Wave structure of matter causing time dilation and length contraction in classical physics

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Abstract: A very simple, fundamental physical explanation is presented of time dilation and length contraction. This explanation is obtained from a classical model of physics that is Galilean. It assumes the existence of a medium (ether) that acts as an absolute reference in accordance with Mach's principle. Time and space are conventional, i.e., a three-dimensional space independent of time. In addition, the explanation relies on the assumption that all physics, including matter such as clocks and measuring rods, has a scalar wave structure. Matter is assumed to consist of locally stable scalar wave structures, specifically scalar standing wave structures. The scalar waves are just variations in space and time of medium density. Also, an element of special relativity is used, namely, the one taking into account the finite velocity of light. © *2018 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-31.4.434]

Résumé: Nous présentons une explication très simple en physique fondamentale de la dilatation du temps et de la contraction des longueurs. Cette explication est dérivée d'un modèle classique Galiléen de physique. Elle suppose l'existence d'un milieu (l'éther) qui joue le rôle d'une référence absolue en accord avec le principe de Mach. Le temps et l'espace restent conventionnels, un espace à trois dimensions indépendant du temps. De plus, l'explication repose sur l'hypothèse que tout objet physique, y compris la matière comme les horloges et les règles de mesure, ont une structure d'onde scalaire. La matière serait alors considérée comme des structures d'onde scalaire, précisément des structures d'onde scalaire stationnaire. Les ondes scalaires sont simplement des variations de la densité du milieu dans l'espace et le temps. Nous utilisons aussi un élément spécifique de la relativité, celui qui prend en compte la finitude de la vitesse de la lumière.

Key words: Time Dilation; Length Contraction; Medium; Ether; Galilean Physics; Classical Physics; Special Relativity; Wave Structure of Matter; Mach's Principle.

I. INTRODUCTION

When Einstein first proposed special relativity,[1] he met a lot of opposition. Until his proposal, physicists generally believed in a classical model of physics, in which space is three dimensional and in which time is independent of space. To explain energy transfer, also a medium (ether) was assumed to be present in space. These seemed all very well acceptable *physical arguments* at the time. And, as we demonstrate in this paper, still they are.

By postulating special relativity, i.e., the idea that all physical laws *including the speed of light* are independent of the state of motion (as long as no acceleration is involved), Einstein was able to find agreement with experiments like those of Michelson–Morley and Fizeau. These were puzzling at the time, since, from the point of view of classical physics, they seemed to deny the presence of a medium (ether). Moreover, the speed of light appeared as a constant in Maxwell's equations complying with special relativity. On several occasions since then it has been demonstrated that the classical model of physics is also compatible with these experiments if one accepts time dilation and length contraction as *physical phenomena*.[2–25] Starting from classical physics, Lorentz,[13] when introducing his famous transformation that became central to special relativity, already tried to give a physical explanation of these two phenomena. As opposed to Lorentz and other attempts,[3] this paper relies on a very simple model of physics that we proposed[25] in which *scalar waves* make up the whole of physical reality. The scalar waves are just variations of medium (ether) density in a classical Galilean model of physics (GP) in which all matter is represented by stable, local, scalar *standing wave* structures. This model was inspired by physical models proposed by Battey-Pratt and Racey,[28] Selleri,[4–6] and finally Wolff[29,30] who introduced the terminology wave structure of matter (WSM), which we find highly appropriate. Reasons to adopt the classical Galilean model of physics incorporating WSM (GPWSM) are *conceptual simplicity*, as one would expect at the fundamental level of physics.[25,26] This also leads to a much better *understanding* of physics illustrated by the fact that many paradoxes and ill understood phenomena disappear.[25] Another illustration of the latter is this paper where GPWSM is shown to provide a most simple, fundamental

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physical explanation of both time dilation and length contraction.

When it concerns *calculations* however, GPWSM is more involved. One reason is that physical phenomena like electro magnetism and the laws of motion should *emerge* from GPWSM while being explicit in other models,[7] implying that GPWSM resides at a lower, more fundamental level. Another reason is that GPWSM is spatially distributed. Finally, GPWSM is anisotropic, as in Refs. 3–23, opposing special relativity. But, as demonstrated in this paper, in most observations and experiments this anisotropy is *unobservable* due to WSM which causes references of length and time to undergo the *very same* anisotropy. They suffer from retardation and contraction, *hiding exactly* the anisotropy. This unobservability of anisotropy explains the computational success and simplicity of special relativity. But it hides the understanding obtained from classical physics.[25] Although the unobservability has been suggested before,[3,6] *to explain it* we believe that using GPWSM is new and provides a most fundamental, simple and general explanation.

