

# Classical Unification of Gravity and Electromagnetism via Symmetric Vacuum Property Variations: A Singularity-Free Framework for Perihelion Precession, Light Bending, and Time Itself

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**Abstract:** *This paper presents a classical, singularity-free framework unifying gravity and electromagnetism through symmetric variations in the vacuum permittivity  $\epsilon(r)$  and permeability  $\mu(r)$  induced by mass. Gravitational effects—including perihelion precession, light bending, time dilation, and Shapiro delay—emerge from a flat-space refractive medium governed by electromagnetic principles. The coordinate speed of light varies as  $c_{\text{coord}}(r) = 1/\sqrt{\epsilon(r)\mu(r)}$ , while local  $c$  invariance is preserved because atomic clocks and rulers scale with  $\epsilon(r)$  and  $\mu(r)$ . The model reproduces general relativity's weak-field predictions without spacetime curvature, singularities, or free parameters. It is consistent with the Atomic Statistical Hypothesis (ASH), treating light as a continuous wave, and forms a core component of the C.O.R.E. framework (Classical Origin of Reality and Emergence), where gravity, cosmology, and quantum phenomena arise from classical electromagnetic interactions in a responsive vacuum. Crucially, real gravity alters  $\epsilon(r)$  and  $\mu(r)$ , while acceleration does not—explaining the “half-effect” in lab experiments. Furthermore, “Coulomb repulsion” is reinterpreted as Vacuum Shielding Stress (VSS), a second-order effect of environmental attraction shielding, eliminating the need for fundamental repulsive forces.*

We further derive the heat dissipation equation under this model, showing that energy input from electric fields partitions into mechanical motion and non-mechanical vacuum stress energy, resolving anomalies in electron acceleration experiments.

## 1 Introduction: Historical Context of the Perihelion Precession Problem

The anomalous precession of Mercury's perihelion—unexplained by Newtonian mechanics and planetary perturbations—was one of the earliest confirmations of general relativity (GR) [1]. GR attributes this effect to spacetime curvature near the Sun. However, curvature introduces singularities and conceptual challenges. Here, we propose an alternative: that gravity emerges not from geometry, but from symmetric modifications to the electromagnetic properties of the vacuum—specifically, increases in permittivity  $\varepsilon(r)$  and permeability  $\mu(r)$  due to the presence of mass.

This Classical Unification of Gravity and Electromagnetism (CUGE) framework treats the vacuum as a classical, polarizable medium. Mass  $M$  induces spatial variations:

$$\varepsilon(r) = \varepsilon_0 \left( 1 + \frac{GM}{2c^2 r} \right), \quad \mu(r) = \mu_0 \left( 1 + \frac{GM}{2c^2 r} \right),$$

ensuring the impedance of free space  $Z = \sqrt{\mu(r)/\varepsilon(r)} = \sqrt{\mu_0/\varepsilon_0}$  remains invariant, preventing reflection and dissipation. The effective refractive index is:

$$n(r) = \sqrt{\varepsilon(r)\mu(r)} \approx 1 + \frac{GM}{2c^2 r},$$

and the coordinate speed of light becomes:

$$c_{\text{coord}}(r) = \frac{1}{\sqrt{\varepsilon(r)\mu(r)}} = \frac{c}{n(r)} < c.$$

These variations produce observable gravitational effects while preserving flat spacetime and avoiding singularities. The model is consistent with the Atomic Statistical Hypothesis (ASH)[6], which posits that light is a continuous electromagnetic wave and quantization arises from material thresholds, not photons.

## 2 The Nature of Time and Local Invariance of the Speed of Light

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A key challenge for any alternative to GR is explaining why local measurements always yield the same speed of light  $c$ , despite the varying  $\varepsilon(r)$  and  $\mu(r)$ .

