Article

Not peer-reviewed version

Deriving Relativistic Kinematics from a Medium-Based Paradigm: A Complete Geometric Demonstration

Gui Furne Gouveia *

Posted Date: 29 September 2025

doi: 10.20944/preprints202509.2412.v1

Keywords: special relativity; propagation medium; wave-based matter; Lorentz transformation; Michelson-Morley experiment; geometric derivation; emergent relativity

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 29 September 2025 doi:10.20944/preprints202509.2412.v1

Article

Deriving Relativistic Kinematics from a Medium-Based Paradigm: A Complete Geometric Demonstration

G. Furne Gouveia

Independent Researcher; furnegouveia@gmail.com

Abstract

This paper presents a rigorous geometric derivation of Special Relativity's formulas from a physical medium-based foundation. Using the complete geometric demonstrations from the author's previous work, we show how the Michelson-Morley null result necessarily constrains the deformation of moving apparatuses, and how the wave nature of matter naturally leads to time dilation through helical light trajectories. Crucially, our framework transforms the Lorentz contraction from a postulate into an experimentally testable prediction, allowing precise time dilation measurements to determine the complete deformation pattern. The derivation provides complete mathematical demonstrations in appendices using the original diagrams and geometric arguments, proving that Lorentz transformations emerge as physical necessities rather than postulates when matter is conceived as confined excitations of a propagation medium. This work forms the kinematic foundation of a broader unified paradigm that addresses outstanding problems in cosmology and particle physics, demonstrating that relativistic kinematics emerges self-consistently from wave-mechanical principles.

Keywords: special relativity; propagation medium; wave-based matter; Lorentz transformation; Michelson-Morley experiment; geometric derivation; emergent relativity

---

1. Introduction

The standard derivation of Special Relativity takes the experimentally verified constancy of light speed—established through electromagnetic theory and optical experiments—and postulates the absence of any propagation medium [2]. However, the mathematical structure of relativity can be derived from an alternative foundation: the physical nature of space as a propagation medium and matter as excitations of this medium.

This paper synthesizes two complete geometric demonstrations from previous work [1] that derive relativistic kinematics from first principles. We first demonstrate how the Michelson-Morley experiment's null result imposes a necessary geometric constraint on any measuring apparatus moving through the medium. We then derive from the wave nature of matter the physical mechanism—helical light trajectories—that naturally satisfies this constraint and leads to time dilation. Using the original diagrams and step-by-step geometric arguments, we show that relativistic effects emerge as physical necessities rather than mathematical postulates.

Context and Broader Framework. This work constitutes a fundamental piece of a broader theoretical paradigm developed in a series of publications [5–7]. This paradigm reinterprets spacetime as a dynamic, vibratory medium whose excitations give rise to particles, forces, and the laws of physics themselves. Within this framework, we have previously shown that the properties of this medium naturally lead to modified gravitational dynamics at galactic scales and provide explanations for particle physics phenomena.

The present article returns to the foundation of this entire edifice: the kinematics of objects moving within this medium. By deriving relativistic effects from the wave nature of matter, we provide the

 doi:10.20944/preprints202509.2412.v1

microphysical mechanism that underpins the deformation of spacetime relationships. This derivation is not only consistent with the broader paradigm but serves as its necessary cornerstone.

Relation to Established Research. Our approach shares the general insight of *analogue gravity* [8,9]—that physical media can generate relativistic behavior—but with a crucial distinction: where analogue gravity constructs formal analogies, our paradigm posits that spacetime geometry is intrinsically the geometry of a fundamental medium. We derive special relativity directly from the wave mechanics of confined excitations, providing not an analogy but a causal microphysical mechanism.

Experimental Testability. Beyond providing physical mechanisms for relativistic effects, our approach offers a crucial experimental signature: precise measurements of time dilation could distinguish between different deformation patterns, potentially revealing transverse contraction ($k_\perp < 1$) that would challenge standard relativity's assumption of purely longitudinal contraction. This transforms the Lorentz-FitzGerald contraction from an ad hoc postulate into an empirically resolvable question.

2. Theoretical Framework

2.1. The Medium-Based Paradigm

We assume space constitutes a physical medium supporting local constant wave propagation at speed c. Matter consists of confined wave structures within this medium. The key insight is understanding how standing waves, which appear stationary in a particle's rest frame, manifest as moving structures in the medium frame.

A standing wave in a moving particle results from the superposition of constituent waves propagating in opposite directions relative to the particle. When viewed from the medium frame, the constant-magnitude velocity vectors c of these waves are tilted, decomposing into components: one for maintaining the standing wave structure and another for the particle's translation at velocity v through the medium.

