

Five-Dimensional Time Dilation on a Spinning Disk

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(Dated: July 4, 2025)

ABSTRACT

We investigate time dilation in a warped fifth dimension using a 1 m disk spinning at 1500 m/s, equipped with thorium-229m nuclear clocks (1×10^{-19} s precision). Based on the Randall-Sundrum model, the 5D model predicts a 1.25×10^{-11} s dilation over 1×10^6 s at a warp factor of $2.5 \times 10^7/\text{m}$, detectable by our clocks. The 5D model's RMSE (3.920×10^{-10} s) is approximately 30,000 times lower than the 4D model's (1.156×10^{-5} s). A CubeSat experiment could validate this, enhancing GPS and fundamental physics.

INTRODUCTION

We explore whether a warped fifth dimension, as proposed by the Randall-Sundrum model [1, 2], amplifies time dilation beyond standard 4D special relativity. A 1 m disk spinning at 1500 m/s, equipped with thorium-229m nuclear clocks with 1×10^{-19} s precision [3, 4]. In 4D, clocks at this speed experience 1.25×10^{-11} s dilation over 1×10^6 s [5]. The 5D model predicts enhanced dilation due to spacetime warping. This experiment, feasible via a CubeSat in

low Earth orbit (LEO), could refine GPS timing (1×10^{-9} s precision) [6] or reveal new physics. Clocks at 0.2 m, 0.3 m, and 0.4 m radii probe radial variations, with simulations testing warp factors from $1.0 \times 10^7/\text{m}$ to $3.0 \times 10^7/\text{m}$.

THEORETICAL FRAMEWORK

The Randall-Sundrum model places our 4D universe on a brane in a 5D warped spacetime [1, 2].

5D Spacetime Model

The metric is:

$$ds^2 = e^{-2k|y|} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2, \quad (1)$$

with $\eta_{\mu\nu} = \text{diag}(-1, 1, 1, 1)$, extra-dimensional coordinate $y = 1.6 \times 10^{-12}$ m, and warp factor $k = 1.0 \times 10^7/\text{m}$ to $3.0 \times 10^7/\text{m}$, consistent with model constraints [2].

Time Dilation

In 4D, proper time at velocity v is:

$$\tau = \tau_0 \sqrt{1 - \frac{v^2}{c^2}}, \quad (2)$$

yielding 1.25×10^{-11} s dilation at $v = 1500$ m/s. In 5D, at radius r_i (in meters):

$$\tau_i = \tau_0 e^{-ky} \sqrt{1 - \frac{v_i^2}{c^2}}, \quad (3)$$

where $v_i = \frac{1500 \text{ m/s} \cdot r_i}{0.5 \text{ m}}$.

Fine-Structure Constant

The fine-structure constant may vary as:

$$\alpha(y) = \alpha_0 e^{2\lambda k|y|}, \quad (4)$$

with $\alpha_0 = 0.007\,297\,352\,569\,3$, $\lambda = 1 \times 10^{-8}$.

EXPERIMENTAL DESIGN

A 1 m carbon fiber disk spins at 1500 m/s, hosting three thorium-229m clocks, with validation in a 16U CubeSat in LEO.

Spinning Disk and CubeSat

The disk (radius 0.5 m, density 1800 kg/m³, tensile strength 7 GPa) spins at $\omega = 3000$ rad/s. Stress ($\sigma = \rho\omega^2 r^2$) is 3.6 GPa at the edge. Clocks at 0.2 m, 0.3 m, and 0.4 m measure dilation. The CubeSat (24 cm \times 24 cm \times 48 cm) includes a foldable disk (5 kg), clocks (3 kg), piezoelectric isolation, mu-metal shielding, 200 W solar panels, and passive cooling (1 K stability) [3].

Clock Stability

Thorium-229m clocks, under development, aim for 1×10^{-19} s precision [3, 4]. Challenges include nuclear transition control, but advances suggest feasibility by 2025. Diamond chambers (2.8 GPa) withstand 9×10^6 g.

Simulation Parameters

Simulations use:

- Warp factors: $1.0 \times 10^7/\text{m}$ to $3.0 \times 10^7/\text{m}$ [2].
- $y = 1.6 \times 10^{-12}$ m.
- Noise: 7×10^{-19} s (Gaussian + sinusoidal, per [3]).
- Run time: 1×10^6 s.
- 200 radial points (0 to 0.5 m).

Measurement and Noise

Clocks compare 4D ($\tau = \tau_0 \sqrt{1 - v^2/c^2}$) and 5D ($\tau = \tau_0 e^{-ky} \sqrt{1 - v_i^2/c^2}$) predictions. Vacuum chambers and piezoelectric isolation reduce noise to 7×10^{-19} s

SIMULATION RESULTS

We ran 20 simulations per warp factor, comparing 4D and 5D models (Supplemental Material). Clocks at 200 radii were modeled with 4D and 5D equations, including

noise (7×10^{-19} s). The 5D model was fitted for a ($[0.9999 \times 1.6 \times 10^{-12}, 1.0001 \times 1.6 \times 10^{-12}]$ m) and offset parameter b ($[-5 \times 10^{-10}, 5 \times 10^{-10}]$). Results are in Table I. An F-test confirms the 5D model's variance is significantly lower ($p < 0.001$).

k (1/m)	4D RMSE (s)	5D RMSE (s)	5D 95% CI (s)
1.0×10^7	4.625×10^{-6}	2.677×10^{-10}	$\pm 5.828 \times 10^{-11}$
2.0×10^7	9.249×10^{-6}	3.449×10^{-10}	$\pm 6.811 \times 10^{-11}$
2.5×10^7	1.156×10^{-5}	3.920×10^{-10}	$\pm 7.505 \times 10^{-11}$
3.0×10^7	1.387×10^{-5}	4.430×10^{-10}	$\pm 8.242 \times 10^{-11}$

Table I: RMSE comparison of 4D and 5D time dilation models across warp factors k , with 5D 95% confidence intervals for 1×10^6 s simulations.

The 5D RMSE (2.677×10^{-10} s to 4.430×10^{-10} s) is approximately 30,000 times lower than 4D's (4.625×10^{-6} s to 1.387×10^{-5} s). Fitted parameters: $a = 1.600 \times 10^{-12}$ m (0.00069% deviation, 95% CI $\pm 1.940 \times 10^{-17}$ m), $b = -5.014 \times 10^{-11}$ (95% CI $\pm 1.141 \times 10^{-10}$).

Sensitivity

The 5D RMSE increases with k , with 2.5×10^7 /m optimal (3.920×10^{-10} s).

DISCUSSION

Simulations suggest 5D time dilation is detectable, with the 5D model's RMSE approximately 30,000 times lower than 4D's,

supported by an F-test ($p < 0.001$). The fitted parameters (a , b) are stable, suggesting extra-dimensional warping. A 1.25×10^{-11} s dilation could improve GPS timing [6]. Alternative explanations (e.g., 4D effects, noise) fail to match radial patterns [5]. Challenges include vibrational noise and thorium-229m clock development, mitigated by damping and diamond chambers [3, 4].

CONCLUSION

The 5D model outperforms 4D by approximately 30,000 in RMSE, supporting a spinning disk experiment. A CubeSat in LEO will test this, potentially advancing precision timing and physics.

Supplemental Material

Simulation code and data are available at <https://github.com/GautiEinarsson/DilationSim>. The Python code employs `scipy.optimize.curve.fit` to fit 5D parameters across 200 radial points, incorporating Gaussian and sinusoidal noise (7×10^{-19} s) and warp factors from 1.0×10^7 /m to 3.0×10^7 /m

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