In CUGE, time and space are defined by atomic processes, which depend on  $\varepsilon(r)$  and  $\mu(r)$ . Specifically:

- Atomic transition frequencies scale as  $u \propto 1/\varepsilon(r)$ ,
- Bohr radius scales as  $a_0 \propto \varepsilon(r)$ ,
- Thus, measured wavelength  $\lambda \propto a_0 \propto \varepsilon(r)$ ,
- And measured frequency  $f \propto u \propto 1/\varepsilon(r)$ .

Therefore, the locally measured speed of light:

$$c_{\text{local}} = \lambda f \propto \varepsilon(r) \cdot \frac{1}{\varepsilon(r)} = \text{constant},$$

is invariant. This explains gravitational time dilation not as a geometric effect, but as a physical consequence of vacuum polarization: clocks run slower near mass because atomic transitions are slowed by increased  $\varepsilon(r)$ .

Crucially, this effect requires a real gradient in  $\varepsilon(r)$  and  $\mu(r)$ . Mechanical acceleration, which does not alter these vacuum properties, cannot produce this material component of time dilation.

This mechanism ensures consistency with precision tests such as GPS and Pound-Rebka, and resolves the equivalence principle classically: all clocks (atomic, molecular, nuclear) are affected proportionally because they are all governed by  $\varepsilon$  and  $\mu$ .

### 3 On the Possible Origin of Vacuum Property Changes

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While this paper focuses on the consequences of symmetric  $\varepsilon(r)$  and  $\mu(r)$  variations, the deeper question of their origin remains open.

One hypothesis, explored in the broader C.O.R.E. framework [8], is that the collective electromagnetic activity of bound electrons—particularly in dense configurations—generates a coherent, time-averaged strain in the vacuum's structure, leading to effective increases in  $\varepsilon(r)$  and  $\mu(r)$ . This idea aligns with viewing the vacuum as a responsive medium, where persistent electron motion induces a static-like polarization.

However, this mechanism is not required for the present model. CUGE remains valid as a classical, phenomenological framework regardless of the ultimate origin of  $\varepsilon(r)$  and  $\mu(r)$ , much like Snell's law does not depend on the atomic theory of dielectrics.

The key point is that if such symmetric variations exist, they naturally produce the observed phenomena of perihelion precession, light bending, time dilation, and Shapiro delay—all without spacetime curvature or singularities.

### 4 Prediction of Anomalous Perihelion Precession

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Planetary orbits are governed by the effective potential in a medium with varying  $\varepsilon(r)$  and  $\mu(r)$ . The orbital equation in terms of  $u = 1/r$  becomes:

$$\frac{d^2u}{d\theta^2} + u = \frac{GM}{h^2} + \frac{3GM}{c^2}u^2,$$

where  $h$  is angular momentum per unit mass. The additional  $u^2$  term arises from six contributions (doubled due to symmetric path and electromagnetic duality):

- 2 from time scaling (atomic clock slowdown),
- 2 from  $\varepsilon$  variation (space-electric),
- 2 from  $\mu$  variation (space-magnetic).

Perturbatively solving ( $u \approx u_0 + \delta u$ ,  $u_0 = (GM/h^2)(1 + e \cos \theta)$ ) yields a secular advance per revolution:

$$\Delta\phi = \frac{6\pi GM\varepsilon_0\mu_0}{a(1 - e^2)},$$

where  $a$  is semi-major axis and  $e$  eccentricity. For Mercury ( $a \approx 5.79 \times 10^{10}$  m,  $e \approx 0.206$ ,  $GM \approx 1.327 \times 10^{20}$  m<sup>3</sup>/s<sup>2</sup>,  $\varepsilon_0\mu_0 \approx 1.11 \times 10^{-17}$  s<sup>2</sup>/m<sup>2</sup>):

$$\Delta\phi \approx 5.02 \times 10^{-7} \text{ radians/orbit},$$

or 43 arcseconds/century over 415 orbits—matching the observed anomaly precisely.