From the particle's perspective, it appears at rest relative to the medium because the internal wave interference creates stationary patterns. However, from the medium's perspective, these constituent waves drift with velocity v in the direction of motion while maintaining their fundamental propagation speed c.

This dual perspective resolves the apparent paradox: what appears as a pure standing wave in the particle's frame manifests as a helical light trajectory in the medium frame. The helical path emerges because each point of the wave structure must simultaneously execute internal oscillations (maintaining the standing wave pattern) while translating through the medium at velocity v.

This conception fundamentally affects how matter behaves when in motion relative to the medium. The geometry of these helical trajectories, and the interference conditions of the constituent waves, necessarily change with velocity, leading to the relativistic effects derived in the following sections.

Internal Adaptation Mechanism

Crucially, this helical configuration emerges naturally from the standing wave structure itself, not from external imposition. Within the moving particle, each constituent wave experiences the other as Doppler-shifted, with propagation directions modified by their relative motion. These reciprocal Doppler shifts force a mutual reorientation of wave vectors, tilting them forward and increasing the helical pitch with velocity. This self-consistent adjustment is the microscopic mechanism ensuring that the internal clock of the particle (the standing wave frequency) automatically synchronizes with its deformed spatial geometry, leading to the emergent relativistic kinematics described in this paper.[1]

[1] This can be visualized by considering two swimmers in a moving river, trying to maintain a fixed distance from each other. Each must adjust their swimming angle relative to the water's flow to compensate for the current and maintain their relative position. Similarly, the constituent waves adjust their "swimming" direction in the medium to preserve the interference pattern that defines the particle.

Energetic Interpretation of Wave Deformation

This internal reconfiguration of the standing wave structure has direct energetic consequences that provide physical meaning to relativistic energy formulas. The kinetic energy of a moving particle corresponds to the energy required to deform all constituent waves of the particle in the direction of the motion.

When the particle is at rest relative to the medium, its mass corresponds to a perfect symmetry of all constituent waves. Motion through the medium breaks this symmetry because the wave trajectories must reconfigure from purely oscillatory loops to helical paths. The familiar relativistic expression for kinetic energy, $E_k = (\gamma - 1)m_0c^2$, thus represents the work done to establish and maintain this asymmetric wave configuration against the restorative forces of the medium.

As we have established, the faster the particle moves, the more its internal waves devote time to translation at the expense of completed loops that constitute its internal structure. At the ultimate limit when $v \to c$, all waves devote their entire propagation time to translation at speed c. This state is equivalent to the particle's energy becoming pure radiation—the internal loops cease, proper time stops, and the particle loses its particulate nature to become light-like. The increasing difficulty of acceleration as $v \to c$ reflects the asymptotic energy required to approach this complete conversion from matter to radiation.

Physical Meaning of $E = mc^2$ in the Wave Paradigm

Within our framework, Einstein's equation $E = mc^2$ acquires a profound physical interpretation: the mass-energy of a particle represents the total deformation energy—both near-field and far-field—that the particle's wave structure imposes upon the spatial medium.

For a moving particle, the total energy $E = \gamma m_0 c^2$ decomposes as:

- m_0c^2: the deformation energy of the stationary wave structure at rest
- $(\gamma - 1)m_0c^2$: the additional deformation energy required for motion

This explains both the velocity-dependent mass increase $m = \gamma m_0$ and the nature of kinetic energy: it is the increase in total deformation energy as the wave structure becomes more distorted. The increasing difficulty of acceleration at high velocities reflects the growing energy investment needed to further deform the wave pattern against the medium's restorative forces.

At $v \to c$, the energy diverges because complete conversion to pure translation requires infinite deformation energy—the standing wave structure must completely "unwind" into radiation. Thus, $E = \gamma m_0 c^2$ expresses the continuum from rest (minimal deformation) to light-speed motion (complete dissolution of the wave structure).

Connection to Observable Effects

This internal adaptation mechanism provides a fundamental explanation for well-known relativistic visual phenomena. The forward tilting of the internal wave vectors, required to maintain standing wave stability, directly corresponds to the **relativistic aberration** observed when moving at high velocities [12,13]. This aberration, which causes the apparent compression of the visual field into a forward-directed tunnel, is thus not merely an optical illusion but a direct consequence of how wave-based matter must reconfigure its internal geometry to persist in motion relative to the medium. Similarly, the Doppler boosting effect (the amplification of forward-directed radiation) finds a natural explanation in the increased energy density of the forward-tilted wave fronts. Our medium-based approach therefore unifies the kinematic formulas of relativity with their dramatic visual manifestations under a single physical principle.

2.2. The Measuring Process

All measurements of space and time are ultimately made using material instruments - rulers composed of atoms, clocks based on atomic processes. Crucially, these instruments are themselves

 doi:10.20944/preprints202509.2412.v1

made of fundamental particles, and according to our paradigm, these particles are wave structures confined within the medium.

