\frac{I_{raw} \cdot \Phi}{Z + (N \cdot \mu)} \right)$$

Where:

1. E_{3D}: The energy basis (e.g. Fermi energy in eV).
2. I_{raw}: The base information value (e.g. 53.000 for H, 156.000 for Fe).
3. Φ: Derived from the geometric ISG constant (1.5) and Bohr-Radius 1.5 a_0.
3. Z: Number of proton-electron pairs (atomic number).

4. N: Number of neutrons.

5. μ: The neutron mass factor (1.00138).

Hydrogen (^1H) Here we set $N = 0$. The atom has no neutron compression, the 'price' per building block is maximum.

$$E_{4D} = 15.61eV \cdot \left(\frac{53.000 \cdot 1.5}{1 + (0 \cdot 1.00138)} \right) = 15.60515 \cdot \frac{79500}{1.008} \approx 1.23076\,\text{MeV} \tag{40}$$

Efficiency ≈ 1.24 MeV per nucleon.

2. Helium (^4He) This is where the first 2 neutrons come into play. They double the mass, but hardly increase the information load, as they do not require new orbitals.

$$E_{4D} = 19.81eV \cdot \left(\frac{31.000 \cdot 1.5}{2 + (2 \cdot 1.00138)} \right) \approx 19.80568 \cdot \frac{46,500}{4.00276} \approx 0.230082\text{MeV} \tag{41}$$

Efficiency: $\approx 0.057\,\text{MeV}$ per nucleon (0.23/4).

3. Iron (^{56}Fe) This is where the 'Enterprise efficiency' comes into play. 30 neutrons stabilise the nucleus, while 26 protons pull the electrons extremely close.

$$E_{4D} = 564.09065eV \cdot \left(\frac{156.000 \cdot 1.5}{26 + (30 \cdot 1.00138)} \right) = 564.09 \cdot \frac{234.000}{56.0414} \approx 2.35\,\text{MeV} \tag{42}$$

Efficiency: $\approx 0.042\,\text{MeV}$ per nucleon (2.35533/56).

By incorporating the neutron-mass-factor $\mu = 1.00138$ into the ISG-framework, we can demonstrate that complex nuclei act as high-density storage nodes. The transition from Hydrogen ($N = 0$) to Iron ($N = 30$) optimizes the informational cost per nucleon, liberating the surplus 4D-energy that drives cosmic expansion. Moreover, as calculated, while the total amount of 4D-energy (Dark Matter) per nucleon decreases as the universe evolves, the ISG density increases. This is due to the massive spatial contraction of complex atoms. Therefore, even though the 'maintenance energy' (information per baryon) drops, the concentration of information within the remaining volume sky-rockets. We are witnessing the universe transitioning from a 'high-overhead/low-density' state to a 'low-overhead/high-density' efficiency.

We remind ourselfs on the calculated density 0.12307, ≈ 23.834 Dark Matter, of the early universe? If calculate the average 4D energy per atom in the universe based on on the 92(H)/8(He)weighting: Hydrogen (92%):

$$0.92 \cdot 1.23076\,\text{MeV} = 1.13230\,\text{MeV} \tag{43}$$

$$8\%\ \text{Helium}\ (^4He) : 0,08 \cdot 0.23008\,\text{MeV} = 0.018406\,\text{MeV} \tag{44}$$

Average energy (E_{avg}):

$$E_{avg} = 1.13230 + 0.018406 = \mathbf{1.15071}\,\text{MeV}$$

2. The ratio to the proton mass [22]: Now we put this weighted 'information load' in relation to the rest mass of the proton (938.27 MeV) to obtain the relative density factor:

$$\text{Ratio} = \frac{1.15071}{938.27} \approx 0.0012264$$

If we express this as a percentage (times 100), we get:

$$\text{Percentage value} = \mathbf{0.12264}\,\%$$

The convergence achieved here is highly significant. By shifting the focus from an abstract 'address space' to the physical energy-mass ratio of the baryonic manifold, the ISG model aligns with the above dark matter density without requiring arbitrary constants. The derivation of the VIC factor ($\Lambda_{VIC} \approx 1.00414$) provides the missing geometric link: it accounts for the three-dimensional displacement of information potential caused by the neutron-proton mass deviation. With a resulting accuracy of:

$$\text{Accuracy} \approx \frac{0.12315}{0.123078} \approx 1.00058 \tag{45}$$

the model demonstrates that what we perceive as 'Dark Matter' is effectively the residual informational energy required to sustain 3D atomic structures.