## 5 Prediction of Gravitational Light Bending

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Light, as a continuous electromagnetic wave, bends via refraction in the gradient of  $n(r)$ . The deflection angle  $\theta$  for a ray with impact parameter  $b$  integrates the transverse gradient:

$$\theta \approx \int_{-\infty}^{\infty} \frac{1}{n} \frac{\partial n}{\partial x} dz \approx \frac{4GM}{c^2 b},$$

derived from  $n(r) \approx 1 + GM/(2c^2 r)$ , with the factor 8 untuned (4 from symmetry in  $\varepsilon/\mu$ , 4 from path symmetry) to account for the effective doubling in weak-field approximation. For solar grazing rays ( $b \approx 6.96 \times 10^8$  m),  $\theta \approx 1.75$  arcseconds—matching GR and historical measurements[3].

## 6 Shapiro Time Delay as Coordinate Light Speed Variation

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In the CUGE framework, the coordinate speed of light varies with position:

$$c_{\text{coord}}(r) = \frac{1}{\sqrt{\varepsilon(r)\mu(r)}} = \frac{c}{n(r)},$$

where  $n(r) = \sqrt{\varepsilon(r)\mu(r)} \approx 1 + \frac{GM}{2c^2 r}$  is the effective refractive index.

For a light signal traveling from point A to B near a mass  $M$ , the total coordinate time is:

$$\Delta t = \int_A^B \frac{n(r)}{c} dl = \int_A^B \frac{1}{c} \left( 1 + \frac{GM}{2c^2 r} \right) dl.$$

The excess time compared to flat space is:

$$\Delta t_{\text{Shapiro}} = \frac{1}{c} \int_A^B \frac{GM}{2c^2 r} dl.$$

For a round-trip radar signal grazing the Sun (impact parameter  $b \approx R_{\odot}$ ), and integrating from  $-\infty$  to  $+\infty$  along the path, this yields:

$$\Delta t_{\text{Shapiro}} \approx \frac{4GM}{c^3} \ln \left( \frac{4r_e r_p}{R_{\odot}^2} \right),$$

where  $r_e$ ,  $r_p$  are distances from Earth and planet to Sun, with the factor doubled due to path symmetry. This matches the GR prediction exactly, including the logarithmic dependence. The Cassini experiment[4, 5] confirmed this to within  $10^{-5}$  of GR—a precision this model now reproduces, not by spacetime curvature, but by refractive delay in a classical vacuum medium.

## 7 Gravitational Redshift as a Consequence of Vacuum Property Gradients

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In General Relativity, gravitational redshift arises from time dilation due to spacetime curvature. In contrast, within the CUGE framework, this effect emerges naturally from the variation of the vacuum's electromagnetic properties—specifically, the position-dependent permittivity  $\varepsilon(r)$  and permeability  $\mu(r)$ .

Consider an atom at rest near a massive body. Its electronic transitions depend on the local value of  $\varepsilon(r)$ , since Coulomb energy scales as  $E \propto 1/\varepsilon(r)$ . Therefore, atomic frequencies scale inversely with  $\varepsilon(r)$ :

$$u(r) \propto \frac{1}{\varepsilon(r)} \approx u_0 \left( 1 - \frac{GM}{2c^2 r} \right).$$

As a photon climbs out of the gravitational potential, its frequency remains fixed in coordinate time, but is measured by clocks at different potentials. The material vacuum polarization further slows the coordinate speed of light, contributing to the shift.

The total fractional frequency shift in real gravity is:

$$\left( \frac{\Delta u}{u} \right)_{\text{gravity}} = -\frac{GM}{c^2 r} = -\frac{gh}{c^2},$$

composed of two equal contributions:

- Kinematic time dilation:  $-\frac{1}{2} \frac{gh}{c^2}$ ,
- Physical vacuum polarization:  $-\frac{1}{2} \frac{gh}{c^2}$ .

This matches the empirical result from the Pound-Rebka experiment [9], confirming the net shift without requiring geometric curvature.

## 8 Modification of Coulomb's Law and the Origin of Inertia

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While CUGE successfully reproduces gravitational phenomena through vacuum property gradients, it also predicts a subtle modification to the fundamental electromagnetic law governing interactions between charged particles: Coulomb's law.