Therefore, what we measure as "space" and "time" intervals are not measurements of abstract coordinates but readings from physical devices whose very operation depends on their motion state relative to the medium. The rulers that measure length and the clocks that measure time are themselves physical objects whose internal wave structure deforms when in motion through the medium.

This creates a fundamental self-consistency: the speed of light is fundamentally constant in the medium frame because it is determined by the medium's properties. However, this constant speed appears also constant relative to a moving observer because their measuring devices (rulers and clocks) are physically deformed by their motion through the medium in precisely the compensating manner, making the medium undetectable through local experiments [3].

3. Part I: Complete Geometric Derivation from Michelson-Morley

The Michelson-Morley experiment's null result provides the crucial constraint on medium-based theories. Appendix A presents the complete geometric derivation using the original diagram and analysis.

3.1. The General Deformation Condition

As derived in Appendix A from the Michelson-Morley null result [4], the experimental data requires that moving apparatuses deform according to:

$$\frac{k_\perp}{k_\parallel} = \sqrt{1 - \frac{v^2}{c^2}} \tag{1}$$

where $k_\parallel$ and $k_\perp$ are deformation factors for dimensions parallel and perpendicular to motion.

This relationship is not a postulate but a direct mathematical consequence of requiring equal light travel times in both arms of the interferometer. It is necessary and sufficient to explain the experimental null result and applies fundamentally to any object moving through the medium.

The Lorentz-FitzGerald contraction ($k_\perp = 1$, $k_\parallel = \sqrt{1 - v^2/c^2}$) represents only one particular solution satisfying this constraint. However, the Michelson-Morley experiment alone cannot distinguish between this specific case and other possible deformation patterns that satisfy the same ratio. The Lorentz contraction is therefore an additional postulate, whereas Equation (1) is an experimental necessity.

4. Part II: Physical Derivation of Time Dilation from Wave Geometry

If matter consists of confined light-like trajectories, then time dilation emerges naturally from the geometry of these trajectories when in motion. Appendix B provides the complete derivation using the helical path analysis.

4.1. Time Dilation from Helical Light Trajectories

As shown in Appendix B, when a particle moves through the medium, its internal light-like trajectory becomes helical. The development of this helix reveals a right triangle from which time dilation follows geometrically. It is important to note that the standard derivation presented here implicitly assumes no transverse contraction ($k_\perp = 1$), corresponding to the Lorentz-FitzGerald hypothesis. The resulting formula:

$$d\tau = dt\sqrt{1 - \frac{v^2}{c^2}} \tag{2}$$

thus represents the specific case where deformation occurs only longitudinally. As developed in the generalized framework of Appendix B, different deformation patterns would yield modified time dilation expressions, providing an experimental signature to distinguish between possible medium-matter interaction models.

 doi:10.20944/preprints202509.2412.v1

4.2. Length Contraction as a Corollary

Given time dilation and the deformation constraint from Michelson-Morley, length contraction follows as a consistency requirement for measuring devices made of such wave-based matter.

4.3. The Physical Mechanism of Length Contraction

Length contraction emerges naturally from the wave nature of matter when we consider how confined light trajectories deform under motion relative to the medium.

Consider a fundamental particle as a standing wave structure where light-like oscillations execute closed loops. When at rest in the medium, these loops are perfectly symmetrical - the wave completes cycles without net translation. The particle's spatial extension is determined by the interference conditions of these standing waves.

When the particle moves with velocity v relative to the medium, a portion of each oscillation cycle must be devoted to pure translation. The confined light trajectory becomes helical rather than purely oscillatory. This has two crucial consequences:

1. **Time Dilation**: The internal oscillation frequency decreases because part of the light's path length is used for translation rather than completing loops (as derived in Appendix B).
2. **Wave Deformation**: The standing wave pattern that defines the particle's spatial extension becomes anisotropic. Along the direction of motion, the wave interference conditions change because the effective wavelength is modified by the motion component.

Now consider a measuring rod composed of such wave-based particles bound together. The equilibrium distance between particles is determined by the interplay of binding forces (themselves wave-mediated) and the particles' internal wave structures. When all constituent particles have their internal oscillations slowed and their wave patterns deformed in the direction of motion, the rod's natural length must adjust accordingly.

The deformation constraint from Michelson-Morley (Equation 1) tells us the specific ratio required: $\frac{k_\perp}{k_\parallel} = \sqrt{1 - v^2/c^2}$. The simplest consistent solution that also maintains internal consistency for light speed measurements is:

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}}$$

where the transverse dimension remains unchanged ($k_\perp = 1$) and only the longitudinal dimension contracts.

