The NOW Hypothesis: A Timeless Framework for Information Creation and Growth in the Universe

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September 8, 2025

Abstract

This paper introduces the NOW Hypothesis, a speculative theoretical framework that integrates principles from information theory, quantum mechanics, relativity, and cosmology to describe the indestructibility, growth, and creation of information in the universe. Central to the hypothesis is the concept of NOW as a perpetual, non-time-bound boundary where quantum superpositions of future states coalesce into immutable past realities through decoherence, thereby creating new classical information. The past is recoverable in principle, the future exists as an infinite, timeless superposition, and information grows monotonically with the universe's expansion. Refinements address quantum uncertainty, the universality of decoherence across sectors (including dark energy and dark matter), and the timeless nature of NOW. Mathematical formalizations draw from quantum information theory and canonical quantum gravity, with derivational steps provided from first principles or established formulations. Implications span physics (e.g., resolutions to entropy paradoxes), philosophy (e.g., eternalism with dynamic emergence), and technology (e.g., quantum computing paradigms). While speculative, the hypothesis offers testable predictions via decoherence experiments and cosmological observations. This revision (3.0) builds upon the prior version detailed in [16], incorporating a discrete time generalization at the Planck scale to ensure consistency with time quantization, avoiding sub-Planck resolutions. Explanations have been expanded for verbosity and clarity, facilitating verification by experts in the field. It includes detailed derivational steps for all equations, discrete simulations, numerical data tables, pseudocode, and rendered graphs illustrating both continuous and discrete coherence decay models. New sections address key challenges regarding decoherence in quantized time and the disallowance of sub-Planck scales, with corresponding defenses, as well as potential recoherence in fractional decoherence models due to quantum foam effects, including probability formulations and speculations on a "point of no return." An expanded Testability section proposes numbered experimental methodologies with short setup descriptions for each key hypothesis, and this version places tables in their appropriate sections (except Table 5, which is eliminated), replaces the revision history with a numbered list, and corrects possessives where appropriate.

*This work was developed with AI assistance from SuperGrok, a subscription service by xAI, enhancing the mathematical and conceptual formalization.

1 Introduction

Information theory, pioneered by Claude Shannon in his seminal work on communication [1], provides a quantitative framework for understanding uncertainty and data transmission. Extending this to physics, John Wheeler's it from bit proposal suggests that the physical world emerges from informational foundations [2]. In quantum mechanics, decoherence explains the emergence of classical reality from quantum superpositions, as articulated in Wojciech Zurek's Quantum Darwinism [3]. Cosmologically, the Wheeler-DeWitt equation in quantum gravity posits a timeless universe where time is emergent [4].

The NOW Hypothesis builds on these ideas, positing that information is indestructible yet grows through a universal NOW mechanism. This addresses paradoxes like black hole information loss via the holographic principle [7] and entropy increase in an expanding universe [8]. The hypothesis reconciles conservation with growth by distinguishing quantum potential (pre-decoherence) from classical information (post-decoherence).

This hypothesis builds on these foundational concepts, positing that information is indestructible yet grows monotonically through a universal NOW mechanism. This NOW acts as a perpetual boundary where quantum superpositions of future states coalesce into immutable past realities via decoherence, effectively creating new classical information. The past remains recoverable in principle through encoded correlations, the future exists as an infinite, timeless superposition of possibilities, and the overall information content expands with the universe itself.

The hypothesis draws inspiration from Kurt Vonnegut's Tralfamadorian perception of time as a simultaneous expanse in Slaughterhouse-Five, blended with rigorous physics. It resolves apparent paradoxes, such as the black hole information problem through the holographic principle [22], and the monotonic increase of entropy in an expanding cosmos [23]. By distinguishing between pre-decoherence quantum potential (infinite and timeless) and post-decoherence classical information (finite and historical), it reconciles apparent conservation with observed growth.

