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Measuring Velocity Using Moving Clocks—The Surprising Test of Tangherlini's Theory

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Abstract

Motivated by the work of Matsas et al. (2024), which demonstrates that time can serve as the fundamental unit for physical quantities—obviating the need for traditional Length-Mass-Time (LMT) dimensions—this research evaluates the operational resolution of velocity within relativistic frameworks. Utilizing a Lorentz transformation matrix approach, we first validate the Matsas three-clock protocol, confirming the derivation of distance as a function of three proper clock times in Minkowski spacetime and uncovering two novel velocity expressions derived solely from these temporal intervals. The investigation was extended to Tangherlini's 4D spacetime framework (1958) to test the hypothesis that absolute velocity could be resolved through subluminal signaling. While the initial three-clock scenario resulted in the systematic cancellation of the Base system's absolute velocity, a breakthrough was achieved by applying the Relativistic Doppler Effect within the Tangherlini metric. This approach effectively circumvents the mathematical cancellations prevalent in standard relativistic "null" experiments. The findings reveal that the Tangherlini and Minkowski frameworks are intimately related; the former serves as a necessary complement to the Special Theory of Relativity (STR) rather than an antagonist. This theoretical advancement suggests a plausible methodology for the measurement of absolute velocity without the requirement of instantaneous signals. By resolving the longitudinal Doppler shift within a preferred-frame geometry, this research provides fresh impetus for the historical debate on absolute motion initiated by Poincaré and Einstein.

Keywords: absolute rest; absolute velocity; Tangherlini transformation; postulate of relativity; physical units

1. Introduction

In a 2024 study, Matsas et al. [1] introduced a compelling conceptual framework in which time serves as the sole fundamental unit for all physical quantities, effectively superseding the traditional Length-Mass-Time (LMT) dimensional system. A particularly significant implication of this framework is the ability to measure spatial distance using only three inertial clocks. This is possible by employing the Unruh protocol[1]. This an unusual measurement can be achieved via a round-trip configuration involving one stationary clock C_3 and two relatively moving clocks C_1 and C_2, as illustrated in in Figure 1.While such a result is unattainable within a Galilean coordinate system, it becomes viable in Minkowski spacetime. This is due to the reduction in degrees of freedom caused by the implementation of Einstein's light-speed isotropy postulate. The distance-measurement formula derived in [1] is based on the world lines of three inertial clocks forming a triangle in Minkowski diagram, expressed as:

$$D = \frac{\sqrt{[(\tau_3{}^2 - \tau_1{}^2 - \tau_2{}^2)^2 - 4\tau_1{}^2\tau_2{}^2]}}{2\tau_3}, \qquad (1)$$

[1] Bill Unruh undisclosed private communication according to [1].

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where τ_3 is the C3 clock time at the stationary system origin and τ_1, τ_2 are the moving clocks' (C1 and C2) respective trips durations at unspecified velocities. This formula can be expanded to the following equivalent expression:

$$D = \frac{\sqrt{\tau_1{}^4 - 2\tau_1{}^2\tau_2{}^2 - 2\tau_1{}^2\tau_3{}^2 + \tau_2{}^4 - 2\tau_2{}^2\tau_3{}^2 + \tau_3{}^4}}{2\tau_3} \tag{2}$$

Experimental Protocol

In this paper, we employ a motion protocol that differs slightly from the original arrangement in [1] but remains physically equivalent.

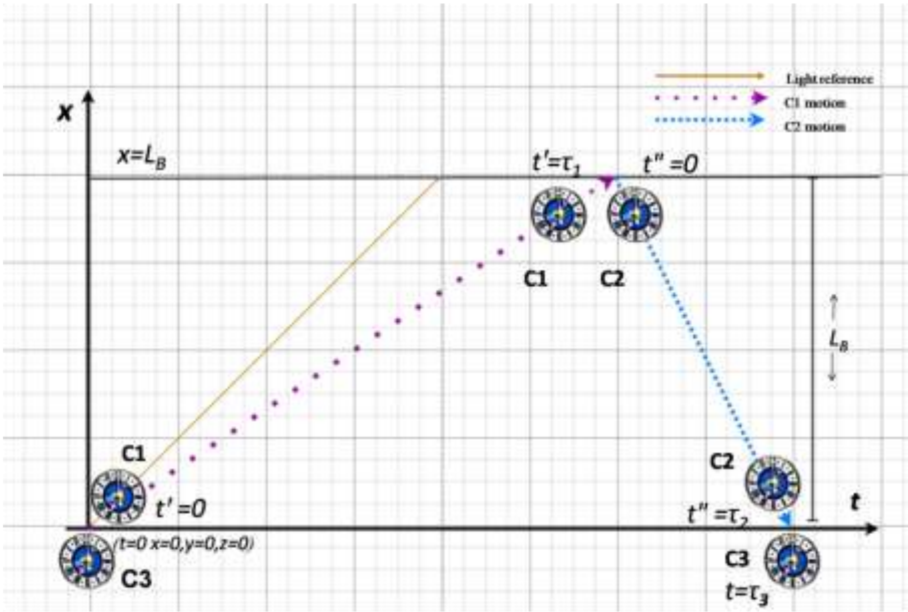

Figure 1. The three clocks scenario (angles not to scale).

1. **Reference Frame:** The stationary laboratory frame is designated as System ***B*** (Base platform).
2. **Clock C1 Initiation:** Clock C1 approaches from the negative x-axis at a constant, unknown velocity v_1. Upon passing the origin, it is synchronized to $t' = 0$.
3. **Base Synchronization:** The stationary clock C3 is simultaneously reset to $t = 0$ at the moment of C1's departure from the origin.
4. **Clock C2 Wordline:** Clock C2 is launched from a distant point on the positive x-axis at velocity v_2 on a reciprocal heading toward the origin. To ensure a continuous trajectory, a negligible y-axis offset is assumed. Upon its encounter with C1 at unknown position $x = L_B$, C2 is synchronized to $t'' = 0$.
5. **Procedural Independence**: While this round-trip arrangement aligns with the triangular geometry in Minkowski spacetime used in [1], the individual legs of the trip may be executed sequentially in practice, as the recorded durations are independent of the specific epoch of initiation. The delay δ between C1 arrival and C2 arrival can be measured by an additional non synchronized clock similar to C3 at $x = \tau_2$,. It increases the accumulated total duration of the clock C3. In this case the distance L_B, must be fixed rather emerging dynamically from the collision at random time. For derivation clarity, we assume δ=0 to maintain consistency with [1].
6. **Data Transmission C1**: At the point of encounter with C2, clock C1 transmits its elapsed proper time τ_1 to the origin of ***B***, to support future calculations while C2 resets the time t'' to 0.
7. **Data Transmission C2:** Upon reaching the origin, clock C2 communicates its recorded duration τ_2 to the Base to support future calculations.

