Chapter 21: Ron Folman's Tş Quantum Gravity Experiment in Fractal T0-Geometry

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The Tş experiment ("T-cubed", Ron Folman et al., 20212025) shows in high-precision atom interferometry a gravitational phase shift $\Delta\phi \propto gT^3$, which deviates from the classical expectation T^2. In the fractal Fundamental Fractal-Geometric Field Theory (FFGFT) with T0-Time-Mass Duality, this explains a direct measurement of the fractal vacuum phase curvature, derived from 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
$\Delta\phi$	Gravitational phase shift	dimensionless (radian)
g	Gravitational acceleration	$\mathrm{m\,s^{-2}}$
T	Interferometer time (separation time)	s
m	Atomic mass	kg
$\hbar$	Reduced Planck constant	J s
Δz	Vertical path separation	m
$\partial_i\theta$	Gradient of vacuum phase	$\mathrm{m^{-1}}$
$\theta(z)$	Vacuum phase at position z	dimensionless (radian)
$\partial_z\theta$	Partial derivative of phase with respect to z	$\mathrm{m^{-1}}$
$\partial_z^2\theta$	Second derivative of phase with respect to z	$\mathrm{m^{-2}}$
a_ξ	Fractal correction constant	dimensionless
$\mathcal{F}(X)$	Fractal function correction	dimensionless

Unit Check (classical phase shift):

$$[\Delta\phi_{\text{class}}] = \text{kg} \cdot \text{m}\,\text{s}^{-2} \cdot \text{m} \cdot \text{s}/\text{J}\,\text{s} = \text{dimensionless (radian)}$$

Units consistent.

1.2 The Tş Experiment Precise Description

In standard atom interferometry (light-pulse Ramsey-Bordé), a $\pi/2$-pulse splits the wave packet, gravitation shifts the paths by $\Delta z = \frac{1}{2}gT^2$, and a second pulse recombines. The phase is:

$$\Delta\phi_{\text{class}} = \frac{mg\Delta zT}{\hbar} = \frac{mg^2T^3}{2\hbar} \tag{1}$$

However, a deviation is observed that effectively yields $\Delta\phi \propto T^3$ when the full wave packet dynamics is considered (based on results from 20212025).

Unit Check:

$$\left[\frac{mg^2T^3}{\hbar}\right] = \text{kg} \cdot (\text{m}\,\text{s}^{-2})^2 \cdot \text{s}^3/\text{J}\,\text{s} = \text{dimensionless}$$

1.3 Detailed Derivation in T0

In T0, gravitation is a gradient of the vacuum phase:

$$g_i = -\xi \cdot \partial_i\theta \tag{2}$$

The phase of an atom along a worldline $x^i(t)$ accumulates:

$$\phi(t) = \int_0^t \theta(x^i(t'))\,dt' \tag{3}$$

For two paths with vertical separation $\Delta z(t) = \frac{1}{2}gt^2$:

$$\Delta\phi = \int_0^T [\theta(z + \Delta z(t')) - \theta(z)]\,dt' \tag{4}$$

Taylor expansion of the phase:

$$\theta(z + \Delta z) = \theta(z) + (\partial_z\theta)\Delta z + \frac{1}{2}(\partial_z^2\theta)(\Delta z)^2 + \mathcal{O}((\Delta z)^3) \tag{5}$$

Inserting $\Delta z(t) = \frac{1}{2}gt^2$:

$$\begin{aligned}
\Delta\phi &= \int_0^T \left[(\partial_z\theta) \cdot \frac{1}{2}gt^2 + \frac{1}{2}(\partial_z^2\theta)\left(\frac{1}{2}gt^2\right)^2 + \mathcal{O}(t^6)\right] dt' \\
&= (\partial_z\theta) \cdot \frac{1}{2}g\frac{T^3}{3} + \frac{1}{2}(\partial_z^2\theta) \cdot \frac{1}{4}g^2\frac{T^5}{5} + \mathcal{O}(T^7) \\
&= \xi g\frac{T^3}{6} + \xi^2 \cdot \frac{g^2T^5}{40} \cdot (\partial_z^2\theta) + \mathcal{O}(T^7)
\end{aligned} \tag{6}$$

The leading term is $\Delta\phi \propto T^3$, with coefficient $\xi g/6$ (adjusted for fractal normalization).

1.4 Higher Corrections and Testability

Nonlinearities in the fractal function $\mathcal{F}(X)$ generate higher terms:

$$\Delta\phi = \xi \frac{gT^3}{6} + \xi^{3/2} \frac{g^2 T^5}{40} \cdot a_\xi + \xi^2 \frac{g^3 T^7}{336} + \cdots \tag{7}$$

Future experiments with longer T can measure these corrections and directly determine ξ.

1.5 Comparison with Standard Quantum Mechanics + GR

Standard QM+GR expects pure T^3 only under special conditions (full wave packet overlap). T0 predicts T^3 as a fundamental consequence of the vacuum phase, independent of pulse timing.

Standard QM + GR	**T0-Fractal FFGFT**
$\Delta\phi \propto T^2$ (classical)	$\Delta\phi \propto T^3$ (fractal)
Wave packet effects ad-hoc	Structural phase curvature
No intrinsic scale	ξ sets coefficient
No higher terms	Predictable $\xi^{3/2}T^5$-correction

1.6 Conclusion

The Tş experiment is a direct measurement of the fractal vacuum phase curvature in T0-theory. The T^3-scaling is not a coincidence, but proof of the Time-Mass Duality with $\xi = \frac{4}{3} \times 10^{-4}$. Precise future measurements can calibrate ξ and test the theory, while deviations from the standard expectation confirm T0.

This interpretation reduces the experiment to an elegant consequence of the dynamic fractal spacetime structure.