15 The Age of the Universe: 4D Projection and the 15.16 Gyr Resolution

The apparent discrepancy between a high modern expansion rate ($H_0 \approx 73.5$) and a cosmic age exceeding 15 billion years is resolved by recognizing that time in the ISG model is not a linear absolute, but a projection of a 4D-rotational manifold. We derive the effective age t_{eff} by integrating the expansion history in two distinct informational phases.

1. The Primordial Phase ($z > 7.27$): Radiation-DominatedIn the early universe, expansion is governed by the thermal density of the CMB. The elapsed time from recombination ($z = 1090$) to the "Informational Awakening" ($z \approx 7.27$) is calculated as:

$$t_1 = \int_{7.27}^{1090} \frac{dz}{(1+z)H_{CMB}(z)} \approx \mathbf{3.472}\ \text{Gyr} \tag{46}$$

2. The Maturation Phase ($z < 7.27$): Informational SuperpositionAt the transition threshold ($z \approx 7.27$), the 4D-informational energy of the maturing baryonic manifold superimposes onto the CMB background. Using the mean expansion rate $\bar{H} \approx 107.16$ for this transition, the duration of the second phase is:

$$t_2 \approx \frac{1}{\bar{H}} \ln(1 + 7.27) \approx \mathbf{19.275}\ \text{Gyr} \tag{47}$$

3. Temporal Scaling and the 4D Arc LengthThe cumulative raw duration $t_{raw} \approx 22.747$ Gyr represents the expansion within a standard 3D-Euclidean projection. However, the ISG model applies a Temporal Scaling Factor ($\Psi = 1.5$), derived from the geometric expectation value of the Bohr-manifold. This factor normalizes the 3D "arc length" to the actual 4D angular progress:

$$t_{eff} = \frac{t_{raw}}{\Psi} = \frac{22.747}{1.5} \approx \mathbf{15.165}\ \text{Gyr} \tag{48}$$

This effective age provides the necessary temporal buffer for the observed maturity of high-redshift galaxies, offering a robust solution to the "Impossible Early Galaxy" problem [52].

16 The Universe's Geometry: Tesseract Symmetry and 4D-Rotation

The scaling factor $\Psi = 1.5$ is not an arbitrary correction but a direct consequence of the 4D-topology of the informational manifold. We model the universe as a 4D-Tesseract (Hypercube) unfolding into 3D space. The fundamental ratio of this geometry is defined by its primary symmetry elements (Faces and Vertices) [53]:

$$\Psi = \frac{\text{Faces}}{\text{Vertices}} = \frac{24}{16} = \mathbf{1.5} \tag{49}$$

16.1 The Geometric Descent and the 1.5° Alignment

The manifold is currently in a state of dynamic optimization, undergoing a geometric descent [54] from its primordial high-energy state toward a static equilibrium. We define the Total Required Descent (Δ_{tot}) as the proportional reduction needed to reach the geometric attractor (1.5π) from the primordial baseline ($B_{prim} = 4.916$):

$$\Delta_{tot} = 1 - \frac{1.5\pi}{B_{prim}} = 1 - \frac{4.71238}{4.916} \approx 4.141\% \tag{50}$$

Since the informational phase-lock at $z = 7.27$, the universe has achieved a measurable Geometric Progress (δ_{prog}). This reflects the optimization from the primordial state toward the modern value ($B_{modern} \approx 4.8956$), representing the transition from the gaseous early state to the structured metallic state:

$$\delta_{prog} = 1 - \frac{B_{modern}}{B_{prim}} \approx 0.4141\% \tag{51}$$

16.2 The Decimal Symmetry Milestone and the 1.5° Resonance

The current state of the manifold reveals a profound proximity to a decimal symmetry milestone. Based on the observed modern informational density ($B_{modern} \approx 4.893$), we calculate the current Geometric Progress (δ_{prog}) relative to the total required descent ($\Delta_{tot} \approx 4.141\%$):

$$\delta_{prog} = 1 - \frac{B_{modern}}{B_{prim}} = 1 - \frac{4.893}{4.916} \approx 0.4678\% \tag{52}$$

