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Medium and Waves Clarifying Fundamental Physics

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Although quantum theory, relativity and gravity provide excellent predictions of observations in their corresponding domains, a *qualitative understanding* of these three pillars of fundamental physics *and their connection*, is still very much lacking. As shown in this paper, by considering a medium (ether) in three-dimensional Euclidean space, representing potential energy, and waves in this medium representing all physical objects and phenomena, all three can be much better connected and understood. All waves move with the velocity of light *c* which is only approximately constant because it is assumed to depend on medium density. From this medium with waves model of physics, *three delusions* obscuring fundamental physics are identified. These prevent connecting relativity, gravity and quantum theory and obscure their *qualitative* understanding. As to the *quantitative* understanding, the waves are shown to connect to the mathematics of relativity and gravity. In connecting to the mathematics of quantum theory, a specific type of wave, called luminal waves, is shown to have a huge advantage. On the other hand, this type of wave is shown to reside at a less fundamental level than a second type of wave that is also considered in this paper.

Keywords: Wave structure of matter; relativity; quantum theory; gravity; distributed (inter)action; potential energy; manifest energy.

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1. INTRODUCTION

Around 1970, in a magnificent television series and accompanying book [1], both called “The Ascent of Man”, Jacob Bronowski enthusiastically and magically told viewers about the “wonders of the world and cosmos” as discovered and explained by science over many centuries. One episode considered what goes on at the most fundamental level being quantum theory, relativity and gravity. Their explanation, especially in terms of the latest scientific developments known around 1970, were truly miraculous, mysterious and complicated. This made Jacob Bronowski even more enthusiastic and magic. Fifty years later, Jacob Bronowski’s presentation of these matters still stands.

Complexity is an emergent property [2]. At the fundamental level, things must be simple, not complicated. But even among physicists themselves the advice is heard not to try to understand quantum theory, relativity and gravity, but to just follow their rules [3]. If applications are the only concern, this may be alright. But *science is mostly about understanding* [2], [3]. Being electrical engineers as well as system scientists, we want to try to understand and reverse engineer physics at the fundamental level. And this should *not* be too complicated. Not only should things be simple at the fundamental level, but also, to *qualitatively* understand things, it is not necessary to go into all the details.

This paper shows that by considering a medium in three-dimensional Euclidean space, and waves propagating through this medium making up all physical objects and phenomena, one gets rid of a large series of paradoxes and mysteries surrounding quantum theory, relativity and gravity. In this way one obtains a *qualitative* understanding of them, as well as *connections* between them. If we take the waves to be *scalar longitudinal waves*, representing medium density variations propagating at c, as in [4-7], a “model of physics” is obtained that is largely equivalent to acoustic waves moving in air, which is not difficult to understand. Instead of scalar longitudinal waves, *luminal waves* have been considered for the same purpose. These waves also move at c and transfer energy and momentum. When representing electrons, luminal waves make up the de Broglie wave [8],[9]. Recently, experiments have been proposed to investigate the ontic nature of such waves [10]. As to the *quantitative* understanding provided by both scalar longitudinal and luminal waves, this paper shows how both connect to the mathematics of both relativity and gravity. But luminal waves have a huge advantage in connecting to the mathematics of quantum theory [8],[9]. On the other hand, luminal waves are shown to reside at a less fundamental level than scalar longitudinal waves.

The existence and need for a medium in physics, has been extensively discussed after Special Relativity was introduced [11]. As to gravity, ever since Newton, action at a distance, that also appears as nonlocality in quantum theory, notably EPR experiments, is another heavily debated topic [12]. A major contribution of this paper, derived from the medium with waves “model of physics” is the identification of *three delusions* obscuring fundamental physics. These prevent connecting relativity, gravity and quantum theory and obscure their understanding. Like looking behind the scene of magicians, these three delusions take away mysteries and paradoxes surrounding quantum theory, relativity and gravity, among them the appearance of action at a distance and nonlocality. Another thing coming out is the fundamental energy/interaction mechanism in physics, being frequency modulation between overlapping waves. The “model of physics” considered in this paper is very much in the spirit of [7], [8], [13-18] that suggest significant changes may be needed to connect relativity and quantum theory, as confirmed by the three delusions identified in this paper.

