**Note on Version 2**: This version updates Section XIII A and Appendix B to reformulate the rigidity calculations, associating lepton masses with pairs of rigidities ($\lambda_2/\lambda_1$, $\lambda_3/\lambda_1$, $\lambda_3/\lambda_2$) to reflect the three orthogonal planes.

# A Vibrational Model of Space: Anisotropy, Granularity, and Gravitational Effects

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We propose a novel theoretical framework where space is a vibrational medium composed of granular entities, characterized by intrinsic anisotropy $(\lambda_1, \lambda_2, \lambda_3)$. Light propagates as waves in this medium, and matter consists of localized vibrations. Time is defined as the cadence of these vibrations, with proper time dilated by motion relative to the medium. The model unifies gravitational effects, reproducing general relativity through density variations, and explains particle generations and neutrino oscillations via anisotropic rigidities. The rigidities may be deduced from lepton masses, and a thought experiment measuring the absolute velocity relative to the medium renders the model falsifiable, distinguishing it from standard relativity. Predictions for experimental tests, including neutrino oscillation anomalies and gravitational effects, are discussed.

## I. INTRODUCTION

The nature of space and time remains a fundamental question in physics. While Einstein's relativity [1] describes space-time as a smooth, four-dimensional manifold, alternative models propose a physical medium underlying space [2]. We introduce a vibrational model where space is a granular, anisotropic medium of vibrating entities, propagating light as waves and hosting matter as localized vibrations. Time emerges as the cadence of these vibrations, and gravitational effects arise from density variations in the medium. This model represents a paradigm shift in conceptualizing space and time, with calculations presented as simplified demonstrations of its internal consistency, inviting further refinement and experimental validation.

This framework unifies particle physics and cosmology, offering testable predictions for neutrino oscillations, gravitational effects, and absolute velocity measurements. Section II outlines the model's principles, followed by detailed discussions of its implications (Sections III–XIV). Section XV proposes a falsifiable experiment to measure the absolute velocity relative to the medium. Appendices provide mathematical derivations, and Section XVI summarizes future tests.

## II. MODEL OVERVIEW

The model posits that:

1. Space is a physical medium of granular entities vibrating at $\nu_g \sim 10^{43}$ Hz, with density $\rho = \rho_0 + \rho_m$.
2. Light propagates as waves with direction-dependent speeds $c_i = c/\sqrt{\lambda_i}$, where $\lambda_i$ are anisotropic rigidities.
3. Matter consists of localized vibrations, with mass $m = h\nu/c^2$.
4. Time is the cadence of vibrations, with proper time $\tau = t\sqrt{1 - v^2\lambda_i/c^2}$.
5. Density variations reproduce general relativity, and anisotropy explains particle generations and neutrino oscillations.

## III. SPACE AS A VIBRATIONAL MEDIUM

The medium consists of $N_g$ grains per volume $V$, with density:

$$\rho = \rho_0 + \rho_m, \quad \rho_m = N_g \frac{h\nu_g}{V}. \tag{1}$$

The grains synchronize via a Kuramoto-like mechanism [3] (Appendix E).

## IV. TIME AS CADENCE

Time is defined as the oscillation frequency of grains or particles. For a clock moving at velocity $v$ along axis $i$:

$$\tau = t\sqrt{1 - \frac{v^2\lambda_i}{c^2}}. \tag{2}$$

## V. LIGHT PROPAGATION

Light travels as waves with speed:

$$c_i = \frac{c}{\sqrt{\lambda_i}}. \tag{3}$$

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## VI. MATTER AS LOCALIZED WAVES

Particles are vibrations with energy $E = h\nu$, yielding mass:

$$m = \frac{h\nu}{c^2}. \tag{4}$$

## VII. PROPER TIME OF PARTICLES

The proper time of a particle moving at $v$ is dilated as in Equation (2).

## VIII. DENSITY OF THE MEDIUM

Near a mass $m$, the density increases:

$$\rho_m \propto \frac{mc^2}{h\nu_g}. \tag{5}$$

## IX. GRAVITATIONAL EFFECTS

Density variations reproduce Einstein's field equations:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \tag{6}$$

## X. MICHELSON-MORLEY NULL RESULT

The null result of Michelson-Morley [4] is explained by length contraction:

$$L'_x = L_0 \sqrt{1 - \frac{v^2 \lambda_1}{c^2}}. \tag{7}$$

## XI. ABSOLUTE SPACE FRAME

The medium acts as an absolute frame, masked by generalized Lorentz transformations (Appendix C).

