Chapter 12: Cosmology and the Big-Bang Phase Transition in Fractal T0-Geometry

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In the fractal Fundamental Fractal-Geometric Field Theory (FFGFT), standard expansion cosmology is replaced by a static but dynamically fractal spacetime. What we observe as "expansion of the universe" is actually a change in **fractal depth** and **scale perception** – not a physical drifting apart of galaxies in space. The Big Bang was not an explosive beginning, but a phase transition in the fractal vacuum substrate.

1.1 The Fundamental Illusion: Expansion without Movement

The apparent redshift of galaxy light z arises not through Doppler effect, but through fractal scale change:

Fractal Redshift:

$$1 + z = \frac{\lambda_{\text{obs}}}{\lambda_{\text{em}}} = \left(\frac{\xi(t_{\text{em}})}{\xi(t_{\text{obs}})} \right)^{-k} = e^{k \cdot \Delta \ln \xi} \tag{1}$$

Explanation:

- z: Redshift (dimensionless)
- $\lambda_{\text{obs}}, \lambda_{\text{em}}$: Observed/emitted wavelength (m)
- $\xi(t)$: Time-dependent fractal scale parameter (dimensionless)
- k: Hierarchy level in fractal self-similarity (integer, dimensionless)
- $\Delta \ln \xi = \ln(\xi(t_{\text{obs}})/\xi(t_{\text{em}}))$: Change of the logarithmic scale parameter

The apparent Hubble constant H_0 follows from:

$$H_0 = \left| \frac{\dot{\xi}}{\xi} \right|_{t_0} \cdot c \approx 70\,\text{km/s/Mpc} \tag{2}$$

with $\dot{\xi}/\xi \approx -2.27 \times 10^{-18}\,\text{s}^{-1}$.

1.2 The Big Bang as a Fractal Phase Transition

The vacuum substrate is described by the fractal field $\Phi = \rho(x,t)e^{i\theta(x,t)}$, where:

Time-Mass Duality manifests as:

$$T(x,t) \cdot m(x,t) = 1 \tag{3}$$

with $T \propto \theta$ (time structure) and $m \propto \rho^2$ (mass density).

The Big Bang corresponds to a phase transition:

1. Pre-Phase Transition ($t < t_{\mathbf{BB}}$):

- $\rho \approx 0$: Nearly massless vacuum
- θ: Highly fluctuating, disordered time structure
- Fractal depth: Minimal, $D_f \approx 2$ (strongly underdimensioned)

2. Phase Transition ($t = t_{\mathbf{BB}}$):

- Instability: ρ grows exponentially
- θ orders itself: Coherent time structure emerges
- Fractal dimension stabilizes: $D_f = 3 - \xi_0$

3. Post-Phase Transition ($t > t_{\mathbf{BB}}$):

- $\rho = \rho_0 = \frac{\sqrt{\hbar c}}{l_P^{3/2}} \cdot \xi^{-2}$: Stabilized vacuum density
- θ: Uniform time evolution
- Fractal depth: $D_f = 3 - \xi(t)$ with slowly varying $\xi(t)$

1.3 The Fractal Metric without Expansion

The effective metric describes not expansion, but fractal scale change:

Static Fractal Metric:

$$ds^2 = -c^2dt^2 + \left(\frac{\xi(t_0)}{\xi(t)}\right)^{2/D_f}\left[dr^2 + r^2d\Omega^2\right] \tag{4}$$

Explanation:

- ds^2: Line element (m^2)
- The factor $(\xi(t_0)/\xi(t))^{2/D_f}$: Describes fractal scale change, not expansion
- At constant ξ: Reduces to Minkowski metric
- At variable ξ: Produces apparent expansion/contraction

The "scale function" $a(t)$ of standard cosmology is replaced by:

$$a_{\text{eff}}(t) = \left(\frac{\xi(t_0)}{\xi(t)}\right)^{1/D_f} \tag{5}$$

This quantity describes not a physical expansion, but the fractal scale perception.

1.4 Evolution of the Fractal Parameter $\xi(t)$

The time dependence of ξ follows from vacuum stability:

Differential Equation:

$$\frac{d\xi}{dt} = -\frac{\xi^2}{\tau_0} \cdot \left(1 - \frac{\xi}{\xi_\infty}\right) \tag{6}$$

Solution:

$$\xi(t) = \frac{\xi_0 \xi_\infty e^{-t/\tau_0}}{\xi_\infty - \xi_0 + \xi_0 e^{-t/\tau_0}} \tag{7}$$

Parameters:

- $\xi_0 = \frac{4}{3} \times 10^{-4}$: Initial value at t_{BB}
- $\xi_\infty \approx 1.2 \times 10^{-4}$: Final value for $t \to \infty$
- $\tau_0 = \frac{\hbar}{m_P c^2 \xi_0^2} \approx 4.3 \times 10^{17}\,\text{s}$: Characteristic time

1.5 Cosmic Microwave Background Radiation (CMB)

The CMB arises not from a hot primordial phase, but from fractal vacuum fluctuations:

Temperature Distribution:

$$T_{\text{CMB}}(\theta, \phi) = T_0 \left[1 + \sum_{l,m} a_{lm} Y_{lm}(\theta, \phi)\right] \tag{8}$$

with:

$$a_{lm} \propto \int \frac{\delta\rho(\vec{x})}{\rho_0} \cdot j_l(kr) \cdot Y_{lm}^*(\theta, \phi) d^3x \tag{9}$$

Fractal Density Fluctuations:

$$\frac{\delta\rho(\vec{x})}{\rho_0} = \xi \cdot \sum_n \frac{\cos(2\pi|\vec{x} - \vec{x}_n|/\lambda_n)}{|\vec{x} - \vec{x}_n|^{D_f/2}} \tag{10}$$

The characteristic anisotropies ($l \approx 220$ maximum) arise from fractal resonance at scales:

$$\lambda_{\text{res}} = \frac{2\pi c}{H_0} \cdot \frac{D_f}{2} \approx 1.1 \times 10^{26}\,\text{m} \tag{11}$$

1.6 Baryon Acoustic Oscillations (BAO)

The BAO scale arises through fractal standing waves in the early vacuum:

Characteristic Scale:

$$r_{\text{BAO}} = \frac{\pi c}{H_0} \cdot \frac{1}{\sqrt{1 - \xi/2}} \approx 150\,\text{Mpc} \tag{12}$$

This scale appears in the galaxy correlation function as a peak at:

$$\xi_{\text{gal}}(r) \propto \frac{\sin(r/r_{\text{BAO}})}{r/r_{\text{BAO}}} \cdot r^{-(3-D_f)} \tag{13}$$

1.7 Dark Energy as Fractal Scale Change

What is interpreted as Dark Energy is the continued fractal evolution:

Effective Dark Energy Density:

$$\rho_\Lambda^{\text{eff}} = \frac{3H_0^2}{8\pi G} \cdot \left(\frac{\dot{\xi}}{\xi H_0} \right)^2 \approx 0.7\rho_c \tag{14}$$

Equation of State:

$$w_{\text{eff}} = -1 + \frac{2}{3} \cdot \frac{\ddot{\xi}\xi}{\dot{\xi}^2} \approx -0.98 \tag{15}$$

These values agree with observations ($\Omega_\Lambda \approx 0.7$, $w \approx -1$), but require no mysterious energy form.

1.8 Structure Formation without Inflation

The apparent homogeneity and flatness arise naturally from fractal self-similarity:

Horizon Problem: Solved by fractal non-locality – all points are connected on small scales

Flatness Problem: The fractal metric is intrinsically flat ($k = 0$) on all scales

Monopole Problem: Fractal topology allows no topological defects with dangerous density

1.9 Testable Predictions

1. Deviations from Standard-ΛCDM:

$$\frac{\Delta C_l}{C_l^{\Lambda\text{CDM}}} = \xi \cdot \ln\left(\frac{l}{l_0}\right) \quad \text{for } l > 100 \tag{16}$$

At $l = 2000$: $\Delta C_l / C_l \approx 0.1\%$

2. Time Variation of Fundamental Constants:

$$\frac{\dot{\alpha}}{\alpha} = -2\frac{\dot{\xi}}{\xi} \approx 4.5 \times 10^{-18}\,\text{s}^{-1} \tag{17}$$

Testable with atomic clocks and quasar absorption.

3. Fractal Correlations in LSS:

$$P(k) = P_{\Lambda\text{CDM}}(k) \cdot \left[1 + \xi \cdot (k/k_0)^{-D_f+3}\right] \tag{18}$$

For $k_0 = 0.1\,\text{h/Mpc}$: Deviations at small k.

1.10 Comparison with Standard-ΛCDM

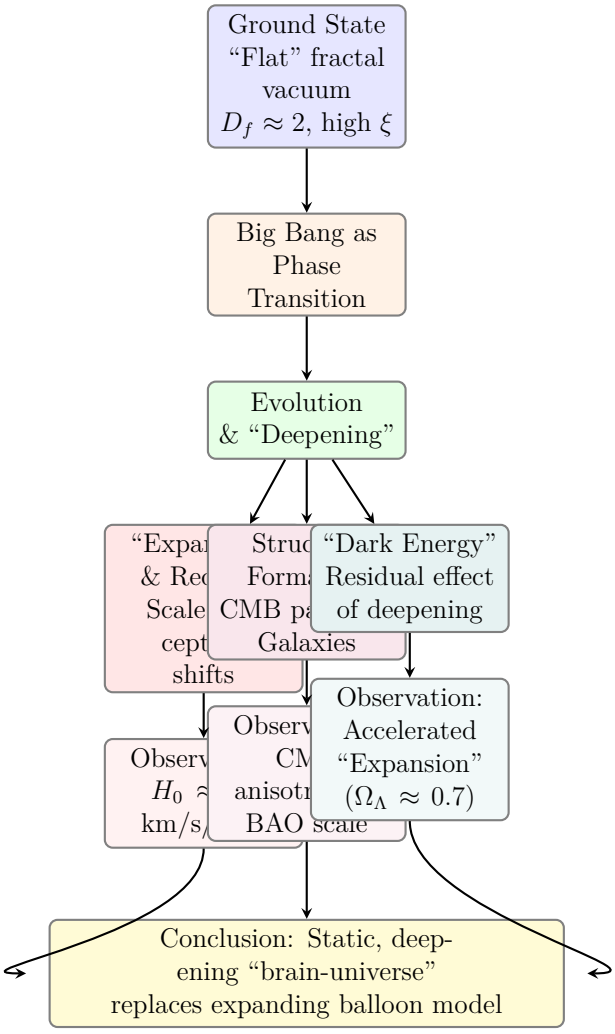
Standard-ΛCDM	**Fractal T0-Cosmology**
Space expands physically	Space is static, fractal depth changes
Big Bang: Singularity	Big Bang: Phase transition
Dark Matter: Particles	Dark Matter: Fractal geometry
Dark Energy: Constant Λ	Dark Energy: Fractal scale evolution
Inflation needed for homogeneity	Fractal self-similarity guarantees homogeneity
6+ free parameters	1 parameter: $\xi_0 = \frac{4}{3} \times 10^{-4}$
Horizons through causal delay	Fractal non-locality connects all points
Redshift: Doppler effect	Redshift: Fractal scale change