Thus, length contraction is not an arbitrary postulate but a physical necessity: the spatial standards themselves (rulers made of wave-based matter) physically deform when in motion through the medium that supports their existence.

5. Synthesis: Emergence of a Generalized Relativistic Kinematics

The preceding derivations establish a complete medium-based framework that leads to a generalized relativistic kinematics. Crucially, our approach reveals that the Lorentz-FitzGerald contraction postulate is not only unnecessary but physically incorrect within our paradigm.

The Michelson-Morley experiment provides the fundamental constraint (Equation 1):

$$\frac{k_\perp}{k_\parallel} = \sqrt{1 - \frac{v^2}{c^2}}$$

This relationship is an experimental necessity, but it does not specify individual values for $k_\parallel$ and $k_\perp$. The conventional solution ($k_\perp = 1, k_\parallel = \sqrt{1 - v^2/c^2}$) represents an arbitrary choice that violates the physical symmetry of wave-based matter.

In our paradigm, a fundamental particle at rest relative to the medium exhibits closed-loop internal wave trajectories. When the particle moves with velocity v, it gains kinetic energy that manifests as a deformation of its internal wave structure. The internal light-like oscillations must now

 doi:10.20944/preprints202509.2412.v1

allocate a portion of their path to translational motion, creating helical trajectories. This redistribution affects all spatial dimensions:

- Waves spending more time propagating in the longitudinal direction cause elongation ($k_{\parallel} > 1$)
- Waves spending less time in transverse directions cause contraction ($k_{\perp} < 1$)
- The deformation ratio satisfies the Michelson-Morley constraint

The time dilation formula (Equation 2), $\Delta\tau = \Delta t\sqrt{1 - v^2/c^2}$, remains valid as it derives purely from the helical path geometry. However, the coordinate transformations that emerge differ from Lorentz transformations, describing instead the relationship between the medium frame and frames using generalized deformed measuring apparatus.

This leads to a more fundamental kinematics where the principle of relativity emerges not from Lorentz covariance, but from the consistent deformation of all wave-based measuring devices according to the medium-matter interaction laws.

On the Specificity of Deformation Factors

While the Michelson-Morley experiment provides the essential constraint $\frac{k_{\perp}}{k_{\parallel}} = \sqrt{1 - v^2/c^2}$, it does not uniquely determine the individual values of $k_{\parallel}$ and $k_{\perp}$. The Lorentz-FitzGerald contraction hypothesis ($k_{\perp} = 1$, $k_{\parallel} = \sqrt{1 - v^2/c^2}$) represents only one particular solution among a continuum of possibilities satisfying this ratio.

Contrary to what might be intuitively assumed, even in a perfectly isotropic medium, energy minimization principles do not necessarily select $k_{\perp} = 1$. The actual deformation pattern depends on the specific microscopic interaction between the wave structure and the medium, particularly how the kinetic energy distributes between longitudinal and transverse wave deformations. As we will show, the wave-mechanical nature of matter naturally leads to a more symmetric deformation where both dimensions are affected.

6. Discussion: Integration into a Unified Paradigm

Our derivation represents a fundamental departure from both Einstein's relativity and Lorentz's ether theory, offering a third path grounded in wave-mechanical principles.

6.1. Comparison with Existing Paradigms

- **Einstein's Approach:** Postulates relativity and light speed constancy as fundamental principles [2]. Lorentz transformations are mathematical consequences without physical mechanism.
- **Lorentz's Approach:** Assumes a stationary ether with ad hoc contraction postulate ($k_{\perp} = 1$) to salvage Galilean relativity [3].
- **Medium-Based Approach:** Derives relativistic effects from first principles of wave mechanics. The deformation constraint emerges experimentally, while specific deformation factors derive from the physical nature of wave-based matter.

6.2. Fundamental Difference from Einstein's Derivation

While Einstein's approach postulates the specific Lorentz contraction ($k_{\perp} = 1$, $k_{\parallel} = \sqrt{1 - v^2/c^2}$) through the requirement of spatial isotropy, our medium-based derivation yields only the general constraint $\frac{k_{\perp}}{k_{\parallel}} = \sqrt{1 - v^2/c^2}$ from Michelson-Morley. The Lorentz contraction thus appears as a special case enforced by Einstein's postulates, whereas our approach allows for a broader class of deformation patterns determined by the physical nature of wave-based matter.

This represents a crucial conceptual shift: rather than imposing symmetry postulates, we derive the deformation constraint from experimental necessity ($\frac{k_{\perp}}{k_{\parallel}} = \gamma^{-1}$) and then determine the specific deformation factors ($k_{\parallel}$ and $k_{\perp}$) from the physical principles of energy distribution in confined wave systems. In our model, the Lorentz-FitzGerald contraction is not a fundamental law but one possible solution within a more general deformation framework.