## XII. EQUIVALENCE OF REFERENCE FRAMES

The apparent equivalence of frames arises from Doppler effects:

$$\nu' = \nu \frac{\sqrt{1 - v^2 \lambda_1 / c^2}}{1 - (v/c)\cos\theta \sqrt{\lambda_1}}. \tag{8}$$

## XIII. PARTICLE GENERATIONS

The three rigidities correspond to the three generations of leptons and quarks, with masses:

$$m_i = \frac{h\nu_i}{c^2}. \tag{9}$$

### A. Determining Rigidities from Lepton Masses

The three rigidities $\lambda_1, \lambda_2, \lambda_3$ may be deduced from the masses of the electron ($m_e \approx 0.511\,\mathrm{MeV}/c^2$), muon ($m_\mu \approx 105.66\,\mathrm{MeV}/c^2$), and tau ($m_\tau \approx 1776.86\,\mathrm{MeV}/c^2$) [5], which correspond to vibrational modes in the anisotropic medium. Each lepton forms a closed light trajectory in a specific plane ($yz$, $xz$, $xy$), with its frequency determined by a pair of rigidities:

- Electron: plane $yz$, frequency dependent on $\lambda_2$ and $\lambda_1$.
- Muon: plane $xz$, frequency dependent on $\lambda_3$ and $\lambda_1$.
- Tau: plane $xy$, frequency dependent on $\lambda_3$ and $\lambda_2$.

The frequency is modeled as:

$$\nu_i = \kappa' \sqrt{\frac{\lambda_i}{\lambda_j}}, \tag{10}$$

yielding mass:

$$m_i = \frac{h\nu_i}{c^2} = \frac{h\kappa'}{c^2} \sqrt{\frac{\lambda_i}{\lambda_j}}, \tag{11}$$

where $\kappa' \propto \sqrt{\rho_0 c^2 / \mu}$, with $\rho_0$ the medium's base density and $\mu$ the effective mass. Specifically:

$$\begin{aligned} m_e &= \frac{h\kappa'}{c^2} \sqrt{\frac{\lambda_2}{\lambda_1}}, \\ m_\mu &= \frac{h\kappa'}{c^2} \sqrt{\frac{\lambda_3}{\lambda_1}}, \\ m_\tau &= \frac{h\kappa'}{c^2} \sqrt{\frac{\lambda_3}{\lambda_2}}. \end{aligned} \tag{12}$$

The mass ratios are:

$$\begin{aligned} \frac{m_\mu}{m_e} &= \sqrt{\frac{\lambda_3/\lambda_1}{\lambda_2/\lambda_1}} = \sqrt{\frac{\lambda_3}{\lambda_2}} \approx 206.73, \\ \frac{m_\tau}{m_e} &= \sqrt{\frac{\lambda_3/\lambda_2}{\lambda_2/\lambda_1}} = \sqrt{\frac{\lambda_3}{\lambda_1}} \approx 3477.22, \\ \frac{m_\tau}{m_\mu} &= \sqrt{\frac{\lambda_3/\lambda_2}{\lambda_3/\lambda_1}} = \sqrt{\frac{\lambda_1}{\lambda_2}} \approx 16.82. \end{aligned} \tag{13}$$

These yield:

$$\begin{aligned} \lambda_3/\lambda_2 &\approx (206.73)^2 \approx 42737, \\ \lambda_3/\lambda_1 &\approx (3477.22)^2 \approx 1.209 \times 10^7, \\ \lambda_2/\lambda_1 &\approx (3477.22/206.73)^2 \approx 282.89. \end{aligned} \tag{14}$$

Normalizing $\lambda_1 = 1$, we estimate:

$$\lambda_1 \approx 1, \quad \lambda_2 \approx 282.89, \quad \lambda_3 \approx 1.209 \times 10^7. \tag{15}$$

This framework, detailed in Appendix B, ensures that the three lepton generations correspond to the three possible rigidity pairs, eliminating the need for a fourth generation.

## XIV. NEUTRINO OSCILLATIONS

Neutrino oscillations arise from anisotropy, with oscillation length [5]:

$$L_{ij} \approx \frac{4\pi E}{\Delta m_{ij}^2 c^4}. \tag{16}$$

The MSW effect is reproduced (Appendix D).