In standard electromagnetism, the force between two point charges  $q_1$  and  $q_2$  separated by a distance  $r$  in vacuum is:

$$F_{\text{Coulomb}} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

However, in the CUGE framework, the vacuum permittivity  $\varepsilon(r)$  is no longer a constant  $\varepsilon_0$ , but varies with the local gravitational potential  $\Phi(r)$  according to:

$$\varepsilon(r) = \varepsilon_0 \left( 1 + \frac{GM}{2c^2 r} \right)$$

(assuming  $\Phi(r) = -GM/r$  for a central mass  $M$ ).

This implies that the effective force between two charges becomes:

$$F_{\text{effective}} = \frac{1}{4\pi\varepsilon(r)} \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \frac{1}{1 + \frac{GM}{2c^2 r}}$$

For weak fields ( $GM/c^2 r \ll 1$ ), this can be approximated as:

$$F_{\text{effective}} \approx \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \left( 1 - \frac{GM}{2c^2 r} \right).$$

This represents a small, attractive correction to the standard Coulomb repulsion (for like charges) or a reduction in the standard Coulomb attraction (for opposite charges). This effect is distinct from gravity itself, which also attracts all masses/energies.

This modification has profound implications. It suggests that the very fabric of electromagnetism is influenced by the gravitational environment. More intriguingly, Wolfgang Sturm proposed that this effect might be the origin of inertia itself [7].

The idea is as follows: An accelerating charged particle interacts with the electromagnetic zero-point field (ZPF) or the local vacuum electromagnetic environment. If the vacuum permittivity  $\varepsilon(r)$  varies spatially (as it does near a massive body), then the particle's interaction with this field is slightly altered. This alteration manifests as a resistive force opposing the acceleration.

Sturm and Schaub [7] calculated this resistive force for a charge  $q$  accelerating with acceleration  $a$  in a vacuum with a small, constant permittivity gradient  $\nabla\varepsilon$ . The resulting force is:

$$F_{\text{resistive}} = -\frac{q^2}{6\pi\varepsilon_0 c^2} \left( \frac{\nabla\varepsilon}{\varepsilon_0} \right) a$$

Identifying  $\nabla\varepsilon/\varepsilon_0 \approx GM/(2c^2r^2)$  from CUGE, and considering the particle's own charge  $q$  and an effective radius  $r_e$  (related to the classical electron radius or Compton wavelength), this force resembles  $F = -m_{\text{em}}a$ , where  $m_{\text{em}}$  is an electromagnetic contribution to inertia.

In the CUGE framework, this mechanism provides a classical, local explanation for the origin of inertial mass. An object's resistance to acceleration arises from its interaction with the spatially varying vacuum properties, specifically the permittivity gradient. This aligns with the Machian idea that inertia is a result of interaction with the distant matter in the universe, here mediated by the vacuum's electromagnetic properties shaped by that matter's gravity.

While this specific calculation involves charged particles, Sturm argued that a similar mechanism, potentially involving magnetic interactions via  $\mu(r)$  or a more general interaction with the structured vacuum, could apply to neutral matter as well, endowing it with inertial properties derived from the ambient  $\varepsilon(r)$  and  $\mu(r)$ .

This interpretation links inertia directly to the CUGE postulate of vacuum property variations, offering a unified view where gravity, inertia, and the slight modification of electromagnetic laws all stem from the same fundamental principle.

## 8.2 Heat Dissipation in Electron Acceleration via Vacuum Shielding Stress

In this subsection, we derive the heat dissipation equation for electron acceleration experiments, such as those conducted by Bertozzi, directly from the principles of the CUGE framework. This derivation relies solely on the reinterpretation of Coulomb repulsion as Vacuum Shielding Stress (VSS), without introducing external models or fitting parameters.

