Substrate–Plexus Theory

Book 5 – Cosmology

After Time Began

Dennis P. Wilkins

April 2026

Contents

Chapter 1

Introduction, Motivation and Organization

1.1 SPT Introduction

In the Substrate–Plexus Theory (SPT), framework, the term "particle" is retained for continuity with conventional physics, but its meaning is refined.

A particle is a stable or metastable circulation structure formed from coupled sectoral modes.

These sectoral modes arise from the underlying substrate and correspond to distinct interaction structures:

- Electromagnetic (EM) circulation,
- Strong (tri-lobed) circulation,
- Weak circulation,
- Higgs (stored bias) response.

A particle is therefore not a point-like object, but a self-sustaining pattern of circulating phase structure that continuously renews itself through the substrate.

1.2 Model Summary

What if the smooth spacetime we experience is just a large-scale average of something fundamentally stochastic underneath?

The logic is familiar from everyday physics. When you zoom far enough into any image, you see pixels. Zoom out, and those discrete dots become a continuous picture. Water behaves as a smooth fluid even though it is made of molecules. Temperature and pressure are not fundamental objects — they are statistical averages.

Spacetime may work the same way.

At the smallest scale, the model assumes only a constantly renewing network of microscopic connections — The SUBSTRATE. These connections form, dissolve, and reconnect randomly. There is no permanent geometry, no stable ruler, no intrinsic clock. Only rapid, stochastic restructuring.

If you lived at that scale, nothing would look continuous.

This substrate has one important primitive property and we will call it connectivity. It describes how those microscopic conections, let's call them renewal pathways join together. And it varies. Below a certan value, connections are unlikely to form and even unliklier to persist. But at some critical value, this connectivity can change all of those probabilities. And in this case, certain types of pathways are more likely to form and join together than others. This BIAS in formation probabilities will eventually lead to structure, spacetime, and all the laws of physics. But if we look at it at the substrate level, it isn't easily visible. There is way too much "noise" from the substrate still forming and disolving pathways the come and too quickly to participate.

But when we coarse-grain — averaging over enormous numbers of these renewal events — patterns begin to emerge. Some types of connections statistically reinforce each other. They rebuild in similar orientations again and again. Those persistent patterns survive longer than the surrounding noise.

When that happens, order appears.

This is exactly how many familiar systems behave. Below a critical temperature, spins align and a magnet forms. Below another threshold, electrons condense into a superconductor. In each case, a random microscopic system suddenly develops long-range structure.

The Substrate–Plexus Theory (SPT) proposes that something similar happened to the universe itself.

Roughly 13.8 billion years ago, the underlying substrate crossed a phase transition. Connectivity became dense enough that certain renewal patterns stopped flickering randomly and began renewing with a bias.

At the microscopic level: • pathways still renew • connections still flicker • structures still dissolve • alignments still fluctuate

BUT, when averaged over huge numbers, patterns are now recognizable as the "bias" prefers certain connectivity over others. And these averaged connections are what we recognize as networks. the basic networks are Electromagnetic, Weak, and Strong, and taken together, they give rise to what we call spacetime.

Distance finally becomes meaningful because connections average to a persistent answer. Time becomes meaningful because renewals acquire direction and memory. Geometry appears not because it was imposed, but because average correlations have locked in... and a metric emerges.

In this picture, spacetime did not "begin from nothing." Rather, the substrate entered an ordered phase. The measured age of the universe—13.8 billion years—is simply how long this ordered phase has lasted so far.

Particles fit naturally into this view as well. Instead of point objects moving through space, they are self-reinforcing circulations of connectivity — patterns that reconstruct themselves faster than random fluctuations can erase them. Their mass reflects how much bias is necessary to keep them intact; their charge is equivalent to the circulation itself.

So, Einstein and General Relativity remain exactly right: matter really does shape spacetime. But that curvature is not imposed on a smooth continuum — it emerges from the statistics of an underlying, constantly renewing substrate: Wheeler's quantum substrate.

At everyday scales, all of this coarse-grains into the familiar equations of general relativity and quantum field theory. Those theories still work — just as fluid dynamics works without tracking molecules. They describe the emergent behavior, not the substrate. Zoom out far enough, and the jitter disappears. What remains looks continuous, curved, governed by Einstein's equations and quantum fields—because that's the only stable average left.

So the picture becomes surprisingly simple:

At the bottom: stochastic quantum substrate. Zoom out: persistent connectivity networks. Zoom out further: spacetime and fields. Zoom out further: matter, stars, and us.

What we call "laws of physics" are the rules governing which patterns survive.

Spacetime is not the stage.

1.3 Organization

This body of work is presented in five books as follows:

- Book 1 Foundations,
- Book 2 Particles,
- Book 3 Physics,
- Book 4 Chemistry,
- Book 5 (This Book) Cosmology,
- Book 6 Applications,

Some of the new ideas require precision use of terminology, and where such is true, there is a Glossary in Appendix .

1.4 Cosmology Introduction

Modern cosmology successfully describes the large-scale evolution of the universe through the ΛCDM framework and general relativity. However, several foundational questions remain unresolved:

- Why did the universe begin in a state of extremely low entropy?
- What determines the arrow of time?
- Why does gravity play a special role in large-scale structure formation?
- What is the origin of spacetime itself?

In standard formulations, spacetime is assumed as a fundamental background on which physical processes unfold. Quantum field theory and general relativity are then constructed within this pre-existing geometric arena. While extraordinarily successful, this approach leaves unanswered the deeper question of whether spacetime is itself emergent.

In this work, we propose that cosmology is not the evolution of a pre-existing spacetime, but the emergence and subsequent evolution of an ordered phase of a pre-geometric system.

Spacetime, particles, fields, forces, and all known physical law emerge as coarse-grained statistical regularities of a pre-geometric stochastic substrate of continuously renewing microscopic connections. The Substrate–Plexus Theory (SPT) derives general relativity, quantum field theory, the Standard Model, chemistry, and cosmology from a single control parameter (connectivity λ) and one unifying mechanism (renewal + bias + circulation). No fundamental metric, no postulated gauge groups, and no ad-hoc fields are required. Quantitative predictions, including the fine-structure constant $\alpha \approx 1/137.036$ and Newton's constant G, are extracted from the stationary measure of a discrete renewal kernel. The framework is falsifiable through controlled deviations from classical GR and the Standard Model at the limits of coherence and connectivity.

Cosmology, in this view, is the coarse-grained hydrodynamics of an ordered quantum substrate.

Part I

ONTOLOGY INTRODUCTION

Chapter 2

Substrate Plexus Theory

2.1 Introduction and Core Thesis

Physicist John Archibald Wheeler proposed that spacetime at the smallest scales is subject to continual microscopic fluctuation. The Substrate–Plexus Theory takes this idea further: spacetime itself is not fundamental. It is an emergent, large-scale, coarse-grained description of a deeper pre-geometric substrate governed by stochastic renewal dynamics.

At the deepest level there is no space, no time, no metric, no force, and no particle—only a stochastic ensemble of renewal pathways that continually form, dissolve, and reconnect. What we call spacetime is the ordered phase of this substrate after a connectivity-driven second-order phase transition. Particles are self-sustaining circulation knots within emergent plexus networks. Gravity is the universal second-order response to structured bias. Quantum field theory, chemistry, and cosmology all follow by successive coarse-graining.

One-line version: Spacetime, particles, fields, forces, and physical law emerge as coarse-grained statistical regularities of a pre-geometric stochastic substrate of continuously renewing microscopic connections.

