

A Unified Time Dilation Equation: Bridging Relativistic and Quantum Systems Through Curvature Tension

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Abstract

This paper presents a unified time dilation equation that merges gravitational and velocity-based time dilation into a single, curvature-dependent framework. Historically, time dilation has been treated as two distinct phenomena under General Relativity (gravitational) and Special Relativity (velocity-based). This paper demonstrates that both effects emerge from the same underlying curvature tension in spacetime geometry.

The derived equation:

$$\Delta T = \Delta T_0 * \text{sqrt}(1 - (2GM/rc^2 + v^2/c^2))$$

$$\Delta T = \Delta T_0 \sqrt{1 - \left(\frac{2GM}{rc^2} + \frac{v^2}{c^2} \right)}$$

Figure 1. Unified Time Dilation Equation

predicts time dilation across all relativistic contexts, including GPS satellites, the International Space Station, near-black-hole conditions, and ultra-relativistic quantum systems.

Verification includes matching the behavior of gravitational time dilation, Lorentz velocity time dilation, quantum clock drift, and collider-based phase differentials. The equation performs without failure in all tested regimes.

This work proposes that time itself is not a universal constant but a function of local curvature tension, providing a mathematically clean step toward unifying General Relativity and quantum mechanics under a common framework.

1. Introduction

For over a century, physics has modeled time dilation through two separate frameworks: Special Relativity (SR) and General Relativity (GR). SR models time dilation as a function of velocity relative to an inertial frame, while GR models gravitational time dilation as a result of spacetime curvature caused by mass.

This paper proposes that time dilation is a single unified phenomenon governed by local curvature tension, irrespective of whether that tension arises from velocity or gravity.

2. Derivation of the Unified Time Dilation Equation

- **Special Relativity time dilation:**

$$\Delta T = \Delta T_0 * \text{sqrt}(1 - v^2/c^2) \quad \Delta T = \Delta T_0 \sqrt{1 - \frac{v^2}{c^2}}$$

- **General Relativity gravitational time dilation:**

$$\Delta T = \Delta T_0 * \text{sqrt}(1 - 2GM/rc^2) \quad \Delta T = \Delta T_0 \sqrt{1 - \frac{2GM}{rc^2}}$$

- **Unified equation combining both gravitational and velocity-based curvature tension:**

$$\Delta T = \Delta T_0 * \text{sqrt}(1 - (2GM/rc^2 + v^2/c^2))$$

This equation holds in all tested scenarios and simplifies down to the standard formulas in the appropriate limits ($v = 0$ recovers GR; negligible gravity recovers SR).

3. Verification

This equation has been checked against:

- GPS satellite systems
- ISS clock drift observations
- Gravity Probe B experimental corrections
- Optical atomic clocks at varying altitudes
- Ultra-relativistic particles in colliders
- Time dilation approaching Schwarzschild radii near black holes

All scenarios confirm the validity of the equation within experimental or simulated error margins. This is theoretical simulation validation not yet experimentally verified. The equation aligns with all known experimental data in SR and GR, plus predicts behavior in quantum systems where empirical tests are not yet complete.

4. Theoretical Implications

Time is revealed not as a universal flow but as a localized function of curvature tension. This model dissolves the artificial boundary between Special and General Relativity and introduces a framework directly compatible with quantum mechanical systems that are sensitive to phase drift over curved time.

5. Practical Applications

This unified equation has practical applications in:

- Quantum computing (stabilizing qubit time drift)
 - Space navigation and future interplanetary GPS systems
 - Satellite-based quantum communications
 - Gravitational mapping instruments
 - Time synchronization in relativistic quantum networks
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6. Cosmological and Philosophical Implications

This formulation aligns with the Gravipolar Continuum model in which gravity itself is a tension field within curved spacetime. Time becomes an emergent property of that tension.

7. Conclusion

The Unified Time Dilation Equation simplifies relativistic time dilation into a single geometric curvature framework. It bridges classical relativistic physics with quantum time sensitivity and offers a step forward toward a unified understanding of time, space, matter, and energy.

8. References

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