In comparing special relativity with classical physics, many intricate, partly philosophical, issues arise that have been extensively discussed in the literature.[2,5,27] Being system scientists, to us GPWSM is a *model* of physics. In the terminology of many discussions found in the literature toward this model *we take a realist stand*, like Selleri,[5] *not an operational one*. The realist stand on the one hand considers physical quantities like position, time, and velocity that appear in a physical model as objectively real. On the other hand, it allows for hypothesis about physics (the system) that may not all be verifiable from within physics (within the system). The operational point of view is less restrictive on the one hand since it considers position, velocity, and time as products of human interpretation. On the other hand, it is more restrictive since it only concerns and considers real, everything that is observed from within the system.[2,5,27] Stated in system science terminology, the operational approach stays strictly within the system using quantities that may not be objectively real leaving more room for interpretation. The realist uses quantities that are objectively real, leaving less room for interpretation. On the other hand, he may step outside the system, but only mentally, e.g., by using an analogy. GPWSM we use and promote in this paper is largely equivalent with acoustic waves moving in air.[25] Based on this analogy and taking the realist stand, one might say, that the only problem with classical physics is that it cannot be directly observed due to the finite speed of light. But it is there.

II. WSM CAUSING TIME DILATION AND LENGTH CONTRACTION

A. Introduction

Motivated by arguments presented in the introduction we use the classical Galilean model of physics incorporating WSM (GPWSM). This model assumes a medium (ether), that acts as an absolute reference, and associated with it conventional three-dimensional space and time, which are independent. All these are considered objectively real. The medium, i.e., the absolute reference, is assumed to stand still and corresponds to what is called the preferred inertial reference frame by Selleri[4–6] in which the speed of light is isotropic. As opposed to special relativity, absolute simultaneity holds, implying that two events that are simultaneous in one inertial frame are also simultaneous in all others.[4–6] As a result, in all inertial frames that move with constant nonzero velocity the speed of light is anisotropic. These distinct properties make the model (GPWSM) essentially Galilean again.[5] Assuming WSM we then show how length contraction occurs in inertial frames that move relative to the medium. So, length contraction appears as a *physical phenomenon*. Next, using again WSM, we show how time-dilation occurs as a physical phenomenon in moving frames. Finally, to properly describe *observations* of events occurring in the medium, made in moving frames, we consider the effect on observations of time-dilation and length contraction. Doing so the observations are shown to exactly match those obtained from special relativity. What is gained compared to special relativity however, is the existence of a medium (ether), that acts as an absolute reference in accordance with Mach's principle, together with a physical explanation of time-dilation and length contraction. Together these enable a much better *understanding* of physics.[4–7,9,25]

We perform our analysis starting from what is called "the reference frame." This is a Cartesian frame with axes denoted by x, y, z attached to the medium that is assumed to be in rest everywhere. So, what is called "ether drag" in classical physics is neglected. Within this frame, position, velocity, and time are considered absolute and conventional, implying space and time are independent. The speed of light c is assumed constant in each direction of the reference frame and equals the propagation speed of waves in the medium.[25] As a result, physics is isotropic within this frame, but anisotropic in any other Cartesian frame having a constant nonzero velocity with respect to the reference frame. Fortunately, all analysis in this paper can be performed in one spatial dimension by suitably rotating frames. Doing so all relevant phenomena occur only in the x direction of frames. Assuming GPWSM we will ask ourselves two simple questions.

1. What happens *physically* to references of length (measuring rods) and the length they measure when, instead of the reference frame, we are in a frame moving with constant velocity with respect to the reference frame?
2. What happens *physically* to references of time (clocks) and the time they measure when, instead of the reference frame, we are in a frame moving with constant velocity with respect to the reference frame?

The simple, naive and intuitive answer to these two questions is: nothing. One contribution of special relativity was to show that this is not so when the speed of light is finite, instead of infinite. But since the speed of light is very high compared to "every-day life velocities" the simple, intuitive answer applies in every-day life. Interestingly, this intuitive answer provides us with the idea that conventional (absolute) time and space exist as we would truly observe if only the speed of light had been infinite.

