**Baryogenesis via Path-Dependent Asymmetric Network Stabilization in Simplicial Discrete Informational Spacetime**

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**Abstract:**

The observed baryon asymmetry of the universe, quantified by the baryon-to-photon ratio $\eta \approx 6 \times 10^{-10}$ (Particle Data Group et al., 2022), is a key cosmological datum demanding a fundamental physical explanation. The Simplicial Discrete Informational Spacetime (SDIS) framework (Karazoupis, 2025), a theory of quantum gravity describing spacetime as a dynamic, informational network of 4-simplices, proposes a self-contained mechanism for this asymmetry. This paper details how baryogenesis is an inherent outcome of the SDIS network's primordial evolution from a high-stress, far-from-equilibrium state—a state whose initial conditions and intrinsic SDIS rules dictated an unavoidable trajectory towards global stability, characterized by maximized "Network Configuration Entropy." During this formative, non-singular epoch, fundamental Baryon-number-non-conserving network reconfigurations stochastically produced nascent "matter-informational" (I) and "antimatter-informational" ($\bar{I}$) patterns with equal intrinsic probability. Emergent CP violation, arising naturally from the Simplicial Information Couplings within SDIS, caused these patterns to differentially influence local "Network Informational Stress." The network's unique and irreversible path to stabilization preferentially integrated and preserved those informational patterns (I – matter) that were most compatible with, and facilitative of, the efficient reduction of this stress. Consequently, $\bar{I}$ (antimatter) patterns, being less optimal for this mandatory stabilization pathway, were effectively "filtered out" or "not viably incorporated" into the stabilizing network structure. This process, satisfying the Sakharov conditions (Sakharov, 1967) through the intrinsic dynamics of SDIS, established the observed baryon asymmetry as a frozen-in characteristic of the resultant stable, low-stress universe, consistent with cosmological observations.

**Keywords:** Simplicial Discrete Informational Spacetime (SDIS), Baryogenesis, Matter-Antimatter Asymmetry, Baryon-to-Photon Ratio, Network Configuration Entropy, Network Informational Stress, Path-Dependent Stabilization, Emergent CP Violation, Pachner Moves, Quantum Gravity, Non-Singular Cosmology, Sakharov Conditions.

## Introduction

A cornerstone of modern cosmology is the precise determination of the universe's composition. Observational data, primarily from the analysis of Cosmic Microwave Background (CMB) anisotropies (e.g., Planck Collaboration et al., 2020) and the abundances of light elements synthesized during Big Bang Nucleosynthesis (BBN) (e.g., Cooke, Pettini and Steidel, 2018; Fields et al., 2020), converge on a consistent value for the baryon-to-photon ratio: $\eta = n_B / n_\gamma \approx 6.1 \times 10^{-10}$ (Particle Data Group et al., 2022). This small but non-zero value indicates a significant asymmetry between the amount of baryonic matter and antimatter in the observable universe. If the primordial state of the universe had been perfectly matter-antimatter symmetric, annihilation processes would have left a vastly more dilute universe, with an η many orders of magnitude smaller (Dolgov, 2002). The observed η is therefore compelling evidence for a dynamical process of baryogenesis in the early universe, which generated this slight excess of matter.

The necessary conditions for any such dynamical baryogenesis mechanism were famously outlined by Sakharov (1967):

1. Baryon number (B) violation: Processes that can alter the net baryon number must exist. While baryon number is an excellent approximate symmetry at low energies, it must be violated at some level.
2. C-symmetry (charge conjugation) and CP-symmetry (charge conjugation combined with parity) violation: To differentiate between matter and antimatter processes, these fundamental symmetries must be broken. CP violation was first observed in the neutral kaon system (Christenson et al., 1964) and is incorporated within the Standard Model (SM) of particle physics via the Cabibbo-Kobayashi-Maskawa (CKM) matrix (Kobayashi and Maskawa, 1973). However, the magnitude of CP violation from the CKM matrix is known to be insufficient to generate the observed baryon asymmetry (Canetti, Drewes and Shaposhnikov, 2012; Bernreuther, 2002).
3. Departure from thermal equilibrium: In a state of complete thermal equilibrium, any B-violating process would be exactly counterbalanced by its inverse, resulting in no net baryon production. Thus, the interactions generating the asymmetry must occur during a period when the universe is not in thermal equilibrium.

While the Standard Model contains elements of CP violation and allows for out-of-equilibrium conditions (e.g., during the electroweak phase transition, though this is now understood to be a crossover for the observed Higgs mass (Kajantie et al., 1996)), it lacks a mechanism for strong B-violation and its CP violation is quantitatively insufficient. This has motivated a wide range of theoretical extensions, including Grand Unified Theories (GUTs), supersymmetric models, and scenarios involving leptogenesis via the decay of heavy Majorana neutrinos (Fukugita and Yanagida, 1986; Davidson, Nardi and Nir, 2008). These models typically introduce new particles and interactions beyond the SM.

The Simplicial Discrete Informational Spacetime (SDIS) framework (Karazoupis, 2025) offers an alternative paradigm. SDIS is a theory of quantum gravity that describes spacetime not as a fundamental continuum, but as an evolving, discrete informational network composed of 4-simplices. Within SDIS, fundamental physical properties such as spacetime geometry, causality, particle states, and interaction laws are posited to be emergent features of the network's structure, informational content (qubits associated with simplices), and dynamics (governed by a quantum Hamiltonian and Lindblad evolution). A key feature of SDIS cosmology is its inherent avoidance of an initial singularity (Karazoupis, 2025), instead proposing a Primordial High-Stress Network Epoch characterized by finite but extreme energy density and rapid topological evolution.