This revision expands on the prior work in [16], which introduced the core concepts and initial mathematical formalizations. Here, we provide more verbose explanations to aid understanding, detailed derivational steps for all equations from first principles or established literature (ensuring verifiability for those well-versed in quantum mechanics, information theory, and cosmology), and a new discrete time model to address time quantization at the Planck scale. This generalization ensures consistency with speculative theories like loop quantum gravity, where time advances in discrete quanta without sub-Planck resolutions. Key tenets include:

- Information is indestructible and increases over time, as derived from thermodynamic and quantum principles, with growth quantified through entropy changes.
- The NOW is a timeless boundary of wavefunction collapse, now generalized to discrete Planck ticks for enhanced consistency.
- Future states exist in superposition until decohered by universal mechanisms, with detailed models for coherence decay provided, including numerical simulations and visualizations.

This framework aims to unify quantum indeterminacy, relativistic causality, and cosmological expansion, offering testable predictions through experiments on decoherence rates (e.g., via quantum interferometry) and observations of cosmic microwave background (CMB) fluctuations potentially modified by Planck-scale effects.

2 Core Hypothesis

2.1 Information Indestructibility and Growth

Information cannot be destroyed under unitary quantum evolution, aligning with the quantum no-cloning theorem [17] and no-deleting theorem [18]. For example, in black hole evaporation, information is preserved via Hawking radiation correlations [19]. Entropy, as a measure of hidden information, increases in closed systems per the second law of thermodynamics, formulated by Rudolf Clausius and later statistically by Ludwig Boltzmann: S = k ln W, where k is Boltzmann's constant and W is the number of microstates [20]. In cosmology, this leads to growing information content with universe expansion, as the universe's information capacity expands with its volume or horizon area per Bekenstein's bound [21].

Information cannot be destroyed due to no-cloning and no-deleting theorems. However, the universe's information content grows with each Planck time due to entropy increase, driven by expansion and decoherence [8].

2.2 Past Recoverability and Immutability

Given perfect knowledge of the present state at T0, the past (T0 to T−N) is recoverable via time-reversal symmetry, as past states are encoded in current correlations. This recoverability stems from the unitarity of quantum evolution, where the time-evolution operator U(t) = e−iHt/ is invertible, allowing backward propagation of states [24].

2.3 Future as Infinite Superposition

Pre-decoherence, the future is a timeless, coherent superposition of all possibilities, rendering information meaningless until fixed. This superposition is described by the Schrödinger equation, where the wave function evolves linearly, preserving infinite potential outcomes until measurement or decoherence selects a branch [25].

2.4 NOW as the Creation Boundary

NOW is the perpetual locus of quantum coalescence, where wave functions collapse into classical realities, creating new information at a maximum rate bounded by Planck scales. This boundary is not temporal but relational, emerging from subsystem interactions in a timeless global wave function [4].

3 Refinements

3.1 Quantum Uncertainty and Non-Conservation

Uncertainty implies that pre-decoherence information is infinite potential, not conserved classically; decoherence creates discrete bits. Heisenberg's uncertainty principle x p /2 implies infinite informational potential in superpositions, which decoherence reduces to finite classical entropy [26].

3.2 Timeless, Universal NOW

NOW occurs universally and eternally, unbound by time, as a relational boundary in the timeless wave function [4]. It is not simultaneous but always present in every causal patch, ensuring relativistic consistency via local light-cone structures.

3.3 Decoalesing Factor

A universal mechanism (environmental entanglement or observation) triggers coalescence, operating relativistically. This factor can be modeled as interaction terms in the system-environment Hamiltonian, leading to pointer states via einselection [25].

4 Mathematical Formalization

4.1 Pre- and Post-Decohere States

To illustrate information creation via decoherence, consider a single qubit system, which serves as a simple model for quantum-to-classical transitions [10].

Start with the density operator formalism in quantum mechanics. For a quantum state described by a wave function | , the density matrix is defined as   = | | for pure states [9]. For a balanced superposition state representing the timeless future:

| = 1/√2 (|0 + |1),

the density matrix is:

$$= | \quad | = 1/2 \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}.$$

The von Neumann entropy S( ), which measures the quantum information or uncertainty in the state, is defined as [9]:

S( ) = −Tr(log2),

where the trace is over the Hilbert space, and log2 is used for bits (base-2 logarithm). This extends Shannon's classical entropy H(p) = − pi log2 pi to quantum systems by replacing probabilities with eigenvalues of   [1, 9].