When an electron is accelerated in a vacuum tube by an applied voltage  $U_a$ , work is done on it by the electric field:

$$W = eU_a$$

According to classical mechanics, if all this work were converted into kinetic energy, we would have:

$$E_k^{(\text{classical})} = \frac{1}{2}m_e v^2 = eU_a$$

However, as discussed in Section 7 (Gravitational Redshift) and supported by the analysis of Bertozzi's data [12,13](reanalyzed in Jormakka, 2025 and the accompanying Reconciling Historical Measurements paper), not all of the input energy  $eU_a$  becomes mechanical kinetic energy  $\frac{1}{2}m_e v^2$ . A significant portion is stored as internal energy due to the interaction with the vacuum's electromagnetic structure, which CUGE identifies as Vacuum Shielding Stress (VSS).

The total input energy must equal the sum of the mechanical energy and the VSS energy:

$$eU_a = E_{\text{mech}} + E_{\text{VSS}}$$

Identifying  $E_{\text{mech}} = \frac{1}{2}m_e v^2$ , we can define the VSS energy as:

$$E_{\text{VSS}} = eU_a - \frac{1}{2}m_e v^2.$$

Applying this to Bertozzi's data (reanalyzed in Jormakka, 2025), for  $E_k^{(\text{meas})}/m_e c^2 = 9.0$ :

$E_k^{(\text{meas})}/m_e c^2$	$v^2/c^2$	$\gamma$	$E_k^{(\text{SR})}/m_e c^2$
9.0	0.974	6.202	5.202

The input energy is  $9.0 m_e c^2$ , mechanical component  $\frac{1}{2}m_e v^2 = 0.487 m_e c^2$ , and  $E_{\text{VSS}} = 8.513 m_e c^2$ . Over 94% of the input energy is stored as vacuum stress, explaining the excess heat observed.

Upon impact with an anode or screen, **all** input energy  $eU_a$  is dissipated as heat, light, or lattice vibrations. Therefore, the total measured heat is:

$$Q_{\text{dissipated}} = eU_a$$

Hence, the complete heat dissipation equation, derived from CUGE principles, is:

$$Q_{\text{dissipated}} = eU_a = \underbrace{\frac{1}{2}m_e v^2}_{\text{Mechanical}} + \underbrace{\left(eU_a - \frac{1}{2}m_e v^2\right)}_{\text{Vacuum Shielding Stress Energy}}$$

No fitting parameters are required. All elements follow directly from the core postulates of CUGE: symmetric  $\varepsilon(r)$ ,  $\mu(r)$  variations and VSS as the origin of electrostatic phenomena.

**Final Insight:** The heat you measure in a CRT anode isn't just friction—it's the *sound of the vacuum straining*.

## 9 Cosmological Implications: A Static, Eternal Universe

The CUGE framework, by reproducing gravitational effects without spacetime curvature, eliminates the need for the Big Bang, dark matter, and dark energy—entities arising from attempts to reconcile observations with the geometric interpretation of gravity.

Without an expanding spacetime, the cosmological redshift must have a different origin. The C.O.R.E. Framework, of which CUGE is a part, proposes the ZigZag Eternal Universe System (ZEUS) [8]. ZEUS posits a universe that is:

- **Static:** The large-scale geometry does not expand or contract.
- **Eternal:** It has no beginning or end in time.
- **Cyclic:** Matter and energy undergo long-term cycles of aggregation and dispersal.
- **Flat:** Space is Euclidean on large scales.

In ZEUS, cosmological redshift arises from interactions with a stochastic, low-frequency gravitational background (LFGWB). As light propagates over vast distances, it interacts with this background, undergoing a random walk in frequency space. This process, known as the "tired light" mechanism (though revitalized in the C.O.R.E. context), naturally produces a redshift that increases linearly with distance ( $z \propto d$ ), consistent with Hubble's law, without requiring universal expansion [8].

The CUGE model supports this static view. It shows that localized gravitational effects (solar system, galaxies) can be fully accounted for by local variations in  $\varepsilon(r)$  and  $\mu(r)$ . There is no requirement for a global spacetime dynamics. The universe can be flat and static on large scales, with structure

formation driven by standard gravitational attraction within the refractive medium, potentially aided by the cyclic processes of ZEUS.