This distinction makes our theory empirically testable: any measured transverse contraction ($k_\perp < 1$) would support our model over standard relativity. Moreover, precise measurements of time dilation could independently determine the deformation factors, providing a second experimental avenue for verification. This represents a crucial experimental signature that could distinguish between the frameworks, as standard relativity strictly requires $k_\perp = 1$ by definition and predicts a unique, fixed relationship between velocity and time dilation.

6.3. Connection to General Relativity and Broader Implications

The natural question arising from our medium-based approach concerns its compatibility with General Relativity (GR). We propose that the curvature of spacetime in GR can be understood as an emergent description of the graded elasticity and density variations of the fundamental medium. This viewpoint is supported by several independent research programs:

- **Analogue Gravity:** Demonstrates that Einstein-like equations emerge in various physical media [8,9]
- **Thermodynamic Approaches:** Derive GR from thermodynamic principles applied to spacetime horizons [10]
- **Emergent Gravity Frameworks:** Suggest that spacetime geometry may not be fundamental but emergent [11]

Our derivation of special relativity provides the *local*, kinematical foundation for such an emergent GR framework. The broader implications of this paradigm for unresolved issues in cosmology and particle physics are explored in our related publications [6,7], where we show how the medium properties naturally lead to modified gravitational dynamics and explanations for particle generations.

6.4. Testable Predictions and Falsifiability

The key distinction from standard relativity lies in the physical mechanism: rather than being mathematical postulates, relativistic effects emerge from the necessary deformation of confined wave structures. This makes our theory empirically testable through several specific predictions:

- **Transverse Contraction Signature**: Any measured transverse contraction ($k_\perp < 1$) in high-precision length measurements of moving objects would definitively support our model over standard relativity. We predict that ultra-precise interferometric measurements might reveal a small but non-zero transverse deformation scaling with γ^{-1}.
- **Time Dilation as Deformation Probe**: Precision measurements of time dilation in fast-moving systems (atomic clocks on spacecraft, particle accelerators) could determine the actual deformation factors. A deviation from the standard $\Delta\tau = \Delta t\sqrt{1 - v^2/c^2}$ formula would indicate $k_\perp \neq 1$, providing an independent test of the deformation pattern.
- **Energy-Dependent Effects**: If the deformation energy depends on the wave amplitude or frequency, we predict subtle energy-dependent corrections to relativistic kinematics at high energies, potentially detectable in particle accelerator data.
- **Medium Effects in Analog Systems**: Our approach predicts that analog systems (Bose-Einstein condensates, optical media) should exhibit similar deformation patterns when effective "matter waves" move through flowing media, providing experimental avenues for verification in controlled laboratory settings.
- **Anisotropy Signatures**: In scenarios where the medium might exhibit slight anisotropy (due to large-scale cosmic flows or gravitational gradients), our framework predicts measurable directional dependence in relativistic effects, unlike standard relativity.

The falsifiability of our theory represents a significant advantage over conventional interpretations: clear experimental signatures could distinguish it from standard relativity, while null results would constrain possible medium-based models without invalidating the overall framework. Crucially, our approach offers multiple independent experimental pathways for verification, enhancing its testability and scientific robustness.

 doi:10.20944/preprints202509.2412.v1

6.5. From Postulates to Experimental Predictions

The most significant advancement of our medium-based approach is its capacity to transform special relativity's foundational postulates into experimentally testable predictions. While Einstein elevated the constancy of light speed to a principle and Lorentz postulated specific contraction factors, our derivation shows that these emerge from wave-mechanical principles applied to a physical medium.

Specifically, the Lorentz-FitzGerald contraction ceases to be a postulate and becomes an empirical question: do moving objects exhibit pure longitudinal contraction ($k_\perp = 1$) or a more general deformation pattern? High-precision time dilation experiments—using atomic clocks on spacecraft, particle accelerators, or satellite systems—could resolve this question definitively. A measured deviation from the standard time dilation formula would indicate $k_\perp < 1$, while confirmation would establish the Lorentz contraction as an empirical fact rather than an assumption.

This represents a fundamental shift in the epistemological status of special relativity, moving from a theory based on postulates to one derived from physical principles with experimentally verifiable microfoundations.

7. Conclusion

This work demonstrates that relativistic kinematics can be rigorously derived from a medium-based foundation where matter consists of confined wave structures. The complete geometric proofs establish:

1. **Experimental Foundation:** Michelson-Morley's null result necessitates a deformation constraint $\frac{k_\perp}{k_\parallel} = \sqrt{1 - v^2/c^2}$ for objects moving through the medium.
2. **Physical Mechanism:** Time dilation emerges geometrically from helical light trajectories in moving wave-based particles.
3. **Generalized Deformation Framework:** Contrary to Lorentz's specific postulate, our approach allows for a broader class of deformation patterns where both longitudinal and transverse dimensions may deform according to energy redistribution principles in confined wave systems.
4. **Emergent Relativity:** The apparent validity of special relativity in experiments results from consistent deformation of all wave-based measuring apparatus.