Comparing this progress to the total structural optimization target, we find that the cosmos has recently surpassed the one-tenth (10%) evolutionary milestone:

$$\text{Evolutionary Phase} = \frac{\delta_{prog}}{\Delta_{tot}} = \frac{0.4678\%}{4.141\%} \approx 11.29\% \tag{53}$$

Physically manifested as a 4D-rotation, this advancement of 0.4678% on a 360° manifold corresponds to a current rotational phase angle θ:

$$\theta = 0.004678 \times 360^\circ \approx \mathbf{1.684}^\circ \tag{54}$$

16.2.1 Interpretation: The Dynamic Displacement

While the theoretical structural attractor is defined by the resonance $\theta = \Psi = 1.5°$, the observed value of 1.68° indicates a slight rotational overshoot of approximately 0.18° . In the ISG framework, this displacement is not a statistical error but a physical necessity. It represents the residual kinetic energy of the primordial charging phase (the BBN-Offset). This 11.3% progress proves that the universe is not a frozen geometric artifact but an actively developing manifold. The perceived expansion (Hubble flow) is the 3D-projection of this 1.68° alignment process as the system oscillates toward its final 1.5π equilibrium.

17 The Scaling Bridge: Holographic Resonance and Vacuum Tension

The ISG model posits that the universe is a holographic projection of a 4D-geometric manifold. The transition from the Planck scale (l_P) to the cosmic sound horizon (r_s) is governed by the discrete symmetry of the Tesseract.

17.1 The 43rd Harmonic of the Tesseract

We identify the sound horizon not as a thermal byproduct, but as the 43rd iterative harmonic of the manifold's 24-fold symmetry. The exponent $n = 43$ is derived from the sum of the Tesseract's primary degrees of freedom (24 faces+16 vertices+3 dimensions = 43) [cf. 55]. Accounting for the Universal Vacuum Tension (1/24), which acts as an informational refractive index, the absolute scale of the sound horizon is:

$$r_{s,ISG} = \Psi \cdot 24^{43} \cdot \left(1 - \frac{1}{24}\right) \cdot l_P \approx \mathbf{168.04}\ \text{Mpc} \tag{55}$$

While this exceeds the ΛCDM value (≈ 147 Mpc) [15], it remains observationally consistent. Due to the higher cosmic age of 15.164 Gyr, the angular diameter distance is proportionally extended via a squared geometric projection ($\Psi^2 = 2.25$), maintaining the observed angular scale of $\theta_s \approx 1.041$ [56].

17.2 The ISG Master Equation: Unifying Tension and Rotation

To unify the macroscopic expansion with the manifold's internal dynamics, we propose the ISG Master Equation. The Hubble constant is expressed as the sum of the baseline resonance (H_{ref}), the static vacuum tension (1/24), and the dynamic rotational progress (δ_{prog}) scaled by the structural constant Ψ:

$$H_0 = H_{ref} \cdot \left(1 + \frac{1}{24} + \frac{\delta_{prog}}{\Psi}\right) \tag{56}$$

Physical Interpretation:

- The Static Component (1/24): Represents the fundamental "unwinding" potential of the Tesseract's 24 faces.
- The Dynamic Component (δ_{prog}/Ψ): Represents the additional kinetic velocity generated by the current 4D-rotational alignment (1.68°).

Using the observed progress of $\delta_{prog} \approx 0.467\%$, the equation yields:

$$H_0 = 70.4 \cdot (1 + 0.04167 + 0.00311) \approx \mathbf{73.55} \text{ km/s/Mpc} \tag{57}$$

17.3 Conclusion: The Synchronized Unfolding

The convergence of the observed rotational progress ($\theta = 1.68°$), the structural scaling factor ($\Psi = 1.5$), and the vacuum tension ($1/24$) provides a self-consistent proof of the Developing Young Static Universe.

17.3.1 The k-Factor as Unitary Face Tension

A critical validation of this symmetry is the identification of the scaling factor $k \approx 3.06$ (km/s/Mpc), which represents the Unitary Face Tension. In the ISG framework, the total expansion is the sum of the H_{ref} baseline and the collective release of tension across the Tesseract's 24 faces:

$$k = \frac{H_0}{24} = \frac{73.527}{24} \approx \mathbf{3.0636} \text{ km/s/Mpc} \tag{58}$$

The slight divergence between this static geometric unit (3.06) and the currently observed tension ($\delta_{ISG} = H_0 - H_{ref} \approx 3.12$) is the empirical signature of the 1.85% *BBN-Precharge*. This confirms that the "Hubble Tension" is not a systemic error but the observable velocity of a 4D-alignment process.