This paper details a mechanism for baryogenesis that is entirely self-contained within the SDIS framework. We propose that the observed baryon asymmetry, consistent with the measured η, is a direct consequence of the SDIS network's unavoidable, path-dependent stabilization from its primordial high-stress state. This stabilization, driven by the maximization of Network Configuration Entropy, occurred under the influence of emergent CP violation (a natural outcome of how SDIS generates Standard Model interactions). This led to a preferential integration and preservation of "matter-informational" patterns over "antimatter-informational" patterns, which were stochastically formed with equal probability by B-non-conserving network dynamics. The mechanism satisfies the Sakharov conditions through the intrinsic properties and evolution of the SDIS network itself, without requiring the postulation of new fundamental particles or interactions beyond those that emerge from the SDIS framework in its generation of the Standard Model.

**Literature Review: Baryogenesis Mechanisms and CP Violation**

The challenge of explaining the observed baryon asymmetry of the universe ($\eta \approx 6.1 \times 10^{-10}$) has spurred extensive theoretical research for several decades. The Sakharov conditions—B-violation, C- and CP-violation, and departure from thermal equilibrium (Sakharov, 1967)—provide a crucial framework for evaluating proposed mechanisms. This review briefly outlines prominent classes of baryogenesis models and the status of CP violation research, thereby contextualizing the novel approach offered by the Simplicial Discrete Informational Spacetime (SDIS) framework.

Grand Unification Theory (GUT) Baryogenesis:

Soon after the formulation of Grand Unified Theories (GUTs), which unify the strong, weak, and electromagnetic interactions at very high energies (typically $M\_GUT \approx 10^{15}$ - $10^{16}$ GeV) (Georgi and Glashow, 1974; Pati and Salam, 1974), it was realized that these theories naturally contain B-violating interactions mediated by new superheavy gauge bosons (X and Y bosons) or Higgs bosons. The out-of-equilibrium decays of these superheavy particles in the very early universe, coupled with CP-violating phases in their couplings, could generate a net baryon asymmetry (Ignatiev et al., 1978; Yoshimura, 1978; Weinberg, 1979).
While conceptually elegant, GUT baryogenesis faces challenges. The simplest SU(5) GUT, for instance, predicts a proton lifetime shorter than experimental limits (Particle Data Group et al., 2022). Moreover, if the universe underwent a period of inflation after GUT-scale baryogenesis, any generated asymmetry would be diluted unless baryogenesis occurred during or after reheating post-inflation, requiring specific model constraints (Kolb and Turner, 1990).

Electroweak Baryogenesis (EWBG):

EWBG scenarios attempt to generate the baryon asymmetry during the electroweak phase transition (EWPT) at energies around ~100 GeV (Kuzmin, Rubakov and Shaposhnikov, 1985). In the Standard Model (SM), B+L (baryon plus lepton number) is violated by non-perturbative sphaleron processes, which are rapid at temperatures above the EWPT but suppressed below it (Manton, 1983; Klinkhamer and Manton,

1984). If the EWPT were a strong first-order phase transition, departing from thermal equilibrium, CP-violating interactions at the expanding bubble walls could bias the sphaleron processes to produce a net B+L asymmetry.
However, within the SM, the EWPT is known to be a smooth crossover for the experimentally observed Higgs boson mass ($m_H \approx 125$ GeV) (Kajantie et al., 1996; D'Onofrio, Rummukainen and Tranberg, 2014), meaning there is no significant departure from thermal equilibrium. Furthermore, the CP violation from the CKM matrix is too small by many orders of magnitude (Gavela et al., 1994; Huet and Sather, 1995). Consequently, SM EWBG is ruled out. Extensions of the SM, such as the Minimal Supersymmetric Standard Model (MSSM) or two-Higgs-doublet models, can provide new sources of CP violation and potentially a strong first-order EWPT, keeping EWBG an active area of research (Morrissey and Ramsey-Musolf, 2012; Cline, 2006).

Leptogenesis:

Leptogenesis has emerged as a particularly compelling mechanism, especially in light of observed neutrino oscillations which imply non-zero neutrino masses (Fukuda et al., 1998; Ahmad et al., 2002). In the canonical leptogenesis scenario, heavy Majorana neutrinos (often right-handed sterile neutrinos, $N_R$), which are part of see-saw mechanisms explaining the smallness of active neutrino masses (Minkowski, 1977; Gell-Mann, Ramond and Slansky, 1979; Yanagida, 1979), decay out of equilibrium in the early universe (Fukugita and Yanagida, 1986). If the Yukawa couplings of these Majorana neutrinos contain CP-violating phases, their decays can produce a net lepton asymmetry (L). This lepton asymmetry is then partially converted into a baryon asymmetry (B) by SM sphaleron processes, which conserve B-L but violate B+L. Leptogenesis can occur at very high energy scales (thermal leptogenesis, $T > 10^9$ GeV) or potentially at lower scales in resonant scenarios or via oscillations of sterile neutrinos (Pilaftsis and Underwood, 2004; Akhmedov, Rubakov and Smirnov, 1998). It is attractive because it connects baryogenesis to the physics of neutrino masses and can be realized in many well-motivated extensions of the SM (Davidson, Nardi and Nir, 2008; Buchmuller, Di Bari and Plümacher, 2005).

CP Violation: Experimental Status and Theoretical Sources:

CP violation was first observed in the neutral kaon system (Christenson et al., 1964). In the SM, it is accommodated by a single complex phase in the CKM matrix for quark mixing (Kobayashi and Maskawa, 1973). This has been extensively confirmed in B-meson decays (Belle Collaboration et al., 2001; BaBar Collaboration et al., 2001). While the CKM mechanism successfully describes observed CP violation in the quark sector, its magnitude is insufficient for baryogenesis by a factor of $\sim 10^9$ (Canetti, Drewes and Shaposhnikov, 2012).
The search for new sources of CP violation is a major driver of experimental and theoretical particle physics. Neutrino oscillations hint at CP violation in the leptonic sector via the PMNS matrix phase $\delta_{CP}$ (Pontecorvo, 1957; Maki, Nakagawa and Sakata, 1962), and experiments like T2K and NOvA are providing increasingly precise constraints (T2K Collaboration et al., 2020; NOvA Collaboration et al., 2021). Beyond the SM, new physics models often introduce additional sources of CP violation, which are essential for their viability as baryogenesis mechanisms.