The paper is organized as follows. In section 2, the medium with waves “model of physics” is introduced and the three delusions preventing the understanding and connection of relativity, quantum theory and gravity are identified. Section 3 considers interaction in physics as realized by the two types of waves and how these waves cause all the relativistic phenomena as well as gravity. Luminal waves are shown to have a huge advantage in connecting to the mathematics of quantum theory, whereas scalar longitudinal waves are shown to reside at a more fundamental level. Both types of wave are shown to connect to the mathematics of relativity and gravity. Using the results of this paper, section 4 expands on the clarification of fundamental physics as presented in [4], [5]. In section 5 that concludes the paper, among other things, we conclude that the results of this paper are *complementary* to current main-stream fundamental physics.

2. MEDIUM WITH WAVES CLARIFYING FUNDAMENTAL PHYSICS

A medium representing potential energy in three-dimensional Euclidean space with scalar longitudinal waves representing manifest energy, i.e. all physical objects and phenomena, constitutes the "model of physics" considered in this paper. It is obtained from results presented in [4], [5], [19]. Fig. 1 shows a Venn diagram of this model, in which slashes indicate equivalences, and in which three-dimensional Euclidean space and time are independent and Galilean. Both potential energy and manifest energy are conserved, being both zero in total. The only difference between them is that manifest energy has a stable structure, as opposed to potential energy. Annihilation and symmetry breaking convert one into the other, see Fig. 1.

Before Einstein proposed Special Relativity [20], a medium called "ether" was hypothesized that offered a physical explanation for propagation of matter and waves through three-dimensional Euclidean space. In Fig. 1 it still does, although matter is wave structures, called the wave structure of matter (WSM) [5-9], removing at once the wave-particle duality paradox. That matter is considered separate from waves is one delusion in fundamental physics. Matter appears to us as point-like and local, whereas waves extend much further in space. As a result, interaction occurs at every location where waves overlap and therefore is fundamentally distributed in space, called *distributed (inter)action,* as opposed to *retarded interaction* that presumes interaction to take place by matter or energy that travels from a source particle to a target particle. This is the second delusion preventing our understanding of fundamental physics. What appears as action at a distance in gravity and EPR experiments is explained by replacing retarded interaction with distributed (inter)action [8], [21]. So a particle and its associated field should be considered as just one comoving wave structure. The third delusion preventing our understanding of fundamental physics relates to Special Relativity but also affects General Relativity and is considered next.

2.1 The Paradoxes of Relativity and the Medium with Waves Solution

Special relativity was inspired by failing attempts to identify the medium (ether), Maxwell's equations in which the speed of light appeared as a constant, independent of the state of motion (as long as no acceleration was involved), as well as the observation that the laws of physics appeared to be independent of this state of motion. Einstein hypothesized the laws of physics, *including the speed of light*, to be constant for any observer, independent of his state of motion.

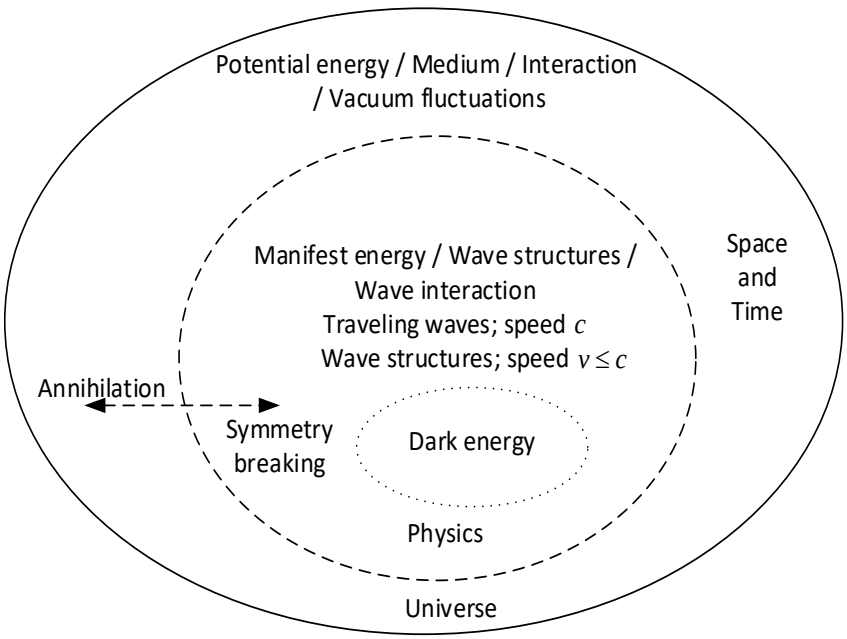

Fig. 1. A Venn diagram of "the model of physics" as obtained from [4], [5], [19]. Slashes indicate equivalences

Suppose you and I do not accelerate, and you move with a fixed velocity with respect to me. Also, we both have a clock and ruler next to us, comoving with us. When we are asked who's clock is running slower and who's ruler is shorter, we both answer, *after applying the rules of relativity*, that it is the clock and ruler of the other. So, *relativity runs into an inconsistency*. Therefore, something must be wrong with relativity, but what is wrong is so subtle that many chose to deny it, or reason that it is irrelevant, also because Special Relativity correctly predicts relativistic phenomena that could not be predicted by Newtonian physics. So, what is going wrong?