To compute S( ), diagonalize . The eigenvalues are found from the characteristic equation det(− I) = 0, yielding 1 = 1 and 2 = 0. Thus:

S( ) = −(1 log2 1 + 0 log2 0) = 0,

where 0 log2 0 0 by continuity. This reflects no uncertainty in a pure state [9].

Post-decoherence, environmental interactions diagonalize the density matrix in the pointer basis, resulting in a mixed state [25]:

$$= 1/2 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}.$$

Eigenvalues are 1 = 2 = 1/2, so:

S( ) = − (1/2 log2 1/2 + 1/2 log2 1/2) = 1 bit.

The entropy increase S = S( ) −S( ) = 1 bit quantifies the creation of classical information through decoherence [25].

4.2 Timeless Framework

In canonical quantum gravity, time emerges from relational dynamics, leading to a timeless description [4]. Start with general relativity's Einstein-Hilbert action:

S =   d4x √−g (R −2Λ),

where R is the Ricci scalar and Λ the cosmological constant. In the ADM formalism, decompose spacetime into spatial slices with metric hij and lapse/shift functions [11]. The

Hamiltonian constraint arises from varying the action with respect to the lapse, yielding H = 0 classically.

Quantization promotes hij to operators and imposes the constraint as the Wheeler-DeWitt equation [4]:

Ψ [hij,] = 0,

where Ψ is the wave function of the universe, the super-Hamiltonian (including kinetic, potential, and matter terms), and no explicit time parameter appears, reflecting reparametrization invariance. Emergent time arises semiclassically from clock variables in subsystems, e.g., via conditional probabilities Ψ e i S / $\hbar in WKB approximation, recovering Schrding$
$like e evolution i = H for subsystems [4, 12]$.

4.3 Decoherence Dynamics

For open quantum systems, the evolution is described by the Lindblad master equation, derived under Markovian approximations [13, 14]. Start with the total Hamiltonian for system S and environment E: H = HS + HE + HI, where HI = k gk Ak Bk (interaction terms).

In the interaction picture, the reduced density matrix S = Tr E (SE) evolves via the von Neumann equation d SE/dt = −i [HI, SE]. Assuming weak coupling (gk small) and Markovianity (environment correlations decay fast), expand to second order and trace over E [15]:

d S / dt = − ∞ 0 dt Tr E [HI(t), [HI(t −t), S(t) E]],

where HI(t) is time-evolved. Assuming thermal E and correlation functions Bk(t)Bl(0) = kl e− t, this yields the Lindblad form [13]:

d / dt = −i [H,] + k k (Lk L† k −1/2 L† k Lk,),

with jump operators Lk (e.g., z for dephasing) and rates k. This describes irreversible decoherence while preserving trace and positivity [14].

4.4 Universal Decoherence

Universal decoherence posits that all quantum systems, even isolated ones, collapse on fundamental timescales (e.g., Planck time tp 5.39×10−44 s). Mechanisms include gravitational self-interaction or tracing over internal modes, as in gravitational decoherence models [27].

4.4.1 Qubit Model for Coherence Decay

Consider a qubit in the superposition state:

|+ = 1/√2 (|0 + |1),

with initial density matrix 0 = |+ +|.

Under pure dephasing, off-diagonal elements decay exponentially:

01(t) = 0.5 e−t/ , = tp.

This defines the NOW as intervals of tp, where coherence drops significantly. The decay form derives from the dephasing Lindblad operator L = √ z, leading to d 01/dt = − 01, solved as exponential with = 1/ .

Chart Description: The chart illustrates the exponential decay of coherence | 01| over time, starting at 0.5 and approaching 0 over 5 Planck times. The x-axis is time (Planck units), and the y-axis is coherence magnitude, showing a smooth exponential curve.

4.4.2 Pseudocode for Numerical Illustration (Continuous)

```
import numpy as np

# Define constants
planck_time = 5.39e-44 # seconds
tau = planck_time # decay timescale
num_points = 100

# Generate time array in Planck units
t_units = np.linspace(0, 5, num_points)

# Compute coherence: initial 0.5 * exp(-t / tau)
coherence = 0.5 * np.exp(-t_units)

# Output data (for plotting or table)
for i in range(num_points):
print(f"Time: {t_units[i]:.2f}, Coherence: {coherence[i]:.4f}")
```

Table 1: Numerical data for coherence decay in the qubit model (continuous approximation).