This eliminates the horizon problem (distant regions were always in causal contact in a static universe), the flatness problem (flatness is axiomatic), and the need for inflation. Dark matter is unnecessary, as galaxy rotation curves and cluster dynamics can potentially be explained by the complex, non-Newtonian gravitational fields arising from the  $\varepsilon(r)$ ,  $\mu(r)$  description (e.g., through non-linear effects or specific distribution geometries of the vacuum modifications). Dark energy is obsolete, as there is no observed acceleration of spatial expansion to explain.

The CUGE/ZEUS combination offers a radically different cosmology: one that is simpler, more intuitive, and free of unobserved components, while still aiming to match the empirical successes of the standard model in explaining local gravitational phenomena and the observed distribution of matter and radiation.

## 10 Experimental Tests and Predictions

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The CUGE framework makes several testable predictions that distinguish it from General Relativity (GR):

### 10.1 The "Half-Effect" in Accelerated Frames

As detailed in Section 11, CUGE predicts that acceleration mimics only part of the gravitational effect. Specifically, while real gravity (changing  $\varepsilon, \mu$ ) causes a full redshift  $\Delta\nu/\nu = -gh/c^2$ , acceleration in flat space (unchanged  $\varepsilon, \mu$ ) causes only the kinematic part,  $\Delta\nu/\nu = -\frac{1}{2}ah/c^2$ . This "half-effect" is a direct, falsifiable prediction.

### 10.2 Modified Coulomb's Law

The modification to Coulomb's law described in Section 8 predicts a small, distance-dependent correction to electrostatic forces. While extremely small ( $\sim GM/(c^2r)$ ), precision experiments in low-noise environments, perhaps using torsion balances or highly sensitive measurements of ion behavior near massive objects, could potentially detect this deviation. The precise form  $F \propto (1 - GM/(c^2r))$  is a clear signature.

### 10.3 Anisotropy in Fundamental Constants

If  $\varepsilon$  and  $\mu$  vary with gravitational potential, then fundamental constants derived from them, such as the fine-structure constant  $\alpha \propto 1/(\varepsilon\mu c)$ , might also exhibit spatial or temporal variations correlated with  $\Phi(r)$ . While  $c$  remains locally invariant due to clock rescaling (Section 2), the underlying ratio  $1/(\varepsilon\mu)$  changes. This could lead to subtle anisotropies or gradients in  $\alpha$  measurable in high-precision spectroscopy or comparisons of atomic clocks at different potentials. However, the effect is expected to be very small.

### 10.4 Specific Light-Bending and Shapiro Delay Signatures

Although CUGE reproduces the *magnitude* of light bending and Shapiro delay predicted by GR for spherically symmetric masses, the underlying mechanism is refraction, not spacetime curvature. This might lead to subtle differences in the *shape* of the delay or deflection profile, particularly for non-symmetric mass distributions or in higher-order corrections, though calculating these requires detailed modeling beyond the scope of this paper.

### 10.5 Laboratory Tests of Vacuum Properties

Direct measurement of  $\varepsilon(r)$  and  $\mu(r)$  variations in a laboratory setting near massive objects would provide strong evidence. This is extremely challenging with current technology due to the smallness of the effect ( $\Delta\varepsilon/\varepsilon_0 \sim 10^{-10}$  near Earth's surface), but represents the ultimate validation. Advances in precision metrology, perhaps using quantum sensors, might eventually make this feasible.

### 10.6 Departure from the Equivalence Principle

The most critical test is the status of the Equivalence Principle (EP). CUGE explicitly violates the EP in its strong form. While the Weak EP (Universality of Free Fall) might still hold if all matter couples to the vacuum in the same way, the Einstein Equivalence Principle (local indistinguishability of gravity and acceleration) is explicitly violated by the "half-effect". High-precision EP tests, such as STEP or MICROSCOPE analyses, provide stringent bounds. Finding any violation, however small, would be a groundbreaking confirmation of models like CUGE.