When we assume all physics, *including our clocks and rulers*, to consist of wave structures in the medium, and we move with constant velocity with respect to this medium, our clocks are slowing down and our rulers are shrinking. However, all physical phenomena that move with us are slowing down and shrinking *by the same amount* [5], [7-9]. Therefore, to both you and I, who are moving with different velocities with respect to the medium, it *seems* that all physics including the speed of light (to be precise: the two-way speed of light) is unchanged. You might say that Special Relativity is a perfect description of what we *observe,* whatever our velocity with respect to the medium, but it *hides* the unobservable relativistic changes that occur in our own frame. These changes are the ones that should be properly accounted for when making *comparisons* between physics observed in frames moving with different velocities with respect to the medium, as we do in the clock (and ruler) paradox just described. Relativity only does that properly, *if we modify it to include a preferred frame*, being the frame attached to the medium. Then your clock runs faster if mine runs slower, and your ruler is larger if mine is smaller, and vice versa, and the inconsistencies disappear [14]. This modification of relativity also tells us that *the speed of light is only constant in the preferred ether frame*, which makes sense physically, but is *observed* to be the same constant in any other frame moving with constant velocity with respect to the medium (to be precise: the two-way velocity of light is observed to be constant while the one-way velocity is not, but difficult to measure because it involves the synchronization of clocks, which in turn requires knowledge of the one way velocity of light). Moreover, this modification tells us that *space and time should be considered independent and Galilean.* This restores *causality* and *absolute simultaneity*, two properties that are considered fundamental in physics. Nevertheless these properties are lost in Einstein's Special Relativity which denies the existence of a medium and a corresponding preferred frame. But then the question returns as to how the relativistic effects of time dilation and length contraction can occur in all other frames that move with constant velocity with respect to the medium/preferred frame. This question is answered by the wave structure of physical objects and phenomena providing *a physical explanation* of these phenomena [5], [7-9]. But, as we just explained, we do not observe these relativistic effects when these take place in our own frame, although they are there. Finally the medium/preferred frame complies with Mach's principle in which "the fixed stars" act as this reference.

In summary, to get rid of inconsistencies in relativity, it needs a preferred frame/medium. This restores independence of space and time, causality, absolute simultaneity, and with these a physical intuition that makes sense and complies with Mach's principle. Despite the many proposals to adopt this change, main stream physics appears to be very much opposed to it [14], [22].

2.2 The Use of Ontology, Epistemology and Mathematics to Deny and Defend a Preferred Frame

Ontology, epistemology and mathematics all play a definite role in the reluctance to adopt the improved version of relativity. Roughly speaking, ontology means "what is physically real" and epistemology "what appears real to a human observer". As humans we are a part of physics, and therefore we can never know and observe it perfectly, because for that, we should be able to step outside physics. But what we can do is *step outside physics mentally*, *by making hypotheses.* And the only other things that we can do is search for inconsistencies in our hypotheses or find observations not complying with them. In each case these provide information as to *how to improve on our hypotheses*. In this way improving our hypotheses is what science is all about, not only in physics, but in every domain.

Since epistemology is "what appears real to a human observer" it depends on our observations and the way in which we interpret them. When interpreting observations the way Special Relativity prescribes, we conclude that all

physics, including the speed of light, is independent of the state of motion/frame we are in. As we have shown, this causes inconsistencies with regards to time and distance when two observers in different frames consider the same physical phenomena. So, following the scientific approach, we should look for an improvement of relativity that removes the inconsistencies while complying with all virtues of it. And that is precisely what the introduction of a medium/preferred frame does! This refutes the common defense of relativity stating that epistemology is all that counts or matters. The other argument used, is that one cannot detect the medium/preferred frame. Although it has been detected [23], [24], even if one could not do so [14], is no reason to deny it, if it removes inconsistencies from the model, as it does.