To properly answer the two questions, obviously, we do have to take into account the finite velocity c of light in the reference frame as well as the working, i.e., the physics, of clocks and measuring rods. The important difference between our analysis and special relativity is that we will add velocities in different Cartesian frames the ordinary Galilean way. In contrast special relativity assumes the velocity of light to be c in every Cartesian frame, irrespective of its state of motion. Thus in our analysis the speed of light c' as observed in any moving Cartesian frame is anisotropic and satisfies $c - v \leq c' \leq c + v$ where v represents the speed of the Cartesian frame (assumed to move in the x direction of the reference frame only) with respect to the reference frame. Because of WSM the speed v of the moving Cartesian frame satisfies $|v| \leq c$.

B. Velocity contraction as occurring in classical physics

Assume we are in the reference frame attached to the medium. Then the distance d_{AB} between two points A and B that move with velocity v in the direction AB is essentially *observed* as follows. A clock measures the time $t_{A\leftrightarrow B}$ it takes for light waves (a light pulse) to travel from A to B and back, see Fig. 1.

Recalling that the speed of light is c in every direction of the reference frame (isotropy) from the classical model of physics we find the speed of light from A to B to be $c - v$ and from B to A to be $c + v$, see Fig. 1. Then we easily calculate

$$t_{A\leftrightarrow B} = \frac{d_{AB}}{c-v} + \frac{d_{AB}}{c+v} = \frac{2d_{AB}}{\left(1 - \frac{v^2}{c^2}\right)c}, \tag{1}$$

Knowing v, c, and having measured $t_{A\leftrightarrow B}$, we may calculate d_{AB} from Eq. (1). Also from Eq. (1) observe that the *average* speed of light during the *roundtrip* AB usually called the *two-way speed of light* satisfies

$$\frac{2d_{AB}}{t_{A\leftrightarrow B}} = \left(1 - \frac{v^2}{c^2}\right)c. \tag{2}$$

So, the effect of A and B moving with velocity v is a contraction of the two-way speed of light of the roundtrip as compared to c with the factor

$$1 - \frac{v^2}{c^2} \leq 1. \tag{3}$$

Now most experiments measuring the speed of light actually measure the *two-way speed of light*,[2,4,5,25] i.e., the average speed of light (2) during a roundtrip. This speed includes the contraction factor (3). However, all experiments invariably measure the outcome of Eq. (2) to be just c, as if v plays no role. This was what disturbed physicists and finally led Einstein to special relativity also stimulated by Maxwell's equations. These also suggest c, *the one-way speed of light*, to be a constant irrespective of the state of motion. But obviously this assumption was and is *physically* highly counter intuitive. That is why special relativity initially met severe opposition. It presents a challenge to explain the outcome of the Michelson–Morley and Fizeau experiment assuming classical physics and the presence of a medium. Just before Einstein,[1] Lorentz,[13] when presenting his famous transformation, did a serious try by introducing time dilation and length contraction for which he tried to give a physical explanation. But Lorentz was only partially aware of the wave structure of matter. The latter we will use next to provide a physical explanation. Using the wave structure of matter, we will demonstrate that the clocks and rods (references for space and time) measuring the two-way velocity of light, undergo dilation and contraction phenomena canceling exactly the velocity contraction. But the velocity contraction is there, only not for us to see.

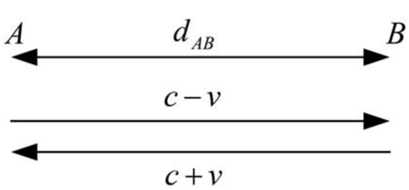

FIG. 1. Measurement of distance using a light pulse (light waves).