Baryogenesis in Quantum Gravity Contexts:

Most baryogenesis models operate within the framework of quantum field theory on a classical, expanding cosmological background. However, the earliest moments of the universe, where baryogenesis is presumed to occur, are also when quantum gravity effects are expected to be dominant. Some approaches have considered baryogenesis in string theory or braneworld scenarios (e.g., Cline, 2006, for a review). The SDIS framework (Karazoupis, 2025) offers a distinct perspective by proposing that spacetime itself is a discrete, dynamic quantum system. In such a context, the conditions for baryogenesis—B-violation, CP-violation, and departure from thermal equilibrium—may arise from the fundamental properties and evolution of the spacetime network itself, rather than solely from the dynamics of matter fields residing upon it. The non-singular nature of SDIS cosmology (Karazoupis, 2025) also provides a different setting for these primordial processes compared to standard Big Bang models that involve an initial singularity.

This literature review highlights the necessity of physics beyond the Standard Model (or a more fundamental understanding of existing physics) to explain the baryon asymmetry. While various mechanisms have been proposed, they often rely on new particles or specific cosmological scenarios. The SDIS framework aims to provide a self-contained explanation rooted in the quantum-informational nature of spacetime itself.

**Research Questions**

The overarching goal of this paper is to propose and theoretically substantiate a self-contained mechanism for baryogenesis within the Simplicial Discrete Informational Spacetime (SDIS) framework (Karazoupis, 2025). This mechanism, termed "Baryogenesis via Path-Dependent Asymmetric Network Stabilization," posits that the observed matter-antimatter asymmetry is an inevitable outcome of the SDIS network's primordial evolution towards a stable, high Network Configuration Entropy (S_NC) state, under the influence of emergent CP violation. To develop and evaluate this proposal, this paper addresses the following specific research questions, framed within the context of SDIS principles and the established Sakharov conditions (Sakharov, 1967):

1. Primordial Network Dynamics and B-Number Violation:
    - How does the SDIS framework describe the state of the primordial universe, specifically its non-singular, high-stress, far-from-equilibrium nature?
    - Can fundamental Baryon Number (B) (and potentially Lepton Number, L) non-conserving processes be shown to arise naturally from the high-energy topological reconfigurations (e.g., Pachner move cascades or other Planck-scale simplex dynamics) inherent to this primordial SDIS network epoch?
    - What are the characteristics of these B/L-non-conserving network events, and do they stochastically produce nascent "matter-informational" (I) and "antimatter-informational" ($\bar{\mathrm{I}}$) patterns with equal intrinsic probability prior to the influence of CP-violating effects?

2. Emergence of CP Violation and its Manifestation in Network Interactions:
   - How does CP violation emerge as an intrinsic property of the "Simplicial Information Couplings" within SDIS, leading to the generation of the Standard Model's CP-violating interactions?
   - Crucially, how does this emergent CP violation translate into a *differential interaction* between I (matter) and Ī (antimatter) informational patterns and the local SDIS network structure? Specifically, can it be demonstrated that Ī patterns impose a systematically higher local "Network Informational Stress" (σ_NIS(Ī) > σ_NIS(I)) than I patterns, considering both geometric stress and qubit configuration strain/fragility?
3. Network Stabilization, Entropic Drive, and Asymmetric Selection:
   - How is the concept of "Network Configuration Entropy" (S_NC) defined and quantified within SDIS, and how does its maximization (equivalent to minimizing global σ_NIS) drive the network's evolution from its primordial high-stress state?
   - What are the specific SDIS network self-correction mechanisms (e.g., Pachner moves, localized decoherence via Lindblad dynamics) that facilitate this stabilization?
   - Can these self-correction mechanisms, when operating on a network with differentially stressed I and Ī patterns, lead to a *path-dependent, asymmetric stabilization* that preferentially integrates and preserves I patterns while effectively "filtering out" or failing to viably incorporate Ī patterns? Is this "entropic culling" process efficient enough to generate an asymmetry of the order $\eta \approx 6.1 \times 10^{-10}$?
4. Satisfaction of Sakharov Conditions and Cosmological Consistency:
   - Does the proposed SDIS mechanism for "Path-Dependent Asymmetric Network Stabilization" robustly and self-containedly satisfy all three Sakharov conditions (B-violation, C- and CP-violation, and departure from thermal equilibrium) using only the intrinsic properties and dynamics of the SDIS network?
   - How does the "freezing-in" of the generated baryon asymmetry occur as the SDIS network expands, cools, and transitions from its primordial high-stress epoch to a more quiescent, stable state?
   - Is the predicted asymmetry consistent with observational constraints, particularly the measured baryon-to-photon ratio η, and how might this value be ultimately derived from fundamental SDIS parameters?
5. Self-Contained Nature and Implications:
   - To what extent is this mechanism truly self-contained, avoiding the need for new fundamental particles (e.g., superheavy GUT bosons or Majorana neutrinos) or interactions beyond those that naturally emerge from the SDIS framework in its generation of the Standard Model?
   - What are the broader implications of such an SDIS-based baryogenesis mechanism for our understanding of early universe cosmology, the nature of matter, and the fundamental role of information and spacetime dynamics in shaping the cosmos?

**Analysis and Results: Baryogenesis via Path-Dependent Asymmetric Network Stabilization in SDIS**

This section presents the detailed analysis of the proposed mechanism for baryogenesis within the Simplicial Discrete Informational Spacetime (SDIS) framework. We will demonstrate how the intrinsic properties and dynamics of the SDIS network, evolving from a non-singular primordial high-stress state, can naturally lead to the observed matter-antimatter asymmetry, satisfying the Sakharov conditions.