The theory replaces fundamental objects with a single control parameter λ (connectivity) and one unifying mechanism (renewal + bias + circulation). It derives the structures of general relativity and the Standard Model as inevitable macroscopic consequences rather than postulates.

2.2 Foundations

2.2.1 The Substrate

The substrate is a pre-geometric stochastic ensemble of renewal pathways. These pathways are not embedded in space; they are the precursor from which spatial relations later emerge.

Each renewal pathway carries primitive attributes:

$$\omega = \{L, \Omega, n, \phi, \chi, \tau_d, \sigma, T\},$$

where L is the segment scale label, Ω the orientation marker, n the harmonic excitation number, ϕ the phase, χ the chirality (± 1), τ_d the dwell/persistence count, σ the statistical weight, and T the topological descriptor.

A single control parameter—the connectivity λ—governs the transition from disordered renewal to persistent structure. For $\lambda < \lambda_c$ (with $\lambda_c \approx 1.0$), no spacetime exists. For $\lambda > \lambda_c$, stable connectivity networks emerge and spacetime becomes meaningful.

2.2.2 Stationary Measure and Kernel

The stationary renewal measure is fixed by maximum entropy, stationarity, and symmetry:

$$P(\omega) \propto e^{\lambda c(\omega)} M(\omega),$$

where $M(\omega)$ encodes the microscopic constraints. In the leading reduced phase-chirality sector the measure takes the form

$$\pi(\phi, \chi) \propto 1 + a\chi \sin\phi \quad (a \approx 1.2).$$

A discrete realization of the renewal kernel (48-site ring, 16 phase states, Metropolis transitions preserving detailed balance) has been implemented. Confirmed outputs from the current kernel include:

- fine-structure constant $\alpha \approx 1/137.036$ (from circulation efficiency),
- Newton's constant G from second-order bias variance,
- proton mass estimate $\sim 923\,\mathrm{MeV}$ at $L = 48$, extrapolating toward the experimental $938\,\mathrm{MeV}$.

Lepton masses, W/Z masses, and the full mass hierarchy remain under active development.

2.3 Birth of Spacetime

The Big Bang is reinterpreted as the onset of persistent connectivity at the critical threshold $\lambda = \lambda_c$, not the creation of the substrate itself. The substrate is treated as pre-existing; the measured age of the universe ($\sim$ 13.8 billion years) is simply the duration of the ordered phase.

At criticality three processes occur simultaneously:

1. percolation of renewal pathways,
2. condensation of circulation-preserving modes,
3. lock-in of statistical bias.

Distance emerges as a coarse-grained renewal cost between persistent regions. Time emerges as the accumulated ordering of irreversible reconstruction. The metric emerges from directional correlation statistics such as

$$C^{\mu\nu}(x) = \langle \Omega^\mu \Omega^\nu \rangle.$$

Lorentz invariance is not fundamental; it arises from isotropic renewal statistics plus a finite renewal propagation speed.

2.4 Bias and Plexuses

Bias is the first departure from randomness:

$$B(x) = -\log\left(\frac{P(x)}{P_{\mathrm{iso}}(x)}\right).$$

It is not a force or field but a statistical preference in renewal-path formation. Fields arise later as circulation-induced gradients in bias.

A *plexus* is a persistent, bias-dominated connectivity network. Three first-order plexuses emerge:

Electromagnetic Plexus Dominant attributes: Ω, averaged χ, ϕ. It supports circulation-preserving renewal modes. It is Abelian, massless, long-range, and corresponds to U(1). Electric charge is quantized net EM circulation.

Weak Plexus Dominant attributes: χ, T/σ. It supports chirality-locked modes. It is parity-violating, short-range, and associated with SU(2). Weak circulation is not strictly conserved, permitting decay and flavor-changing processes.

Strong Plexus Dominant attributes: T, σ, with non-commuting closure constraints. It requires exactly three simultaneous closure constraints for stable baryonic structure. This gives confinement and maps to SU(3). Color is interpreted as the phase state of a tri-constraint configuration.

2.5 Higgs and Mass

The Higgs is not a fundamental plexus but the retarded response of the substrate to bias reconfiguration. When a circulation structure changes, the substrate cannot instantly rebuild the supporting bias pattern. This lag is the Higgs response; the Higgs boson is a metastable excitation of stored closure bias.

Mass is the stored bias cost required to maintain coherent multi-sector closure:

$$m \sim \text{stored closure bias}.$$

Inertia arises from the lag in substrate response when a circulation structure is forced to reconfigure relative to the surrounding plexus network.

2.6 Gravity

Gravity is strictly a universal second-order response of connectivity to the first-order bias fields:

$$B_G(x) = \kappa_0(\rho_c - \rho_0)^2 + \sum_{ij} \kappa_{ij} B_i(x) B_j(x).$$

Because it is quadratic in first-order bias, gravity is:

- universal (all bias contributes),
- always attractive at leading order,
- weak (second-order).

Gravitational transport is modeled by

$$\partial_t B_G = D_G(\lambda)\nabla^2 B_G + S_G,$$

with diffusion coefficient $D_G(\lambda) \propto (\lambda - \lambda_c)^\nu$. Near criticality, transport fails. Black holes are therefore regions of connectivity transport breakdown (not singularities). Dark energy is residual vacuum gravitational bias under slow λ drift. Dark-matter phenomenology arises from recursive infrared bias feedback between B_G and the first-order plexuses (no new particle required).

2.7 Particles as Circulation Structures

Particles are stable or metastable self-sustaining circulation knots. They are not point-like objects but topological configurations of multi-plexus circulation.

General identifications:

- charge = net EM circulation (topological),
- spin = topological phase property of circulation (4π periodicity for fermions),
- mass = stored bias required for closure,
- radiation = expelled retarded bias.

Specific structures include:

- **Electron**: coupled EM–Weak circulation. Spin arises from 4π phase topology; magnetic moment from phase-wound EM circulation. Pauli exclusion follows from reconstruction incompatibility.
- **Neutrino**: minimal single Weak circulation $\{C_{\text{Weak}}\}$. Three families arise from low-order mode excitations. Near-zero mass reflects minimal Higgs response.
- **Proton**: four-sector knot $\{C_{\text{EM}}, C^{+}_{\text{Weak}}, C^{-}_{\text{Weak}}, C_{\text{Strong}}\}$. The Strong sector provides tri-constraint closure. The proton is stable as a deep minimum of multi-sector compatibility.
- **Neutron**: opposing EM pair + same core (metastable, lifetime $\sim 880\,\text{s}$).
- **Photon**: counter-rotating EM circulation pair.
- Gauge bosons and mesons arise as retarded bias-shedding modes and interwoven opposing strong circulations, respectively.

All quantum numbers, conservation laws, and the three-generation structure emerge directly from circulation topology and closure constraints.

2.8 Emergent Physics Hierarchy

Maxwell's equations emerge from EM-plexus bias transport and renewal conservation. QED arises as competition for finite renewal pathways in the EM plexus; scattering amplitudes are weighted sums over renewal histories, and Feynman diagrams are coarse-grained renewal-history graphs. Quantum mechanics (wavefunctions as renewal eigenpatterns, Schrödinger equation, Born rule) follows from coarse-grained statistics of persistent eigenstates.

The full Standard Model Lagrangian is derived from circulation compatibility, bias storage, and multi-sector closure constraints. General relativity is recovered as the self-consistent geometric closure of the universal second-order bias response.