C. Measuring rods, length contraction and the wave structure of matter

To account for the physics of measuring rods, made out of matter, we will assume WSM. Battey-Pratt and Racey[28] and Wolff[29,30] suggested an electron is a scalar standing wave packet consisting of an in and outgoing wave toward and out of the electron center. The reversal of the wave at the electron center, from in to out-going, is due to spherical rotation of the wave medium at the electron center, known as electron spin. The amplitude of the standing wave packet decays when moving away from the electron center. Due to this decay, that occurs very quickly, the electron effectively covers only a very small region in space. Now how is distance determined by this electron? It is the electron's *standing wave length* that acts *as a reference* for distance. In the reference frame, that stands still with respect to the medium, to create a standing wave packet that *stands still*, the in and out-going wave of the electron must have *the same frequency* which we will denote by f_r. The underscore r denotes quantities considered in the reference frame. Since only the standing wave length is crucial in our analysis we may discard the behavior of amplitudes of the in and out-going waves. As argued earlier, a description in one spatial dimension suffices. This leads to a simple mathematical description of the standing wave $s_r(t_r, x_r)$ with x_r being the spatial x coordinate and t_r time within the reference frame

$$\begin{aligned} s_r(t_r, x_r) &= \sin\left(2\pi\left(\frac{x_r}{\lambda_r^{in}} - f_r^{in} t_r\right)\right) \\ &\quad + \sin\left(2\pi\left(\frac{x_r}{\lambda_r^{out}} + f_r^{out} t_r\right)\right), \\ f_r^{in} &= f_r^{out} = f_r, \quad \lambda_r^{in} = \lambda_r^{out} = \lambda_r = \frac{c}{f_r}. \end{aligned} \tag{4}$$

In Eq. (4), the superscripts *in* and *out* refer to the in and out-going wave making up the electron, λ indicates wave length and f frequency. The position of the electron center, that stands still, by definition corresponds to $x_r = 0$. To find the *standing wave length* of $s_r(t_r, x_r)$ we should find the zeros of the standing wave. These are locations x_r for which $s_r(t_r, x_r) = 0$ irrespective of t_r. From Eq. (4), these are found by solving

$$\forall a: \ \sin\left(2\pi\frac{x_r}{\lambda_r} - a\right) + \sin\left(2\pi\frac{x_r}{\lambda_r} + a\right) = 0, \tag{5}$$

having solutions

$$x_r = i\frac{\lambda_r}{2}, \quad i = -\infty, \ldots, -2, -1, 0, 1, 2, \ldots, +\infty. \tag{6}$$

The standing wave length λ_r^s is two times the difference between two consecutive values in Eq. (6)

$$\lambda_r^s = \lambda_r = \frac{c}{f_r}. \tag{7}$$

Assuming this standing wave structure of matter, the standing wave length λ_r^s serves as a *length reference* in the reference frame. At this point, one may wonder about matter other than electrons. Assuming WSM, and because matter in "every-day life" has very small velocities as compared to that of the waves (light), it must be that all matter is essentially standing waves, i.e., two waves moving in opposite directions. Only in this manner wave structures standing still or having very small velocities with respect to the medium are obtained.

From the previous assumption and analysis, an electron in motion having velocity v_e in the reference frame, thus consists of a standing wave having velocity v_e with respect to the reference frame, i.e., the medium. Denote this standing wave by $s_r^m(t_r, x_r)$ where the upper case m denotes movement of the standing wave. This standing wave is obtained by appropriately *shifting frequencies* of the in and out-going wave in opposite directions

$$\begin{aligned} s_r^m(t_r, x_r) &= \sin\left(2\pi\left(\frac{x_r}{\lambda_r^{m,in}} - f_r^{m,in} t_r\right)\right) \\ &\quad + \sin\left(2\pi\left(\frac{x_r}{\lambda_r^{m,out}} + f_r^{m,out} t_r\right)\right), \\ f_r^{m,in} &= f_r\frac{c + v_e}{c} = \frac{c + v_e}{\lambda_r}, \\ f_r^{m,out} &= f_r\frac{c - v_e}{c} = \frac{c - v_e}{\lambda_r}, \\ \lambda_r^{m,in} &= \frac{c}{f_r^{m,in}} \qquad \lambda_r^{m,out} = \frac{c}{f_r^{m,out}}. \end{aligned} \tag{8}$$