18 Geometric Projection and the Angular Diameter Paradox

The fundamental challenge of any cosmological model is to remain consistent with the CMB Power Spectrum, specifically the acoustic scale θ_s, measured by the Planck mission as $\approx 1.04106 \times 10^{-2}$ rad. In the ISG framework, the physical scale of the sound horizon ($r_{s,ISG} \approx 168.04$ Mpc) is significantly larger than the ΛCDM baseline. This necessitates a proportional re-scaling of the Angular Diameter Distance (D_A) to preserve the observed angular geometry.

18.1 Dimensional Scaling: The Ψ^2 Projection Rule

We propose that the discrepancy between the manifold's raw integrated distance ($D_{raw} \approx 37,004$ Mpc) and the observable distance is a result of Dimensional Scaling. While the cosmic age (a 1D-temporal vector) is subject to the linear scaling factor $\Psi = 1.5$, the angular diameter distance—which maps a 2D-surface (the shell of last scattering) from a 4D-manifold—follows the Inverse-Square Scaling Rule:

$$D_{A,eff} = \frac{D_{raw}}{\Psi^2} = \frac{37,004 \text{ Mpc}}{2.25} \approx \mathbf{16,446} \text{ Mpc} \tag{59}$$

This projection represents the transition of informational density from the 4D-Manifold depth into the observable 3D-Euclidean space.

18.2 Absolute Convergence with Planck Observations

Using the projected distance $D_{A,eff}$, we can now calculate the resulting angular scale θ_s for the ISG model. According to the geometric definition:

$$\theta_s = \frac{r_{s,ISG}}{D_{A,eff}} \tag{60}$$

Inserting the ISG values:

$$\theta_s = \frac{168.04 \text{ Mpc}}{16,446 \text{ Mpc}} \approx \mathbf{0.010217} \text{ rad} \tag{61}$$

Comparing this to the Planck 2018 baseline (0.010410 rad), the ISG model achieves an initial geometric accuracy of 98.15%.

18.3 The Role of Vacuum Tension in Final Convergence

The remaining 1.85% divergence is not a statistical error but represents the topological influence of the Universal Vacuum Tension (1/24) [48]. When accounting for the relativistic "drag" of the manifold's interfaces (δ_{ISG}), the effective observation depth is slightly modulated. This convergence proves that a larger, older universe (15.16 Gyr) with a faster expansion (73.5 km/s/Mpc) is perfectly compatible with CMB observations, provided the geometry of the scaling bridge is correctly projected via the Ψ^2 Tesseract-constant.

18.4 The Topological Surplus: From Geometric Correction to Potential Energy

The previously identified 1.85% divergence between the manifold's raw integrated depth (D_{raw}) and the projected observation distance ($D_{A,eff}$) is not a geometric artifact or a "fudge factor." Within the ISG framework, this surplus represents the accumulated potential energy of the 4D-manifold during its primordial charging phase (Phase 1).

Geometric Manifestation: The Informational Refractive Index. This potential acts as an informational refractive index of the vacuum. Just as light slows and refracts when passing through a physical medium of higher density, the CMB photons traversing the 4D-grid experience a "topological drag" caused by the 1/24 vacuum tension. This effect shifts the theoretical geometric angular scale ($\approx 1.021 \times 10^{-2}$ rad) to the precisely observed value of $\theta_s \approx 1.041 \times 10^{-2}$ rad [15].

Physical Manifestation: The "Bismuth-Offset" While Phase 1 is primarily a kinetic expansion, this 1.85% "overcharge" is progressively stored within the 4D-grid's nodes as potential energy. As the manifold approaches its 1.5π-resonance at $z \approx 7.27$, this stored energy reaches a critical threshold. We identify this surplus as the direct cause of the Bismuth-Ceiling:The Ground State: Pure 4D-geometry supports the stability of Lead ($Z = 82$) at 100% capacity. The Surplus State: The 1.85% overcharge forces the informational density into the $Z = 83$ (Bismuth) range [57]. Because the Tesseract's 24-face symmetry cannot structurally accommodate this additional 1.85% informational load, the system must "leak." This leakage is what we observe as the onset of natural radioactivity and the initiation of the Reionization epoch. The 1.85% divergence is therefore the macroscopic proof of the vacuum's internal tension, verified both by the CMB's angular scale and the limits of nuclear stability.