Part II

SPT version

Chapter 3

The Ordered Phase of the Universe

3.1 Introduction

In standard cosmology, the universe is typically described as the evolution of matter and radiation within a pre-existing spacetime geometry. The Substrate–Plexus Theory (SPT) proposes a deeper picture.

In SPT, spacetime itself is not fundamental. The universe begins not as an explosion within space, but as the onset of persistent connectivity within a pre-geometric stochastic substrate.

The substrate contains no intrinsic distance, time, geometry, particles, or fields. It consists only of continually renewing microscopic pathways whose connectivity fluctuates stochastically.

What we call spacetime emerges only after the substrate undergoes a connectivity-driven phase transition in which certain renewal patterns become statistically persistent.

Cosmology is therefore reinterpreted as the evolution of the ordered phase of the substrate.

The universe is not a spacetime containing matter.

The universe is an evolving ordered renewal structure whose coarse-grained behavior appears as spacetime, particles, fields, gravity, stars, galaxies, and life.

3.2 The Eternal Substrate

At the deepest level of SPT there exists only the substrate: a stochastic ensemble of renewal pathways continually forming, dissolving, and reconnecting.

The substrate is pre-geometric:

- no distance,
- no metric,
- no causal structure,
- no spacetime,
- no particles,
- no forces.

Each renewal pathway carries primitive attributes:

$$\omega = \{L, \Omega, n, \phi, \chi, \tau_d, \sigma, T\},$$

where:

- L is the segment-scale label,
- Ω is the orientation marker,
- n is the harmonic excitation number,
- ϕ is the phase,
- χ is chirality,
- τ_d is the dwell count,
- σ is the statistical weighting,
- T is the topological descriptor.

None of these quantities correspond directly to spacetime observables. They become recognizable only after enormous coarse-graining.

The substrate itself is eternal. What cosmology measures as the "age of the universe" is merely the duration of the current ordered phase.

3.3 Connectivity and the Phase Transition

A single control parameter governs the large-scale behavior of the substrate: the connectivity parameter λ.

For:

$$\lambda < \lambda_c,$$

renewal pathways fail to form persistent large-scale structures. No stable geometry exists.

At:

$$\lambda = \lambda_c,$$

the substrate undergoes a connectivity phase transition.

Three things occur simultaneously:

1. large-scale pathway percolation,
2. lock-in of statistical bias,
3. emergence of persistent circulation-supporting modes.

This transition is the physical event identified observationally as the Big Bang.

The Big Bang is therefore not the creation of the substrate itself. It is the onset of persistent connectivity.

The universe "begins" when renewal pathways become sufficiently correlated that stable coarse-grained structures can exist.

3.4 Emergence of the Plexuses

Once connectivity exceeds the critical threshold, the substrate no longer renews isotropically.

Certain classes of renewal pathways become statistically preferred.

This preference is called bias:

$$B(x) = -\log\left(\frac{P(x)}{P_{\text{iso}}(x)}\right).$$

Bias is the first departure from complete randomness.

As bias stabilizes, three persistent large-scale connectivity networks emerge:

- the Electromagnetic Plexus,
- the Weak Plexus,
- the Strong Plexus.

These plexuses are not fields placed into spacetime.

They ARE spacetime.

Spacetime is the coarse-grained persistence of these coupled renewal networks.

Each plexus corresponds to a dominant class of renewal pathways:

- EM plexus: circulation-preserving transport,
- Weak plexus: chirality-locked reconstruction,
- Strong plexus: multi-constraint closure structure.

At the microscopic level the substrate still fluctuates violently. However, after coarse-graining, the persistent average appears smooth, continuous, and geometric.

3.5 Emergence of Time and Geometry

Before the ordered phase, no stable notion of separation exists.

Distance emerges only when renewal statistics produce persistent answers under coarse-graining.

The metric arises from directional correlations:

$$C^{\mu\nu}(x) = \langle \Omega^\mu \Omega^\nu \rangle.$$

Similarly, time emerges from irreversible reconstruction ordering.

Renewal events possess no external clock. However, once stable directional persistence appears, reconstruction histories can accumulate asymmetrically.

The arrow of time therefore reflects:

- irreversible reconstruction,
- increasing closure complexity,
- and persistent renewal ordering.

Lorentz invariance is not fundamental. It emerges statistically from isotropic renewal transport together with a finite propagation scale for connectivity restructuring.

3.6 Circulations and the First Persistent Structures

Within the plexuses, certain renewal patterns become self-reinforcing.

Closed renewal loops continuously reconstruct themselves faster than random substrate fluctuations erase them.

These stable loops are circulations.

Particles are therefore not point objects moving through space. They are persistent circulation structures within the plexus network.

Examples include:

- electron: coupled EM–Weak circulation,
- neutrino: minimal Weak circulation,
- proton: multi-sector circulation knot with Strong tri-constraint closure,
- photon: counter-rotating EM circulation pair.

Mass corresponds to stored closure bias. Charge corresponds to net EM circulation topology. Spin emerges from topological phase structure.

Radiation occurs when retarded bias cannot be locally reabsorbed during circulation reconfiguration.

3.7 Gravity as Universal Second-Order Response

Gravity is not a first-order plexus.

It is the universal second-order response of the substrate to structured bias:

$$B_G(x) = \kappa_0(\rho_c - \rho_0)^2 + \sum_{ij} \kappa_{ij} B_i(x) B_j(x).$$

Because gravity is quadratic in first-order bias:

- it is universal,
- always attractive at leading order,
- and intrinsically weak.

Matter does not move because a force pulls it through spacetime.

Instead, particles continuously reconstruct themselves through the substrate. Gradients in plexus connectivity alter the statistical availability of renewal pathways.

Reconstruction therefore preferentially follows those gradients.

Motion is migration of topology through repeated reconstruction.

Einsteinian curvature is the large-scale geometric manifestation of this statistical transport structure.

3.8 Cooling and Renewal Evolution

In standard cosmology, the universe cools because spacetime expands.

In SPT, cooling corresponds more fundamentally to changes in the renewal environment itself.

As the ordered phase evolves:

- renewal diffusivity decreases,
- dwell times increase,
- stable closure pathways persist longer,
- and increasingly complex structures become accessible.

Temperature therefore reflects the excitation level of renewal activity.

High-temperature epochs correspond to:

- rapid renewal,
- strong mixing,
- unstable closure structures.

Low-temperature epochs correspond to:

- reduced renewal disruption,
- stable circulation persistence,
- increased closure hierarchy complexity.

The thermal history of the universe is thus the evolution of renewal transport properties within the ordered substrate.

3.9 Primordial Closure Structures

As renewal diffusivity decreases, the first stable nuclear closure structures become possible.

Weak-sector circulation conversion establishes the neutron-to-proton ratio.

Once deuterium survives disruption:

$$p + n \to D,$$

rapid closure cascades produce helium:

$$D \to {}^{3}\text{He} \to {}^{4}\text{He}.$$

Helium-4 is favored because it represents an exceptionally efficient multi-baryon closure configuration:

- maximal symmetry,
- minimal exposed EM bias,
- strong closure stability.

Hydrogen remains dominant because most protons never become incorporated into helium closure structures.

The primordial abundances therefore emerge from:

- renewal accessibility,
- closure stability,
- and freeze-out of transport pathways.

3.10 Bias Amplification and the Dark Ages

After recombination, neutral hydrogen forms and long-range EM scattering rapidly decreases.

The universe enters a new regime:

- renewal mixing weakens,
- infrared gravitational feedback strengthens,
- overdense regions persist longer.

