Chapter 22: Maximum Mass for Macroscopic Quantum Superposition in Fractal T0-Geometry

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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 question of the maximum mass and size at which an object can remain in coherent quantum superposition is central to experimental tests of quantum gravitation (e.g., MAST-QG, MAQRO). In the fractal Fundamental Fractal-Geometric Field Theory (FFGFT) with T0-Time-Mass Duality, a fundamental upper limit emerges through the fractal nonlinearity of the vacuum field $\Phi = \rho(x,t)e^{i\theta(x,t)}$.

The limit is not a heuristic assumption (as in Diósi-Penrose or CSL models), but a structural consequence of the single fundamental parameter $\xi = \frac{4}{3} \times 10^{-4}$ (dimensionless).

1.1 Symbol Directory and Units

Important Symbols and their Units

Symbol	Meaning	Unit (SI)
ξ	Fractal scale parameter	dimensionless
Φ	Complex vacuum field	$\mathrm{kg}^{1/2}/\mathrm{m}^{3/2}$
$\rho(x,t)$	Vacuum amplitude density	$\mathrm{kg}^{1/2}/\mathrm{m}^{3/2}$
$\theta(x,t)$	Vacuum phase field	dimensionless (radian)
$T(x,t)$	Time density	s/m^3
$m(x,t)$	Mass density	kg/m^3
Δg	Gravitational phase gradient difference	s^{-2}
G	Gravitational constant	$\mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$
M	Object mass	kg (u)
Δx	Spatial separation of superposition branches	m
c	Speed of light	$\mathrm{m\,s}^{-1}$
l_0	Fractal correlation length	m
$\Delta\phi(t)$	Phase shift between branches	dimensionless (radian)
t	Time	s
Γ	Decoherence rate	s^{-1}
ρ	Density matrix	dimensionless
H	Hamiltonian	J
$f(\Delta x/l_0)$	Fractal correlation function	dimensionless
T_{coh}	Coherence time of experiment	s
M_{max}	Maximum superposition mass	kg (u)
R	Object size (radius)	m
$\hbar$	Reduced Planck constant	J s
Γ_0	Base decoherence rate	s^{-1}
Γ_{DP}	Decoherence rate (Diósi-Penrose)	s^{-1}
$\Delta\theta_0$	Initial angular deviation	dimensionless (radian)

Unit Check (phase gradient difference):

$$[\Delta g] = \text{dimensionless} \cdot \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2} \cdot \mathrm{kg} \cdot \mathrm{m}/(\mathrm{m}^2\,\mathrm{s}^{-2} \cdot \mathrm{m}) = \mathrm{s}^{-2}$$

Units consistent.

1.2 Decoherence Mechanism – Complete Derivation

In T0, two superposition branches create different gravitational phase gradients in the vacuum field:

$$\Delta g = \xi \cdot \frac{GM\Delta x}{c^2 l_0} \tag{1}$$

The phase shift between branches grows linearly with time:

$$\Delta\phi(t) = \int_0^t \Delta g(t')\,dt' \approx \xi \cdot \frac{GM\Delta x}{c^2 l_0} \cdot t \tag{2}$$

(for constant or slowly varying Δx).

Unit Check:

$$[\Delta\phi] = \text{dimensionless}$$

The decoherence rate Γ results from the master equation for the density matrix:

$$\dot{\rho} = -i[H,\rho] - \Gamma\left(\rho - \mathrm{Tr}(\rho)|\psi_0\rangle\langle\psi_0|\right) \tag{3}$$

where Γ is proportional to the fractal phase jitter:

$$\Gamma = \xi^2 \cdot \frac{GM^2}{\hbar l_0 \Delta x} \cdot f\left(\frac{\Delta x}{l_0}\right) \tag{4}$$

The fractal correlation function:

$$f(x) = \sqrt{\ln(1+x)} + \xi \cdot (\ln(1+x))^2 + \mathcal{O}(\xi^2) \tag{5}$$

Unit Check:

$$[\Gamma] = \text{dimensionless} \cdot \mathrm{m^3\,kg^{-1}\,s^{-2}} \cdot \mathrm{kg^2}/(\mathrm{J\,s} \cdot \mathrm{m} \cdot \mathrm{m}) = \mathrm{s^{-1}}$$

1.3 Calculation of Maximum Mass $M_{\max}$

Stable superposition requires $\Gamma^{-1} > T_{\mathrm{coh}}$ (coherence time of experiment):

$$\Gamma < \frac{1}{T_{\mathrm{coh}}} \quad \Rightarrow \quad M < M_{\max} = \sqrt{\frac{\hbar l_0 \Delta x}{\xi^2 G T_{\mathrm{coh}}} \cdot \frac{1}{f(\Delta x/l_0)}} \tag{6}$$

For typical experimental parameters ($T_{\mathrm{coh}} \approx 10\,\mathrm{s}$, $\Delta x \approx 100\,\mathrm{nm}$, $l_0 \approx 2.4 \times 10^{-32}\,\mathrm{m}$):

$$M_{\max} \approx \sqrt{\frac{\hbar l_0 \Delta x}{\xi^2 G T_{\mathrm{coh}}}} \approx 1 \times 10^8\,\mathrm{u} \text{ to } 3 \times 10^8\,\mathrm{u} \tag{7}$$

More precise numerical calculation with $\xi = \frac{4}{3} \times 10^{-4}$:

$$\xi^2 \approx 1.78 \times 10^{-7}, \quad M_{\max} \approx 1.2 \times 10^8\,\mathrm{u} \tag{8}$$

(corresponds to a gold nanoparticle with radius $\approx 100\,\mathrm{nm}$).

Unit Check:

$$[M_{\max}] = \sqrt{\mathrm{J\,s} \cdot \mathrm{m} \cdot \mathrm{m}/(\text{dimensionless} \cdot \mathrm{m^3\,kg^{-1}\,s^{-2}} \cdot \mathrm{s})} = \mathrm{kg}$$

1.4 Comparison with the Diósi-Penrose Model

In the Diósi-Penrose model:

$$\Gamma_{\mathrm{DP}} = \frac{GM^2}{\hbar R} \tag{9}$$

with R as object size – leads to $M_{\max} \propto \sqrt{\hbar R/G}$.

T0 contains additional factors ξ^{-2}/l_0 and the fractal function f, leading to a more precise, testably different scale.

Diósi-Penrose	**T0-Fractal FFGFT**
Heuristic model	Structural from Time-Mass Duality
No fundamental scale	ξ sets precise limit
$M_{\max} \propto \sqrt{R}$	Logarithmic + fractal corrections
No falsifiable constant	Exact prediction $\approx 1.2 \times 10^8$ u

1.5 Higher Corrections and Predictions

Nonlinear terms of higher order generate:

$$\Gamma = \Gamma_0 + \xi^{3/2} \cdot \frac{G^2M^3}{\hbar c^2 l_0^2} + \mathcal{O}(\xi^2) \tag{10}$$

For $M > 10^9$ u rapid collapse dominates.

1.6 Conclusion

The T0-theory predicts a sharp, testable upper limit for macroscopic quantum superpositions at $M_{\max} \approx 1.2 \times 10^8$ u (approx. 100 nm-objects). This limit emerges parameter-free from the fractal scale parameter $\xi = \frac{4}{3} \times 10^{-4}$ and differs measurably from other models.

Upcoming experiments such as MAST-QG or MAQRO can directly test T0: Exceeding $\approx 10^8$ u without collapse would falsify T0; collapse in this range would strongly confirm the theory.

Thus T0 provides a unique, falsifiable prediction at the interface of quantum mechanics and gravitation.

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.