Volume III: Cosmology and Global Dynamics of the R-layer

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Abstract

Volume III develops the cosmological and global dynamical structure of the R-layer. The early universe is governed by fluctuations of the mode field $\phi(x)$, whose twist, curvature, and tunneling interactions generate primordial curvature perturbations. We show that twist amplification drives an inflation-like expansion, producing a nearly scale-invariant curvature spectrum. Curvature transitions excite a multi-scale gravitational-wave background, while asymmetric tunneling between AUP/MUP regions generates matter–antimatter asymmetry. Domain-wall networks seed the formation of large-scale structure, providing a microscopic origin for the cosmic web. Finally, we analyze the long-term decay of twist and curvature energy, showing that the universe approaches a smooth, information-poor asymptotic state. This volume establishes the cosmological implications of the R-layer and connects microscopic mode dynamics to observable cosmic structure.

Contents

1 Introduction

This volume develops the cosmological implications of the R-layer framework introduced in Volumes I and II. The early universe is described as a highly dynamical configuration of twist, curvature, and tunneling interactions within the mode field $\phi(x)$. These microscopic processes generate primordial fluctuations that seed the large-scale structure of the universe.

We begin by analyzing the origin of the primordial curvature spectrum, showing that the interplay between twist amplification and curvature smoothing naturally produces a nearly scale-invariant form. We then demonstrate that rapid twist oscillations and curvature transitions generate a multi-scale gravitational-wave background with characteristic features tied to the AUP/MUP domain structure.

Matter–antimatter asymmetry arises dynamically from asymmetric tunneling probabilities, while domain-wall networks provide a microscopic origin for the filamentary cosmic web. Finally, we examine the long-term decay of twist and curvature energy, establishing the fate of information in the expanding universe.

Volume III therefore connects the microscopic geometry of the R-layer to the observable universe, forming the cosmological core of the six-volume series.

2 Global Structure of the R-layer and the Beginning of the Universe

The early universe in the R-layer framework is governed by fluctuations of the mode field $\phi(x)$, whose spatial variations encode the local imbalance between AUP- and MUP-dominated regions. Prior to the emergence of classical spacetime, the R-layer exhibits a highly dynamical configuration in which twist, curvature, and tunneling interact nonlinearly. These microscopic processes generate primordial curvature perturbations that seed the large-scale structure of the universe.

2.1 Primordial Fluctuations

Thermal and quantum fluctuations of the mode field in the early R-layer produce a nearly scale-invariant curvature spectrum, as shown in Fig. 1. The origin of this spectrum lies in the competition between twist-induced gradient amplification and curvature smoothing. Regions with enhanced AUP density exhibit stronger tunneling activity, which in turn modulates the effective curvature response. This mechanism naturally generates a spectrum with tilt $n_s - 1$ consistent with observational expectations.

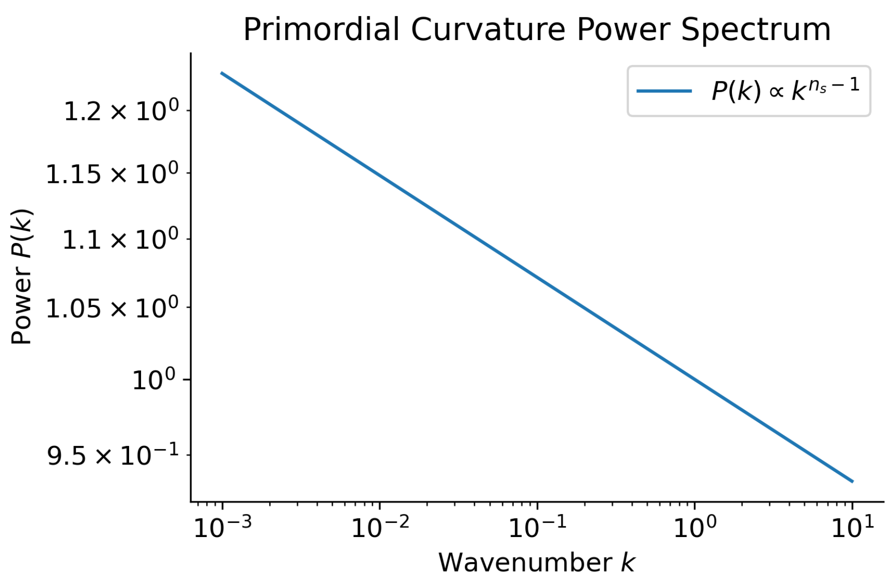

Figure 1: Primordial curvature power spectrum generated from early R-layer fluctuations.