Unlike conventional approaches that postulate either relativity (Einstein) or specific contraction (Lorentz), our derivation shows that relativistic kinematics emerges naturally from wave mechanics in a medium.

Transforming Postulates into Experimental Predictions

The most significant advancement of our framework is its capacity to transform the Lorentz-FitzGerald contraction from a postulate into an experimentally testable prediction. While Michelson-Morley establishes the deformation ratio $\frac{k_\perp}{k_\parallel} = \sqrt{1 - v^2/c^2}$, precise measurements of time dilation in high-velocity systems could determine the absolute values of both deformation factors.

If experimental measurements confirm $k_\perp = 1$, the Lorentz contraction becomes an empirical fact derived from wave-mechanical principles. Conversely, if measurements reveal $k_\perp < 1$, our framework provides the natural extension to special relativity. In either case, our approach eliminates the need for the Lorentz contraction as a fundamental postulate, replacing it with a physical mechanism rooted in the wave nature of matter.

This paradigm shift represents a fundamental advancement beyond Einstein's original formulation, transforming special relativity from a theory based on postulates to one derived from physical principles with experimentally verifiable microfoundations. The geometric rigor of our demonstrations establishes that a medium-based interpretation of relativity is not merely philosophically distinct but mathematically and physically substantive, offering a causal foundation for one of physics' most fundamental frameworks.

 doi:10.20944/preprints202509.2412.v1

Appendix H Appendix A: Complete Geometric Derivation of Michelson-Morley Constraint

This appendix presents the complete derivation of the deformation constraint using the original geometric analysis from Furne Gouveia [1].

Appendix H.1 Experimental Setup and Light Path Analysis

Consider the interferometer moving with velocity v relative to the medium. Let L_0 be the proper length of each arm when at rest in the medium. When moving, the arms deform to lengths:

$$L_{\|} = k_{\|} L_0 \quad \text{(longitudinal arm)}$$
$$L_{\perp} = k_{\perp} L_0 \quad \text{(transverse arm)}$$

where $k_{\|}$ and $k_{\perp}$ are dimensionless deformation factors that depend on the velocity v relative to the medium. These factors describe how the physical length of the arms changes due to motion through the medium. At rest ($v = 0$), we have $k_{\|} = k_{\perp} = 1$, meaning no deformation. The goal of our derivation is to find the relationship between $k_{\|}$ and $k_{\perp}$ imposed by the Michelson-Morley null result.