## XV. PROPOSED EXPERIMENT: MEASURING ABSOLUTE VELOCITY RELATIVE TO SPACE

To test the hypothesis that space acts as an absolute vibrational medium, we propose a thought experiment to measure the absolute velocity $\vec{V} = (V_x, V_y, V_z)$ of a laboratory relative to this medium. The experiment leverages the model's intrinsic anisotropy, characterized by directional rigidities $\lambda_1, \lambda_2, \lambda_3$, which affect the proper time of material clocks moving through the medium.

Consider two material clocks, $A$ and $B$, moving toward each other at a relative velocity $v$ in a laboratory frame, with velocities $\vec{v}_A = (v/2, 0, 0)$ and $\vec{v}_B = (-v/2, 0, 0)$ along a chosen direction. Each clock measures the proper time of an external event, such as the interval between two light signals emitted by a stationary source. Due to their motion relative to the medium, their absolute velocities are $\vec{v}_{A,\text{abs}} = \vec{V} + \vec{v}_A$ and $\vec{v}_{B,\text{abs}} = \vec{V} + \vec{v}_B$, leading to different proper times:

$$\begin{aligned} \tau_A &= \Delta t \sqrt{1 - \frac{1}{c^2}\left[\lambda_1\left(V_x + \frac{v}{2}\right)^2 + \lambda_2 V_y^2 + \lambda_3 V_z^2\right]}, \\ \tau_B &= \Delta t \sqrt{1 - \frac{1}{c^2}\left[\lambda_1\left(V_x - \frac{v}{2}\right)^2 + \lambda_2 V_y^2 + \lambda_3 V_z^2\right]}. \end{aligned} \tag{17}$$

The relative proper time difference, $\Delta\tau_{\text{rel}} = |\tau_A - \tau_B|/\Delta t$, is measured for multiple directions in the $xy$-plane, parameterized by angle $\theta$. The direction $\theta_{\min}$ where $\Delta\tau_{\text{rel}} \approx 0$ indicates that the effective absolute velocities are equal, satisfying:

$$\lambda_1 V_x \cos\theta_{\min} + \lambda_2 V_y \sin\theta_{\min} \approx 0. \tag{18}$$

Repeating the experiment in the $xz$-plane yields $\phi_{\min}$ such that:

$$\lambda_1 V_x \cos\phi_{\min} + \lambda_3 V_z \sin\phi_{\min} \approx 0. \tag{19}$$

By combining these constraints with the maximum time difference, which scales as $\Delta\tau_{\text{rel,max}} \approx vV/c^2$, the components $V_x, V_y, V_z$ can be determined, yielding the absolute velocity $\vec{V}$.

This experiment, though challenging due to the required precision (e.g., $\Delta\tau \sim 10^{-12}$ s for $v = 1000$ m/s, $V = 370$ km/s), renders the model falsifiable. A null result would challenge the existence of an absolute medium, while a positive detection would distinguish this framework from standard relativity. See Appendix F for a detailed derivation, including mathematical constraints and experimental challenges.

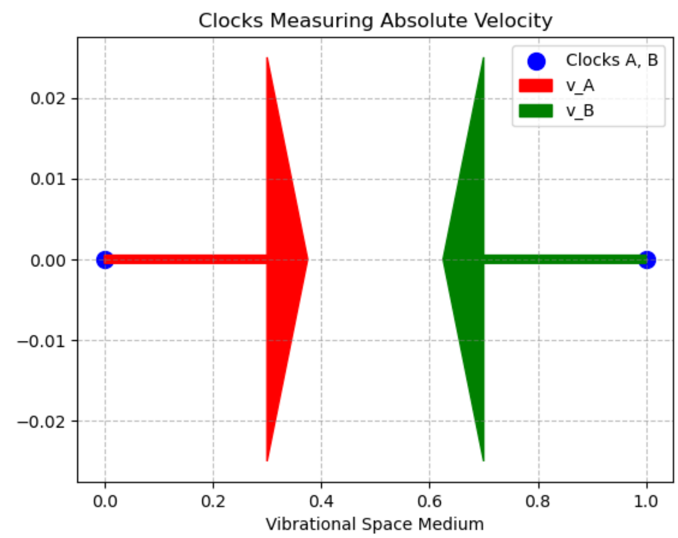


FIG. 1. Two clocks moving toward each other in the vibrational space medium, measuring proper time differences to detect the absolute velocity $\vec{V}$.