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8. **Final Measurement:** The stationary clock C3 records the total round-trip time τ_3 representing the total duration for the clock C1 τ_1 to reach the unknown distance L_B plus C2 $\tau_2$to reach to the origin.

Through this protocol, we demonstrate that the acquired data $\tau_1, \tau_2\ \tau_3$ appear sufficient to resolve not only the unknown distance L_B but also the previously undetermined velocities v_1 and v_2.

2. Distance and Velocities Calculation in Minkowski Spacetime

The following derivations implicitly assume the idealisations and simplifications of physical reality typical of the STR [2]. The preferred method for these derivations is linear algebra, utilising the Lorentz Transformation (LT) matrix defined as:

$$\Lambda_v = \begin{bmatrix} \gamma_v & -v\frac{\gamma_v}{c} & 0 & 0 \\ -v\frac{\gamma_v}{c} & \gamma_v & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

$$\gamma_v = 1/\sqrt{1 - v^2/c^2},$$

We assume a stationary inertial Base system, System ***B***, is represented by a 4D Cartesian coordinate system. Within this frame, we analyse the motion of two inertial point masses, PM1 and PM2 represented by clocks C1 and C2, moving along the x-axis. The 4-vector XL_B represents an unknown, reference distance:

$$XL_B = \begin{bmatrix} ct \\ L_B \\ 0 \\ 0 \end{bmatrix}. \tag{4}$$

The transformation of the fixed XL_B in ***B*** to the local C1 coordinates using Lorentz transformation matrix Λ_{v1} multiplied by X_{LB} yields the moving point X_{LB1} approaching the *C1*,which is in the origin of the inertial system designated as ***B1*** :

$$\Lambda_{v1} \begin{bmatrix} ct \\ L_B \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{c^2 t - L_B v_1}{\sqrt{c^2 - {v_1}^2}} \\ \frac{L_B - v_1 t}{\sqrt{c^2 - {v_1}^2}} \\ 0 \\ 0 \end{bmatrix} \equiv X_{LB1}. \tag{5}$$

The transformed vector X_{L1} is initially expressed in terms of the Base system time t and must be converted to the local proper time t' of C1:

$$XL_{B1}[1]/c = t' \Rightarrow t = \frac{\sqrt{c^2 - {v_1}^2}ct + L_B v_1}{c^2}. \tag{6}$$

The converted vector in the local primed coordinates is obtained by the substitution of the t expression from equation (6) and subsequent simplifications:

$$X'_{LB1} = \begin{bmatrix} ct' \\ \frac{-c\sqrt{c^2 - {v_1}^2 v_1 t'} + L_B c^2 - L_B {v_1}^2}{c\sqrt{c^2 - {v_1}^2}} \\ 0 \\ 0 \end{bmatrix}. \tag{7}$$

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The time it takes for the L_B to come in contact with C1 origin can be found, when $X'_{LB1}[1] = 0$, calculated from the following equation:

$$-c\sqrt{c^2 - {v_1}^2}v_1 t' + L_B c^2 - L_B {v_1}^2 = 0 \Rightarrow t' = \frac{L_B\sqrt{c^2 - {v_1}^2}}{v_1 c} \equiv \tau_1, \quad (8)$$

where τ_1 is the proper time of the clock C1.

C2 differs from C1 only by the magnitude of the velocity and sign, hence it can be deduced from Minkowski diagram and Figure 1. Then by analogy:

$$c\sqrt{c^2 - {v_2}^2}v_2 t'' + L_B c^2 - L_B {v_2}^2 = 0 \Rightarrow t'' = \frac{L_B\sqrt{c^2 - {v_2}^2}}{-v_2 c} \equiv \tau_2. \quad (9)$$

In the Clock C3, the duration of the round-trip is the sum of successive durations on each segment given by the elementary expression:

$$\tau_3 \equiv \frac{L_B}{v_1} + \frac{L_B}{-v_2}. \quad (10)$$

The minus sign in the denominator makes the C2 clock duration positive.

Given the clock times were measured, we have three equations and three unknowns: L_B, v_1 and v_2:

$$\begin{cases} \tau_1 = \dfrac{L_B\sqrt{c^2 - {v_1}^2}}{v_1 c} \\ \tau_2 = \dfrac{L_B\sqrt{c^2 - {v_2}^2}}{-v_2 c} \\ \tau_3 = \dfrac{L_B}{v_1} + \dfrac{L_B}{-v_2}. \end{cases} \quad (11)$$

The solution of the non-linear system of equations (11) with respect to L_B, v_1 and v_2 is:

$$\begin{cases} L_B = \dfrac{\pm c\sqrt{{\tau_1}^4 - 2{\tau_1}^2{\tau_2}^2 - 2{\tau_1}^2{\tau_3}^2 + {\tau_2}^4 - 2{\tau_2}^2{\tau_3}^2 + {\tau_3}^4}}{2\tau_3} \\ v_1 = \dfrac{\pm c\sqrt{{\tau_1}^4 - 2{\tau_1}^2{\tau_2}^2 - 2{\tau_1}^2{\tau_3}^2 + {\tau_2}^4 - 2{\tau_2}^2{\tau_3}^2 + {\tau_3}^4}}{{\tau_1}^2 - {\tau_2}^2 + {\tau_3}^2} \\ v_2 = \dfrac{\pm c\sqrt{{\tau_1}^4 - 2{\tau_1}^2{\tau_2}^2 - 2{\tau_1}^2{\tau_3}^2 + {\tau_2}^4 - 2{\tau_2}^2{\tau_3}^2 + {\tau_3}^4}}{{\tau_1}^2 - {\tau_2}^2 - {\tau_3}^2}. \end{cases} \quad (12)$$

The expression for L_B in (12) is valid only for positive values. Although it appears algebraically distinct from the original Equation (1), it is equivalent to the expanded original form in Equation (2). Naturally, the constant speed of light c is absent in (2), as it was suppressed to the non-dimensional one in [1], in accordance with Minkowski diagram convention.