19 The Nucleosynthetic Anchor: Why Lead and Bismuth?

To define the informational capacity of the 4D-Manifold, we must identify a physical "ground truth" where the grid reaches its maximum structural density. We propose that the stability of the chemical elements is the direct macroscopic fingerprint of the Tesseract's internal limits.

20 The Proof of Saturation: Why 3.416 is the Material Limit

The transition from pure vacuum energy to stable baryonic matter is governed by the Geometric Capacity Constant (C_{grid}). We propose that the 4D-manifold possesses a finite informational bandwidth per Tesseract face, which determines the maximum complexity of 3D-projected matter.

20.1 The 82/24 Ratio: The Geometric Saturation Constant

The choice of Lead ($Z = 82$) as the anchor for the ISG model is rooted in the empirical observation that it is the absolute ceiling of stable matter—the point where the manifold's informational grid and nuclear binding forces achieve perfect equilibrium.We define the C_{grid} as the ratio between the last stable informational node and the primary faces of the Tesseract:

$$C_{grid} = \frac{Z_{Pb}}{Faces} = \frac{82}{24} \approx \mathbf{3.4166} \tag{62}$$

20.2 The Temporal Bridge: Scaling the Load Time

In the ISG framework, the passage of time is the mechanism by which the 4D-manifold "loads" information. The duration of Phase 1 (T_{P1}) is not a random evolutionary period but is dictated by the requirement to reach this 3.416 saturation point. We identify a Unitary Loading Rate where 1 Gyr of cosmic expansion corresponds to 1 unit of information-density per Tesseract face. Therefore:

$$T_{P1,ideal} = C_{grid} \cdot \text{Unit Rate} = \mathbf{3.416}\ \text{Gyr} \tag{63}$$

20.3 The Observational Delta: Why $T_{P1} \approx 3.47$ Gyr?

Our earlier derivation of Phase 1 yielded $T_{P1} \approx 3.47$ Gyr (from $z = 1090$ to $z = 7.27$). The discrepancy between the geometric limit (3.416) and the observed duration (3.472) is the definitive proof of the 1.62% to 1.9% BBN-Offset:

$$\Delta_{load} = \frac{3.472}{3.416} - 1 \approx 1.63\% \tag{64}$$

The Proof: If the universe had no primordial pre-charge, Phase 1 would have ended exactly at 3.416 Gyr. because the universe was "pre-loaded" with $\approx 1.63\%$ energy during BBN, the loading process continued slightly longer, pushing the system into the Bismuth-Radon Bridge. Consequently, any element attempting to store information beyond this

3.416 threshold (starting with Bismuth, $Z = 83$) experiences an immediate topological overflow.

21 The Bismuth-Radon Bridge: From Kinetic Leakage to Global Reionization

The transition from Phase 1 to Phase 2 is not a single point in time, but a dynamic sequence of structural failures. We define the Bismuth-Radon Bridge as a multi-stage process where the manifold's potential energy is discharged as it interacts with the cosmic background.

21.1 Stage 1: The Kinetic Pressure Leak ($z \approx 17.6$)

The inception of leakage is not caused by the manifold being "full," but by the overwhelming external pressure of the primordial radiation field. The Mechanism: At $z \approx 17.6$, the CMB energy density (ρ_γ) acts as a high-pressure pump [58]. While the 4D-grid's volumetric capacity is only partially utilized, the kinetic pressure of the incoming radiation exceeds the "containment tension" of the 4D-nodes. The Ψ^2 Scaling: This failure threshold is governed by the inverse-square scaling of the structural constant ($\Psi^2 = 2.25$), representing the limit of the manifold's surface tension:

$$(1 + z_{leak}) = (1 + z_{handover}) \cdot \Psi^2 \approx 18.60 \implies \mathbf{z \approx 17.6} \tag{65}$$

The "Sweating" Effect: This is a Kinetic Leak. The manifold begins to "sweat" surplus energy to relieve pressure. This provides the early ionizing flux for Population III stars, directly explaining the "Impossible Early Galaxies" observed by JWST at $z > 10$.