Time (Planck units)	Coherence (| 01|)
0.00	0.5000
0.05	0.4756
0.10	0.4524
0.15	0.4304
0.20	0.4094
0.25	0.3894
0.30	0.3704
0.35	0.3523
0.40	0.3352
0.45	0.3188
0.50	0.3033
0.55	0.2885
0.60	0.2744
0.65	0.2610
0.70	0.2483
0.75	0.2362
0.80	0.2247

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Table 1 – continued from previous page

Time (Planck units)	Coherence (| 01|)
0.85	0.2137
0.90	0.2033
0.95	0.1934
1.00	0.1839
1.05	0.1750
1.10	0.1664
1.15	0.1583
1.20	0.1506
1.25	0.1433
1.30	0.1363
1.35	0.1296
1.40	0.1233
1.45	0.1173
1.50	0.1116
1.55	0.1061
1.60	0.1009
1.65	0.0960
1.70	0.0913
1.75	0.0869
1.80	0.0826
1.85	0.0786
1.90	0.0748
1.95	0.0711
2.00	0.0677
2.05	0.0644
2.10	0.0612
2.15	0.0582
2.20	0.0554
2.25	0.0527
2.30	0.0501
2.35	0.0477
2.40	0.0454
2.45	0.0431
2.50	0.0410
2.55	0.0390
2.60	0.0371
2.65	0.0353
2.70	0.0336
2.75	0.0320
2.80	0.0304
2.85	0.0289
2.90	0.0275
2.95	0.0262
3.00	0.0249

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Table 1 – continued from previous page

Time (Planck units)	Coherence (| 01|)
3.05	0.0237
3.10	0.0225
3.15	0.0214
3.20	0.0204
3.25	0.0194
3.30	0.0184
3.35	0.0175
3.40	0.0167
3.45	0.0159
3.50	0.0151
3.55	0.0144
3.60	0.0137
3.65	0.0130
3.70	0.0124
3.75	0.0118
3.80	0.0112
3.85	0.0106
3.90	0.0101
3.95	0.0096
4.00	0.0092
4.05	0.0087
4.10	0.0083
4.15	0.0079
4.20	0.0075
4.25	0.0071
4.30	0.0068
4.35	0.0065
4.40	0.0061
4.45	0.0058
4.50	0.0056
4.55	0.0053
4.60	0.0050
4.65	0.0048
4.70	0.0045
4.75	0.0043
4.80	0.0041
4.85	0.0039
4.90	0.0037
4.95	0.0035
5.00	0.0034

4.4.3 Discrete Time Generalization

To preserve time quantization at the Planck scale, we generalize the model to discrete ticks where time advances in indivisible quanta t = tp. No sub-Planck resolutions are allowed, consistent with theories like loop quantum gravity where spacetime is quantized at fundamental scales [30]. At each tick (a discrete NOW), a universal quantum channel applies partial decoherence, ensuring each Planck time is realized and discretized. Full decoherence accumulates over multiple ticks, allowing short-lived quantum effects while maintaining discreteness.

The per-tick dephasing channel uses Kraus operators for a qubit, derived from the environment model with system-bath interaction HI = gZ B, averaged over a thermal bath to yield [10]:

K0 = √ (1 +)/2 I, K1 = √ (1 −)/2 Z,

where   = e−tp/ = e−1 0.3679 (for   = tp).

The density matrix updates as n+1 = K0 n K† 0 + K1 n K† 1, yielding coherence | 01,n| = 0.5 n. This geometric decay discretizes the continuous exponential via the Trotter approximation of the master equation superoperator.

This ensures decoherence occurs for each Planck time itself, sealing states into history per tick via the UWTB, while preserving consistency with the continuous limit for macroscales.