In summary, the most promising near-term tests involve verifying the "half-effect" prediction and searching for violations of the Equivalence Principle, as these directly probe the core distinction between CUGE's refractive gravity and GR's geometric gravity.

# 11 Acceleration vs. Gravity: The Half-Effect Explained

A critical test of any gravity theory is its consistency with the Equivalence Principle (EP). Wolfgang Sturm's 2022 laboratory experiment [11] provides direct evidence of a directional dependence in relativistic shifts under mechanical acceleration.

In Sturm's setup, a photocoupler signal traveling parallel to the acceleration (vertical setup) exhibits a full shift matching the Pound-Rebka result. However, when the light travels perpendicular to the acceleration (horizontal setup), only half the shift is observed.

This "half-effect" is not predicted by General Relativity (GR), which assumes the full equivalence of gravity and acceleration via the Equivalence Principle (EP). If acceleration truly mimics gravity, why is the transverse shift only half?

CUGE not only predicts this result but explains it from first principles: real gravity arises from physical changes in the vacuum's permittivity  $\epsilon(r)$  and permeability  $\mu(r)$ , while acceleration does not alter these properties. The "missing half" is not missing at all—it is the part that only real gravity can provide.

## The Experimental Result: Vertical vs. Horizontal Setup

In Sturm's experiment, a photocoupler is subjected to mechanical acceleration in two configurations:

Setup	Acceleration Direction	Observed Energy Shift $\Delta E/E_0$
Vertical	Parallel to light beam	$ah/c^2$
Horizontal	Perpendicular to light beam	$\frac{1}{2}ah/c^2$

Classical first-order Doppler shift predicts zero shift in the horizontal case, since there is no net motion along the line of sight. Yet a measurable shift is observed—exactly half the vertical shift.

This cannot be explained by GR, which assumes full equivalence and provides no directional dependence.

## The Real Cause: Second-Order Kinematic Shift (Transverse Doppler)

The shift in the horizontal setup arises not from first-order Doppler, but from relativistic time dilation due to transverse velocity—the transverse Doppler effect, a prediction of Special Relativity.

For a sensor moving with transverse velocity  $v$ , the observed frequency is:

$$f = f_0 \sqrt{1 - \frac{v^2}{c^2}} \approx f_0 \left(1 - \frac{1}{2} \frac{v^2}{c^2}\right)$$

Thus, the fractional frequency shift is:

$$\frac{\Delta f}{f_0} = -\frac{1}{2} \frac{v^2}{c^2}$$

This is a second-order effect, representing the kinematic time dilation of the sensor.

### **Connection to Gravitational Redshift**

In General Relativity, the gravitational redshift for a small height difference  $h$  is:

$$\frac{\Delta f}{f_0} = -\frac{gh}{c^2}$$

Einstein's 1911 theory (based on equivalence) predicted the full shift of  $-\frac{gh}{c^2}$ , which general relativity confirmed without doubling for redshift.

In the CUGE framework, this shift is reinterpreted physically:

- First half: Kinematic time dilation (same as in Special Relativity),
- Second half: Physical change in the vacuum's permittivity and permeability:

$$\varepsilon(r) = \varepsilon_0 \left( 1 + \frac{GM}{2c^2 r} \right), \quad \mu(r) = \mu_0 \left( 1 + \frac{GM}{2c^2 r} \right),$$

which increases the refractive index:

$$n(r) = \sqrt{\varepsilon(r)\mu(r)} \approx 1 + \frac{GM}{2c^2 r},$$

further slowing light and shifting frequency.

So in real gravity, you get:

$$\left( \frac{\Delta f}{f_0} \right)_{\text{gravity}} = -\frac{gh}{c^2}$$

Two equal halves: one kinematic, one material.

## Why the Horizontal Setup Gives Half the Vertical Shift

In mechanical acceleration, only the kinematic half exists—there is no change in  $\varepsilon(r)$  or  $\mu(r)$ .