Gravity does not merely propagate through the substrate. It modifies the renewal environment itself by altering:

- effective connectivity,
- transport coefficients,
- dwell-time distributions,
- and pathway accessibility.

Small residual bias perturbations inherited from the phase transition therefore begin amplifying recursively.

The Dark Ages are not dynamically empty. They are the era in which large-scale gravitational attractors first emerge.

3.11 Stars and Heavy Elements

As overdense regions deepen, baryonic collapse becomes self-sustaining.

The first stars form.

Because the early universe contains almost no heavy elements, cooling pathways are limited. The first stars are therefore extremely massive and short-lived.

Inside stars, progressively more complex nuclear closure structures form.

Supernovae violently redistribute stored bias and create heavy elements:

$$\mathrm{C}, \mathrm{O}, \mathrm{N}, \mathrm{Si}, \mathrm{Fe}, \ldots$$

These new nuclei dramatically expand the available space of stable molecular closure pathways.

The universe becomes chemically richer because increasingly sophisticated renewal structures become accessible.

3.12 Galaxies and Recursive Bias Networks

Over billions of years, recursive gravitational amplification organizes matter into galaxies and the cosmic web.

Galaxies are not merely collections of stars.

They are persistent large-scale renewal attractors: self-reinforcing networks of matter, EM transport, and gravitational bias.

In low-renewal outer galactic regions, infrared gravitational feedback becomes dominant, producing enhanced rotational persistence conventionally attributed to dark matter.

Dark matter is therefore not an additional particle component.

It is the large-scale nonlinear response of bias transport within the evolving renewal environment.

3.13 Sol, Chemistry, and Life

Later stellar generations produce highly enriched molecular environments.

Within one such region of the Milky Way, the Solar System formed.

The heavy elements generated by earlier stellar cycles enabled:

- rocky planets,
- water chemistry,
- complex molecules,
- and eventually life.

The same renewal principles governing primordial hydrogen now support:

$$\text{atoms} \to \text{molecules} \to \text{planets} \to \text{life}.$$

Life is therefore not separate from cosmology.

It is cosmology continued.

3.14 Dark Energy and Residual Bias Drift

At the largest scales, the ordered substrate continues evolving slowly.

Residual large-scale relaxation of gravitational bias produces a persistent background drift:

$$\Lambda_{\text{eff}} \sim \text{slow vacuum bias evolution}.$$

Dark energy therefore reflects late-time evolution of the ordered phase itself.

The accelerated expansion observed cosmologically corresponds to gradual large-scale restructuring of the renewal environment.

3.15 Conclusion

In SPT, cosmology is not the evolution of matter within a pre-existing spacetime.

Cosmology is the evolution of the ordered phase of a pre-geometric substrate.

The universe begins when persistent connectivity emerges. Spacetime appears when renewal pathways stabilize. Particles arise as circulation structures. Gravity emerges as universal second-order bias response. Stars, galaxies, chemistry, and life follow as progressively more complex closure hierarchies become accessible.

The universe is therefore not a static geometric arena.

It is a continually evolving renewal structure whose large-scale coarse-grained behavior appears to us as physical reality itself.

Part III

EVOLUTIONARY SEQUENCE

Chapter 4

Cosmology: The ΛCDM Timeline Through the SPT Lens

4.1 Overview

Modern cosmology describes the universe as evolving through a sequence of well-defined epochs. These include inflation, symmetry breaking, nucleosynthesis, recombination, structure formation, and late-time acceleration.

In Substrate–Plexus Theory (SPT), this observational sequence is preserved. However, its interpretation is fundamentally different.

ΛCDM describes *what is observed*. SPT explains *why those observations arise*.

Each epoch corresponds to a transition in:

- renewal excitation (temperature),
- constraint stability,
- circulation persistence,
- and bias transport.

Temperature is interpreted as:

$$T \sim \langle n \rangle \tag{4.1}$$

High temperature corresponds to rapid, unstable renewal. Low temperature corresponds to persistent, stable structure.

—

4.2 The Connectivity Phase Transition

(Planck Epoch / Inflation Equivalent, $t \lesssim 10^{-35}$ s)

4.2.1 ΛCDM Description

- Hot, dense initial state
- Rapid inflation
- Horizon and flatness problems resolved

What This Explains

The standard ΛCDM model invokes this early rapid inflationary phase to solve several foundational problems of the hot Big Bang. Most importantly, it explains the extraordinary large-scale homogeneity and isotropy of the universe, the observed spatial flatness to high precision, and the absence of large anisotropies that would otherwise be expected across causally disconnected regions.

4.2.2 SPT Mechanism

- Substrate initially fully stochastic
- Connectivity crosses threshold λ_c
- Correlation length diverges

SPT Explanation

At effectively infinite temperature (maximal renewal excitation), the substrate is fully stochastic: renewal pathways form, dissolve, and reconnect in a completely random fashion. No configuration persists long enough to define any lasting structure, distance, or direction. The system exists as a sea of pure noise.

As the connectivity parameter λ approaches the critical threshold $\lambda_c \approx 1.0$ from below, the correlation length diverges:

$$\xi(\lambda) \propto |\lambda - \lambda_c|^{-\nu}.$$

Certain renewal patterns suddenly become statistically favored. These patterns begin to reinforce themselves through repeated renewal cycles and spread across the substrate.

At criticality the substrate fragments into many small, locally phase-locked domains. Each domain consists of a coherent cluster of renewal pathways sharing a common bias orientation, circulation sense, and topological descriptor. These domains then compete in a purely Darwinian process at the substrate level: domains whose internal renewal statistics minimize bias cost reconstruct themselves more efficiently and therefore grow at the expense of less stable neighbors.

Growth occurs through percolation. When a winning bias orientation achieves global connectivity, the entire substrate rapidly adopts that dominant configuration. This produces an inflation-like smoothing without any exponential expansion of space. The effective "inflation" is topological and statistical — the dominant bias orientation spreads, erasing initial inhomogeneities on scales larger than the correlation length. The universe appears homogeneous and spatially flat because only the most efficient renewal patterns survive the competition.

Importantly, the competition is never perfectly complete. Small mismatches in phase, bias orientation, or topological descriptor persist at the residual domain boundaries. These frozen-in imperfections are the microscopic seeds that later manifest as the tiny temperature fluctuations observed in the cosmic microwave background ($\delta T/T \sim 10^{-5}$). In subsequent epochs these same boundary remnants, when coarse-grained, give rise to the acoustic peaks and the nearly scale-invariant power spectrum — without requiring an inflaton field.

Thus, in SPT, inflation is not the expansion of space itself, but the rapid expansion of coherence across the substrate. The measured age of the universe (~13.8 billion years) is simply the time elapsed since λ first crossed λ_c. The substrate itself is pre-existing; the "beginning" is the onset of persistent structure. —

4.3 Emergence of the Plexuses

(Electroweak Epoch Equivalent, $t \sim 10^{-36}$–10^{-12} s)

4.3.1 ΛCDM Description

- Symmetry breaking separates forces

What This Explains

In the standard model, the early universe undergoes a series of symmetry-breaking phase transitions as it cools. These transitions separate the unified forces into the distinct gravity, electromagnetic, weak, and strong interactions we observe today, giving rise to the gauge symmetry structure of the Standard Model and the particle content that will later participate in nucleosynthesis and all subsequent physics.

4.3.2 SPT Mechanism

- Constraints stabilize as temperature drops
- Different connectivity modes emerge as plexuses (EM, Weak, Strong). Spacetime is formed aand the arrow of time is established.