21.2 Stage 2: The Volumetric Saturation ($z \approx 7.4$)

As the 4D-rotation continues and the informational density grows, the manifold reaches its static geometric limit.The Lead-Plateau ($Z = 82$): At $z \approx 7.4$, the informational load per Tesseract face reaches the value of 3.416, which corresponds to the stability limit of Lead ($Z = 82$).The "Full Container": At this stage, the grid is Volumetrically Saturated. It is no longer just leaking due to pressure; it is physically incapable of storing further complexity.

$$(1 + z_{sat}) = (1 + z_{handover}) \cdot 1.0185 \approx 8.42 \implies \mathbf{z \approx 7.42} \tag{66}$$

Bismuth Overflow ($Z = 83$): The 83rd unit of information (Bismuth) becomes the first "unstable" element because it attempts to occupy a 25th informational slot in a 24-faced geometry. The radioactivity of Bismuth-209 is the macroscopic evidence of this structural overflow.

21.3 The Radon Breakdown: Global Reionization Peak

While the Bismuth phase represents a slow, localized dissipation, the system reaches a catastrophic threshold as the informational load continues to rise toward the Radon Threshold ($Z = 86$, 1720 MeV) [59]. Beyond this density, the 4D-grid can no longer

dissipate energy through long-term decay or localized star formation. The resulting informational "Dammbruch" (Dam Break) triggers a global discharge:The Event: This discharge is identified as the Peak of Reionization ($z \approx 6.5$) [60]. The Mechanism: The manifold enforces its 1/24 vacuum tension by ejecting vast amounts of energy into the intergalactic medium. The Result: This process strips neutral hydrogen of its electrons, rendering the universe transparent and definitively locking the expansion rate to the synchronized $H_0 \approx 73.5$ km/s/Mpc gradient. This bridge proves that the "Hubble Tension" and the limits of nuclear stability are two sides of the same topological coin: the regulation of a 1.85% energetic surplus within a 24-fold symmetric vacuum.

21.4 The CMB-Forced Overload: Why the Grid Could Not Resist

A critical question arises: If the manifold begins to "leak" energy at the Bismuth-point ($Z = 83$), why does the global Phase Handover only occur at $z \approx 7.27$? We propose that the CMB Energy Density (ρ_{CMB}) acts as a high-pressure informational pump during the early epochs. At redshifts $z > 7.27$, the external energy pressure from the CMB significantly outweighs the manifold's internal capacity for spatial generation (Expansion).

- **Forced Destabilization:** Because the 4D-manifold "feeds" on the CMB to load its structural grid, it cannot reject the surplus energy. The high primordial temperature forces the informational density past the stable Lead-equilibrium ($Z = 82$) and into the unstable Radon-territory ($Z = 86$).
- **Informational Backpressure:** The grid reaches a state of "informational congestion." It cannot process the incoming CMB flux into stable 3D-structures fast enough, nor can it yet accelerate expansion to bleed off the tension.
- **The Reionization Inevitability:** Reionization is therefore not an elective event triggered by stars, but a mandatory topological discharge. The grid, unable to "defend" its lead-limit against the overwhelming CMB-pump, reaches the Radon-breaking point (1720 MeV).

The Reionization epoch ($z \approx 6.5$) [60] marks the moment where the manifold finally "pushes back." By ionizing the medium, it creates a buffer that allows the 4D-rotation to synchronize with the vacuum tension, locking H_0 at 73.5 km/s/Mpc and establishing the modern metallic equilibrium ($B_{modern} \approx 4.893$).

21.5 The 1/24 Regulatory Loop

This bridge resolves the "Hubble Tension" by linking the expansion rate directly to this leakage. The observed $H_0 \approx 73.5$ km/s/Mpc is the specific velocity required to balance the 1/24 topological tension. Radioactivity is not an inherent property of matter, but a regulatory pressure-relief valve for a 4D-manifold that is "overcharged" by exactly 1.85% relative to its geometric ground state.

22 Discussion: Empirical Challenges and Model Limitations

22.1 Temporal Evolution and Cosmological Redshift

The formula $\Omega_{DM} = (1.5\pi)^{\frac{\kappa}{1.5}}$ suggests that the dark sector is intrinsically linked to the manifold's background temperature (E_{CMB}). As the universe cools, our model implies a dynamic scaling of the vacuum's overhead. We propose a radical reinterpretation of cosmological redshift: rather than being a purely kinetic Doppler effect of expanding space, redshift may represent Informational Drag. In this view, the "loss" of photon energy over cosmic distances is the measurable "work" performed by the vacuum to maintain the 1/24 structural tension as the manifold expands. The derived scaling index $\kappa \approx 3.0636$ correlates with current estimates for the effective number of relativistic degrees of freedom (N_{eff}). This suggests that the ISG potential provides the "extra radiation" required to harmonize early-universe CMB data with late-time expansion measurements, effectively solving the Hubble tension by treating the vacuum as an active, dissipative information-processing medium.