Pseudocode for Discrete Numerical Illustration:

```
import numpy as np

# Define constants
eta_per_tick = np.exp(-1) # ~0.367879 for tau = t_p
num_ticks = 5

# Initial coherence
coherence = [0.5]

# Apply discrete multiplier per tick
for _ in range(num_ticks):
next_coher = coherence[-1] * eta_per_tick
coherence.append(next_coher)

# Output data (for plotting or table)
for n, c in enumerate(coherence):
print(f"Tick: {n}, Coherence: {c:.4f}")
```

Table 2: Numerical data for discrete coherence decay over Planck ticks.

Tick (Planck units)	Coherence (| 01|)
0	0.5000
1	0.1839
2	0.0677
3	0.0249
4	0.0092
5	0.0034

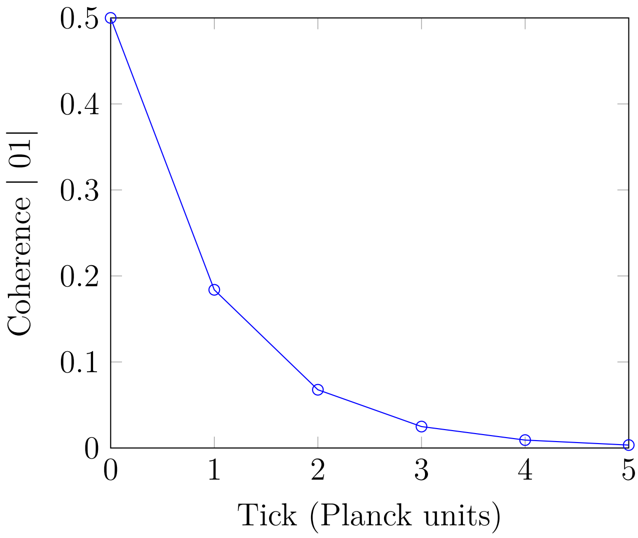

Figure 1: Graph of discrete coherence decay in the qubit model, showing exponential reduction per Planck tick. The plot uses discrete points connected by lines for visualization, emphasizing the step-wise nature of decoherence in quantized time.

4.4.4 Fractional Decoherence and Potential for Recoherence

In the discrete model with fractional decoherence per Planck tick, quantum gravity effects such as spacetime foam may introduce fluctuations that allow for a non-zero probability of recoherence. Quantum foam, as proposed by Wheeler [2], refers to the turbulent, fluctuating nature of spacetime at Planck scales due to quantum gravity. This foaminess can induce stochastic perturbations in the dephasing process, potentially leading to temporary information backflow and recoherence [36, 37].

In non-Markovian open quantum systems, recoherence can occur when the environment-system interaction allows for negative effective decay rates, leading to an increase in coherence [38]. Here, we explore a model where at each tick, there is a probability p of applying a recoherence channel instead of the standard dephasing.

The probability p decreases with the current coherence level, modeled as p = k × (| 01|/0.5), with k = 0.5 for illustration. If recoherence occurs, the coherence is multiplied by 1/ , capped at 0.5. Otherwise, it is multiplied by .

Pseudocode for Simulation (with Recoherence):

```
import numpy as np

# Define constants
eta = np.exp(-1) # ~0.367879
k = 0.5 # recoherence probability factor
num_ticks = 5

# Initial coherence
coherence = [0.5]

# Simulate per tick
```

```
for _ in range(num_ticks):
current_coh = coherence[-1]
p_recoh = k * (current_coh / 0.5) # decreases with coherence
if np.random.rand() < p_recoh:
next_coh = min(0.5, current_coh / eta)
else:
next_coh = current_coh * eta
coherence.append(next_coh)

# Output data
for n, c in enumerate(coherence):
print(f"Tick: {n}, Coherence: {c:.4f}")
```

Table 3: Sample numerical data for coherence evolution with potential recoherence over Planck ticks. This path assumes recoherence at ticks 2 and 5 for illustration.