## XVI. CONCLUSIONS AND FUTURE DIRECTIONS

This model offers a unified framework for space, time, matter, and gravity, with testable predictions for neutrino oscillations, gravitational effects, and absolute velocity measurements. The rigidities $\lambda_i$, deduced from lepton masses using rigidity pairs, provide a link to particle physics. The proposed velocity experiment enhances the model's falsifiability, inviting further theoretical and experimental scrutiny. While the calculations herein are simplified to illustrate the model's coherence, they establish a foundation for future refinements, such as precise calibration of $\lambda_i$ or experimental designs at facilities like DUNE or LHC.

### Appendix A: Density of the Medium

The density is derived as:

$$\rho = \rho_0 + \rho_m, \quad \rho_m = N_g \frac{h\nu_g}{V}. \tag{A1}$$

### Appendix B: Determination of Rigidities from Lepton Masses

The rigidities $\lambda_1, \lambda_2, \lambda_3$ determine the vibrational frequencies of the electron, muon, and tau, each associated with a plane ($yz$, $xz$, $xy$). The frequency depends on a pair of rigidities:

$$\nu_i = \kappa' \sqrt{\frac{\lambda_i}{\lambda_j}}, \tag{B1}$$

where $\kappa' \propto \sqrt{\rho_0 c^2/\mu}$. The lepton mass is:

$$m_i = \frac{h\nu_i}{c^2} = \frac{h\kappa'}{c^2}\sqrt{\frac{\lambda_i}{\lambda_j}}. \tag{B2}$$

Using experimental masses ($m_e \approx 0.511\,\mathrm{MeV}/c^2$, $m_\mu \approx 105.66\,\mathrm{MeV}/c^2$, $m_\tau \approx 1776.86\,\mathrm{MeV}/c^2$) [5], we assign:

$$\begin{aligned} m_e &= \frac{h\kappa'}{c^2}\sqrt{\frac{\lambda_2}{\lambda_1}}, \quad \text{(plane } yz\text{)}, \\ m_\mu &= \frac{h\kappa'}{c^2}\sqrt{\frac{\lambda_3}{\lambda_1}}, \quad \text{(plane } xz\text{)}, \\ m_\tau &= \frac{h\kappa'}{c^2}\sqrt{\frac{\lambda_3}{\lambda_2}}, \quad \text{(plane } xy\text{)}. \end{aligned} \tag{B3}$$

The mass ratios give:

$$\begin{aligned} \sqrt{\frac{\lambda_3}{\lambda_2}} &= \frac{m_\mu}{m_e} \approx 206.73, \\ \sqrt{\frac{\lambda_3}{\lambda_1}} &= \frac{m_\tau}{m_e} \approx 3477.22, \\ \sqrt{\frac{\lambda_1}{\lambda_2}} &= \frac{m_\tau}{m_\mu} \approx 16.82. \end{aligned} \tag{B4}$$

Thus:

$$\begin{aligned} &\lambda_3/\lambda_2 \approx 42737, \\ &\lambda_3/\lambda_1 \approx 1.209 \times 10^7, \\ &\lambda_2/\lambda_1 \approx 282.89. \end{aligned} \tag{B5}$$

Assuming $\lambda_1 = 1$:

$$\lambda_1 \approx 1, \quad \lambda_2 \approx 282.89, \quad \lambda_3 \approx 1.209 \times 10^7. \tag{B6}$$