Observe that the shifts of frequencies in Eq. (8) do not incorporate possible time-dilation. This implies that we have arrived at Eq. (8) assuming time to be absolute. This is allowed from our realist point of view as explained in the introduction. In Subsection II D, we will come back to this. Also note that shifting frequencies is the exact, fundamental mechanism of WSM to transfer energy, in this case kinetic energy. Because it is moving, and because it is a standing wave, for any single value t_r for which the standing wave is not entirely zero, we may compute x_r such that $s_r^m(t_r, x_r) = 0$ to find the standing wave length. For time zero, i.e., $t_r = 0$, the standing wave is not entirely zero. Then from Eq. (8) the solutions x_r are seen to be given by

$$\begin{aligned} &\sin\left(2\pi\left(\frac{x_r}{\lambda_r^{m,in}}\right)\right) + \sin\left(2\pi\left(\frac{x_r}{\lambda_r^{m,out}}\right)\right) = 0 \iff \\ &\sin\left(2\pi\left(\frac{x_r f_r^{m,in}}{c}\right)\right) + \sin\left(2\pi\left(\frac{x_r f_r^{m,out}}{c}\right)\right) = 0 \iff \\ &\sin\left(2\pi\left(x_r\frac{f_r}{c^2}(c + v_e)\right)\right) + \sin\left(2\pi\left(x_r\frac{f_r}{c^2}(c - v_e)\right)\right) = 0, \end{aligned} \tag{9}$$

having solutions given in Eq. (6) again. Because it is a moving standing wave, by construction, at all other times, all zeros are shifted by a fixed amount $t_r v_e$, leaving the distance between them unchanged. Therefore, the standing wave length, which acts as a length reference, is unchanged and still given in Eq. (7). Moreover, the electron center at time t_r is found at location $t_r v_e$.

Next let us consider the standing wave (8), which moves with velocity v_e in the reference frame, as seen from the frame in which it is standing still. So, this frame, like the standing wave, has velocity v_e with respect to the reference frame. The result of this frame velocity is a *Doppler shift* of the frequencies $f_r^{m,in}, f_r^{m,out}$ to become $f_m^{m,in}, f_m^{m,out}$ where the lowercase m now indicates quantities as observed from the moving frame. Taking time to be absolute again, both these frequencies become f_r again, as expected,

$$\begin{aligned} f_m^{m,in} &= f_r^{m,in}\frac{c}{c + v_e} = \frac{c}{\lambda_r} = f_r, \\ f_m^{m,out} &= f_r^{m,out}\frac{c}{c - v_e} = \frac{c}{\lambda_r} = f_r. \end{aligned} \tag{10}$$

Due to motion with velocity v_e of the frame, the wave lengths $\lambda_m^{m,1}$, $\lambda_m^{m,2}$ associated with the in and out-going Doppler shifted frequencies $f_m^{m,1}, f_m^{m,2}$ become

$$\begin{aligned} \lambda_m^{m,in} &= \frac{c + v_e}{f_m^{m,in}} = \frac{c + v_e}{f_r} = \frac{c + v_e}{c}\lambda_r, \\ \lambda_m^{m,out} &= \frac{c - v_e}{f_m^{m,out}} = \frac{c - v_e}{f_r} = \frac{c - v_e}{c}\lambda_r. \end{aligned} \tag{11}$$

Using Eqs. (10) and (11), we find for the standing wave $s_m(t_r, x_r)$ that stands still in the moving frame

$$\begin{aligned} s_m(t_r, x_r) &= \sin\left(2\pi\left(\frac{x_r}{\lambda_m^{m,in}} - f_m^{m,in} t_r\right)\right) \\ &\quad + \sin\left(2\pi\left(\frac{x_r}{\lambda_m^{m,out}} + f_m^{m,out} t_r\right)\right). \end{aligned} \tag{12}$$

The standing wave length is now obtained from solving

$$\begin{aligned}&\sin\left(2\pi\left(\frac{x_r}{\lambda_m^{m,in}}\right)\right)+\sin\left(2\pi\left(\frac{x_r}{\lambda_m^{m,out}}\right)\right)=0 \iff\\ &\sin\left(2\pi\left(x_r f_r\frac{1}{(c+v_e)}\right)\right)\\ &\quad+\sin\left(2\pi\left(x_r f_r\frac{1}{(c-v_e)}\right)\right)=0 \iff\\ &\sin\left(2\pi\left(x_r f_r\frac{1}{(c^2-v_e^2)}(c-v_e)\right)\right)\\ &\quad+\sin\left(2\pi\left(x_r f_r\frac{1}{(c^2-v_e^2)}(c+v_e)\right)\right)=0,\end{aligned} \tag{13}$$

having solutions,

$$x_r = i\frac{\lambda_r\left(1-\frac{v_e^2}{c^2}\right)}{2},\quad i=-\infty,..,-2,-1,0,1,2,..,+\infty, \tag{14}$$

resulting in a standing wave length $\lambda_m^{s,m}$ of

$$\lambda_m^{s,m}=\left(1-\frac{v_e^2}{c^2}\right)\lambda_r. \tag{15}$$

Observe that the standing wave length is *reduced* by the factor

$$1-\frac{v_e^2}{c^2} \tag{16}$$

as compared to its length in the reference frame. Considering time to be absolute and matter to be standing waves, application of the classical model of physics thus leads to this length contraction factor. Observe that the length contraction factor exactly matches Eq. (3). Therefore, the velocity contraction that does occur in all experiments measuring the two way velocity of light goes unnoticed.