While we reject the negative L_B (unless it can be a coordinate on the negative side of x') we need to decide which velocity variant to chose. It was determined that in this scenario all roots not preceded by the minus sign are consistent. It is interesting to note another feature of this system. We can calculate the travel times of clocks C1, C2 in ***B*** to $x = L_B$, $x = 0$ respectively.

$$\begin{aligned} \tau_{C1} &= \frac{L_B}{v_1} = \frac{\tau_1^2 - \tau_2^2 + \tau_3^2}{2\tau_3} \\ \tau_{C2} &= \frac{L_B}{v_2} = \frac{\tau_3^2 + \tau_2^2 - \tau_1^2}{2\tau_3} \end{aligned} \quad (13)$$

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Conceptual Implications

The ability to measure L_B using clocks alone is a noteworthy discovery of Unruh and Matsas et al. [1]; however, the capacity to obtain velocities without using pre-synchronised clocks is arguably more significant. Conventionally, a measurement of a velocity requires two distant, synchronised clocks by definition: $v = dx/dt$ (with some exceptions, like Doppler methods or dual light-pulse round-trip measurements). The surprising element of the velocity expressions in Equation (12) is that no explicit distance is necessary, as it is entirely factored into the temporal parameters arrangement. The three clocks, moving relative to one another, indicate their proper times without regard for any specific coordinate system; clocks possess no inherent knowledge of other sensors or reference frames. Once we proved Equations (12) , the result in Equations (13) is not unexpected. However, this simple beautiful formula add to overall amazing result that three convention independent invariant clock proper times may practically determine $L_B, v_1, v_2, \tau_{C1}, \tau_{C2}$ without any physical implementation of a coordinates system or pair-wise synchronised clocks, and at worst using one distant point *designation* as L_B without actually measuring it. It may be a premature conclusion that Equations (13) show Nature's preference for one way velocity of light isotropy convention, because to measure τ_{C1} at $x = L_B$, because τ_{C1} was derived using the STR framework. There are some more interesting consequences of Equations (13) which will be discussed in section 3.3.

This all suggests that the three clock based measurement result is a natural consequence of the spacetime geometry. This fact prompted an investigation into possible implications of the three-clock scenario within Tangherlini spacetime, introduced in the 1958 doctoral thesis at Stanford University [3]. While the mathematical difference between the Lorentz Transformation (LT) and the Tangherlini Transformation (TT) matrices is subtle, the physical ramifications are vast. A similar scenario to that shown in Figure 1 can be applied by employing a hypothetical absolute rest frame concept and three moving clock frames in relative motion in it.

3. Three Clocks in Tangherlini Spacetime

The derivation of the transformations by, Tangherlini provided an analytical relativistic framework similar to STR [2]. Originally named the 'Absolute Lorentz Transformation' (ALT), TT was derived from the Einstein Field Equation in the absence of gravitational sources. We found that the same transformation can be derived from first principles based on fundamental postulates, including the assumption of existence of the Absolute Rest Frame (ARF), and then the core round-trip average speed of light isotropy experimental fact and the controversial invariance of the instantaneous signal hypothesis (see Appendix A for the exact postulates formulation). No relativistic effects were assumed *a-priori*; time dilation and length contraction emerged naturally.

Unlike the STR convention, where absolute velocity is outside the scope of measurement, we treat the ARF as a reference inertial system where t is the absolute time variable, however immeasurable. So far, according to the present consensus, absolute velocity suggestion appears fallacious as once asserted by Eddington [4]. On the other hand, Tangherlini tried to reason about the possibility of detecting absolute motion based on the presented theory. To start with, he pointed out that if two distant clocks are not absolutely synchronised, it is not possible to calculate the one-way relative velocity of anything, because there is no way of correlating the time of arrival in terms of the time of departure. [3] p58. In Chapter 6 of [3] p73-74 a claim is made that using subluminal signals it would be possible to detect the absolute motion of the Earth. However, despite the focused analysis, no closed form explicit solution or the exact details of the measurement method demonstrating this possibility is provided. Additionally, the final chapter of [3] p101, Tangherlini concluded that in examples presented in the doctoral thesis, absolute velocity always cancels out when measurements are performed *"in the usual manner"*. We assume these are methods not depending on the prior absolute synchronization of separated clocks which is impossible without instantaneous signals.

After discovering that velocities can be measured with only three clocks as shown in Equation (12), the question emerged whether this method was sufficiently 'unusual' to prove absolute velocity.

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The Unruh three clock protocol [1] requires only three measurable proper times and no two distant clocks appear to be synchronised other than by coincidence of their positions. We attempted the proof based on similar methodology as in section 2 but with the TT matrix which is represented as follows:

$$\Omega^{v}_{\infty} = \begin{bmatrix} 1/\gamma_v & 0 & 0 & 0 \\ -v\frac{\gamma_v}{c} & \gamma_v & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \tag{14}$$

where $\gamma_v = 1/\sqrt{1 - v/c^2}$.

The infinity subscript in the TT matrix symbol emphasises the role of the instantaneous signal postulate. Matrix (14) differs from the LT matrix (3) by the absence of the space-dependent time coordinate, which is now zero. While the impossibility of absolute synchronisation with infinitely fast signals appears as a fundamental obstacle, the significance of the TT framework would be profound if such obstacle could be circumvented.

3.1. Three Clocks Thought Experiments in Tangherlini 4D Spacetime

The graphical representation of the scenario slightly differs from the previous case by symbols of axes as shown in shown in Figure 2.

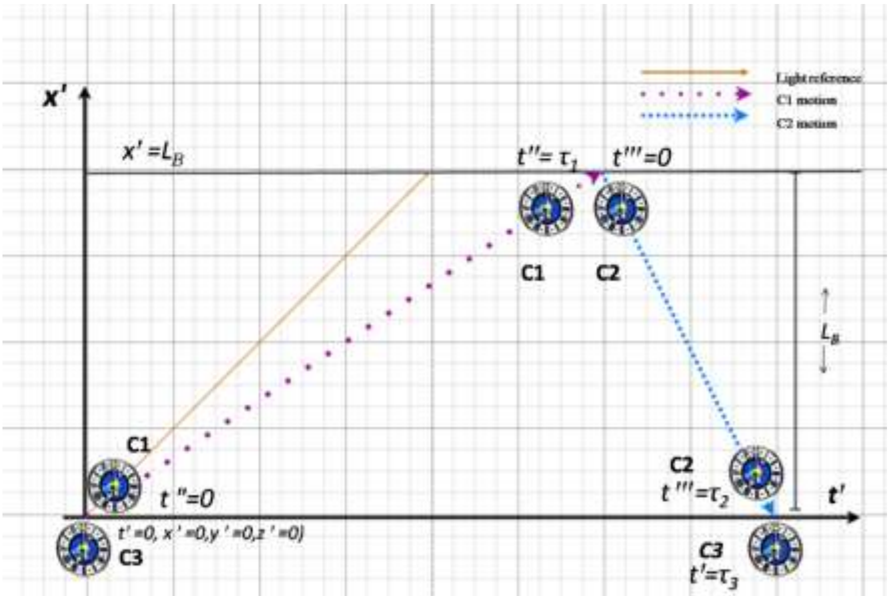

Figure 2. Two clocks round trip scenario in the system *B* (angles not to scale).

This shows the perspective of the Base system denoted by ***B*** with the system clock C_3 which is an inertial moving system with respect to the hypothetical ARF denoted by ***A***, which so far, according to the present consensus, cannot be identified. However, it is treated here as a special purpose inertial system with time variable t where no measurement can be made because no reference points are known in empty space.