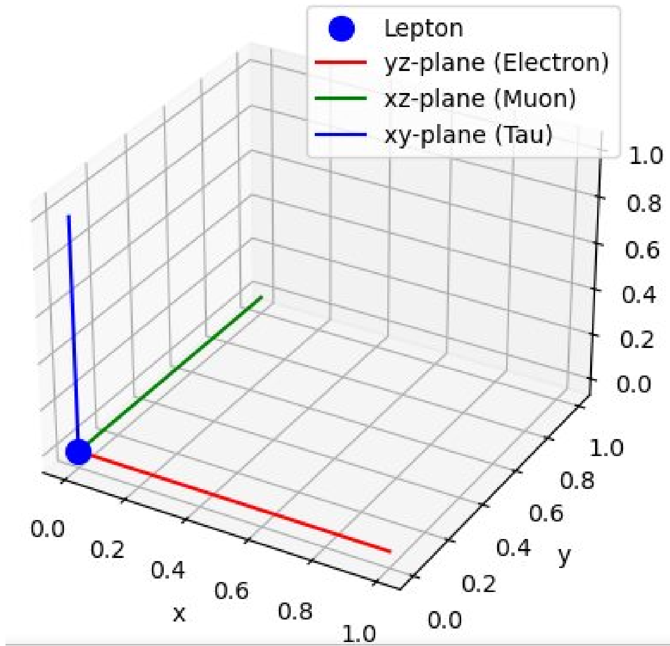


FIG. 2. Three vibrational modes.

The vibrational modes occur in perpendicular planes, with transitions driven by energy thresholds:

$$E_{i+1} - E_i \propto \sqrt{\frac{\lambda_i}{\lambda_j}} - \sqrt{\frac{\lambda_k}{\lambda_l}}. \tag{B7}$$

These rigidities must be validated experimentally, e.g., through neutrino oscillations or the absolute velocity experiment (Appendix F).

### Appendix C: Generalized Lorentz Transformations

The transformations are:

$$\begin{aligned} x' &= \gamma\left(x - vt\sqrt{\lambda_1}\right), \\ t' &= \gamma\left(t - \frac{vx\lambda_1}{c^2}\right), \\ \gamma &= \frac{1}{\sqrt{1 - v^2\lambda_1/c^2}}. \end{aligned} \tag{C1}$$

### Appendix D: MSW Effect for Neutrinos

The oscillation length is:

$$L_{ij} \approx \frac{4\pi E}{\Delta m_{ij}^2 c^4}. \tag{D1}$$

### Appendix E: Kuramoto Synchronization

The grain synchronization follows:

$$\frac{d\theta_i}{dt} = \omega_i + \frac{K}{N_g} \sum_{j=1}^{N_g} \sin(\theta_j - \theta_i). \tag{E1}$$

### Appendix F: Absolute Velocity Measurement

To test the model's prediction of an absolute vibrational medium, we propose an experiment to measure the laboratory's absolute velocity $\vec{V} = (V_x, V_y, V_z)$ relative to this medium. The experiment uses two material clocks, $A$ and $B$, moving toward each other at relative velocity $v$, leveraging the medium's anisotropy $(\lambda_1, \lambda_2, \lambda_3)$ to detect differences in proper time.

Consider a laboratory frame moving at $\vec{V}$ relative to the medium. Clocks $A$ and $B$ have velocities $\vec{v}_A = (v/2\cos\theta, v/2\sin\theta, 0)$ and $\vec{v}_B = (-v/2\cos\theta, -v/2\sin\theta, 0)$ in the $xy$-plane, parameterized by angle $\theta$. Their absolute velocities are:

$$\begin{aligned} \vec{v}_{A,\mathrm{abs}} &= \left(V_x + \frac{v}{2}\cos\theta, V_y + \frac{v}{2}\sin\theta, V_z\right), \\ \vec{v}_{B,\mathrm{abs}} &= \left(V_x - \frac{v}{2}\cos\theta, V_y - \frac{v}{2}\sin\theta, V_z\right). \end{aligned} \tag{F1}$$

Define intermediate variables for clarity:

$$\begin{aligned} u_A &= V_x + \frac{v}{2}\cos\theta, \quad w_A = V_y + \frac{v}{2}\sin\theta, \\ u_B &= V_x - \frac{v}{2}\cos\theta, \quad w_B = V_y - \frac{v}{2}\sin\theta. \end{aligned} \tag{F2}$$

The effective squared velocities, accounting for anisotropy, are:

$$\begin{aligned} v_{A,\mathrm{eff}}^2 &= \lambda_1 u_A^2 + \lambda_2 w_A^2 + \lambda_3 V_z^2, \\ v_{B,\mathrm{eff}}^2 &= \lambda_1 u_B^2 + \lambda_2 w_B^2 + \lambda_3 V_z^2. \end{aligned} \tag{F3}$$