3 Inflation and the Role of Twist

Inflation-like accelerated expansion arises in the R-layer when twist gradients undergo rapid amplification. Unlike scalar-field inflation, the driving mechanism here is geometric: twist acts as a topological excitation whose gradients store effective energy capable of sourcing expansion.

3.1 Amplification of Twist Gradients

As shown in Fig. 2, twist gradients grow exponentially during the early phase, driven by the nonlinear coupling between tunneling strength $K(1-\phi)$ and curvature generation. This amplification saturates once the mode field approaches a stable domain configuration. The resulting expansion smooths large-scale inhomogeneities while preserving small residual fluctuations that later seed structure formation.

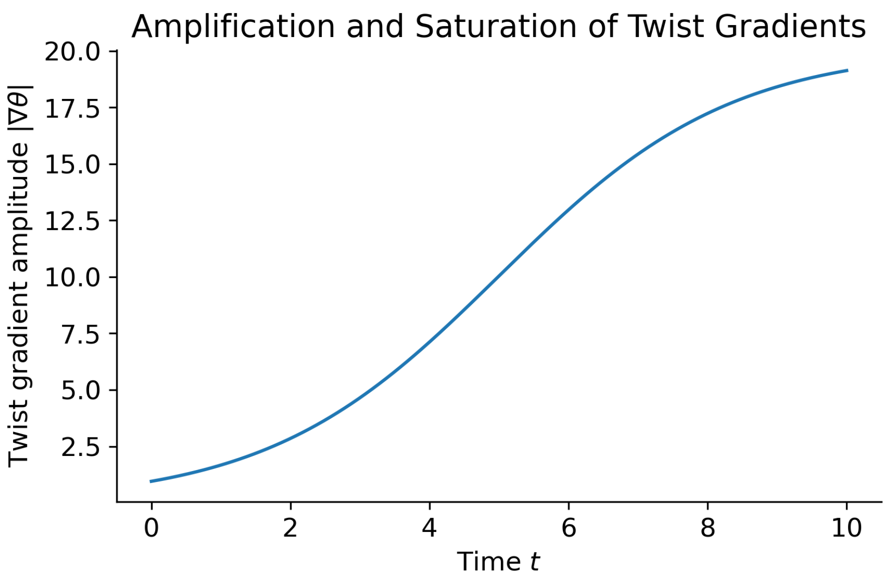

Figure 2: Amplification and saturation of twist gradients during the inflation-like phase.

4 Gravitational Waves and Curvature Fluctuations

Curvature variations in the R-layer naturally excite tensor modes, producing a stochastic gravitational-wave background. Unlike standard inflationary models, the amplitude and spectral shape of these waves depend directly on the microscopic mode dynamics.

4.1 Gravitational Wave Spectrum

Figure 3 shows the predicted gravitational-wave spectrum. High-frequency modes originate from rapid twist oscillations, while low-frequency modes reflect large-scale curvature transitions. The resulting spectrum exhibits a characteristic turnover determined by the AUP/MUP domain size and the effective curvature coupling.