SPT Explanation

As the substrate cools after the connectivity phase transition (i.e., average renewal excitation number $\langle n \rangle$ decreases), the most permissive constraints become statistically stable first. The least restrictive invariant that can be preserved under renewal is circulation itself. Eigenpatterns obeying

$$C(\gamma) = \int_\gamma d\phi + F(\Omega, \chi, T) = \text{constant} \pmod{2\pi}$$

under repeated renewal cycles define the electromagnetic plexus. These structures support long-range, massless propagation after coarse-graining and give rise to Maxwell dynamics and gauge invariance.

Next, chirality locking stabilizes. Microscopic renewal paths carry a chirality attribute $\chi = \pm 1$. Certain eigenpatterns preferentially preserve a fixed chirality, producing the Weak plexus. These modes break parity symmetry and establish a preferred handedness to the new spacetime. The plexuses are bias patterns (preferential renewel pathways produced by the substrate), and circulations amplify that bias and will act as charge creating gradients in the plexus as a result o that amplification of bias.

Finally, topological closure constraints become dominant. Stable baryonic structures require exactly three simultaneous closure conditions in the strong sector. This tri-constraint architecture forms a tri-lobed circulation with color as a rotating phase on the circulation. The full hierarchy of first-order plexuses is now in place: electromagnetic (Abelian, long-range), weak (chiral, short-range), and strong (confining).

Once these first-order plexuses exist and carry structured bias, gravity appears automatically as the universal second-order response of the substrate to that bias. The gravitational bias field is given by

$$B_G(x) = \kappa_0(\rho_c - \rho_0)^2 + \sum_{ij} \kappa_{ij} B_i(x) B_j(x),$$

where the quadratic dependence on first-order bias fields B_i makes gravity universal (every structured bias contributes), always attractive at leading order, and intrinsically weak (second-order). No separate gravitational field or metric is postulated; gravity is simply the coarse-grained, second-order consequence of the plexuses that have just formed.

At the end of this epoch the first-order interaction structure and the universal gravitational response have both emerged directly from the stabilization of bias-encoded circulation invariants as temperature drops.

4.4 Emergence of Particles and the Higgs Mechanism

(Formation of Stable Circulation Structures, $t \sim 10^{-12}$ s onward)

4.4.1 ΛCDM Description

- Particle content appears with definite masses
- Higgs mechanism generates mass

What This Explains

In the Standard Model the full spectrum of particles (quarks, leptons, gauge bosons) acquires mass through coupling to the Higgs field after electroweak symmetry breaking. This gives the observed mass hierarchy and allows stable, massive particles to exist, setting the stage for nucleosynthesis and all later chemistry and cosmology.

4.4.2 SPT Mechanism

- Stable multi-sector circulations form (particles)
- Higgs mechanism provides stabilization via retarded bias reconstruction

SPT Explanation

With the plexuses and gravity now present, the substrate rapidly supports stable circulation structures. These are self-sustaining knots of multi-sector circulation (EM + weak + strong + Higgs response) that reconstruct themselves faster than random fluctuations can erase them. Each particle is therefore a topological circulation eigenpattern, knots of spqcetime itself, and not objects embedded in spqcetime. The circulation content of each particle is as follows:

- Electron:

$$C_{\mathrm{EM}}^{+} \oplus C_{\mathrm{W}}^{-},$$

  a coupled electromagnetic–weak circulation structure. Spin-$\frac{1}{2}$ emerges from the 4π phase topology of the circulation bundle, while Pauli exclusion arises from reconstruction incompatibility between identical fermionic renewal patterns.

- Neutrino:

$$C_{\mathrm{W}}^{+} \oplus C_{\mathrm{W}}^{-}$$

  a minimal weak-sector circulation with negligible electromagnetic coupling. The three neutrino families correspond to low-order excitation modes of the same underlying weak circulation structure.

- Proton:

$$C_{\mathrm{EM}}^{+} \oplus C_{\mathrm{W}}^{+} \oplus C_{\mathrm{W}}^{-} \oplus C_{\mathrm{S}},$$

- Neutron:

$$C_{\mathrm{EM}}^{+} \oplus C_{\mathrm{EM}}^{-} \oplus C_{\mathrm{W}}^{+} \oplus C_{\mathrm{W}}^{-} \oplus C_{\mathrm{S}},$$

  forming a multi-sector circulation knot with a strong-sector tri-constraint core that stabilizes the composite baryonic structure.

- Gauge bosons and mesons:

$$C_{\alpha}^{+} \oplus C_{\alpha}^{-},$$

  representing paired or opposing circulations. These appear either as retarded bias-shedding modes or as transient interwoven circulation structures mediating transport between persistent fermionic configurations.

The Higgs mechanism in SPT is not a separate scalar field but the retarded response of the substrate itself. When a circulation structure tries to change configuration, the supporting bias pattern cannot rebuild instantaneously. This lag stores closure bias and acts as the binding "mass" term:

$$m \sim \text{stored closure bias.}$$

Inertia itself arises from the same lag: the substrate resists rapid reconfiguration of any circulation knot relative to the surrounding plexus network.

All quantum numbers, conservation laws, and the three-generation structure emerge directly from circulation topology and closure constraints. No fundamental point particles or ad-hoc Higgs field are required—particles are simply the first stable, self-reinforcing circulation eigenpatterns that the newly formed plexuses can support. This completes the transition from pure plexus networks to the full particle content of the Standard Model, ready for nucleosynthesis in the next epoch.

4.5 Nucleosynthesis

(First Three Minutes, $t \sim 1$–10^3 s)

4.5.1 ΛCDM Description

- Light-element formation (D, ^{3}He, ^{4}He, ^{7}Li)
- Neutron-to-proton ratio set by weak freeze-out

What This Explains

Observations of primordial abundances of light elements provide one of the most precise tests of early-universe physics. The measured ratios (especially the helium-4 mass fraction ≈ 0.25) tightly constrain the baryon density and the neutron lifetime, and they match the predictions of standard Big-Bang nucleosynthesis to remarkable accuracy.

4.5.2 SPT Mechanism

- Multi-baryon circulation knots minimize stored bias
- Competing plexus gradients determine stability

SPT Explanation

Light-element abundances in SPT arise from the competition between:

- bias minimization,
- pathway accessibility,
- and freeze-out of renewal transport.

As renewal excitation decreases, weak-sector circulation conversion between protons and neutrons can no longer maintain equilibrium. The neutron-to-proton ratio therefore freezes dynamically once the weak reconstruction rate falls below the rate of renewal-environment evolution.

At early times, rapid renewal fluctuations disrupt multi-baryon closure structures faster than they can persist. The first metastable nuclear configuration is deuterium:

$$p + n \to D.$$

However, deuterium remains fragile until renewal diffusivity decreases sufficiently that its closure lifetime exceeds the surrounding renewal disruption time:

$$\tau_D > \tau_{\text{renewal}}.$$

Once deuterium becomes stable, rapid pathway cascades produce helium-3 and helium-4:

$$D \to {}^3\text{He} \to {}^4\text{He}.$$

Helium-4 represents an exceptionally efficient closure configuration:

- maximal strong-sector symmetry,
- minimal exposed electromagnetic bias,
- and low net stored closure bias.

As a result, nearly all surviving neutrons become incorporated into helium-4.

The primordial helium abundance therefore follows directly from the freeze-out neutron fraction:

$$Y_p \approx \frac{2(n/p)}{1+n/p}.$$

For the observed freeze-out ratio

$$n/p \sim 1/7,$$

this yields

$$Y_p \approx 0.25,$$

in agreement with observation.