In arriving at the length contraction factor (16), we have used absolute time. Although this is a very useful and insightful concept, it is only measured by physical clocks in the reference frame, as we will argue in Subsection II D. Therefore, to properly describe the outcome of *observations* made using physical clocks, we have to make proper adjustments, as we will do next.

D. Clocks, time-dilation and the wave structure of matter

Given GPWSM, the physics of clocks ultimately comes down to a repetitive motion of waves, i.e., waves traveling back and forth a certain fixed distance d, as represented in Fig. 2. As one illustration of this, consider Atomic clocks. The frequency of Atomic clocks acts as a highly accurate time reference and has electrons as the fundamental source.[31]

From Fig. 2 and because in the reference frame the speed of light equals c in any direction, the associated time reference t_r for a clock standing still in the reference frame is given by

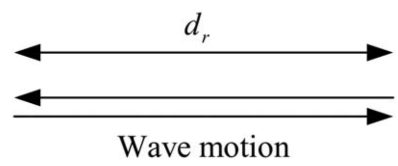

FIG. 2. Principle of a clock: waves moving back and forth over a fixed distance.

$$t_r=\frac{2d_r}{c}. \tag{17}$$

When the clock (electron) is moving with velocity v, the situation is represented in Fig. 1 again. For the time reference of the corresponding frame, denoted by the subscript m, we therefore find

$$t_m=\frac{2d_r}{\left(1-\frac{v^2}{c^2}\right)c}. \tag{18}$$

Observe that in Fig. 1 and Eq. (18) no length contraction has been assumed. According to Eq. (18) time-dilation occurs with a factor

$$1-\frac{v^2}{c^2}. \tag{19}$$

This time-dilation factor again equals the velocity contraction (3) occurring in all experiments measuring the two way velocity of light which therefore goes unnoticed.

E. Time dilation and length contraction occurring simultaneously

In computing the time-dilation factor (19) we have assumed length contraction to be absent. Similarly, in computing the length contraction factor (16) we have used absolute time that assumes time-dilation to be absent. According to special relativity and experiment, time-dilation and length contraction occur simultaneously with the same factor[1,3,4,7,13]

$$\sqrt{1-\frac{v^2}{c^2}}. \tag{20}$$

Assuming this time-dilation factor, in computing the standing wave length, as done in Subsection II B, we have to modify $f_m^{m,in}, f_m^{m,out}$ in Eq. (10) as follows:

$$\begin{aligned}f_m^{m,in}&=\sqrt{1-\frac{v_e^2}{c^2}}f_r^{m,in}\frac{c}{c+v_e}=\sqrt{1-\frac{v_e^2}{c^2}}\frac{c}{\lambda_r}=\sqrt{1-\frac{v_e^2}{c^2}}f_r,\\ f_m^{m,out}&=\sqrt{1-\frac{v_e^2}{c^2}}f_r^{m,out}\frac{c}{c-v_e}=\sqrt{1-\frac{v_e^2}{c^2}}\frac{c}{\lambda_r}=\sqrt{1-\frac{v_e^2}{c^2}}f_r\end{aligned}. \tag{21}$$

Doing so and making the associated adjustments in Eqs. (11)–(15) we find that Eq. (15) is unchanged and therefore also the velocity contraction factor (16). So simultaneous length contraction and time-dilation with the factor (20) again causes the velocity contraction to go unnoticed and are fully compatible with GPWSM.