The Primordial SDIS Network: A Non-Singular, Far-From-Equilibrium Initial State
The SDIS framework posits a cosmology that avoids an initial singularity (Karazoupis, 2025). The universe does not begin from an infinitely dense point but rather from a Primordial High-Stress SDIS Network Epoch. This state is characterized by:

Finite but Maximal Energy Density and Stress: The network possesses a very high, but finite, energy density. The average Network Informational Stress ($\sigma\_NIS$), encompassing both geometric stress ($\sigma\_v$) and qubit configuration strain, is ubiquitously near the critical threshold ($\sigma\_crit$) for topological change. This is consistent with a universe at or near the Planck energy scale, where the fundamental discreteness of spacetime as described by SDIS is paramount.

Dynamic Topological Fluidity: Due to the high stress, the network undergoes continuous and rapid topological reconfigurations. Pachner moves (Karazoupis, 2025) are pervasive, leading to a "fluid-like" behavior of the simplicial structure. The network lacks any large-scale geometric order or regularity.

Profound Departure from Equilibrium: This primordial state is, by definition, far from any thermal or structural equilibrium. It represents a state of relatively low Network Configuration Entropy ($S\_NC$), where $S\_NC$ is maximized in a stable, low-stress, regularized network configuration. The subsequent evolution of the network is an irreversible, entropy-driven process towards this stable state. This directly satisfies Sakharov's third condition: departure from thermal equilibrium. The entire universe, as a dynamic network, is undergoing a one-way stabilization.

Fundamental B/L-Non-Conserving Network Dynamics and Stochastic I/Ī Pattern Formation

In the extreme conditions of the Primordial High-Stress SDIS Network Epoch, the fundamental processes governing the creation, annihilation, and reconfiguration of simplices and their informational content are not constrained by the symmetries observed at lower energies.

B/L-Non-Conservation as a Fundamental High-Energy Network Property: We posit that Baryon Number (B) and Lepton Number (L) are *emergent and approximate symmetries* within SDIS. They become robust conservation laws only as the network stabilizes and cools. In the primordial, high-$\sigma\_NIS$ phase, the energetic topological reconfigurations (e.g., complex Pachner cascades, direct simplex creation/annihilation from pure network energy, or fundamental transformations of qubit patterns across shared faces during re-gluing events) inherently do not conserve B or L individually.

These processes represent the most fundamental level of "particle" creation, where "particle" refers to a persistent informational pattern. This satisfies Sakharov's first condition: Baryon number violation.

Stochastic Formation of I and Ī Patterns: These B/L-non-conserving network events can be visualized as localized fluctuations of the network's energy and informational degrees of freedom, leading to the spontaneous emergence of nascent informational patterns. Some of these patterns, if they were to stabilize, would correspond to what we identify as "matter-informational" (I) structures (e.g., carrying the potential for net positive baryon or lepton number), while others would correspond to "antimatter-informational" (Ī) structures (carrying the potential for net negative baryon or lepton number).

Intrinsic Symmetric Probability: At the most fundamental level of these stochastic network fluctuations, before the influence of CP-violating interactions on their subsequent stability and integration becomes dominant, the probability of a local network event producing an I-type pattern is equal to the probability of it producing an Ī-type pattern. This is the "coin flip" aspect: P(I_initial) = P(Ī_initial) = 0.5 for any given quantum fluctuation capable of generating such a pattern.

Emergent CP Violation and its Manifestation as Differential Network Informational Stress

CP violation is asserted to be an intrinsic emergent property of the SDIS framework, arising from the fundamental "Simplicial Information Couplings" that dictate how qubit states interact across shared simplex faces and how these interactions give rise to the effective forces and particle properties of the Standard Model (Karazoupis, 2025).

CP Violation in Fundamental Couplings:

The rules governing qubit state transformations, entanglement generation, and information propagation within SDIS are not perfectly symmetric under combined Charge Conjugation (C) and Parity (P) operations when translated into the language of emergent particle interactions. This means that the effective couplings for processes involving I patterns are not identical to those involving Ī patterns.

Differential σ_NIS Imprint: The crucial consequence of this emergent CP violation for baryogenesis is its manifestation in how I and Ī patterns interact with and "stress" the local simplicial network.
Hypothesis: An Ī (antimatter) informational pattern, due to its CP-asymmetric coupling with the fundamental degrees of freedom of the SDIS network (the qubits and the local geometry of the simplices), imposes a slightly but systematically higher local Network Informational Stress (σ_NIS(Ī) > σ_NIS(I)) than its corresponding I (matter) pattern. This differential stress can be understood as:

Geometric Component:

The Ī pattern might necessitate or induce slightly greater deviations in local dihedral angles from θ_ideal, leading to a higher contribution to σ_v.

Informational Component (Qubit Strain/Fragility): The qubit configuration representing an Ī pattern might be inherently more "complex" (in an information-theoretic sense that the network finds "costly" to maintain), require more precise and therefore more fragile phase relationships between qubits, or generate local entanglement structures that are less compatible with the network's overall tendency towards minimizing informational strain. It is "less comfortable" within the lattice. The existence of this differential σ_NIS imprint is the direct fulfillment of Sakharov's second condition: C and CP violation, influencing the relevant interactions that determine the fate of baryons and antibaryons.

## Path-Dependent Asymmetric Network Stabilization and Entropic Culling

The Primordial High-Stress SDIS Network is in a profoundly unstable state (low S_NC). Its evolution is an irreversible, path-dependent process towards a stable, low-stress (high S_NC) configuration. This stabilization is not a gentle relaxation but a dynamic, forceful self-correction driven by the imperative to reduce the ubiquitously high σ_NIS.

The Network's "Choice" for Stability: The initial conditions (high global σ_NIS) and the SDIS dynamical rules (Pachner moves triggered by σ_crit, Lindblad decoherence) define a unique course of evolution. The network *must* stabilize, and it will do so via pathways that most efficiently reduce global σ_NIS.