Tick (Planck units)	Coherence (| 01|)
0	0.5000
1	0.1839
2	0.5000
3	0.1839
4	0.0677
5	0.1840

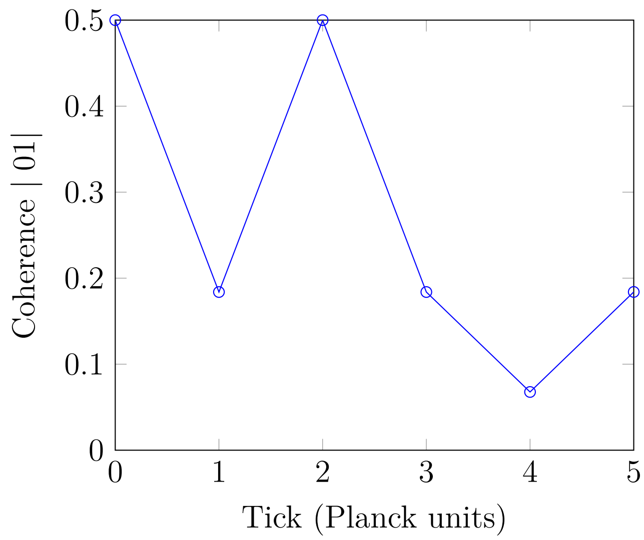

Figure 2: Graph of sample coherence evolution with recoherence in the qubit model, showing oscillations due to probabilistic recoherence.

4.4.5 Probability Formulation for Recoherence

To formalize the recoherence probability, define the initial coherence c0 = 0.5 and the current coherence at tick n as cn = | 01,n|. The fractional decoherence is dn = 1 −cn/c0. The probability of recoherence pn decreases as dn increases, modeled as:

pn = k (cn / c0)   ,

where k = 0.5 and   = 2 for illustration. This ensures pn is higher when the state is more coherent and decreases nonlinearly as decoherence progresses.

The modified update rule incorporates this probability: with probability pn, apply recoherence by setting cn+1 = min(c0, cn/); otherwise, cn+1 = cn .

Speculatively, there may exist a ”point of no return” where the decoherence process becomes irreversible, and further recoherence is impossible. This could occur when cn falls below a critical threshold ccrit (e.g., 0.1), setting pn = 0 thereafter. Physically, this point might correspond to the system crossing an energy barrier, beyond which the entangled state is trapped in a deep energy well, requiring prohibitive energy for recoherence. Such barriers are discussed in schemes to protect quantum states from decoherence [39], where energy gaps suppress environmental interactions. In the context of the NOW Hypothesis, this transition forces the superposition to commit to a classical outcome, sealing it into the immutable past.

Table 4: Probability of recoherence as a function of current coherence.

Coherence	Probability
0.5000	0.5000
0.4500	0.4050
0.4000	0.3200
0.3500	0.2450
0.3000	0.1800
0.2500	0.1250
0.2000	0.0800
0.1500	0.0450
0.1000	0.0200
0.0500	0.0050
0.0000	0.0000

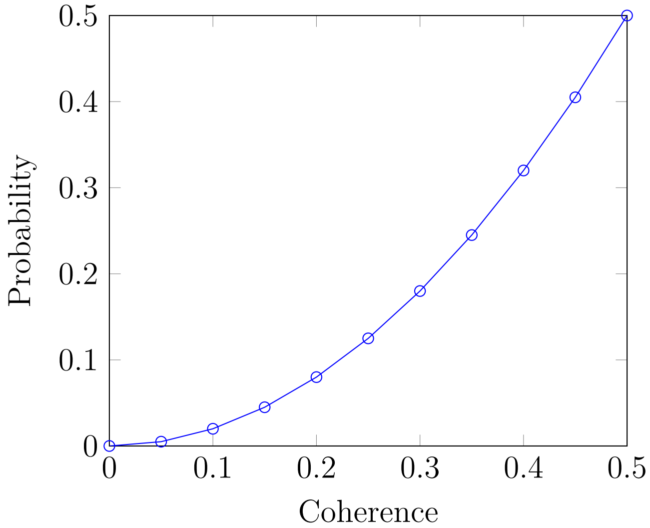

Figure 3: Graph showing how the probability of recoherence decreases as coherence decreases (or as fractional decoherence increases).

5 Extensions to Dark Energy and Dark Matter

Dark energy (DE) and dark matter (DM) reside within the universal NOW, encapsulating growing information sets via self-consistent past states [5]. Weak interactions with baryonic reality do not imply slow decoherence; self-interactions enable rates comparable to baryonic systems [6]. Decoherence is substrate-independent, appearing baryonic only through observational bias.