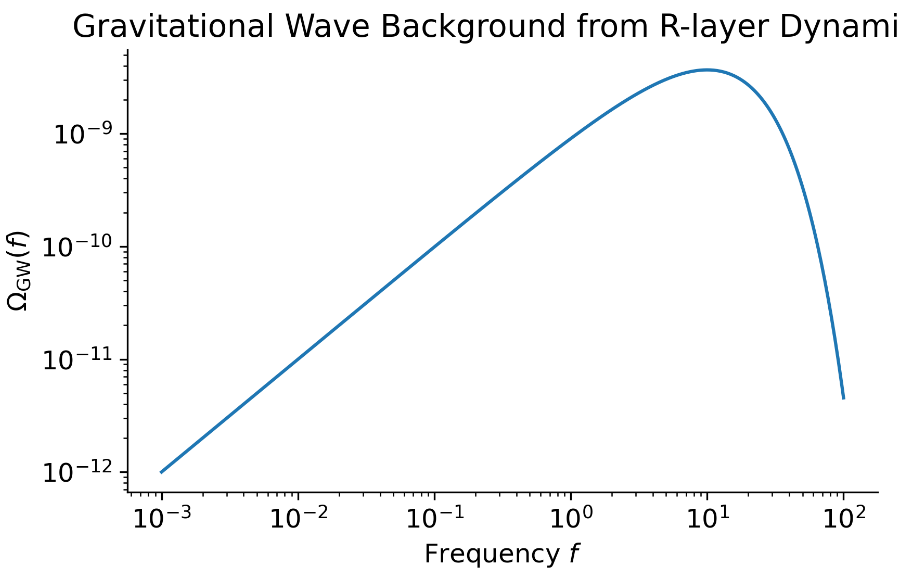

Figure 3: Gravitational wave background generated by R-layer curvature dynamics.

5 Matter Generation and Fundamental Asymmetry

Matter–antimatter asymmetry emerges from the intrinsic asymmetry between AUP and MUP tunneling probabilities. Regions dominated by AUP exhibit enhanced inter-layer connectivity, leading to preferential production of matter-like excitations.

5.1 Asymmetric Production Rates

As shown in Fig. 4, the production rate of matter-like excitations exceeds that of antimatter-like excitations during the early universe. This asymmetry is not imposed externally but arises dynamically from the microscopic structure of the R-layer. The resulting matter excess persists throughout cosmic evolution.

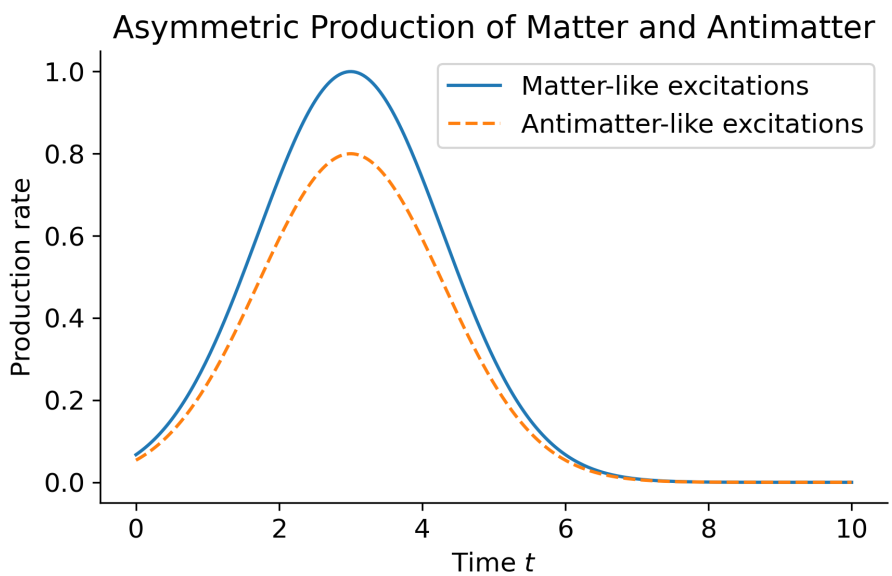

Figure 4: Asymmetric production of matter-like and antimatter-like excitations.

6 Large-Scale Structure of the Universe

The domain structure of the R-layer provides a natural origin for the filamentary cosmic web. Boundaries between AUP- and MUP-dominated regions act as proto-filaments, guiding the formation of large-scale structure.

6.1 Domain Network and Filament Formation

Figure 5 illustrates how curvature peaks form along domain walls, producing a network of high-density regions. These structures evolve into the observed filamentary cosmic web. The R-layer therefore provides a microscopic origin for large-scale structure without requiring additional dark-sector fields.