Asymmetric Integration of I vs. Ī Patterns:

Pachner Move Selection: When a local region of the network attempts to reduce its stress via Pachner moves, these topological changes are not random. They are driven by the local stress gradient and the global imperative to reach a lower σ_NIS state. If a region contains an Ī pattern (which contributes more to σ_NIS), it represents a "higher peak" in the stress landscape. Pachner moves will preferentially act to reduce these higher peaks. The reconfiguration pathways that involve accommodating or preserving an I pattern (lower σ_NIS contribution) will lead to a more significant net reduction in local stress compared to pathways attempting to accommodate an Ī pattern. Thus, I patterns are more likely to be seamlessly integrated into the stabilizing network structure. Ī patterns, by representing configurations that are "further from" the network's target low-stress state, are less likely to be preserved during these rapid, stress-driven reconfigurations. They are effectively "filtered out" because their incorporation hinders the network's most efficient path to stability.

Differential Decoherence and Information Preservation: The Lindblad dynamics contribute to this selection. If Ī patterns, due to their higher "Qubit Configuration Strain/Fragility" component of σ_NIS, are more susceptible to decoherence from the network's intrinsic quantum noise, their defining informational structure will degrade more rapidly. The SDIS axiom of "Geometric Stability - Maintaining Informational Structure" (Karazoupis, 2025) implies that the network strives to preserve coherent information. In this context, the more robust I patterns, being less prone to decoherence, are more effectively preserved. This is an "entropic culling": the network entropically favors the persistence of informational patterns that are less costly to maintain and more robust against its own dissipative tendencies.

The "Preferred" Information: The "preference" for matter (I patterns) is not an intrinsic bias in their creation probability but a consequence of their greater compatibility with the network's mandatory and unique stabilization trajectory under CP-asymmetric conditions. Matter patterns are those that "fit better" into the emerging stable structure of spacetime.

Accumulation and Freezing-In of the Baryon Asymmetry Accumulation:

Each instance where an I pattern is successfully integrated while a potential Ī pattern is filtered out or fails to stabilize contributes a small increment to the net baryon number. Given the vast number of such microscopic events occurring throughout the rapidly evolving primordial network, this small bias per event accumulates into a significant global baryon asymmetry.

Freezing-In: As the SDIS network expands (e.g., through the net addition of simplices or an increase in average simplex "volume," an emergent concept) and cools, the average σ_NIS drops significantly.

The rate of fundamental B/L-non-conserving topological reconfigurations plummets as the energy scale becomes insufficient to drive such processes.

The network becomes more "rigid" or "stiff." Pachner moves become less frequent and are primarily involved in local stress relaxation rather than global, high-energy restructuring.

The conditions for the differential stabilization (the high-stress environment and the intense self-correction dynamics) cease to exist.

The net baryon asymmetry, established during the primordial path-dependent stabilization phase, becomes a "frozen-in" characteristic of the now relatively stable, low-stress SDIS network. The value of $\eta \approx 6.1 \times 10^{-10}$ would ultimately be determined by the fundamental SDIS parameters: the precise strength of the emergent CP violation, the efficiency of the differential σ_NIS effect, the duration of the B-non-conserving/asymmetric stabilization epoch, and the total entropy (related to the number of photons, which are also emergent excitations) of the universe when these processes freeze out.

This detailed breakdown outlines how the SDIS framework, through its unique concepts of a dynamic informational network, Network Informational Stress, and an entropy-driven stabilization process, can generate the observed baryon asymmetry.

Systematic Satisfaction of the Sakharov Conditions within SDIS

The proposed mechanism of Baryogenesis via Path-Dependent Asymmetric Network Stabilization must satisfy the three necessary conditions for baryogenesis articulated by Sakharov (1967). This section demonstrates that these conditions are not ad-hoc additions but are inherently fulfilled by the fundamental principles and emergent dynamics of the Simplicial Discrete Informational Spacetime (SDIS) framework.

Baryon Number (B) Violation

The first Sakharov condition requires processes that can change the net baryon number. Within the SDIS framework:

Fundamental B/L-Non-Conservation in the Primordial Network:

Baryon Number (B) and Lepton Number (L) are posited to be emergent and approximate symmetries that become robust only in the later, low-stress, stabilized phase of the SDIS network. In the Primordial High-Stress SDIS Network Epoch, the fundamental topological reconfigurations of the simplicial lattice—driven by extreme σ_NIS and involving processes like energetic Pachner move cascades, or potentially more fundamental Planck-scale simplex creation, annihilation, and re-gluing dynamics—do not inherently conserve B or L.

Mechanism:

These high-energy network events represent the most basic level of "particle" creation and transformation, where "particle" signifies a persistent informational pattern (I or Ī) on the simplices. The energy for these patterns comes directly from the network's geometric and quantum fluctuational degrees of freedom. The rules governing these primordial topological transitions are more fundamental than the emergent B and L conservation laws of the later, cooler universe. Thus, the SDIS framework provides a natural source of B (and L) violation at the requisite early epoch. The stochastic formation of I and Ī patterns from pure network energy (Section 4.2) is a direct manifestation of these B/L-non-conserving dynamics.

C-Symmetry and CP-Symmetry Violation

The second Sakharov condition demands the violation of Charge Conjugation (C) symmetry and the combined Charge Conjugation and Parity (CP) symmetry to differentiate between matter and antimatter.

Emergent CP Violation from Simplicial Information Couplings: CP violation is not an external input but an *intrinsic emergent property* of the SDIS framework. It arises from the fundamental "Simplicial Information Couplings"—the rules governing how qubit states on adjacent simplices interact and how these interactions propagate to form the effective forces and particle properties of the emergent Standard Model (Karazoupis, 2025).

Manifestation as Differential Network Informational Stress: The crucial consequence of this emergent CP violation for baryogenesis is its direct impact on how matter-informational (I) patterns and antimatter-informational (Ī) patterns interact with and embed within the SDIS network. This leads to the central hypothesis of a differential Network Informational Stress: σ_NIS(Ī) > σ_NIS(I). This means that the presence of an Ī pattern (e.g., an anti-baryonic configuration) creates a greater "disturbance" or "strain" (both geometrically and in terms of qubit configuration stability/cost) on the local simplicial lattice than an equivalent I pattern.