In a partial agreement with the objections of Poincaré [5] regarding the absolute space coordinate axes[2], we consider instead, the absolute rest state being a unique property of the subclass of inertial

[2] This idea came from Poincaré claiming that: "absolute space is nonsense, and it is necessary for us to begin by referring space to a system of axes invariably bound to our body (which we must always suppose put back in the initial attitude)." With no features in space the only way to bootstrap the derivation is to assume that at time *t=0* some abstract coordinate system in ***A*** is momentarily aligned with the moving one and stays where it was as the distance increases. Absolute space then has no role other than being a passive container for inertial systems as far as this simple linear algebra model is concerned.

systems out of the class of all inertial systems, rather than the state of the 'void'. Our position disagrees with Newton's concept of absolute space which "remains always similar and immovable." [], but aligns with Einstein's remark on the ether: "the idea of motion may not be applied to it" [7].

The inaccessibility of the featureless absolute space to measurement and the same with respect to any inertial absolute system ***A*** can be overcome by using the inverse transformation (TT^{-1}) from any inertial system where times and lengths are measurable and they can formally be related to ***A***, based on the presented theory. At this time absolute velocity is hypothetical until possibly found measurable.

3.2. Derivation and Mathematical Reconciliation

In the system ***B***, we designate a fixed distant point XL_B as a 4-vector where the wordline of C_1 ends and C_2 begins

$$XL_B = \begin{bmatrix} ct' \\ L_B \\ 0 \\ 0 \end{bmatrix}. \quad (15)$$

Instead of relative velocities as in the LT based three clocks scenario; we look for absolute velocities with respect to initially undefined absolute frame ***A***. There is no obvious way to measure relative velocity in Tangherlini spacetime, therefore we need to introduce the base system absolute velocity vector $\overrightarrow{\boldsymbol{v_{BA}}}$ in ***A*** of an unknown magnitude v_{BA} For simplicity like in the STR standard configuration, it is aligned with the virtual x-axis of ***A*** and with the co-linear x'-axis of ***B***, as prescribed by the Tangherlini standard coordinates configuration (x- boost) .

The notation used in this paper designates the last one or two symbols in the variable's suffix to determine in which frame the quantity is observed/measured, while one or two preceding characters may define to which frame the quantity belongs, hence v_{BA} reads: 'the velocity of the system ***B*** as measured in ***A***. Similarly for the C_2 clock's frame ***B2*** we have v_{B2A} which is velocity of the system ***B2*** in A. We can determine the vector equation of motion (EOM) of XL_B in ***A*** as X_{LBA}, by applying the inverse Tangherllini Transformation matrix $(\Omega_{\infty}^{v_{BA}})^{-1}$.

$$\left(\Omega_{\infty}^{v_{BA}}\right)^{-1} \begin{bmatrix} ct' \\ L_B \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{c^2 t'}{\sqrt{c^2 - v_{BA}{}^2}} \\ \frac{(v_{BA} t' + L_B) c^2 - L_B v_{BA}{}^2}{c\sqrt{c^2 - v_{BA}{}^2}} \\ 0 \\ 0 \end{bmatrix} \equiv X_{LBA}. \quad (16)$$

The variable t' *in* ***B*** needs to be eliminated from the transformed vector so the absolute time t is consistently expressed in absolute coordinates.

$$\frac{X_{LBA}[1]}{c} = t \Rightarrow t' = \frac{t\sqrt{c^2 - v_{BA}{}^2}}{c}. \quad (17)$$

X_{LBA} can now be expressed in the absolute time coordinate as:

$$X_{LBA} = \begin{bmatrix} ct \\ \frac{c\sqrt{c^2 - v_{BA}{}^2} v_{BA} t + L_B c^2 - L_B v_{BA}{}^2}{c\sqrt{c^2 - v_{BA}{}^2}} \\ 0 \\ 0 \end{bmatrix}. \quad (18)$$

The moving clock C_1 is associated with the symbol ***B1*** representing its local coordinate system and X_{LBA} must be converted to this system, in which L_B is seen as a moving point towards the origin of ***B1***. The absolute velocity of ***B1*** in ***A*** is designated as v_{B1A}. So it needs to be transformed using the transformation matrix $\Omega_{\infty}^{v_{B1A}}$.

$$\Omega_{\infty}^{v_{B1A}} X_{LBA} = X_{LBB1} = \begin{bmatrix} \sqrt{c^2 - {v_{B1A}}^2}t \\ \dfrac{ct(v_{BA} - v_{B1A})\sqrt{c^2 - {v_{BA}}^2}c^2 - L_B {v_{BA}}^2}{\sqrt{c^2 - {v_{BA}}^2}\sqrt{c^2 - {v_{B1A}}^2}} \\ 0 \\ 0 \end{bmatrix}, \quad (19)$$

The variable t needs to be eliminated from the transformed vector so it is consistently expressed in t'', x'' coordinates.

$$\frac{X_{LBB1}[1]}{c} = t'' \Rightarrow t'' = \frac{ct}{\sqrt{c^2 - {v_{B1A}}^2}}. \quad (20)$$

After the substitution X_{LBB1} can be expressed in ***B1*** terms of the coordinate t'' as:

$$X''_{LBB1} = \begin{bmatrix} ct'' \\ \dfrac{L_B(c^2 - {v_{BA}}^2)\sqrt{c^2 - {v_{B1A}}^2} + c^2 t'' \sqrt{c^2 - {v_{BA}}^2}(v_{BA} - v_{B1A})}{\sqrt{c^2 - {v_{BA}}^2}(c^2 - {v_{B1A}}^2)} \\ 0 \\ 0 \end{bmatrix}. \quad (21)$$

The X''_{LBB1} marker in ***B1*** frame appears to move towards the ***B1*** origin. The time the clock C_1 coincides with the marker is when its x'' coordinate is 0 :

$$X''_{LBB1}[2] = 0 \Rightarrow t'' = \frac{L_B\sqrt{c^2 - {v_{BA}}^2}\sqrt{c^2 - {v_{B1A}}^2}}{c^2(-v_{BA} + v_{B1A})} \equiv \tau_1. \quad (22)$$

The trip duration τ_1 of the clock C_1 is now found. Because of the downward wordline orientation, the duration τ_2 of the clock C_2, the same formula (22) applies, but with a different velocity symbol and the sign inverted for τ_2 to be positive.

$$X'''_{LBB2}[2] = 0 \Rightarrow t''' = -\frac{L_B\sqrt{c^2 - {v_{BA}}^2}\sqrt{c^2 - {v_{B2A}}^2}}{c^2(-v_{BA} + v_{B2A})} \equiv \tau_2. \quad (23)$$