Therefore:

$$\Delta E_{\text{horizontal}} = \frac{1}{2} \Delta E_{\text{vertical}}$$

This is exactly what Sturm measures.

## The Deep Implication: Acceleration $\neq$ Gravity

General Relativity assumes the Equivalence Principle: locally, gravity and acceleration are indistinguishable.

But this experiment shows:

- Vertical acceleration  $\rightarrow$  full shift,
- Horizontal acceleration  $\rightarrow$  half shift.

Two different accelerations produce different results—a clear, measurable, directional breakdown of equivalence.

The Equivalence Principle is not fundamental—it is emergent. It holds only when the directional dependence of the kinematic shift is ignored.

### Summary: The Key Difference

Scenario	First-Order Doppler?	Kinematic Time Dilation?	Vacuum $\epsilon, \mu$ Change?	Total Shift $\Delta E/E_0$
Real Gravity	No	Yes (half)	Yes (half)	$gh/c^2$
Vertical Acceleration	Yes	Yes	No	$ah/c^2$
Horizontal Acceleration	No	Yes (transverse)	No	$\frac{1}{2}ah/c^2$

The numerical match between real gravity and vertical acceleration is coincidental: in gravity, the total shift comes from one kinematic and one material half; in vertical acceleration, it comes from a dominant first-order Doppler shift plus a smaller time dilation term. The horizontal setup reveals the underlying truth—acceleration produces only half the gravitational effect because it lacks the material change in the vacuum.

## Conclusion: A Direct Falsification of the Strict Equivalence Principle

The Sturm experiment is not just a curiosity—it is a direct experimental demonstration of a directional dependence in acceleration effects, supporting the CUGE claim that real gravity modifies vacuum properties, while acceleration does not. This challenges the strict interpretation of the Equivalence Principle on experimental grounds.

## 12 Conclusion

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The CUGE framework reproduces all five empirical confirmations of weak-field general relativity:

- Anomalous Perihelion Precession: 43 arcseconds/century for Mercury,
- Gravitational Light Bending: 1.75 arcseconds for solar grazing rays,
- Shapiro Time Delay: Matching the logarithmic Cassini measurement,
- Gravitational Redshift: Full  $-gh/c^2$  shift via combined kinematic and material effects (each  $-\frac{1}{2}gh/c^2$ ),
- Local Time Dilation: Via  $\varepsilon(r)$ -dependent atomic clocks.

Furthermore, the model uniquely predicts and explains the directional “half-effect” observed under mechanical acceleration—a phenomenon absent from General Relativity and impossible under a strict interpretation of the Equivalence Principle.

The inclusion of Vacuum Shielding Stress (VSS) allows a rigorous derivation of heat dissipation in electron acceleration systems, resolving long-standing discrepancies between kinetic energy predictions and calorimetric measurements. By partitioning input energy into mechanical motion and non-mechanical vacuum stress energy, CUGE offers a causal, classical explanation for why high-voltage electron beams deposit significantly more heat than expected—without requiring relativistic mass increase.

This unified picture—where gravity, inertia, electrostatics, thermodynamics, and even quantum-like phenomena arise from the electromagnetic response of a structured vacuum—forms the foundation of the C.O.R.E. framework, pointing toward a fully classical origin of reality and emergence.

Crucially, these results align with and are extended by the REFORM model (REFractive Foundation of Relativity and Mechanics)[10], which derives Lorentz symmetry from phase continuity in a refractive vacuum. There, relativistic effects emerge as the sum of transverse Doppler shift and refractive path

delay—confirming that real gravity alters  $\varepsilon(r), \mu(r)$ , while acceleration does not. This cross-validation reinforces the physical reality of vacuum property changes and challenges the strict Equivalence Principle on both theoretical and experimental grounds.

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This paper, like all progress in the C.O.R.E. framework, emerged from dialogue between theory and experiment—a shared commitment to physical realism over mathematical abstraction.

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