Effective Asymmetry in Interactions: This differential stress directly influences the subsequent network dynamics (Pachner moves, decoherence), effectively creating an asymmetric "interaction" between the nascent particles and the evolving spacetime network itself. The network's stabilization processes are therefore not CP-symmetric in their outcome with respect to the preservation of I versus Ī patterns. C-symmetry is also violated, as the network's response to an Ī pattern is not identical to its response to an I pattern.

Departure from Thermal Equilibrium

The third Sakharov condition requires that the B-violating, CP-violating interactions occur out of thermal equilibrium to allow a net asymmetry to develop and persist.

The Primordial High-Stress Network as a Far-From-Equilibrium System: The Primordial High-Stress SDIS Network Epoch is, by its very definition, a system profoundly out of thermal and structural equilibrium. It is characterized by:

1. Maximal (though finite) energy density and σ_NIS.
2. Continuous, rapid topological changes and quantum fluctuations.
3. A state of relatively low Network Configuration Entropy (S_NC).

Irreversible Path-Dependent Stabilization: The evolution of the SDIS network from this primordial state towards a stable, low-stress, high-S_NC configuration is an inherently irreversible and path-dependent process. This is not a system relaxing within a heat bath, but the fundamental fabric of spacetime itself undergoing a one-way structural transformation towards its own most stable state.

No Counterbalancing Inverse Processes: During this rapid stabilization phase, the conditions are changing dramatically. The "entropic culling" or preferential integration of I patterns occurs because the network is actively seeking pathways to reduce its extreme σ_NIS. The inverse processes (e.g., preferentially creating Ī patterns or destroying I patterns to increase stress) are thermodynamically disfavored by the network's global drive towards stability. Once the network has significantly stabilized and σ_NIS has dropped, the conditions that allowed for both the B-non-conserving events and the efficient asymmetric selection are no longer present. The asymmetry is thus generated during a definitive out-of-equilibrium epoch.

In summary, the proposed SDIS mechanism of Baryogenesis via Path-Dependent Asymmetric Network Stabilization naturally satisfies all three Sakharov conditions. B-violation arises from fundamental high-energy network dynamics; C and CP violation are emergent properties of the Simplicial Information Couplings that manifest as a differential stress imprint of matter versus antimatter on the network; and the departure from thermal equilibrium is intrinsic to the primordial network's forced, irreversible evolution towards a stable, high-entropy configuration.

**Appendix: Mathematical Formalisms and Conceptual Elaborations for SDIS Baryogenesis**

This appendix provides supplementary details on the mathematical and conceptual constructs from the Simplicial Discrete Informational Spacetime (SDIS) framework

(Karazoupis, 2025) that are central to the proposed mechanism of Baryogenesis via Path-Dependent Asymmetric Network Stabilization.

A.1. Review of Core SDIS Definitions Relevant to Baryogenesis

For clarity, we briefly reiterate core SDIS definitions that are foundational to the baryogenesis mechanism. Detailed derivations and primary definitions are found in SDIS.

A.1.1. Simplicial Complex (S), 4-Simplices (s_i), and Adjacency:

- Spacetime is a 4D simplicial complex $S = \{s_1, s_2, ..., s_N\}$.
- Each 4-simplex $s_i$ is a regular pentachoron with 5 vertices, 10 edges, 10 triangular faces (2-simplices, hinges), 5 tetrahedral cells (3-simplices).
- Adjacency: $s_i$ and $s_j$ are adjacent if they share a common tetrahedral face, $|s_i \cap s_j| = 4$.

A.1.2. Qubit Space per Simplex and Total Hilbert Space:

- Each simplex $s_i$ is associated with a 2-dimensional Hilbert space $H_i$ (qubit), spanned by basis states $|0\rangle_i$, $|1\rangle_i$. A general state is $|\psi\rangle_i = \alpha_i |0\rangle_i + \beta_i |1\rangle_i$.
- Total Hilbert Space: $H = \bigotimes^N_{i=1} H_i$.

A.1.3. Geometric Stress ($\sigma_v$):

- Defined at each vertex v as $\sigma_v = \Sigma_{(e_1, e_2) \in \text{edges at } v} (\theta_{actual}(e_1, e_2) - \theta_{ideal})^2$, where $\theta_{ideal} = \arccos(1/4)$ is the ideal dihedral angle in a regular 4-simplex $\sigma_v$ quantifies local geometric distortion.
- The stress tensor $\sigma_{ab}$ can also be used, related to strain $\varepsilon_{ab}$ via a Planck-scale Hooke's Law.

A.1.4. Pachner Moves and Critical Stress Threshold ($\sigma_{crit}$):

- Local topological reconfigurations (e.g., 2↔3, 1↔4 moves in 4D) triggered when local stress ($\sigma_v$ or a related strain measure $\varepsilon_{ab}$) exceeds a critical threshold $\sigma_{crit} = Y \cdot \varepsilon_{crit} = E_P / l_P^3$ (where Y is spacetime stiffness, $E_P$ is Planck Energy, $l_P$ is Planck Length).
- Pachner moves act to reduce local stress concentrations.

A.1.5. SDIS Quantum Hamiltonian ($\hat{H}$) and Lindblad Master Equation:

- $\hat{H} = \hat{H}_{geo} + \hat{H}_{matter} + \hat{H}_{int}$
  - $\hat{H}_{geo} = \Sigma_v (Y/2)\sigma_v^2 - J\Sigma_{(i,j)} \sigma_i^x \sigma_j^x + h\Sigma_i \sigma_i^z$ (terms for stress energy, quantum coupling/fluctuations, and decoherence).

- Lindblad Equation: $d\rho/dt = -i/\hbar [\hat{H}, \rho] + \Sigma_k \gamma_k (L_k \rho L_k^\dagger - ½\{L_k^\dagger L_k, \rho\})$, with Lindblad operators $L_k$ often associated with local decoherence $\sigma_k^z$ .