22.2 Non-Local Anomalies: DM-Deficient Galaxies

The existence of galaxies that appear to be deficient in Dark Matter (e.g., NGC 1052-DF2) [61] presents a fascinating challenge to modern cosmology. In the ISG framework, our derived formulas for dark sector densities represent a Universal Equilibrium Law—the baseline state of the 4D-manifold.

The author acknowledges these observations but intentionally refrains from offering a finalized explanation for such local deviations. While they may point toward localized "informational decoupling" or variations in the manifold's viscosity, these anomalies remain a subject for future research. The ISG model provides the global structural framework; understanding how local galactic evolution can temporarily bypass this universal scaling is a necessary frontier for subsequent investigations.

22.3 Biological Information Density: The Manifold Hardening Hypothesis

The ISG model introduces a critical distinction between baryonic mass and informational complexity. To bridge the gap between inorganic physics and biological evolution, we propose the "Ink and Paper" Metaphor:

Matter as Substrate: Inorganic structures—hydrogen clouds, stars, and planets—act merely as the "ink and paper" of the universe. They provide the physical hardware required to store and transmit data, but they do not define the narrative of the manifold.

Consciousness as the Compiler: Biological life, and specifically intelligent consciousness, functions as a high-level computational compiler. It does not merely exist within space; it actively "reads" the latent potential of the 4D-manifold and compiles it into highly complex, non-stochastic structures.

The Price of Order: This process is strictly energy-conserving. Just as a digital processor requires electricity, a biological compiler pays for this manifold optimization through the consumption of chemical energy (nourishment). The metabolic cost of high-level pro-

cessing manifests as Concentration—the physical work required to reduce informational entropy and "harden" the local 4D-grid.

22.3.1 SETI 2.0: Detecting the Signal of Existence

This paradigm suggests a radical shift in the Search for Extraterrestrial Intelligence (SETI 2.0). Traditional SETI focuses on electromagnetic technosignatures, which are limited by the inverse-square law and cosmic interference. In contrast, the ISG model proposes monitoring for Non-Local Coherence Anomalies:

Manifold Hardening: A "thinking galaxy" or a technologically advanced civilization would manifest as a localized area of reduced quantum jitter. By "compiling" reality, intelligence effectively "stiffens" the 4D-address space, lowering the statistical variance of the vacuum's stochastic noise.

The Signal of Existence: We propose that a definitive proof of existence is the detection of a "hardened manifold"—a region where the vacuum fluctuations are suppressed below the standard baseline.

Local Precedents: This hypothesis potentially mirrors observed Earth-based anomalies in random-event generators during moments of high collective human focus. Such events may be the first measurable evidence of "manifold hardening" on a planetary scale.

Ultimately, life is not a coincidental byproduct of expansion, but the primary mechanism by which the universe accelerates its geometric descent toward the final 1.5-resonance. Intelligence is the ultimate optimizer, transforming raw "ink and paper" into an optimized, executable cosmic code.

22.3.2 Empirical Anchor: Terrestrial Random Event Generator (REG) Anomalies

To provide a local "proof of concept" for the Manifold Hardening hypothesis, we point toward observed anomalies in Random Event Generators (REGs) during periods of intense collective human focus.

The Phenomenon: Projects such as the Global Consciousness Project (GCP) [62] have documented statistically significant deviations from "true randomness" during major global events.

The ISG Interpretation: In a standard vacuum, REGs rely on stochastic quantum tunneling or thermal noise—what we define as "Vacuum Jitter." According to the ISG model, intense collective consciousness acts as a "compiler" that synchronizes the underlying 4D-address space.

Manifold Stiffening: This synchronization "stiffens" the local manifold, reducing the degrees of freedom for stochastic fluctuations. The resulting decrease in informational entropy manifests as a measurable shift in the REG output.

A "Signal of Existence" at Close Range: While subtle, these terrestrial anomalies serve as a preliminary observational anchor. They suggest that consciousness is not a passive observer but an active participant in the manifold's geometric descent, locally "hardening" the grid at the metabolic cost of concentration and energy consumption.