When modifying relativity with the medium/preferred frame, what happens to its mathematical description? In all frames, except for the preferred frame, the speed of light is *anisotropic* [14], [25]. Erroneously presuming the observer's frame to be the preferred frame, whatever its state of motion, is what Special Relativity does. In that case one can use the Lorentz transformation to find out about the physics in all other frames. But the outcomes will thus only be correct if we make our observations in the preferred frame. Because relativity effects occurring in our own frame are unobservable, and since our observations are performed in frames moving with very small velocities through the medium (ether) [24], as compared to the speed of light, results are correct to a high degree of accuracy, explaining the success of Special Relativity. But when properly accounting for the preferred frame, the Lorentz transformation must be replaced with inertial transformations [14], except when observations are made in the preferred frame itself. Using the inertial transformations, the attractive mathematical property called Lorentz invariance is lost in all other frames, and is not replaced by a similar attractive property. But if we do not make this replacement, *an asymmetry is introduced* in comparing outcomes obtained in different frames, causing all the paradoxes. In practice this problem becomes manifest in synchronizing data from satellites, moving with different velocities through the medium (ether), to obtain proper GPS data [26].

Relativity, adapted with a preferred frame, successfully describes ordinary and relativistic phenomena while restoring the medium (ether) and independence of three-dimensional Euclidean space and time that become Galilean again. This restores the understanding of physics as it was before relativity entered the scene, but now including the relativistic phenomena being time dilation and length contraction occurring in all frames that move with respect to the medium/preferred frame. Time dilation and length contraction come out as *physical phenomena* if waves are assumed to make up all physical objects and phenomena [5], [7], [8], [9].

3. INTERACTION IN PHYSICS

Potential energy, i.e. interaction, see Fig. 1, appears to be the most fundamental phenomenon in physics, because without it, nothing remains, not even space and time [19]. Therefore, physics is about describing interactions. As to manifest energy, assuming matter to have a wave structure, interaction concerns wave interactions, see Fig. 1.

Interaction in physics is described by conservation of energy and momentum. To account for interaction in Quantum Electro Dynamics, fields are being used. Fields are also used to account for gravity. Assuming matter to have a wave structure, a natural question to ask is: "Can we find a spatially distributed wave interaction mechanism complying with conservation of energy and momentum as well as fields?" Another is: "What kind of interaction mechanism do waves allow at all?" This latter question is easily answered when we take the waves to be scalar longitudinal waves, as in Fig. 1. The first question is more difficult to answer for scalar longitudinal waves but is magnificently circumvented by taking the waves to be *luminal waves* [8], [9] as further explained in the next section.

3.1 The Luminal Wave Structure of Matter that "Puts Together Fundamental Physics"

Luminal waves propagate energy and momentum with light speed c, in the medium/preferred frame. Also by definition, luminal wave interactions satisfy conservation of energy and momentum locally, because they describe the wavefield directly in the conserved quantities, field energy and momentum densities. By considering luminal waves, a qualitative and quantitative connection between relativity, quantum theory and gravity is obtained [8], [9].

This "puts together fundamental physics", a major achievement since physics is searching for this for over a century. In connecting relativity, quantum theory and gravity, de Broglie "matter" waves play a major role, in conjunction with the Dirac equation underlying relativistic quantum theory. In [8], [9], and also in [5], [7], all relativistic phenomena occur as a direct consequence of the wave structure of matter and the fact that all waves propagate with lightspeed *c*, in the medium/preferred frame. Furthermore, assuming a *refractive medium*, in which lightspeed *c* depends on energy and momentum density, explains gravity. Finally, the distributed interaction mechanism describing wave interactions at all locations where wave structures overlap, satisfies conservation of energy and momentum locally. Together with the de Broglie type of waves, that have the same phase throughout space, this causes what appears as action at a distance in gravity and EPR experiments [9], [21], [27].

3.2 Interactions between Waves and Connections to the Mathematical Models of Physics

Of all types of waves, scalar longitudinal waves are probably the simplest. They represent variations of medium density. The velocity of scalar longitudinal waves traveling through the medium is known to depend on medium density. In computing this velocity we generally assume the medium density to be constant, providing a constant wave velocity. One result of this constant wave velocity is that scalar longitudinal waves will not interact, but continue to move with the same velocity and frequency irrespective of the presence of other waves. However, the scalar longitudinal waves themselves constitute *variations of medium density*, thereby creating local changes in their velocity, implying the medium to be refractive. These local velocity changes cause different scalar longitudinal waves to interact by changing their frequency. This constitutes the *single* interaction mechanism, available for scalar longitudinal waves. Other types of waves representing physics, such as electro magnetic waves, emerge from this type of wave.