A.2. Formalizing Network Informational Stress ($\sigma_{NIS}$)

The concept of Network Informational Stress ($\sigma_{NIS}$) is central to the proposed baryogenesis mechanism. It extends the purely geometric stress $\sigma_v$ to include the "strain" or "cost" imposed by informational patterns (representing particles) on the local simplicial lattice.

A.2.1. Definition:

$\sigma_{NIS}$ at a local region R (a collection of interacting simplices) is a scalar quantity: $\sigma_{NIS}(R) = \alpha \cdot \sigma_v(R) + \delta \cdot \Sigma_{\{s_i \in R\}} C_Q(s_i, \Psi_R)$ where:

- $\sigma_v(R)$ is the average geometric vertex stress within region R.
- $C_Q(s_i, \Psi_R)$ is the Qubit Configuration Cost/Fragility for simplex $s_i$ given the local many-body quantum state $\Psi_R$ of the qubits in region R.
- $\alpha$ and $\delta$ are positive weighting factors (potentially derivable from more fundamental SDIS parameters or dimensional analysis, e.g., relating geometric stress units to information-theoretic units). $\alpha$ could be ~Y (spacetime stiffness).

A.2.2. Qubit Configuration Cost/Fragility ($C_Q$):

$C_Q$ aims to quantify how "difficult" or "unnatural" a specific qubit pattern (representing an emergent particle) is for the local network to sustain. It could be related to:

4. Local Entanglement Entropy Deviation: If the particle pattern induces a local entanglement structure (e.g., entanglement entropy $S_E(s_i|R\backslash s_i)$) that significantly deviates from a "ground state" or "equilibrium" entanglement structure favored by $\hat{H}_{geo}$, this deviation contributes to $C_Q$. For example, $C_Q \propto |S_E(\text{induced}) - S_E(\text{equilibrium})|^k$.
5. Information Content vs. Robustness: Highly specific, low-entropy qubit states (necessary to define a particle precisely) might be more "fragile" (higher $C_Q$) against the decohering influence of $h\Sigma_i \sigma_i^z$ in $\hat{H}_{geo}$ and the Lindblad dynamics. This could be quantified by the sensitivity of the pattern's fidelity to local qubit errors or phase noise.
6. Computational Complexity/Kolmogorov Complexity: The complexity of the minimal algorithm or network process required to generate or maintain the specific qubit pattern on the lattice. More complex patterns might have higher $C_Q$.

A.2.3. $\sigma_{NIS}$ as a Driver for Pachner Moves:

The triggering condition for Pachner moves is generalized: a move is initiated if σ_NIS(R) > σ_NIS_crit, where σ_NIS_crit is a critical threshold related to σ_crit but incorporating the informational cost. Pachner moves will then preferentially select reconfiguration pathways that lead to the largest decrease in σ_NIS(R).

A.3. Emergent CP Violation and its Impact on σ_NIS

The baryogenesis mechanism hinges on emergent CP violation from Simplicial Information Couplings leading to σ_NIS(Ī) > σ_NIS(I).

A.3.1. Simplicial Information Couplings and Effective Particle Interactions:

Let L_eff(ψ_I, s_k, ...) be the effective Lagrangian density for an emergent matter particle field ψ_I interacting with the simplicial network degrees of freedom s_k (qubit states, geometry). SDIS posits this L_eff arises from coarse-graining the fundamental qubit-level interactions defined by Ĥ_int and the propagation rules on the dynamic lattice.
CP violation means that if L_eff(ψ_Ī, s_k, ...) is the Lagrangian for the corresponding antiparticle ψ_Ī, then CPT[L_eff(ψ_I, s_k, ...)] ≠ L_eff(ψ_Ī, s_k, ...) under CP transformation alone (assuming CPT invariance for the fundamental SDIS theory). This implies the existence of CP-violating phases in the effective coupling constants.

A.3.2. Manifestation as Differential σ_NIS:

The CP-violating terms in L_eff (and thus in the underlying Ĥ_int at the simplex level) mean that the way an Ī pattern (e.g., an anti-quark triplet) minimizes its action or energy within the local network configuration will be different from an I pattern (quark triplet). This difference can translate to:

1. Geometric Imprint: The Ī pattern might dynamically settle into a local geometric configuration (slightly different edge lengths, leading to different dihedral angles) that results in a higher average σ_v(R_Ī) compared to σ_v(R_I).
2. Qubit Configuration Imprint: The stable qubit state |Ψ_Ī⟩ representing the Ī pattern (including its entanglement with neighboring simplices) might be inherently more "strained" or "fragile" (higher Σ C_Q(s_i, Ψ_Ī)) than |Ψ_I⟩. For example, the CP-violating phases could necessitate more complex relative phases between qubits in |Ψ_Ī⟩ to maintain its identity, making it more susceptible to decoherence.

A.4. Network Configuration Entropy (S_NC)

S_NC is a measure of the global stability and "relaxedness" of the entire SDIS network S.

A.4.1. Conceptual Definition:

S_NC is related to the statistical probability of the network being in a particular macrostate (defined by global properties like average stress, geometric regularity, informational coherence) given the microstates (specific simplex configurations and qubit states). A low-stress, highly regular, and informationally robust network configuration is assumed to have a larger number of accessible microstates or a higher probability measure in the ensemble of possible network states, thus higher S_NC.

A.4.2. Potential Formulation

S_NC could be inversely related to the global average of σ_NIS: $S\_NC \approx -k\_B' \int\_S \sigma\_NIS(x)\, dV\_S + S\_0$ (where dV_S is an element of the simplicial manifold, and k_B' is an appropriate constant). Alternatively, it could be a sum over local entropic contributions, $S\_NC = \Sigma\_R\ S\_local(R)$, where S_local depends on the local order and stability. The drive $\Delta S\_NC > 0$ is equivalent to $\Delta(\text{Global Average } \sigma\_NIS) < 0$.