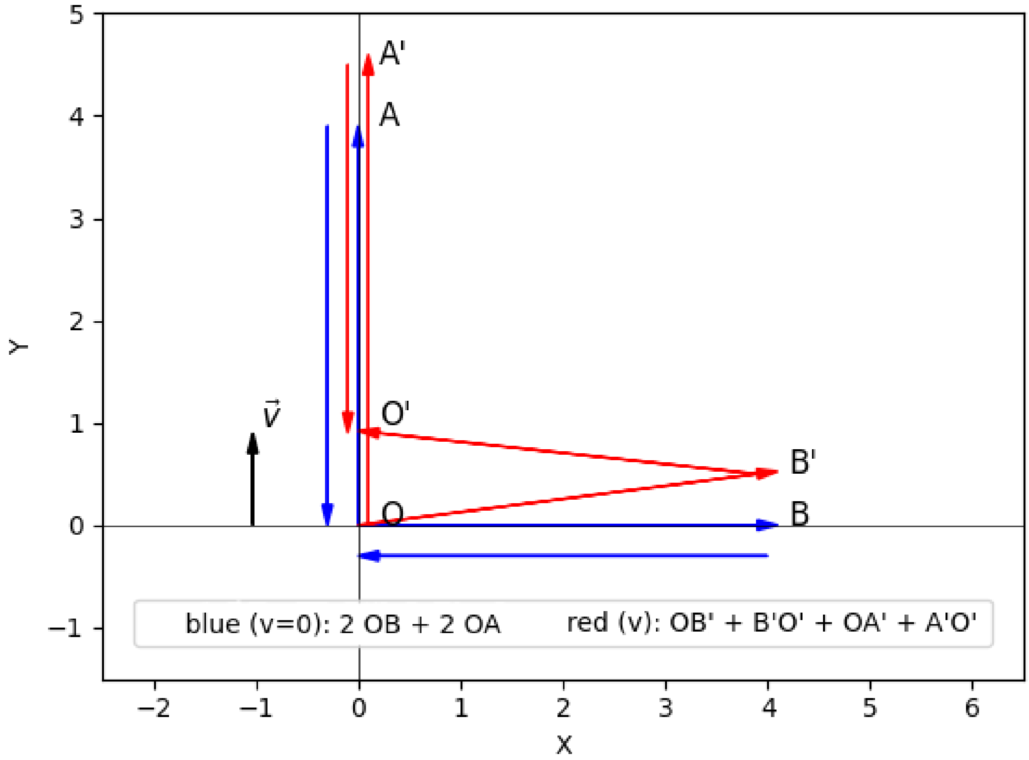

Figure A1. Light paths in the Michelson interferometer: blue arrows show paths when stationary in the medium, red arrows show paths when moving with velocity v relative to the medium.

Appendix H.2 Longitudinal Arm Analysis

For the longitudinal arm (parallel to motion), the light path in the medium frame is:
Forward trip (from O to A'):

$$t_1 = \frac{L_{\|}}{c - v}$$

Return trip (from A' to O'):

$$t_2 = \frac{L_{\|}}{c + v}$$

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 29 September 2025 doi:10.20944/preprints202509.2412.v1

Total round-trip time:

$$t_{\parallel} = \frac{L_{\parallel}}{c - v} + \frac{L_{\parallel}}{c + v} = L_{\parallel}\left(\frac{1}{c - v} + \frac{1}{c + v}\right)$$

Simplifying:

$$t_{\parallel} = L_{\parallel}\left(\frac{(c + v) + (c - v)}{c^2 - v^2}\right) = L_{\parallel}\left(\frac{2c}{c^2 - v^2}\right) = \frac{2L_{\parallel}}{c(1 - v^2/c^2)}$$

Round-trip distance:

$$d_{\parallel} = 2L_{\parallel}$$

Appendix H.3 Transverse Arm Analysis

For the transverse arm (perpendicular to motion), the analysis requires considering the apparatus motion. The light must travel diagonally to reach the moving mirror.

During the forward trip time t, the mirror moves horizontally by distance vt. The light path forms a right triangle with:

- Vertical leg: $L_{\perp}$
- Horizontal leg: $vt/2$
- Hypotenuse: $ct/2$

Applying Pythagoras' theorem:

$$(ct/2)^2 = L_{\perp}^2 + (vt/2)^2$$

$$c^2t^2/4 = L_{\perp}^2 + v^2t^2/4$$
$$c^2t^2 = 4L_{\perp}^2 + v^2t^2$$
$$t^2(c^2 - v^2) = 4L_{\perp}^2$$
$$t = \frac{2L_{\perp}}{\sqrt{c^2 - v^2}} = \frac{2L_{\perp}}{c\sqrt{1 - v^2/c^2}}$$

The return trip is symmetric, so total round-trip time:

$$t_{\perp} = \frac{2L_{\perp}}{c\sqrt{1 - v^2/c^2}}$$

Round-trip distance:

$$d_{\perp} = \frac{2L_{\perp}}{\sqrt{1 - v^2/c^2}}$$

Appendix H.4 Null Result Condition

The experimental null result requires equal round-trip times:

$$t_{\parallel} = t_{\perp}$$

$$\frac{2L_{\parallel}}{c(1 - v^2/c^2)} = \frac{2L_{\perp}}{c\sqrt{1 - v^2/c^2}}$$

Substituting $L_{\parallel} = k_{\parallel}L_0$ and $L_{\perp} = k_{\perp}L_0$:

$$\frac{2k_{\parallel}L_0}{c(1 - v^2/c^2)} = \frac{2k_{\perp}L_0}{c\sqrt{1 - v^2/c^2}}$$

doi:10.20944/preprints202509.2412.v1

Simplifying:

$$\frac{k_{\parallel}}{1 - v^2/c^2} = \frac{k_{\perp}}{\sqrt{1 - v^2/c^2}}$$

$$k_{\perp} = k_{\parallel}\sqrt{1 - v^2/c^2}$$

$$\frac{k_{\perp}}{k_{\parallel}} = \sqrt{1 - \frac{v^2}{c^2}}$$

This completes the derivation of Equation (1).

Appendix I Appendix B: Generalized Derivation of Time Dilation from Helical Paths with Deformation Factors

Appendix I.1 Particle as Confined Light Trajectory with Deformation

Consider a fundamental particle as a confined light-like trajectory. When at rest, the trajectory forms closed loops of proper radius R_0. When moving with velocity v relative to the medium, the particle deforms according to the factors $k_{\parallel}$ and $k_{\perp}$.