The *qualitative* explanatory power of "the model of physics" in Fig. 1 was demonstrated against a large number of paradoxes. Also, by taking the medium to represent potential energy, i.e. interaction (vacuum fluctuations), and waves to represent manifest energy, both types of energy are given an ontological status [4], [19]. Arguing that interaction is fundamental in physics, three-dimensional Euclidean space and time came out as *tools* to represent interaction [19]. Connecting this model to relativity, could be done easily by assuming matter to consist of scalar standing wave structures [5], [7]. Then, like with luminal waves [8], [9], all relativistic phenomena are obtained. As to gravity, like with luminal waves, a refractive medium (ether) was used to explain it. However, linking to quantum theory turns out to be more difficult. Whereas luminal wave interaction satisfies conservation of energy and momentum locally, everywhere in space where waves overlap, scalar longitudinal waves can only interact in the single manner described at the start of this section. Moreover, the way in which energy and momentum are attached to luminal waves, through their frequency, presents a problem for scalar longitudinal waves, because the scalar longitudinal wave amplitude represents manifest energy density. The interaction of waves actually concerns *nonlinear dynamics*, which should be properly modeled such that conservation of energy and momentum is retained. Clearly, the latter depends again on the way energy and momentum are assigned to scalar longitudinal waves. Finding the nonlinear dynamics, as well as a way to attach energy and momentum to scalar longitudinal waves, such that energy and momentum conservation is retained, appears to be a complicated problem involving nonlinear field theory [28]. This problem is magnificently circumvented by luminal waves [8], [9] who's ontology resides at a less fundamental level as represented by Fig. 2.

4. EXPANDING THE CLARIFICATION OF FUNDAMENTAL PHYSICS

From the "model of physics" in Fig. 1, resolutions to a list of twenty paradoxes and mysteries were proposed [4]. Among them were resolutions to interference experiments with single electrons and photons. Also weak and strong nonlocality were presented and discussed. The list excluded gravity, which could have been included since the refractive nature of the medium was recognized in [4]. Based on the three delusions obscuring fundamental physics, as identified in this paper, in this section we will slightly *extend* weak nonlocality and slightly *modify* the resolution to interference experiments, proposed in [4]. But first, we will present a simple qualitative association of physical phenomena with traveling and standing waves.

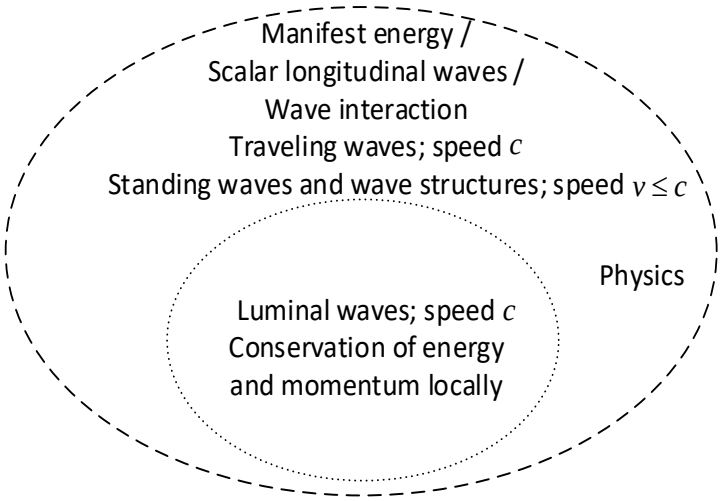

Fig. 2. Venn diagram of luminal and scalar longitudinal waves showing that luminal waves represent a less fundamental level