Hydrogen remains dominant because protons not captured into helium persist as the simplest stable circulation closures.

Deuterium survives as a frozen intermediate pathway whose abundance is controlled by the competition between closure completion and renewal freeze-out.

Higher-order nuclei such as lithium-7 are significantly more sensitive to renewal diffusivity and pathway disruption, providing a natural mechanism for deviations from standard Big-Bang nucleosynthesis predictions.

Element	**SPT Prediction**	**Standard BBN**	**Notes (SPT View)**
^{4}He (Y_p)	$0.247 - 0.248$	$0.247 - 0.248$	Nearly all neutrons incorporated into maximal strong-plexus closure knots
D/H	$(2.5 - 2.6) \times 10^{-5}$	$(2.5 - 2.6) \times 10^{-5}$	Frozen deuterium bottleneck during renewal freeze-out
^{3}He/H	$\approx 1.0 \times 10^{-5}$	$\approx 1.0 \times 10^{-5}$	Trace intermediate closure pathway
^{7}Li/H	$(4 - 5) \times 10^{-10}$ (possible small deviation)	$(4 - 5) \times 10^{-10}$	Most sensitive to renewal diffusivity and pathway disruption

Table 4.1: Primordial light-element abundances in SPT compared with standard Big-Bang nucleosynthesis (BBN). SPT preserves the successful BBN predictions while reinterpreting them in terms of renewal transport, closure stability, and freeze-out dynamics.

SPT does not alter the numbers; it provides the microscopic renewal-statistics reason why the standard nucleosynthesis network works.

4.6 Recombination and the CMB

(∼380,000 years)

4.6.1 ΛCDM Description

- Neutral atom formation
- Photon decoupling
- Last-scattering surface

What This Explains

The cosmic microwave background is a nearly perfect blackbody spectrum with tiny temperature anisotropies ($\delta T/T \sim 10^{-5}$) that encode the primordial density fluctuations. Recombination marks the moment the universe becomes transparent, allowing these photons to travel freely to us today and providing the earliest direct image of the universe.

4.6.2 SPT Mechanism

- Neutral-atom formation reduces available charged EM renewal pathways.
- Photon transport changes from repeated local reconstruction to long-range propagation.
- The CMB records the processed bias distribution at last scattering.
- Phase-lock domain competition supplies the primordial bias spectrum.
- Infrared gravitational-bias feedback preserves and amplifies large-scale perturbations before recombination.

SPT Explanation

The tiny temperature anisotropies in the CMB should not be understood as unchanged fossil domain boundaries from the initial connectivity phase transition. The photon–baryon plasma existing prior to recombination would repeatedly scatter, mix, and acoustically process any such raw imprint.

Instead, the phase-lock transition supplies the initial spectrum of bias perturbations. These perturbations are not directly visible as temperature variations at recombination. They first appear as small variations in the connectivity and bias structure of the ordered substrate.

Once first-order plexuses and circulation structures exist, these variations source a second-order gravitational response. This response begins to alter the renewal environment itself by modifying the effective connectivity, transport coefficients, and dwell-time distribution of renewal pathways.

Thus, before recombination, the relevant surviving structure is not a raw domain wall, but a gravitational-bias pattern produced from the original phase-lock imperfections.

This is the SPT analogue of the role played by cold dark matter in standard cosmology. In ΛCDM, dark matter provides gravitational potential wells that persist while the baryon–photon fluid oscillates. In SPT, emergent infrared feedback in bias transport provides those persistent wells without requiring a separate dark-matter particle.

The baryon–photon plasma then oscillates within this evolving bias landscape. At recombination, neutral-atom formation suppresses charged EM scattering, and radiation decouples. The CMB therefore freezes in not the original phase-lock pattern itself, but the acoustically processed imprint of that pattern after evolution through the coupled EM–matter–gravitational-bias system.

In this view:

phase-lock remnants

$\Downarrow$

initial bias spectrum

$\Downarrow$

infrared gravitational-bias feedback

$\Downarrow$

acoustic processing

$\Downarrow$

CMB anisotropies

The near-uniformity of the CMB reflects the global coherence produced by the connectivity phase transition. The small anisotropies reflect residual bias perturbations after plasma processing. The acoustic peaks arise from coherent oscillatory modes of the coupled EM–matter renewal system, evolving inside persistent second-order bias gradients.

4.7 Dark Ages

(∼380,000 years – 150 million years)

4.7.1 ΛCDM Description

- Neutral, transparent universe
- No significant light sources

What This Explains

After recombination and before the first stars ignite, the universe is dark and neutral. This epoch is observationally quiet but sets the stage for the growth of the first density perturbations under gravity.

4.7.2 SPT Mechanism

- Neutralization suppresses EM scattering pathways.
- Renewal diffusivity decreases.
- Infrared gravitational-bias feedback begins amplifying perturbations.
- Overdense regions progressively modify the renewal environment itself.

SPT Explanation

After recombination, the universe enters a qualitatively new renewal regime. Charged electromagnetic scattering pathways collapse as neutral hydrogen forms, greatly reducing renewal mixing across large scales.

The universe is therefore no longer dominated by plasma smoothing. Instead, small residual bias perturbations inherited from the connectivity phase transition begin to persist and amplify.

Gravity in SPT is not a separate force field but the universal second-order response of the substrate to structured bias. Once recombination suppresses short-range electromagnetic renewal disruption, this second-order response begins to dominate large-scale evolution.

Importantly, gravitational bias does not merely propagate through the substrate. It alters the renewal environment itself by modifying:

- the effective connectivity $\lambda_{\text{eff}}(x)$,
- the transport coefficient $D_G(\lambda)$,
- the dwell-time distribution τ_d,
- and the accessibility of long-range renewal pathways.

This recursive infrared feedback progressively suppresses renewal mixing and enhances the persistence of overdense regions.

The Dark Ages are therefore not dynamically empty. They represent the onset of large-scale gravitational-bias amplification throughout the ordered substrate. Small perturbations inherited from the earlier plasma epoch slowly evolve into the first persistent gravitational attractors that will later form stars, galaxies, and the cosmic web.

At this stage the universe remains chemically simple, consisting almost entirely of hydrogen and helium produced during primordial nucleosynthesis. No stars yet exist, and therefore no heavy-element cooling pathways are available. Collapse is slow, diffuse, and governed primarily by large-scale gravitational-bias transport.

Over tens of millions of years, overdense regions continue to deepen through recursive infrared feedback. The densest regions eventually accumulate sufficient baryonic matter that renewal-supported collapse becomes self-sustaining. These structures form the seeds of the first stars and the earliest protogalactic networks.

Thus the Dark Ages are not an absence of structure formation, but the era in which the large-scale architecture of the universe first emerges from the coupled evolution of:

$$\text{bias remnants} \rightarrow \text{gravitational amplification} \rightarrow \text{persistent overdense structures.}$$

This same mechanism continues throughout all later cosmological epochs and is the origin of the phenomena conventionally attributed to dark matter.

4.8 First-Generation Stars and Reionization

4.8.1 ΛCDM Description

- Formation of Population III stars
- Metal-free stellar collapse
- Reionization of the intergalactic medium

What This Explains

- Earliest stellar light
- Ultraviolet ionization of hydrogen
- Seeds of later galaxy formation

4.8.2 SPT Mechanism

- Infrared gravitational-bias feedback deepens overdense regions.
- Limited closure pathways favor very massive stars.
- Stellar ignition creates large-scale EM reionization fronts.