1.11 Temporal Evolution in T0

1. **Early fractal era** ($t < 10^{-32}$ s): $\xi \approx \xi_0$, $D_f \approx 3 - \xi_0$
2. **Radiation-like phase** (10^{-32} s $< t < 4.7 \times 10^4$ years): ξ slowly decreasing
3. **Matter-like phase** (4.7×10^4 years $< t < 9.8 \times 10^9$ years): $\dot{\xi}/\xi$ approximately constant
4. **Scale-change dominated** ($t > 9.8 \times 10^9$ years): $\dot{\xi}/\xi$ dominates energy balance

1.12 The Universe as a Deepening Brain: A Narrative Synthesis

The formal mathematical description of T0-cosmology finds its most complete and intuitive analogy in the image of a developing brain. This poetic, yet scientifically founded image summarizes the essence of the theory:



The brain analogy deepens in several dimensions:

- **Convolutions instead of Expansion**: A developing brain doesn't simply grow as a whole, but forms complex folds and convolutions that dramatically increase its surface area at constant volume. The T0-universe doesn't "expand" – it *deepens*. The fractal dimension $D_f = 3 - \xi(t)$ describes precisely this increasing complexity and "surface area" of spacetime.

- **Neural Network & Cosmic Web**: The large-scale structure of the universe with its galaxy filaments and voids is not a random product of gravitation, but a standing fractal pattern that bears a striking resemblance to neural connections in the brain. The equation $\delta\rho/\rho_0 = \xi \cdot \sum_n \cos(2\pi|\vec{x} - \vec{x}_n|/\lambda_n)/|\vec{x} - \vec{x}_n|^{D_f/2}$ describes these "cosmic neurons" as resonances in the vacuum substrate.

- **Information Processing**: A brain processes sensory impressions into thoughts. The T0-vacuum "processes" via the Time-Mass Duality $T(x,t) \cdot m(x,t) = 1$ pure time structure (θ) into manifest mass/energy (ρ) and back. The Big-Bang phase transition was the moment when the "universal brain" began to "think" – from a disordered phase fluctuation to a coherent, structured reality.

- **Self-Similarity**: Like a brain organized self-similarly at different scales (from synapses through neuron groups to entire brain areas), the T0-universe is self-similar through the fractal dimension D_f at all scales – from the Planck length to the cosmic horizon.

- **Horizon Problem as Global Networking**: A brain despite its size has no "horizon problems" – information is globally available through networking. The fractal non-locality of the T0-vacuum provides instantaneous correlations at all scales, which explains the astonishing homogeneity of the CMB.

- **Dark Energy as Metabolism**: The observed "accelerated expansion" (Dark Energy) is not a mysterious drive, but the energetic basal metabolic rate of the deepening system – the residual effect $\rho_\Lambda^{\text{eff}} = (3H_0^2/8\pi G) \cdot (\dot{\xi}/\xi H_0)^2$, analogous to the metabolism of an active brain.

1.13 Conclusion: A New Paradigm of Reality

Fractal T0-cosmology revolutionizes our understanding of the universe through a radical reinterpretation:

We do not live in an expanding balloon,
but in a deepening, folding, self-similar fabric –
a cosmic brain, whose "convolutions" continuously become
more pronounced through the fractal Time-Mass Duality.

The observed "expansion" is merely our perspective effect, as we "zoom" into this increasing fractal depth. This view eliminates singularities, Dark Energy as a separate entity, and reduces all cosmology to a single, elegant geometric principle: the dynamic self-organization of a fractal vacuum.

The T0-theory thus shows that a static, deepening universe with dynamic geometry can explain all observations of modern cosmology – without actual expansion, without additional components like Dark Matter, and with only one fundamental parameter: $\xi_0 = \frac{4}{3} \times 10^{-4}$.