We have determined durations on paths from the perspective of moving clocks C_1 and C_2, now we need to find the relative velocities v_1 and v_2 of these clocks in ***B*** and the time of the round-trip τ_3 measured by the clock C_3. The vector EOM of C_1 in ***A*** is given by the 4-vector X_{B1A}:

$$X_{B1A} = \begin{bmatrix} ct \\ v_{B1A}t \\ 0 \\ 0 \end{bmatrix}. \quad (24)$$

Applying TT to X_{B1A} yields:

$$\Omega_{\infty}^{v_{BA}} X_{B1A} = X_{B1B} = \begin{bmatrix} \sqrt{c^2 - {v_{BA}}^2}t \\ \dfrac{ct(-v_{BA} + v_{B1A})}{\sqrt{(c^2 - {v_{BA}}^2)}} \\ 0 \\ 0 \end{bmatrix}. \quad (25)$$

After converting (25) to the local time t' the relative EOM of C_1 is:

$$X''_{B1B} = \begin{bmatrix} ct'' \\ \dfrac{c^2 t''(-v_{BA} + v_{B1A})}{(c^2 - {v_{BA}}^2)} \\ 0 \\ 0 \end{bmatrix}. \quad (26)$$

Similarly for ***B2***:

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$$X'_{B2B} = \begin{bmatrix} ct''' \\ \frac{c^2 t'''(-v_{BA}+v_{B2A})}{(c^2 - v_{BA}{}^2)} \\ 0 \\ 0 \end{bmatrix}. \tag{27}$$

Relative velocities v_{t1} and v_{t2} are then the same formulae except for v_{B2A} replacing v_{B1A}:

$$v_{t1} = \frac{c^2(-v_{BA}+v_{B1A})}{(c^2 - v_{BA}{}^2)}$$

$$v_{t2} = \frac{c^2(-v_{BA}+v_{B2A})}{(c^2 - v_{BA}{}^2)}, \tag{28}$$

The round-trip time registered by clock C_3 is:

$$\tau_3 = \frac{L_B}{v_{t1}} - \frac{L_B}{v_{t2}} =$$

$$= \frac{L_B(c^2 - v_{BA}{}^2)}{c^2(-v_{BA}+v_{B1A})} - \frac{L_B(c^2 - v_{BA}{}^2)}{c^2(-v_{BA}+v_{B2A})}. \tag{29}$$

We obtain the system of the following three non-linear equations from equations from equations (22), (23) and (29).

$$\begin{cases} \tau_1 = \dfrac{L_B\sqrt{c^2 - v_{BA}{}^2}\sqrt{c^2 - v_{B1A}{}^2}}{c^2(-v_{BA} + v_{B1A})} \\ \tau_2 = -\dfrac{L_B\sqrt{c^2 - v_{BA}{}^2}\sqrt{c^2 - v_{B2A}{}^2}}{c^2(-v_{BA} + v_{B2A})} \\ \tau_3 = \dfrac{L_B(c^2 - v_{BA}{}^2)}{c^2(-v_{BA}+v_{B1A})} - \dfrac{L_B(c^2 - v_{BA}{}^2)}{c^2(-v_{BA}+v_{B2A})} \end{cases} \tag{30}$$

From this system, we cannot calculate L_B because we have three unknown velocities and therefore four unknowns with only three equations. We cannot rely on the currently not practically feasible method described in section 2. This is however, not an obstacle because L_B is a free parameter that can be measured by traditional methods, in particular by using return time of the light signal on the round-trip: $L_B = c\Delta t_{ret}/2$.

The system solution was attempted using Maple™ 2019. Unfortunately despite the unusual nature of the three clock method not explicitly relying on distant clock synchronisation, no solution has been found due to usual cancellation.

While confirming and analysing the disappointing but widely expected null result, an important connection was found between the Minkowski and Tangherlini frameworks.

1. Using proper times τ_1, τ_2, τ_3 represented by Equations (30), and
2. Substituting them into the positive root of the equation for L_B and to all velocity roots $v_{11}, v_{12}, v_{21}, v_{22}$, from Equations (12) and
3. Assuming $\{v_{BA} >, 0\ v_{B1A} > v_{BA}, v_{B2A} < v_{BA}, v_{BA} < c, v_{B1A} < c,\ c > 0\}$ and L_B being a real positive number, the result of algebraic simplification was:

$$
\begin{gathered}
D \equiv L_B = L_B \\
v_{11} = \frac{c^2(-v_{BA} + v_{B1A})}{c^2 - v_{BA}\, v_{B1A}} \\
v_{12} = \frac{c^2(v_{BA} - v_{B1A})}{c^2 - v_{BA}\, v_{B1A}} \\
v_{21} = \frac{c^2(-v_{BA} + v_{B2A})}{c^2 - v_{BA}\, v_{B2A}} \\
v_{22} = \frac{c^2(-v_{BA} + v_{B2A})}{c^2 - v_{BA}\, v_{B2A}}
\end{gathered} \tag{31}
$$

This was as expected for L_B. Absolute velocities did cancel out so L_B remained invariant. However, no cancellation can be seen for the STR relative velocities. One instance of the STR velocity can be the result of unlimited number of combinations of v_{BA} and v_{B1A}. Measuring v_1 is insufficient to solve for an absolute velocity because of one extra degree of freedom. At this point all classic predictions seem to confirm the postulate of relativity as formulated by Poincaré [8] (drafted in June 5 1905), placing the inability to detect the absolute movement of the Earth as the foundation (refer to the discussion in page 13). Poincaré found his principle consistent with Lorentz Transformation thoroughly reviewed and re-derived in the full mathematical rigour [8]. This finding made it pointless to look elsewhere for him and most of successors. However, the peculiar relations in Equations (31) and their potential significance triggered further investigations.

3.3. Variable Speed of Light vs Conventional Isotropy

The variable light pulse velocities in the standard coordinate's configuration in Tangherlini framework is given by:

$$
c_{x+} = \frac{c^2}{c + v_{BA}}, c_{x-} = \frac{c^2}{c - v_{BA}}. \tag{32}
$$

where c_{x+} c_{x-} are the positive variable magnitudes of the velocity of light on the x'- axis in the positive and negative directions respectively, hence all relative velocities are functions of absolute velocities. First we analyse the results in Equations (13). Using proper times τ_1, τ_2, τ_3 represented by Equations (30) and substituting them into the first equation from Equations (13) we get:

$$
\begin{gathered}
\tau_{C1} = \frac{\tau_1^2 - \tau_2^2 + \tau_3^2}{2\tau_3} = \frac{L_B(c^2 - v_{BA}v_{B1A})}{c^2(-v_{BA} + v_{B1A})} \Rightarrow \\
t = \frac{x(c^2 - v_{BA}v_{B1A})}{c^2(-v_{BA} + v_{B1A})},
\end{gathered} \tag{33}
$$

where t is the current time coordinate in propagation of C1 in B in the LT based scenario in Figure 1and x is the coinciding position of C1.