For an external event of duration $\Delta t$ in the laboratory frame (e.g., two light signals from a stationary source), the proper times are:

$$\begin{aligned} \tau_A &= \Delta t \sqrt{1 - \frac{v_{A,\mathrm{eff}}^2}{c^2}}, \\ \tau_B &= \Delta t \sqrt{1 - \frac{v_{B,\mathrm{eff}}^2}{c^2}}. \end{aligned} \tag{F4}$$

The relative time difference is:

$$\Delta\tau_{\mathrm{rel}}(\theta) = \frac{|\tau_A - \tau_B|}{\Delta t} = \left| \sqrt{1 - \frac{v_{A,\mathrm{eff}}^2}{c^2}} - \sqrt{1 - \frac{v_{B,\mathrm{eff}}^2}{c^2}} \right|. \tag{F5}$$

Minimizing $\Delta\tau_{\mathrm{rel}}$ occurs when $v_{A,\mathrm{eff}}^2 \approx v_{B,\mathrm{eff}}^2$. Equating the effective velocities:

$$\lambda_1 \left(V_x + \frac{v}{2}\cos\theta\right)^2 + \lambda_2 \left(V_y + \frac{v}{2}\sin\theta\right)^2 \approx \tag{F6}$$

$$\approx \lambda_1 \left(V_x - \frac{v}{2}\cos\theta\right)^2 + \lambda_2 \left(V_y - \frac{v}{2}\sin\theta\right)^2. \tag{F7}$$

Expanding and simplifying:

$$\lambda_1(2V_x v\cos\theta) + \lambda_2(2V_y v\sin\theta) \approx 0, \tag{F8}$$

$$\lambda_1 V_x \cos\theta_{\min} + \lambda_2 V_y \sin\theta_{\min} \approx 0, \quad \tan\theta_{\min} \approx -\frac{\lambda_1 V_x}{\lambda_2 V_y}. \tag{F9}$$

In the $xz$-plane, with velocities $\vec{v}_A = (v/2\cos\phi, 0, v/2\sin\phi)$, $\vec{v}_B = (-v/2\cos\phi, 0, -v/2\sin\phi)$, define:

$$\begin{aligned} p_A &= V_x + \frac{v}{2}\cos\phi, \quad q_A = V_z + \frac{v}{2}\sin\phi, \\ p_B &= V_x - \frac{v}{2}\cos\phi, \quad q_B = V_z - \frac{v}{2}\sin\phi. \end{aligned} \tag{F10}$$

The effective velocities are:

$$\begin{aligned} v_{A,\mathrm{eff}}^2 &= \lambda_1 p_A^2 + \lambda_3 q_A^2, \\ v_{B,\mathrm{eff}}^2 &= \lambda_1 p_B^2 + \lambda_3 q_B^2. \end{aligned} \tag{F11}$$

Minimizing $\Delta\tau_{\mathrm{rel}}(\phi)$ gives:

$$\lambda_1 V_x \cos\phi_{\min} + \lambda_3 V_z \sin\phi_{\min} \approx 0, \quad \tan\phi_{\min} \approx -\frac{\lambda_1 V_x}{\lambda_3 V_z}. \tag{F12}$$

The maximum time difference, when the velocity difference is maximized, scales as:

$$\Delta\tau_{\mathrm{rel,max}} \approx \frac{vV}{c^2}. \tag{F13}$$

For $v = 1000\,\mathrm{m/s}$ and $V = 370\,\mathrm{km/s}$ (e.g., Earth's velocity relative to the CMB), $\Delta\tau_{\mathrm{rel}} \approx 4 \times 10^{-12}$, requiring high-precision clocks (e.g., atomic clocks with $\sim 10^{-18}\,\mathrm{s}$ accuracy).

To determine $\vec{V}$, solve:

$$\begin{aligned} \tan\theta_{\min} &= -\frac{\lambda_1 V_x}{\lambda_2 V_y}, \\ \tan\phi_{\min} &= -\frac{\lambda_1 V_x}{\lambda_3 V_z}, \end{aligned} \tag{F14}$$

and use $\Delta\tau_{\mathrm{rel,max}}$ to estimate $V$. Assuming $\lambda_1, \lambda_2, \lambda_3$ are known (e.g., from neutrino oscillations or particle masses), the components $V_x, V_y, V_z$ are obtained, yielding $\vec{V}$. Challenges include the need for extreme precision and potential masking by matter adaptation (length contraction), but a positive detection would confirm the absolute medium, while a null result would challenge the model.

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