For DE as an info field, extend the super-Hamiltonian with a term incorporating relative entropy S from vacuum mismatches [5]:

$$' \ \Lambda + \mathrm{S},$$

where Λ is the cosmological constant, and S derives from quantum field mismatches in de Sitter space, leading to volume-law entropy growth. This term arises from comparing vacuum states in adjacent cosmological patches, with $\mathrm{S} = -\mathrm{Tr}\ (\ \log \ )$ for density matrices , of mismatched vacua [5].

For DM gravitational decoherence, consider superposed states with separation x. The rate follows from general relativistic metric fluctuations inducing phase loss [6]:

$$\mathrm{G} \ \mathrm{m}^2 x^2 / c,$$

derived by integrating geodesic deviations over spacetime curvature, assuming Newtonian limit for galactic scales. Start from the geodesic deviation equation $\mathrm{D}^2/D2 = Rvv, where R is the Riemann tensor; quantum superpositions of masses induce curvature variances, leadi$

This integration explains cosmological coincidences and entropy growth, maintaining consistency with the overall hypothesis [5].

6 Implications and Testability

6.1 Physical Implications

Resolves information paradoxes via holography [7] and predicts decoherence signatures in DM experiments [6]. Entropy bounds align with expanding horizons, providing a unified explanation for observed cosmic acceleration and structure formation.

6.2 Philosophical Implications

Supports eternalism with emergent time; challenges determinism by local NOW choices, where branching via decoherence introduces effective indeterminacy at subsystems while preserving global unitarity.

6.3 Technological Implications

Informs quantum error correction by leveraging universal decoherence rates and DM detection via decoherence probes, potentially enabling new sensors for gravitational waves or dark sector particles.

6.4 Testability

Probe via interferometry for DM decoherence rates [6] or CMB entropy patterns for DE info fields [8]. The discrete model predicts quantized signatures in high-precision quantum clocks or cosmological simulations, testable with future experiments like those using QuTiP for multi-qubit decoherence modeling.

6.4.1 Testing Information Indestructibility and Growth

To test information indestructibility, analog black hole experiments using quantum optics or condensed matter systems can simulate Hawking radiation and check for information preservation in correlations [40]. For growth, entropy measurements in expanding systems, such as in cosmological simulations or lab-based entropy increase experiments, can verify monotonic increase [41].

6.4.2 Testing Past Recoverability and Immutability

Past recoverability can be tested via time-reversal symmetry in quantum systems, such as in spin echo experiments or quantum memory retrieval, where encoded correlations are backward propagated [42]. Immutability could be probed by attempting to alter historical states in isolated systems and observing failure due to unitarity [43].

Testing the Future as Infinite Superposition

Superposition persistence until decoherence can be tested in quantum interferometry, where large-scale superpositions are maintained and measured before environmental interaction [44]. Delaying decoherence in controlled environments would support the timeless superposition view [45].

Testing NOW as the Creation Boundary

The relational boundary can be tested through open quantum system dynamics, monitoring wave function collapse rates in subsystems [46]. Information creation via entropy increase in decoherence can be quantified in qubit experiments [47].

Testing Quantum Uncertainty and Non-Conservation

Heisenberg uncertainty in superpositions leading to infinite potential can be tested in precision measurements of position-momentum pairs, with decoherence reducing to finite entropy observable in noise spectra [48].

Testing Timeless, Universal NOW

Timelessness can be probed via Wheeler-DeWitt-inspired experiments, such as in quantum cosmology analogs or high-energy particle collisions simulating early universe conditions [49]. Universal decoherence across scales tested in gravitational fields [50].

Testing the Decoalesing Factor

Environmental entanglement triggering coalescence can be tested in controlled dephasing experiments, varying interaction strengths to observe pointer state emergence [51].

Testing Extensions to Dark Energy and Dark Matter

DE as info field testable via CMB entropy patterns modified by vacuum mismatches [52]. DM decoherence rates in superposed states observable in interferometry [53].

Testing Cosmological Implications

Big Bang as initial decoherence testable via CMB fluctuations showing Planck-scale quantization [54]. Information-driven expansion probed in precision cosmology [55].