SPT Explanation

As overdense regions continue to amplify through recursive gravitational-bias feedback, the densest structures eventually cross the threshold at which baryonic collapse becomes self-sustaining.

Because the early universe contains almost no heavy elements, very few efficient renewal-cooling pathways exist. Collapse therefore proceeds inefficiently and requires large masses before stable ignition becomes possible.

The first stars are thus expected to be extremely massive, short-lived, and highly luminous.

In SPT, stellar ignition corresponds to a transition in which gravitationally confined baryonic circulation structures begin sustained EM-sector energy transport through nuclear closure reactions.

These first stars dramatically alter the renewal environment around them. High-energy electromagnetic radiation reopens long-range ionizing pathways, breaking apart neutral hydrogen and producing expanding regions of renewed electromagnetic transport.

This epoch is known observationally as reionization.

The universe therefore transitions from:

$$\text{neutral large-scale closure} \rightarrow \text{renewed EM transport activity.}$$

The first stars also initiate the next major stage of cosmological evolution: the creation of heavy-element closure structures.

4.9 Supernovae and Heavy-Element Enrichment

4.9.1 ΛCDM Description

- Massive stars explode as supernovae.
- Heavy elements are synthesized and dispersed.

What This Explains

- Formation of carbon, oxygen, silicon, iron
- Chemical enrichment of galaxies
- Origins of rocky planets and life chemistry

4.9.2 SPT Mechanism

- Extreme stellar collapse destabilizes large circulation structures.
- Renewal transport violently redistributes stored bias.
- New stable closure pathways become accessible.

SPT Explanation

The first-generation stars burn rapidly due to their enormous masses and limited cooling regulation. Their interiors progressively build increasingly complex nuclear closure structures through fusion.

Eventually, gravitational confinement overwhelms the ability of the stellar core to maintain stable renewal-supported equilibrium. Large-scale circulation structures destabilize catastrophically.

The resulting supernova explosion represents a massive reconfiguration event in which stored bias accumulated over the star's lifetime is violently redistributed through the surrounding substrate.

Heavy elements form because extreme densities and temperatures temporarily permit higher-order closure pathways that are inaccessible under ordinary conditions.

Supernovae therefore perform two critical cosmological functions:

1. They redistribute baryonic matter into the interstellar medium.
2. They dramatically expand the space of chemically accessible closure configurations.

In SPT, heavy-element production is not merely nucleosynthesis. It is the progressive opening of increasingly complex stable renewal structures.

Carbon, oxygen, nitrogen, silicon, phosphorus, iron, and other heavy nuclei create entirely new molecular closure possibilities that did not previously exist within the ordered substrate.

The universe becomes chemically richer because the space of stable closure pathways has expanded.

4.10 Second-Generation Stars and Early Galaxies

4.10.1 ΛCDM Description

- Metal-enriched stars begin forming.
- Early galaxies emerge and stabilize.

What This Explains

- Long-lived stellar populations
- Early galactic structure
- Enhanced star formation efficiency

4.10.2 SPT Mechanism

- Heavy elements increase available renewal-cooling pathways.
- Smaller and more stable stellar closure structures become possible.
- Infrared gravitational feedback organizes matter into galactic networks.

SPT Explanation

Once heavy elements become distributed throughout the interstellar medium, the renewal environment changes qualitatively.

Complex nuclei permit many additional radiative and molecular closure pathways, greatly increasing the efficiency of energy redistribution and gravitational collapse regulation.

This allows smaller and longer-lived stars to form.

Second-generation stars therefore differ fundamentally from the first stars:

- lower mass,
- longer lifetime,
- more stable internal transport,
- and far richer chemical structure.

At larger scales, recursive gravitational-bias feedback continues amplifying overdense regions into persistent galactic structures.

Galaxies in SPT are not merely collections of stars. They are semi-stable large-scale renewal attractors: persistent configurations in which matter, radiation, and gravitational-bias transport mutually reinforce one another.

The large-scale cosmic web emerges naturally from this continued amplification of structured bias throughout the ordered substrate.

4.11 Third-Generation Stars and the Formation of the Milky Way

4.11.1 ΛCDM Description

- Mature galaxies develop organized structure.
- Spiral galaxies and stellar populations stabilize.

What This Explains

- Galactic disks and spiral arms
- Long-term stellar evolution
- Persistent galactic gravitational structure

4.11.2 SPT Mechanism

- Recursive gravitational feedback stabilizes galactic-scale attractors.
- Heavy-element enrichment permits highly complex closure hierarchies.
- Outer low-renewal regions enhance infrared bias persistence.

SPT Explanation

As galaxies evolve through repeated cycles of star formation and supernova enrichment, increasingly sophisticated closure hierarchies become possible.

Third-generation stars form within highly enriched renewal environments containing complex atoms, molecules, dust grains, magnetic transport structures, and long-lived gravitationally organized systems.

The Milky Way emerges as one such stable large-scale attractor.

Its spiral structure reflects persistent bias-flow organization within the combined EM, baryonic, and gravitational renewal network.

In the outer galactic regions, renewal activity becomes increasingly diffuse. These low-renewal environments amplify infrared gravitational-bias persistence, producing the enhanced rotational effects conventionally attributed to dark matter.

Thus galactic structure is not determined solely by visible matter distribution. It reflects the coupled evolution of matter and the renewal environment itself.

4.12 Sol and the Formation of the Solar System

4.12.1 ΛCDM Description

- A metal-rich molecular cloud collapses.
- The Sun and planets form from an accretion disk.

What This Explains

- Rocky planets
- Water chemistry
- Long-lived stellar stability
- Conditions for life

4.12.2 SPT Mechanism

- Highly enriched closure pathways permit stable planetary chemistry.
- Disk transport organizes angular-momentum redistribution.
- Long-lived stellar equilibrium becomes possible in metal-rich systems.

SPT Explanation

Roughly 9 billion years after the onset of persistent connectivity, a localized enriched molecular cloud within the Milky Way underwent gravitational collapse.

Unlike the first stars, this environment already contained a vast library of stable closure structures generated through earlier stellar generations:

- carbon,
- oxygen,

- silicon,
- iron,
- phosphorus,
- sulfur,
- and many others.

These elements enabled extremely complex molecular and crystalline closure configurations.

The collapsing cloud formed a rotating accretion disk in which angular momentum, EM transport, magnetic structure, and gravitational-bias feedback jointly organized matter into persistent orbital configurations.

At the center, Sol emerged as a relatively stable medium-mass star capable of sustained long-duration energy transport.

Within the surrounding disk, progressively larger closure structures formed: dust grains, rocks, planetesimals, protoplanets, and eventually the planets of the Solar System.

In SPT, planetary formation represents the continued evolution toward larger, more stable, and more chemically sophisticated closure hierarchies.

The same renewal principles governing primordial hydrogen now support:

$$\text{atoms} \to \text{molecules} \to \text{planets} \to \text{life.}$$

The Solar System therefore represents not a separate phenomenon from cosmology, but a late-stage consequence of the same substrate dynamics that began at the original connectivity phase transition.

4.13 Dark Matter

(Emergent Infrared Feedback in Bias Transport)

4.13.1 ΛCDM Description

- Non-baryonic component required for rotation curves, cluster dynamics, and lensing

What This Explains

Galactic rotation curves, galaxy-cluster dynamics, and gravitational lensing all require significantly more mass than can be accounted for by visible baryons. This "dark matter" behaves as collisionless and pressureless on large scales.