4.1 Traveling and Standing Waves

Waves that travel with the characteristic velocity *c* through the medium are called *traveling waves*. Physical phenomena like light and other electro-magnetic phenomena, that travel with speed *c*, may therefore be associated with this type of wave. Other physical objects and phenomena that travel with speeds different from *c*, like "particles" and their associated "fields", are represented by wave structures made up by several waves. A particularly simple structure concerns *standing waves*, determined by two waves moving in opposite directions. Standing waves can move at arbitrary velocities $V \leq C$ by changing the frequency of the two individual waves, see Fig. 2. One of the simplest versions is a radially symmetric inward and outward scalar travelling wave, as considered in [5], [6], [7]. Unfortunately, this simple type of wave does not constitute a de Broglie wave, since it fails to comply with interference experiments and Special Relativity, even when modified with a preferred frame [8], [9], [29]. This is another manifestation of scalar longitudinal waves residing at a lower level than luminal waves, as represented by Fig. 2. Luminal waves do connect to de Broglie waves without having to consider the nonlinear dynamics of scalar longitudinal wave interaction [8], [9]. Nevertheless, identifying "particles" together with their comoving "fields" with scalar standing wave structures, provides a simple qualitative understanding. Similarly, one may identify physical phenomena that travel at *c*, like light and other electro-magnetic phenomena, with traveling waves, see Fig. 2.

4.2 Weak Nonlocality, Interference Experiments and Wave Function Collapse

Based on the "putting together of fundamental physics" obtained by considering luminal waves in [8], [9], [21], we first reconsider weak nonlocality and the resolution to interference experiments with single electrons and photons, as presented in [4]. These were based on scalar longitudinal waves, particularly the radial symmetric in and outgoing wave presented first in [6] and later used in [4], [5], [7]. Interestingly, to obtain a physical explanation of the reversal of the wave at the center, reference was made to a geometric model proposed by Battey-Pratt and Racey [30]. This model represents a solution of the Dirac equation underlying relativistic quantum theory. The same model was used in [21] to explain the outcome of interference experiments as well as the appearance of action at a distance in EPR experiments. The model was considered to represent a de Broglie wave, having the same phase everywhere in space which realizes "spatial synchronization" that explains EPR experiments, without violating locality and causality [21]. As to the interference experiments, a picture of the de Broglie wave emerges being a myriad of synchronized tiny "oscillators", having equal amplitude and phase all over the width of the beam going through the slits [8], [9], [21]. What was called "the spreading of wave packets" in [4], must be identified with this myriad of synchronized tiny oscillators representing the de Broglie wave of a single

electron in an interference experiment with single electrons. The same argument then also holds for photons in an interference experiment with single photons.

As an extension to weak nonlocality defined in [4], it admits what appears as instantaneous action at a distance, but actually is a synchronized wave interaction, distributed over space, satisfying locality and causality [21].

In addition to the results in [4], as to the collapse of the wave function and superposition within the Copenhagen interpretation of quantum theory, the model of physics considered here implies that the collapse must be seen as a gain of knowledge, that is initially lacking, as represented by the superposition. The collapse is in fact a spatially distributed and partly synchronized interaction between wave structures [8], [9], [21].

5. CONCLUSIONS

By assuming waves in a three-dimensional Euclidean medium to make up all physical objects and phenomena, mysteries and paradoxes surrounding gravity, relativity and quantum theory have been removed, and a connection between all three is obtained. This "puts together physics" since finding this connection, as well as understanding the fundamentals of physics, have been considered major problems for over a century. Specifically, three delusions concerning fundamental physics were dismantled as follows: 1) a medium (ether) and a corresponding preferred reference frame in relativity complying with Mach's principle exist, 2) a "particle" and associated "fields" make up a single wave structure that largely extends in space and, 3) interaction is fundamentally distributed in space taking place at all locations where wave structures overlap.

Two types of waves were considered, scalar longitudinal waves, that reside at a more fundamental level of physics, and luminal waves, that reside at a higher level, but having the huge advantage of incorporating conservation of energy and momentum in a straightforward manner, resulting in a connection to the mathematics of quantum theory. The connection to the mathematics of relativity and gravity could be made for both types of wave. Relativity effects like time dilation and length contraction, are a direct consequence of the wave structure of physical objects and phenomena. Gravity results from the refractive nature of the medium (the dependence of c on medium density). In the case of scalar longitudinal waves, to connect to the mathematics of quantum theory, their nonlinear dynamic interaction must be considered, as well as a proper way to attach energy and momentum to scalar longitudinal waves. These are two fundamental, complicated issues that deserve further research, while being magnificently circumvented by luminal waves.

Assuming all physical objects and phenomena to be waves, finding their specific wave structures is an interesting difficult topic for further research, not needed for the clarification of fundamental physics provided here. The results presented and referred to in this paper may therefore be considered *complementing current fundamental physics*, which is very well able to predict physics at the fundamental level, but so far failing explanations and connections. Obviously, improvements at all levels of physics may possibly benefit from "the wave structure of physics", underlying the results of this paper.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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