At *the same physical location* in the STR and Tangherlni framework, $x' = x$. Using the first Equation (28) we get:

$$
v_{t1}t' = x' = x = v_1 t = \frac{c^2(-v_{BA}+v_{B1A})}{(c^2 - v_{BA}v_{B1A})} t \qquad 34)
$$

Using Equations (33) and (34) we can solve the following system for t' and v_{B1A}

$$
\begin{cases}
\dfrac{c^2(-v_{BA}+v_{B1A})}{(c^2 - v_{BA}v_{B1A})} t = x \\
\dfrac{c^2(-v_{BA}+v_{B1A})}{(c^2 - {v_{BA}}^2)} t' = x
\end{cases} \tag{35}
$$

The solution of interest is $t' = f(t, x, v_{BA})$ with $x = x'$ while the other for v_{B1A}has no useful value

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$$t' = t + \frac{x v_{BA}}{c^2} \tag{36}$$

This allows bidirectional conversions to/from Tangherlini and STR frameworks because x, x'-axes are identical when statically coinciding in ***B***. This also shows the irreducible degree of freedom with v_{B1A} being eliminated from scope so prime reason behind all cancellations. It now appears that removing this freedom could only happen by the nonexistent instantaneous signal. Fortunately this is not the case.

3.4. Closing the Gap

Our attention shifted toward identifying a missing equation that would allow for the recovery of the absolute velocity v_{BA}. Thus far, our derivation of the TT has assumed an empty, featureless, and passive space, focusing on the relative kinematics between a hypothetical privileged inertial system and any other inertial frame. The relativistic TT relation was derived from the empirical isotropy of the average round-trip speed of light, without assuming a specific physical cause for this behaviour. However, it is logical to conclude that this behaviour is not caused by the inertial systems themselves. This raised a critical question: is there an overlooked property of light that could resolve the absolute velocity? The most vital observation is that while light is emitted and absorbed by atoms to facilitate measurement, its orderly, causal propagation from point to point is a property of the vacuum and the electromagnetic field itself. Once emitted, a beam of light exists independently of any inertial system, propagating as a coherent entity—much like a "rigid rod" of fixed length. Consider light from a distant star that may no longer exist; it travels through the void and interacts with any inertial system it encounters. At the moment of interaction, the original source is irrelevant; only the freely propagating beam matters. While a stationary observer in the ARF would measure an intrinsic frequency, a moving observer in system ***B*** will measure a Doppler-shifted frequency. This invites us to look beyond the average round-trip speed of light and examine the Doppler Effect as an additional fundamental property. We consider a monochromatic electromagnetic wave propagating along the x'-axis from the positive side toward a detector and clock C_3 at the origin of the Base system ***B***

Let ***K*** be a wave 4-vector of the incoming wave in free space or rather in the ARF:

$$\boldsymbol{K_A} = \begin{bmatrix} \frac{\omega_A}{c} \\ \frac{-\omega_A}{c} \\ 0 \\ 0 \end{bmatrix}. \tag{37}$$

To convert this vector to ***B*** we apply TT as follows:

$$\boldsymbol{K_{AB}} \equiv \begin{bmatrix} \frac{\omega_{AB}}{c} \\ k_{xB} \\ k_{yB} \\ k_{zB} \end{bmatrix} = \Omega_{\infty}^{v_{BA}} \begin{bmatrix} \frac{\omega_A}{c} \\ -\frac{\omega_A}{c} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{\omega_A\sqrt{c^2 - v_{BA}^2}}{c \cdot c} \\ -\frac{\omega_A (c + v_{BA})}{c\sqrt{c^2 - v_{BA}^2}} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{\omega_A}{c}\sqrt{1-\beta^2} \\ -\frac{\omega_A}{c}\sqrt{\frac{(1+\beta)}{(1-\beta)}} \\ 0 \\ 0 \end{bmatrix} \tag{38}$$

The explicit presence of v_{BA} in Equation (38) determines absolute velocity assuming the angular frequency ω_{AB} is accurately measured as well as the wave number k_{xB}, which may be much more difficult to accomplish. By shifting focus from the clocks to the light beam in transit, the missing equations are now identified. Unlike clocks, a freely propagating electromagnetic wave-train carries an intrinsic spatial and temporal periodicity (ω_{AB}, k_{xB}) that is governed by the vacuum itself, not the observer's synchronization convention. By measuring the local frequency ω_{AB} and the

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local wave number k_{xB} (e.g. via the movable intensity sensor protocol) we can determine two unknowns: the absolute velocity v_{BA} and the original ω_A which can be obtained by solving the system of equations:

$$\begin{cases} \dfrac{\omega_{AB}}{c} = \dfrac{\omega_A\sqrt{c^2 - v_{BA}^2}}{c^2} \\ k_{xB} = \dfrac{\omega_A(c + v_{BA})}{c\sqrt{c^2 - v_{BA}^2}}. \end{cases} \quad (39)$$

The solution of the above system is:

$$\boxed{\begin{cases} \boldsymbol{\omega_A} = \sqrt{\dfrac{-\boldsymbol{\omega_{AB}}}{2\boldsymbol{k_{xB}} + \boldsymbol{\omega_{AB}}}} ck_{xB} \\ v_{BA} = \dfrac{c(k_{xB} + \omega_{AB})}{k_{xB}}. \end{cases}} \quad (40)$$

This is a very important result. We once declared there are no features in empty space so we cannot find any reference point, anything to measure...except for light. In one go not only we find our absolute velocity in an unknowable ARF but also unknown light angular frequency where no clock and no coordinate system exists. The hypothetical ARF becomes the actual now. This is an ultimate connection with the absolute rest.

The above is the most direct way to find v_{BA}. A better still, is to exploit the property of the ratio $R = \boldsymbol{\omega_{AB}}/\boldsymbol{k_{xB}}$

$$\boxed{\begin{aligned} R &= \frac{\boldsymbol{\omega_{AB}}}{\boldsymbol{k_{xB}}} = -\frac{c}{c - v_{BA}} \Rightarrow \\ v_{BA} &= -\frac{c(R+1)}{R}. \end{aligned}} \quad (41)$$

This equation is of ultimate simplicity but relies on the same direct measurement of $\boldsymbol{\omega_{AB}}, \boldsymbol{k_{xB}}$. W note that if the ratio R = -1 as in the STR framework the v_{BA}=0. While this principle of measurement of absolute velocity is valid, it is just a raw proof of concept requiring the community of physicists to generalise it to a 3D context such that the velocity vector can be fully identified, and engineers to make the method practical and sensitive. The hope is that measurements of velocities with respect to the Cosmic Microwave Background (CMB) is an experimental fact, so the suggested approach or its derivatives should be no exception in due time. We believe we found not only the long sought physical quantity but also reconciling the CMB relative velocity measurements with the underlying fundamental theory without contradicting Special Relativity, which by name and design has no clear concept of the absolute but which is valid and useful given direct examples that absolute velocity does not matter in most physical contexts as seen in Equations (30). This closes the over 120 year's long gap in understanding the fundamental nature of the flat spacetime unaffected by strong gravitational fields. Note: We have checked the round trip scenario which cancelled out by plugging in the equation

