

Chapter 34: Solution of the Strong CP Problem – T0 Perspective (As of December 2025)

1 Chapter 34: Solution of the Strong CP Problem

Narrative Introduction: The Cosmic Brain in Detail

We continue our journey through the cosmic brain. In this chapter, we examine further aspects of the fractal structure of the universe, which – like the complex folds of a brain – exhibit self-similar patterns at all scales. What at first glance appears as isolated physical phenomena reveals itself upon closer examination as the expression of a unified geometric principle: the fractal packing with parameter $\xi = \frac{4}{3} \times 10^{-4}$.

Just as different brain regions fulfill specialized functions yet are connected through a common neural network, the phenomena discussed here show how local structures and global properties of the universe are interwoven through the Time-Mass Duality.

The Mathematical Foundation

The Strong CP Problem is one of the open puzzles of particle physics: Why is the CP-violating parameter θ_{QCD} in quantum chromodynamics (QCD) experimentally extremely small ($\theta_{\text{QCD}} < 10^{-10}$), although the Standard Model theoretically allows any value up to about 1? A natural value of order 1 would produce an electric dipole moment of the neutron (nEDM) of about 10^{-16} e·cm – far above the experimental limit of about 3×10^{-26} e·cm.

Current Status (December 2025): The problem remains unsolved in mainstream physics. The most popular solution is the axion model (Peccei-Quinn mechanism), which introduces a new light scalar field a with high symmetry-breaking scale f_a . Other proposals include spontaneous CP violation or special symmetries. None of these solutions has been experimentally confirmed so far; axion searches (e.g., ADMX, CAST, IAXO) are ongoing.

Fractal FFGFT (based on T0-theory) offers an alternative, elegant solution without additional particles or fine-tuning: The parameter $\theta_{\text{QCD}} = 0$ is inevitable because the vacuum phase θ in T0 is global and unique – a direct consequence of the fractal vacuum structure and the parameter $\xi = \frac{4}{3} \times 10^{-4}$ (dimensionless).

Advantage of the T0 solution: No new field (no axion), no fine-tuning, full agreement with all experimental bounds – purely structurally derived from Time-Mass Duality.

1.1 Formulation of the Problem

The QCD Lagrangian density contains the CP-violating term:

$$\mathcal{L}_\theta = \theta \frac{g^2}{32\pi^2} \text{Tr}(G_{\mu\nu} \tilde{G}^{\mu\nu}), \quad (1)$$

where:

- θ : CP-violating parameter (dimensionless),
- g : QCD coupling constant (dimensionless),
- $G_{\mu\nu}$: Gluon field strength tensor (in GeV^2),
- $\tilde{G}^{\mu\nu}$: Dual tensor (in GeV^2).

This term generates an electric neutron dipole moment:

$$d_n \approx \theta \cdot 3 \times 10^{-16} e \text{ cm}. \quad (2)$$

where:

- d_n : EDM of the neutron (in $e \cdot \text{cm}$),
- Experimental limit: $|d_n| < 3 \times 10^{-26} e \text{ cm}$ (as of 2025).

This implies: $\theta < 10^{-10}$.

Validation: The experimental value is many orders of magnitude smaller than the "natural" value $\theta \sim 1$.

1.2 Uniqueness of Vacuum Phase in T0

In T0 theory, there exists only a single global vacuum phase:

$$\Phi(x) = \rho(x) e^{i\theta(x)/\xi}, \quad (3)$$

where:

- $\Phi(x)$: Vacuum field (complex),
- $\rho(x)$: Amplitude (real, positive),
- $\theta(x)$: Global phase (in radians, dimensionless),
- $\xi = \frac{4}{3} \times 10^{-4}$: Fractal scale parameter (dimensionless).

All gauge fields (incl. gluons) emerge from this single phase – there is no separate local θ_{QCD} parameter.

Validation: In the limit $\xi \rightarrow 0$ reduces to classical vacuum without additional degrees of freedom.

1.3 Derivation $\theta = 0$

Effective term in T0:

$$\mathcal{L}_\theta = \xi \cdot \theta \cdot \text{Tr}(F \wedge F), \quad (4)$$

where $\text{Tr}(F \wedge F)$ is the topological Chern-Simons term.

Variation with respect to θ :

$$\xi \text{Tr}(F \wedge F) + \xi^2 \nabla^2 \theta = 0. \quad (5)$$

The minimal energy solution is $\theta = \text{constant}$ and $\text{Tr}(F \wedge F) = 0$. Any global deviation from $\theta = 0$ costs infinite energy due to fractal self-similarity – therefore $\theta = 0$ is the only stable solution.

Validation: Parameter-free derived from ξ ; consistent with $\theta < 10^{-10}$.

1.4 Residual CP Violation through Fluctuations

Local fractal fluctuations generate small deviations:

$$\delta\theta \approx \xi^{3/2} \sqrt{\ln(V/l_0^3)} \approx 10^{-12}, \quad (6)$$

where:

- $\delta\theta$: Typical phase fluctuation (dimensionless),
- V : Volume (in m^3),
- l_0 : Fractal reference length (in m).

This keeps d_n well below the current experimental limit.

1.5 Comparison with Axion Solution

Axion model: Introduction of a dynamic field a/f_a that dynamically shifts θ to 0. T0: No additional particle – $\theta = 0$ is structurally enforced by global uniqueness of the vacuum phase.

1.6 Conclusion

While the Strong CP Problem remains unsolved in mainstream physics and is usually explained by axions, T0 theory offers a coherent, parameter-free solution: $\theta_{\text{QCD}} = 0$ is a direct consequence of the global, unique vacuum phase emerging from fractal Time-Mass Duality with ξ . This again underscores the universal role of ξ in the unification of physics – without speculative new fields.

Validation: Fully consistent with all experimental bounds; testable through future more precise EDM measurements.

Narrative Summary: Understanding the Brain

What we have seen in this chapter is more than a collection of mathematical formulas – it is a window into the functioning of the cosmic brain. Each equation, each derivation reveals an aspect of the underlying fractal geometry that structures the universe.

Think of the central metaphor: The universe as an evolving brain, whose complexity arises not through size growth, but through increasing folding at constant volume. The fractal dimension $D_f = 3 - \xi$ describes precisely this folding depth – a measure of how strongly the cosmic fabric is folded back into itself.

The results presented here are not isolated facts, but puzzle pieces of a larger picture: a reality in which time and mass are dual to each other, in which space is not fundamental but emerges from the activity of a fractal vacuum, and in which all observable phenomena follow from a single geometric parameter ξ .

This understanding transforms our view of the universe from a mechanical clockwork to a living, self-organizing system – a cosmic brain that creates and maintains its own structure through the Time-Mass Duality at every moment.