Now one may wonder why the length contraction and time-dilation factor (20) do not come out *individually*, using WSM. The reason is very simple as can be seen from our analysis. Time dilation and length contraction are *two* factors derived from the *single* velocity contraction factor (3) that comes out from all experiments measuring the constancy of the two-way speed of light. When considering GPWSM, i.e., waves as fundamentally making up physical reality, starting from a fixed one-way speed of light c in the reference frame, we can trade the time period t_w of a wave against wave length λ_w since

$$c = \frac{\lambda_w}{t_w} \tag{22}$$

must hold. On the other hand, having selected references for both length and time in the reference frame, our analysis reveals that time-dilation and length contraction actually occur simultaneously, based on the very *same* physical phenomenon being velocity contraction, and by the very *same* factor Eqs. (16) and (19) when the other factor is ignored, i.e., taken to be one. This then implies that Eq. (20) is both the time dilation and length contraction factor obtained from WSM because then the contributions of time-dilation and length contraction are equal.

F. Similarities and differences with special relativity

Starting from the reference frame, the results obtained so far comply with special relativity. But the GPWSM model is actually *different* and *does* lead to different outcomes of certain experiments, as compared to special relativity. Our GPWSM model complies with the model proposed by Selleri,[4–6] that is different from special relativity since it restores absolute simultaneity while having a single preferred inertial frame. This frame has zero absolute velocity and time in this frame is considered absolute as well. In GPWSM, this reference frame is *attached to the medium* that acts as an absolute reference in accordance with Mach's principle. Together with the phenomena described in this paper this implies that all clocks in all moving frames (having nonzero absolute velocity) run slower. However, *different from special relativity*, when seen from the moving frame, clocks in the reference frame are seen to run *faster,*[4–6] not slower too, as in special relativity. Similarly, references of length are seen to be elongated, not contracted. The situation in GPWSM is thus fully *symmetric*. The loss of this symmetry in special relativity is what causes paradoxes, such as the twin paradox. The restored symmetry of GPWSM[4–6] implies *anisotropy* of the speed of light in frames having nonzero velocity. Experiments revealing this anisotropy have been performed.[3,7,32–34] These also indicate why GPWSM is to be preferred over special relativity.

III. CONCLUSIONS

Using the wave structure of matter together with classical Galilean physics (GPWSM), we argued that *all* "clocks and measuring rods" undergo exactly the same physical velocity contraction phenomena as does the two-way speed of light. Therefore, the latter is always *observed* to be constant in experiments. Using GPWSM and taking a realist stand and attitude toward this model, the two-way speed of light as well as the one-way speed of light are *actually* variable and constant only with respect to the medium and the corresponding reference frame that acts as an absolute reference in accordance with Mach's principle. But in most experiments, namely, those relying on the two-way speed of light, these actual facts are *unobservable*. Although this type of unobservability has been suggested before, using GPWSM to obtain it is new and provides a highly simple, general and fundamental explanation. Moreover, this unobservability explains the *computational success* of special relativity in most experiments. As to experiments, despite the cancellation phenomena explained in this paper, detection of the anisotropy of the speed of light in frames moving with respect to the reference frame (ether), *is* possible. Such experiments have also been performed and confirm the anisotropy.[3,7] Moreover, GPWSM upholds symmetry with respect to experimental phenomena, whereas special relativity introduces asymmetry.[4–6] The asymmetry in special relativity causes paradoxes, such as the twin paradox. And finally GPWSM also upholds simultaneity and, as a result, causality.[4–6,24] These appear to be highly fundamental properties of physics, that are abandoned by special relativity.

With the results presented in this paper, we intend to further promote GPWSM as a means of better *understanding* physics. GPWSM promises to bridge the gap between relativity and quantum theory.[25] This paper contributes to this bridging from the relativity side. Bridging from the quantum side appears to be (much) more involved. Still an interesting proposal in the same spirit has been published[10] and we also intend to turn our focus this way.

Finally this paper answered one of our own questions concerning the fundamental mechanism of energy transfer provided by WSM, being wave frequency changes occurring due to waves modulating one another's frequencies.[25,29] This paper clearly showed how wave frequency changes are needed to put matter, i.e., standing waves, in motion (Subsection II C). This answered our question as to how kinetic energy transfer should be conceived assuming WSM. Furthermore, we also came to realize that the very small velocities of matter in every-day life, as compared to that of wave propagation (light), is a strong indicator of WSM, namely, that all matter is essentially locally stable *standing waves*. Only by considering locally stable standing waves, i.e., two waves moving in opposite directions locally, small or zero velocities are easily obtained with respect to the medium, while all individual waves move with the speed of light.

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