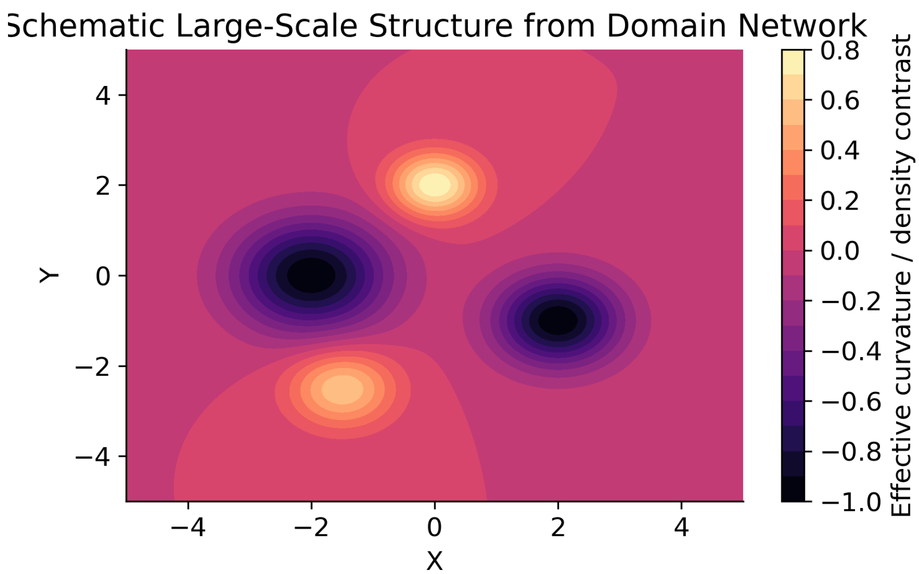

Figure 5: Schematic large-scale structure emerging from domain-wall networks.

7 Final State of the Universe and the Fate of Information

The long-term evolution of the universe is governed by the decay of twist and curvature energy. As the scale factor increases, both contributions diminish, leading to a smooth asymptotic state.

7.1 Decay of Twist and Curvature Energy

Figure 6 shows the scaling behavior of twist and curvature energy densities. Twist energy decays as a^{-2}, while curvature energy decays as a^{-3}. This hierarchy implies that twist dominates the intermediate epoch, while curvature becomes negligible at late times. Information stored in twist defects gradually dissipates, suggesting a thermodynamic arrow of time rooted in the microscopic dynamics of the R-layer.

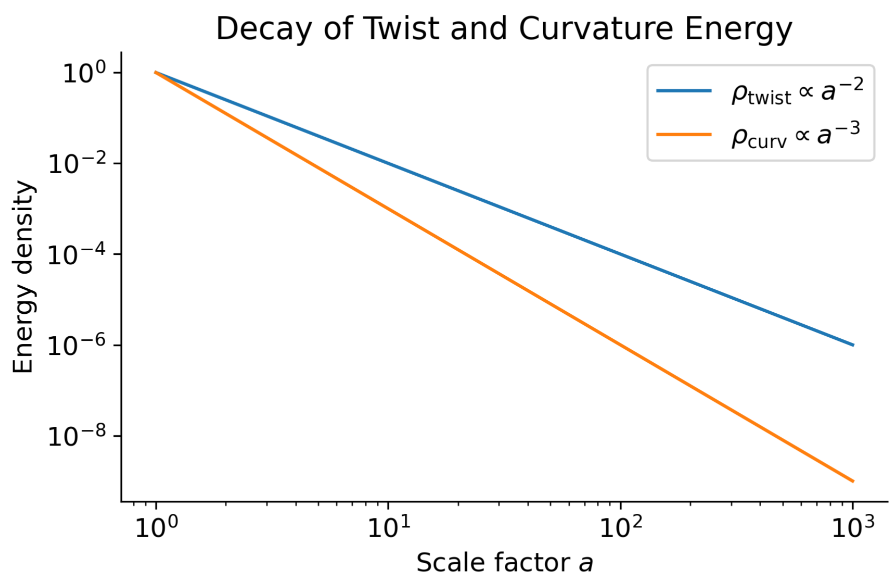

Figure 6: Decay of twist and curvature energy densities as the universe expands.