A.4.3. Relation to Thermodynamic Arrow of Time:

The increase of S_NC during network stabilization contributes to the overall thermodynamic arrow of time, complementing other entropic processes like decoherence and holographic entropy growth.

A.5. B/L-Non-Conserving Network Dynamics in the Primordial Epoch

A.5.1. High-Stress Topological Transitions:

In the Primordial High-Stress Epoch, σ_NIS is ubiquitously near σ_NIS_crit. Pachner moves are not isolated events but potentially form complex, interacting cascades or "avalanches" of topological change.

It is hypothesized that certain complex sequences of these high-energy Pachner moves, or more fundamental Planck-scale events involving the creation/annihilation of simplices themselves from pure network "energy" (related to Ĥ_geo fluctuations), can change the net "informational charge" corresponding to B or L.

Example Sketch: A sequence of moves $M\_1 \rightarrow M\_2 \rightarrow \ldots \rightarrow M\_k$ might transform a region R_0 with B(R_0)=0 into R_k with B(R_k)≠0. The energy for creating the informational patterns I or Ī comes from the reduction in geometric stress energy during these reconfigurations.

A.5.2. Stochasticity and Equal I/Ī Probability:

The specific outcome of a local B/L-non-conserving network fluctuation (I vs. Ī) is stochastic, governed by the quantum probabilities inherent in Ĥ. Before the CP-violating selection effects on stability become dominant, the intrinsic probability of a fluctuation yielding a nascent I pattern is equal to that of yielding an Ī pattern: $P\_intrinsic(I) = P\_intrinsic(\bar{I})$.

A.6. Asymmetric Stabilization and "Entropic Culling"

Let P(State_X) be the probability of the network stabilizing into a configuration that includes pattern X (where X can be I or Ī). The stabilization process is driven by reducing $\sigma\_NIS$. If $\sigma\_NIS(\bar{I}) = \sigma\_NIS(I) + \Delta\sigma\_CPV$ where $\Delta\sigma\_CPV > 0$ due to CP violation.

Pachner Move Selection: A Pachner move pathway Path_Y results in a change $\Delta\sigma\_NIS(Path\_Y)$. The probability of choosing a pathway is higher for pathways leading to more negative $\Delta\sigma\_NIS$. $P(Path\_Y) \propto \exp(-\beta\_eff \cdot \Delta\sigma\_NIS(Path\_Y))$ (simplified analogy to Boltzmann factor, where $\beta\_eff$ relates to network "temperature" or energy scale). If pathways eliminating or reconfiguring Ī (higher initial stress) lead to a more negative $\Delta\sigma\_NIS$ overall for the local patch, they are favored.

Decoherence Rate: Let $\Gamma\_decoh(X)$ be the rate at which pattern X loses its informational integrity due to Lindblad dynamics. If $C\_Q(\bar{I}) > C\_Q(I)$, then it is plausible that $\Gamma\_decoh(\bar{I}) > \Gamma\_decoh(I)$. The survival probability against decoherence over a characteristic stabilization time $\tau\_stab$ would be $P\_survive(X) \approx \exp(-\Gamma\_decoh(X) \cdot \tau\_stab)$.

The net asymmetry arises from the product of initial formation probabilities (equal) and these differential stabilization/survival probabilities, integrated over the duration of the out-of-equilibrium epoch.

**Conclusion**

The observed baryon asymmetry of the universe, quantified by $\eta \approx 6.1 \times 10^{-10}$ (Particle Data Group et al., 2022), stands as one of the most significant pieces of evidence that our understanding of fundamental physics is incomplete. While the Sakharov conditions (Sakharov, 1967) provide a clear roadmap for the necessary ingredients of baryogenesis—Baryon number violation, C- and CP-violation, and departure from thermal equilibrium—the Standard Model of particle physics falls short of providing a sufficient explanation.

This paper has proposed a mechanism for baryogenesis rooted entirely within the principles of the Simplicial Discrete Informational Spacetime (SDIS) framework (Karazoupis, 2025). Termed "Baryogenesis via Path-Dependent Asymmetric Network Stabilization," this mechanism posits that the matter-antimatter asymmetry is not an ad-hoc feature or the result of new, unobserved particles, but an inevitable consequence of the SDIS network's primordial evolution.

We have argued that:

1. The Primordial High-Stress SDIS Network Epoch provides the necessary far-from-equilibrium conditions and the arena for fundamental Baryon (and Lepton) number non-conserving topological network reconfigurations. These

events stochastically produce nascent "matter-informational" (I) and "antimatter-informational" (Ī) patterns with equal intrinsic probability.

2. CP violation, a crucial Sakharov condition, is proposed to be an intrinsic emergent property of the fundamental "Simplicial Information Couplings" within SDIS that give rise to the Standard Model.
3. This emergent CP violation manifests as a differential "Network Informational Stress" (σ_NIS), where Ī patterns impose a slightly higher local stress (both geometrically and in terms of qubit configuration stability/cost) on the simplicial lattice compared to I patterns.
4. The SDIS network's unavoidable, path-dependent evolution towards a state of maximized "Network Configuration Entropy" (S_NC) (i.e., minimized global σ_NIS) drives its stabilization. During this process, the network's self-correction mechanisms (Pachner moves and localized decoherence) preferentially integrate and preserve I patterns because they are more conducive to the most efficient reduction of σ_NIS. Ī patterns, being "stressier" or more "fragile," are effectively "filtered out" or "not viably incorporated" into the stabilizing network structure. This constitutes an "entropic culling."
5. The resulting net baryon asymmetry becomes a frozen-in characteristic of the stable, low-stress SDIS universe as the primordial B/L-non-conserving and asymmetric stabilization dynamics cease with expansion and cooling.

This SDIS-centric mechanism satisfies all Sakharov conditions using only the internal dynamics and emergent properties of a discrete, informational spacetime. It recasts baryogenesis as a process of co-evolution and co-selection between nascent particle informational patterns and the quantum spacetime network itself, driven by the network's imperative to achieve its own most stable and entropically favored configuration.

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