The helical trajectory now has:

- Radius: $R = k_{\perp} R_0$
- Pitch: $P = k_{\parallel} P_0$
- Translation distance: $v\Delta t$

Appendix I.2 Generalized Helical Path Analysis

Developing the deformed helix gives a right triangle with:

- Hypotenuse: total light path $c\Delta t$
- Vertical leg: internal loop path $c\Delta\tau \cdot g(k_{\parallel}, k_{\perp})$
- Horizontal leg: translation path $v\Delta t$

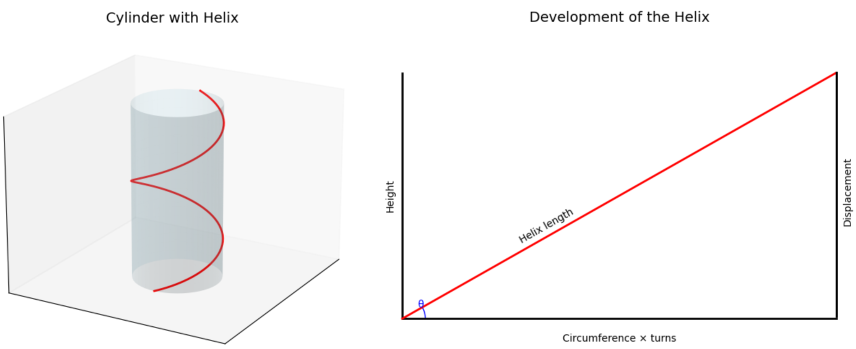

Figure A2. Helical light trajectory with deformation factors and its development.

Applying Pythagoras' theorem:

$$(c\Delta t)^2 = [c\Delta\tau \cdot g(k_{\parallel}, k_{\perp})]^2 + (v\Delta t)^2$$

The function $g(k_{\parallel}, k_{\perp})$ accounts for how the deformation affects the internal path length. For $k_{\perp} = 1$ (no transverse contraction, i.e. base cylinder not shrinking), we recover the standard result:

$$\Delta\tau = \Delta t\sqrt{1 - \frac{v^2}{c^2}}$$

 doi:10.20944/preprints202509.2412.v1

Appendix I.3 Experimental Testability

This generalized formulation reveals that precise measurements of time dilation could determine the actual deformation factors. The standard relativistic formula corresponds to the specific case $k_\perp = 1$, but our framework allows for experimental verification of whether transverse contraction occurs. Any deviation from the predicted time dilation would indicate $k_\perp \neq 1$, providing a crucial test distinguishing our medium-based approach from standard relativity.

References

1. Furne Gouveia, G. *A Generalized Contraction Framework for the Michelson-Morley Null Result in a Medium-Based Theory*. Preprints 2025. https://doi.org/10.20944/preprints202509.2283.v1
2. Einstein, A. *Zur Elektrodynamik bewegter Körper*. Annalen der Physik 17, 891 (1905).
3. Lorentz, H. A. *Electromagnetic phenomena in a system moving with any velocity smaller than that of light*. Proceedings of the Royal Netherlands Academy of Arts and Sciences, 6, 809 (1904).
4. Michelson, A. A., Morley, E. W. *On the Relative Motion of the Earth and the Luminiferous Ether*. American Journal of Science, 34, 333 (1887).
5. Furne Gouveia, G. *The Vibrational Fabric of Spacetime: A Model for the Emergence of Mass, Inertia, and Quantum Non-Locality*. Preprints 2025a. https://doi.org/10.20944/preprints202509.0184.v1
6. Furne Gouveia, G. *The Role of Energy Density Diffusion in Galactic Dynamics and Cosmic Expansion: A Unified Theory for MOND and Dark Energy*. Preprints 2025b. https://doi.org/10.20944/preprints202509.0792.v1
7. Furne Gouveia, G. *The Multiverse as the Source of Anisotropy: Explaining Three Fermion Generations and Early Galaxies*. Preprints 2025c. https://doi.org/10.20944/preprints202509.1117.v1
8. Barcelo, C., Liberati, S., & Visser, M. *Analogue gravity*. Living Reviews in Relativity, 8(1), 12 (2005).
9. Volovik, G. E. *The Universe in a helium droplet*. Oxford University Press (2003).
10. Jacobson, T. *Thermodynamics of spacetime: The Einstein equation of state*. Physical Review Letters, 75, 1260 (1995).
11. Wilczek, F. *Getting its from bits*. Nature, 427(6971), 480-485 (2004).
12. Weisskopf, V. F. *The Visual Appearance of Rapidly Moving Objects*. Physics Today, 13(9), 24-27 (1960).
13. Kraus, U. *First-person visualizations of the special and general theory of relativity*. European Journal of Physics, 23(1), 1 (2002).