4. Discussion and Conclusions

4.1. Historical Perspective of the Absolute Velocity Problem

More than a century long scientific consensus is that absolute velocity cannot be detected or rather, there is no such thing. The detectibility of absolute motion is closely related to the concept of instantaneous signals. Superluminal and instantaneous signals have always been a contentious issue. The instantaneous signal is something that our common sense temporal intuition demands, yet generally this idea is regarded as unscientific. There seems to be a consensus that simultaneity is relative by nature, and the intuitive instantaneous perception, is a mistake according to Canales [9]. Einstein [10] described this mistake as a result of the failure to distinguish between what is simultaneously seen and what is simultaneously happening. However, he also made an interesting remark in 1911 [11] by addressing the concept of a signal propagating infinitely fast, allowing to define time, somewhat in contrast to time that was already defined in the 1905 relativity paper [12] (or in the most recent English translation [2]).

The instantaneous temporal relation between distant events is commonly understood as 'Now.' This was officially abolished by Eddington [4]. He stated that there was no such thing like absolute 'Now', but only the multitude of relative 'Nows' different for every observer. However, this concept was hard to abandon even by some prominent physicists. According to Jammer [13] quoting Rudolf Carnap, the problem of 'Now' seriously worried Einstein. Without expanding on the full complexity of this problem it we may notice, that the instantaneous temporal relation were the source of uncertainty in the minds of other physicists as well, such as Bell [14], who insisted on the existence of a mechanism by which the setting of a measuring device influences the reading on another instrument at any distance, and the signal involved must be instantaneous, implying that the underlying theory cannot be Lorentz invariant.

The nature of an instantaneous signal is that appears as a set of superluminal signals with forever increasing velocity, none of which being the fastest. This peculiar signal could as well be intuitively dismissed. Even the intuition of a creative mind allowing the instantaneous perception of the whole universe at once, may find it hard to picture something like a signal moving from here to a distant galaxy or beyond in no time, let alone the reflected signal returning at the exact moment when it is emitted (but not earlier). Such instantaneous signal appears to be a violation of causality based on a simple local commonsense reasoning. At the time of emission one can expect the signal to be delivered where it isn't, so how it returns now from where it wasn't? The signal is usually a short EM pulse or a small particle like one photon. By being infinitely fast it does not travel. It exists everywhere and nowhere at the same time. Mathematics however, can be more forgiving than the imagination. Instantaneous signal velocity being an open ended series of numbers with no fixed maximum can defeat our intuitive non-causality concerns by the fact that such situation can never happen and the succession of emission-return event is preserved no matter how short. The unreachable limit delineates the boundary of coexistence, which may not necessarily be probed by signals. This opinion however, is naturally open for challenge as any scientific subject,

Inability to find instantaneous signals in nature prevented generations of philosophers and scientists defining the same time in remote locations. The blocking issue was the famous circularity when two clocks at different locations should indicate the same time simultaneously, while 'simultaneously' meant at the same time. Einstein [12] solved the problem assuming the same one-way velocity of light independent on the motion of the observer and the direction of its motion, against common sense, inspired by Michelson and Morley experiments [15] according to which the round-trip average speed of light was constant. However, this was not one-way velocity. With the assumed isotropy and additional assumption Lorentz Transformation was re-derived in a new context by and the STR was born. At about the same time Poincaré [8] published one of the earlier (June 5 1905) versions of the Postulate of Relativity as follows:

> *It seems that this impossibility of experimentally demonstrating the absolute movement of the Earth is a general law of Nature; we are naturally inclined to admit this law, which we will call the Postulate of Relativity, and to admit it without restriction. Whether this postulate, which has so far been in agreement with experience, should be confirmed or refuted later by more precise experiments, it is in any case interesting to see what the consequences may be.*[3]

Unlike in Einstein's systematic derivation approach this formulation seems to assume the absence of *absolute movement of the Earth* a-priori, without mentioning the absence of one-way velocity

[3] Translation from [8] by Google Translate.

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measurement. The uncertainty expressed in the last sentence of the quote may explain the long desire to detect the ether and absolute motion relative to it as well as supports the idea of potential falsification. Michelson and Morley [15] concluded after experiments, that any relative motion between the earth and the ether must at least be very small, which we clearly know now it is not so.

Absolute velocity concept and variable one-way velocity of light have become obsolete in the mainstream physics. Some researchers still continued seeking methods to overcome the burden of instantaneous synchronisation preventing one-way velocity measurement. Several examples can be found in publications of Mansouri and Sexl [16], Selleri [17], [18], Tangherlini [19], Spavieri, Gillies and Haug [20], just to mention a few. The focus is often on rotating frames and the well known experimentally confirmed Sagnac effect. This situation is still not ideal because the general remote clock synchronisation problem for inertial systems in rectilinear uniform motion has not been conclusively solved so far, to the best knowledge at the time of writing, but it is now.

4.2. Results

The main goal of this research was to verify whether an unusual method based on Unruh protocol presented by Matsas et al. [1] that could potentially give an opportunity to detect the ubiquitous absolute velocity because it appears independent on distant clocks state in the inertial frame of interest $\boldsymbol{B}$, given it is moving relative to the hypothetical ARF. This was to verify Tangherlini's claim that the absolute motion of the Earth could be detected using subluminal signals as mentioned in page 5. In the process some interesting results have been presented.