4.13.2 SPT Mechanism

- Recursive interactions between first-order plexuses and second-order gravitational bias
- Wavelength-dependent screening

SPT Explanation

Dark matter is not a new particle species but emergent infrared feedback in bias transport. Recursive interactions between the first-order plexuses and the second-order gravitational bias field produce effective non-baryonic behavior on galactic and cluster scales. The feedback is wavelength-dependent: short-wavelength modes (baryonic) are screened by plexuses, while long-wavelength modes feel only the universal gravitational response. This naturally reproduces rotation curves, cluster dynamics, and gravitational lensing without requiring cold dark-matter particles. The phenomenology is a direct prediction of the same renewal kernel that gives the fine-structure constant.

4.14 Dark Energy

(Residual Bias and Connectivity Drift)

4.14.1 ΛCDM Description

- Late-time accelerated expansion
- Cosmological constant Λ

What This Explains

Observations of distant supernovae, baryon acoustic oscillations, and the CMB all indicate that the expansion of the universe is currently accelerating, consistent with a small positive cosmological constant that dominates the energy budget today.

4.14.2 SPT Mechanism

- Slow residual drift in the connectivity parameter λ
- Residual vacuum gravitational bias

SPT Explanation

At late times the connectivity parameter λ continues to evolve slowly toward a new equilibrium. This drift produces a residual vacuum gravitational bias that acts as dynamical dark energy. The effective cosmological constant is not a fundamental term but a stability condition of the ordered phase. The observed acceleration is therefore a natural consequence of the substrate's approach toward a new equilibrium connectivity. No fine-tuning is required; the value of the dark-energy density is set by the same renewal statistics that determine all other constants.

4.15 Conclusion

The entire cosmological history in SPT is the story of a single connectivity-driven second-order phase transition followed by the successive stabilization of bias-encoded structures. Every epoch of the standard ΛCDM timeline maps directly onto renewal dynamics:

- Connectivity phase transition → Planck epoch / inflation equivalent,
- Plexus emergence → electroweak symmetry breaking,

- Nucleosynthesis → first three minutes,
- Recombination → CMB,
- Bias amplification → structure formation,
- Connectivity drift → late-time acceleration.

Quantitative predictions—including the fine-structure constant, Newton's constant, nuclear binding energies, and small systematic deviations from classical GR in the infrared—emerge naturally from the stationary measure of the discrete renewal kernel. The framework is falsifiable through gravitational-wave signatures, black-hole spectral features, and high-precision CMB or lensing observations.

Cosmology in SPT is not the evolution of a pre-existing spacetime but the coarse-grained hydrodynamics of an ordered quantum substrate—the same substrate that gave rise to particles, chemistry, and all of physics.

Part IV

APPENDICES

Appendix A

Glossary of Core Concepts

This glossary defines the core concepts of the Substrate–Plexus Theory (SPT) in precise terms. These definitions are intended to eliminate ambiguity and distinguish SPT terminology from conventional physics usage.

A.1 Bias

A statistical preference within the connectivity ensemble for pathways with specific properties to occur more frequently than others. Bias represents the first departure from complete randomness and gives rise to persistent structure.

A.2 Charge

Charge is a coarse-grained view of closed Circulation.

A.3 Circulation

A closed, self-sustaining composite of renewal pathways of a specific type (EM, Weak, Strong) that persists under coarse-graining. Circulations are responsible for lepton number, baryon number, and charge.

A.4 Coarse-Graining

The process by which fluctuating connectivity is averaged over many renewal cycles to produce stable, observable structures. Coarse-graining enables persistent pathways, measurable distances, continuous spacetime, and quantum structure.

A.5 Connectivity

The fundamental stochastic structure of the substrate, defined by the ensemble of possible renewal pathways between configurations. Connectivity has no intrinsic geometry, distance, or time prior to coarse-graining.

A.6 Distance

Distance is not fundamental. At the microscopic level, connectivity fluctuates too rapidly to define a stable separation between regions. Distance emerges only after coarse-graining.

A.7 Energy

Energy is the coarse-grained measure of renewal persistence within the quantum Substrate: it quantifies the rate at which a circulation pattern must be maintained through successive substrate reconfigurations.

At the microscopic level, energy is not a kinematic quantity but a statistical one, associated with the dwell time and renewal rate of bias-carrying structures. Short-lived, rapidly renewing configurations correspond to higher energy, while long-lived, slowly evolving configurations correspond to lower energy.

This relationship reflects an underlying uncertainty relation between renewal duration and energy scale,

$$\Delta E \, \Delta t \sim \hbar_{\text{eff}},$$

which emerges from the stochastic renewal dynamics of the substrate.

Once spacetime has stabilized and the ordered phase acquires approximate time-translation invariance, this conserved renewal persistence becomes expressible as the Noether current associated with temporal symmetry. In this regime it is identified with the usual notion of energy E.

For a free particle one recovers the familiar relations

$$E = \hbar\omega, \qquad E^2 = p^2c^2 + m^2c^4,$$

where ω reflects the phase evolution rate of the underlying circulation pattern.

Energy is therefore not a primitive property of matter or motion, but an emergent measure of how strongly the substrate must sustain a given configuration over time. Like momentum, it is relational and acquires its standard form only after spacetime symmetries have emerged.

A.8 First-Order Biases (EM, Weak, Strong)

The three dominant bias modes that emerge from the substrate: Electromagnetic (EM), Weak, and Strong. Each bias corresponds to a preferred class of renewal pathways and defines a distinct connectivity network.

A.9 Gravity

Gravity is the universal second-order substrate response. It is not a first-order plexus but arises from the quadratic collective response of first-order bias fields.

A.10 Higgs (Retarded Response)

The Higgs is not a field or a sector. It is the dynamical response of the substrate to changes in bias configuration. When circulation structures reconfigure, the substrate cannot instantaneously adjust. This produces a delayed (retarded) response.

A.11 Momentum

Momentum is the coarse-grained measure of directed bias transport (connectivity modification) through the plexus network. At the substrate level it is expressed as a conserved bias flux,

$$\mathbf{J}_\alpha \sim -D_\alpha \nabla B_\alpha,$$

where B_α is the local bias field of plexus α and D_α is the corresponding transport coefficient.

Once spacetime and inertial frames have emerged, and the ordered substrate phase acquires approximate spatial translation invariance, this conserved bias flux is expressible as the Noether current associated with that symmetry. In this regime it is identified with the usual relativistic momentum $\mathbf{p}$.

For massive particles one recovers the familiar relation $\mathbf{p} = m\mathbf{v}$ relative to any inertial observer. Directionality is therefore always relational; there is no preferred or absolute frame at the fundamental level.

A.12 Plexus

A dynamic, bias-dominated connectivity network formed by one of the first-order biases. Plexuses are spatially extended, continuously reconstructed, statistically persistent, and free of intrinsic gradients.

A.13 Plexus Gradient

A spatial variation in bias amplitude produced by circulation. Plexuses contain no intrinsic gradients; gradients arise when circulation modifies the local bias (pathway type preference) distribution.

A.14 Radiation

Radiation is the expulsion of retarded bias that cannot be reabsorbed locally. Photons and gluonic modes are interpreted as different manifestations of this process under different constraint structures.

A.15 Retarded Bias

The residual bias pattern corresponding to a previous configuration, which persists temporarily due to finite reconstruction time. When this bias cannot be locally reabsorbed, it may be expelled as radiation.

A.16 Spacetime

Spacetime is the large-scale, coarse-grained description of the ordered phase of the renewal substrate after connectivity condensation.