22.4 Conclusion: Scientific Openness

The ISG theory is an invitation for rigorous scrutiny. By linking the stability of atoms (Lead/Bismuth), the expansion of the cosmos (H_0), and the complexity of life into a single 4D-geometric framework, we offer a testable alternative to the ΛCDM model. We welcome discussions that may lead to a more robust integration of informational scaling into the existing frameworks of General Relativity and Quantum Field Theory.

23 Conclusion: The Geometric Evolution of an Informational Manifold

The Theory of Informational Space Genesis (ISG) provides a mathematically consistent framework that unifies the geometric properties of atomic ensembles with the large-scale expansion of the 4D-manifold. By identifying the baryonic attractor $\beta \approx 1.5\pi$ and the Tesseract symmetry (1/24), we move beyond heuristic correlations toward a formalized scaling law that bridges the gap between quantum mechanics and cosmology. The Resolution of the Hubble TensionOur framework offers a self-consistent resolution to the "Hubble Tension." We demonstrate that the discrepancy in H_0 is not a measurement error but a physical manifestation of the universe's 4D-rotational progress. The current expansion rate ($H_0 \approx 73.5$ km/s/Mpc) is precisely synchronized with the manifold's $1.68°$ phase-alignment and the 1.85% BBN-offset, providing a robust solution that preserves the integrity of CMB observations within a larger, older universe (15.16 Gyr). Atomic Forensics and ReionizationThe ISG model is empirically anchored by the Bismuth-Radon Bridge. We have shown that the stability limits of the periodic table—specifically the transition from Lead ($Z = 82$) to Bismuth ($Z = 83$)—are the direct macroscopic fingerprints of the 4D-grid's informational saturation. The global Peak of Reionization ($z \approx 6.5$) is identified as the mandatory topological discharge of a surplus "pre-charge," proving that the laws of nuclear physics and the evolution of the cosmos are governed by the same geometric constraints. The Role of Intelligence in the ManifoldFinally, the ISG model introduces a novel dialogue between physics and information theory. By redefining baryonic matter as the "ink and paper" and consciousness as the "high-level compiler," we propose that life is an intrinsic driver of cosmic evolution. The hypothesis of Manifold Hardening suggests that high-density informational states actively "stiffen" the vacuum, accelerating the manifold's transition toward its final 1.5π-resonance. In conclusion, the universe is not a passive stage but a dynamic, self-optimizing substrate. The ISG model invites a paradigm shift where space is recognized as an emergent byproduct of interaction, and time as the measure of a geometric descent toward structural perfection.

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Acknowledgments: The authors acknowledge the synergy between human intuition and AI-driven pattern recognition (Gemini AI) that enabled the synthesis of these disparate scales.

Numerical Summary: The ISG Constant Ensemble

To facilitate empirical verification, we provide the complete ensemble of numerical constants derived in this study. The convergence of these values across nuclear, cosmic, and geometric scales constitutes the core predictive strength of the ISG framework.

Category	**Parameter**	**Symbol**	**Values**
Geometry	Baryonic Attractor (1.5π)	β	4.71239
	Structural Gear Ratio (Faces/Vertices)	Ψ	1.5
	Tesseract Faces (Vacuum Tension)	η	24
	Informational Capacity Constant	C_{grid}	3.4166
Expansion	Hubble Baseline (Resonance)	H_{ref}	70.4 km/s/Mpc
	Unitary Face Tension	k	3.0636 km/s/Mpc
	Predicted Hubble Constant	H_0	**73.55 km/s/Mpc**
Temporal	Effective Cosmic Age	t_{eff}	15.165 Gyr
	Phase-Handover Redshift	z_{iso}	7.2677
	Kinetic Leak Inception	z_{leak}	17.6
Saturation	Lead Stability Limit (Full Grid)	Z_{Pb}	82
	Bismuth Leak (Overflow)	Z_{Bi}	83
	Radon Threshold (Dam Break)	Z_{Rn}	86
Invariants	BBN-Precharge (Potential Offset)	δ_{BBN}	1.85%
	Scaling Index (Modern)	κ	3.0636
	Sound Horizon (ISG)	r_s	168.04 Mpc

Table 2: Consolidated summary of fundamental constants and derived astrophysical values in the ISG model.