1. The three clocks scenario based on Unruh protocol described by Matsas et al. [1] in the Minkowski spacetime was implemented as an algebraic STR-based model, leading to the system of Equations (11). The system had solutions (12) consisting of eight roots, half of them being the negative of the counterparts. The original distance formula from [1] has been fully reproduced by the first solution from Equations (12). Two previously unpublished relative velocity expressions for moving clocks not presented in [1] emerged. Only three proper times for each of the scenario clocks are needed to 'reverse engineer' their relative velocities without explicit measurement of the distance and coordinate times in distant locations. These clock trip durations τ_{C1} and τ_{C2} were derived as simple expressions in Equations (13) involving only the three proper times. The τ_{C1} value is the same as the time coordinate in $\boldsymbol{B}$ at $x = L_B$. The time coordinate is paradoxically a function of convention-independent proper time invariants. However, the justification relies on the fact that the derivation was based on Minkowski spacetime properties not implying Nature's preference for STR framework convention.
2. An important connection between Tangherlini and the STR frameworks have been uncovered, proving the complementarity of the former rather than being antagonistic or irrelevant. First, based on Equations (13), the $t = \tau_{C1}$ time coordinate in the STR framework becomes an irreducible function of absolute velocities as shown in Equation (33). Then we simply derive the conversion between the standard STR and Tangherlini coordinates as $\{x' = x, t' = t + xv_{BA}/c^2\}$ resulting from Equations (35) and (36). This shows the two theories intimately related and contradiction free through a shared foundation, rather than juxtapositioned without true correspondence. It is only practical usefulness keeping them apart.
3. Tangherlini prediction of the possibility of detecting absolute velocity using subluminal signals represented by Equations (30) were not initially confirmed as the absolute velocities cancelled out "*in the usual manner*" [3] p101, even though no explicit distant clocks synchronisation was needed in the stationary system while the solution was attempted in Tangherlini spacetime.
4. Tangherlini hoped to resolve absolute velocity cancellation by finding phenomena outside the framework of uniformly translating systems and considered other types of motion such as rotation ([3] p105). Our research in this direction continued and succeeded, however not quite outside uniformly translating systems. The missing extra equation was found from the Doppler Effect that is measurable in the moving system shown in Equations (40) or (41). They present

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possibility to determine v_{BA} by measuring the angular frequency $\boldsymbol{\omega_{AB}}$ and wave number $\boldsymbol{k_{xB}}$ components of the wave 4-vactor K as in equations (37) to (39) The simplest formula for v_{BA} emerges from of the ratio $R = \boldsymbol{\omega_{AB}}/\boldsymbol{k_{xB}}$

$$R = \frac{\boldsymbol{\omega_{AB}}}{\boldsymbol{k_{xB}}} = -\frac{c}{c - v_{BA}} \Rightarrow$$
$$v_{BA} = -\frac{c(R+1)}{R}.$$

This approach requires a public discussion on generalization and practical realisation of the measurement method.

4.3. Conclusions

1. The same reality underlies both investigated models in Minkowski and Tangherlini framework, providing different views of the same. The presented results indicate that their relationship is consistent, not accidental. One three clock scenario in Minkowski spacetime maps to a group of an unlimited number of combinations of absolute velocities in Tangherlini spacetime. Three proper times determine the same distance, bridging the two different theories.
2. Despite general consensus the absolute velocity of an inertial system is detectable by measuring Doppler Effect modeled within the Tangherlini framework. This should not be a surprise given relative velocity measurement with respect to CMB. This work provides additional justification for the observed effect and it does not invalidate the STR which eliminates absolute time from scope based on Einstein convention while retaining the round trip average light speed isotropy which is the real foundation of relativistic effect as demonstrated by Tangherlini.
3. The Poincaré's Postulate of Relativity (p13) survived for more than 120 years because that was just one equation missing unsuspected at that time needed to close the absolute velocity cancellation gap. In most cases, absolute velocities do not have visible effects in the majority of physical processes. Doppler Effect in Electromagnetic waves presence appears a to be notable exception.
4. We hope the results of this work will trigger additional research leading to finding a practical method to measure absolute velocities with high accuracy, which this special case cannot directly support due to the unknown orientation of the absolute velocity vector needed aligne the coordinate system $\boldsymbol{x}$-axis.

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Abbreviations

The following abbreviations are used in this manuscript:

ALT	Absolute Lorentz Transformation
AR	Absolute Rest

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ARF	Absolute Rest Frame
CMB	Cosmic Microwave Background
EOM	Equation of Motion
GR	General Relativity
LT	Lorentz Transformation
STR	Special Theory of Relativity
TT	Tangherlini Transformation

Appendix A. On Absolute Rest, Absolute Velocity and Tangherlini Transformation

Tangherlini's derivation of the transformation used in this paper was based on Einstein Field Equation of General Relativity (GR) resulting in transformation equations compatible in structure to the LT equations derived by Einstein as presented in [2] p.151. The arrangement of the two relatively moving coordinate systems can be referred to as the standard configuration, where the relative velocity vector is aligned with the first spatial axis (usually x). The mathematical representations of the TT, the postulates leading to its derivation and resulting properties may be collectively referred to as the TT framework.

For the TT framework, the absolute rest frame must be postulated *a-priori* to allow derivation, when using other than Tangherlini's approach based on GR. For example, Selleri [17] in section 3 defines the absolute frame as the one where the velocity of light is the same in any direction while not demanding moving frames to follow the same rule. The impossibility of the absolute synchronization with instantaneous signals— let alone without them —appears as the fundamental obstacle for practical use of the TT on a larger scale. The TT framework is the only sensible, however impractical alternative to the STR framework. Both frameworks share the same foundation that is the empirical law of isotropy of the round-trip average speed of light discovered by Michelson and Morley [15].

The TT framework can be derived from first principles of Newtonian kinematics *without* reference to non-inertial rotational motion or forcing postulates of length contraction or time dilation as it was the case in some previous approaches. The Sagnac effect frequently analyzed seems to be a legitimate approach though.

The necessary and sufficient set of postulates/conditions, completely defining the TT are as follows:

Postulate 1: *There exists an absolute rest frame (ARF) represented by an inertial system* ***A****, with three Cartesian coordinate axes that can be bound (aligned) to pre-existing axes of an inertial system* ***M*** *at time t=0 and t´=0. In that system, the one-way velocity of light is constant and equal to c in all directions, and there is only one system* ***A*** *(together with all its possible translations and rotations, all being at rest with it).*

Postulate 2: *The round-trip average speed of light in any inertial system is a constant, whose value c= 299792458 m/s, is independent of the relative direction and velocity of those systems.*

Postulate 3: *An instantaneous signal being represented as the limit of all signals moving in the same direction with ever increasing velocity* $v_{\alpha A}$*, observed in the absolute inertial system* ***A*** *as* $S_{\infty A} \equiv t = x/\lim_{v_{\alpha A}\to\infty} v_{\alpha A}$*, is invariant in all inertial frames such that when observed in an inertial moving system* ***M*** *of the absolute velocity* v_{MA}*, it is* $S'_{\infty M} \equiv t' = x'/\lim_{v_{\alpha M}\to\infty} v_{\alpha M}$ *where* $v_{\alpha M} \neq v_{\alpha A}$

Constraint 1: *The spatial origin of system* ***M*** *moving in the system* ***A*** *coordinates, transforms to the origin point in* ***M*** *at rest with itself as* ***M****(0,0,0) at every instance of time t'*

Constraint 2: *The determinant of the linear coordinates transformation matrix* $\Omega_{\infty}^{\mathrm{v}}$ *is equal to +1, as in the case of the LT and Galilean transformation matrices.*

The TT matrix $\Omega_{\infty}^{\mathrm{v}}$ meeting the postulates and constraints can be derived, and is shown in equation (14).

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