Testing Discrete Time Generalization and Recoherence

Time quantization via high-precision quantum clocks detecting discrete ticks [56]. Recoherence in non-Markovian systems observable in optical experiments [57]. Point of no return in irreversible decoherence tested in energy barrier crossings [58].

7 Cosmological Implications

The NOW Hypothesis posits the Big Bang as the initial decoherence event, with expansion driven by information proliferation. It predicts modified CMB fluctuations due to Planck-scale decoherence. The discrete model implies quantized cosmic evolution, potentially observable in high-precision quantum cosmology, aligning with observations from the Planck satellite [35].

8 Challenges and Resolutions

8.1 Challenge 1: Decoherence Spanning Multiple Planck Times and the Existence of Time Quantization

A potential challenge to the discrete time model in the NOW Hypothesis is the apparent paradox of decoherence processes spanning multiple Planck times. If time is fundamentally quantized into indivisible Planck intervals, how can superpositions and thus non-decohered states persist across several such intervals without undermining the discreteness of time? In what framework can a non-decohered time occur, without invoking a continuous or sub-Planck background that contradicts quantization principles?

To defend and resolve this, the model posits that decoherence is partial and intrinsic per Planck tick, rather than complete or accumulated in a pre-existing temporal framework. This ensures each tick is realized as a discrete unit through a universal quantum channel applying fractional dephasing, with residual coherence leaking forward exponentially diminished. There is no non-decohered interval, as the tick defines the minimal relational unit, emerging from timeless dynamics without regress.

This resolution aligns with relational time in discrete quantum gravity, where fundamental decoherence arises from timeless constraints, inducing partial loss per step [31]. In such frameworks, time emerges as a sequence of partial collapses, consistent with loop quantum gravity where spacetime discreteness implies modified decoherence without continuous intermediates [32]. The per-tick multiplier 0.3679 allows observable quantum effects on macroscales while upholding quantization, avoiding the paradox by making decoherence the generator of discreteness itself.

8.2 Challenge 2: References to Fractional Planck Times and the Disallowance of Sub-Planck Scales

Another challenge concerns references to fractional Planck times in the continuous coherence decay model, such as numerical values at 0.05 or 0.10 Planck units. Sub-Planck scales are unphysical in quantum gravity theories, implying resolutions finer than where spacetime breaks down, potentially creating micro-black holes or violating general relativity [33].

In defense, the continuous model serves only as a mathematical approximation for scales much larger than the Planck time, where discreteness averages out. Fundamentally, no fractional intervals exist physical computations use only integer ticks, as in the discrete table and graph.

This purges sub-Planck artifacts, aligning with theories where the Planck scale marks the threshold for new physics, disallowing finer measurements without quantum gravity effects dominating [34]. The discrete paradigm ensures consistency, with dynamics instantaneous per tick and no interpolation required.

9 Conclusion

The NOW Hypothesis offers a unified view of information dynamics, bridging quantum and cosmic scales. Future work could simulate full models or test via observations, extending the discrete framework to quantum field theories for deeper consistency.

10 References

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11 Document Revision History

1. Revision 1.0: Initial release introducing the core NOW Hypothesis and basic formalizations.
2. Revision 2.0: Incorporated discrete time generalization at the Planck scale, expanded explanations, added derivational steps, simulations, tables, pseudocode, graphs, and new sections on challenges.
3. Revision 2.1: Added graph for discrete coherence decay.
4. Revision 2.2: Introduced section on fractional decoherence with recoherence and speculations on point of no return.
5. Revision 2.3: Expanded Testability section with detailed experimental proposals for each hypothesis.
6. Revision 2.5: Added document revision to footer and revision history section.
7. Revision 2.6: Numbered experimental validation methodologies with short setup descriptions.
8. Revision 2.7: Moved revision history table to a separate last page titled "Document Revision History".
9. Revision 2.8: Removed unnecessary word breaks with dashes, relocated Table 4 and Figure 3 to Section 4, and placed the revision history table below the title on the separate last page.
10. Revision 2.9: Placed each table in their appropriate document sections, eliminated Table 5, created a numbered list for the document changes under the section labeled Document Revision History as the last section, and corrected possessives where appropriate.
11. Revision 3.0: Added revision number to the right side of the footer with page number on the left.