Connecting and unmasking relativity and quantum theory

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Abstract: The answer lies right in front of us, but we refuse to see it. Both relativity and quantum theory, the two pillars of fundamental physics, are modified in this paper to make them also *explain* the physical phenomena they describe. With this explanation, all current inconsistencies between the two vanish. The modifications relate to the presence of a medium, which is in fact potential energy, in three-dimensional space. This medium acts as a reference system, in accordance with Mach's principle. The speed of light, therefore, is not absolute but relative to the medium and thus to the observer. It is also dependent on medium density. Quantum waves are real scalar waves occurring in the potential energy medium, not probabilities of particles being present. Real scalar quantum waves in three-dimensional space make up the whole of physics representing manifest energy. Particles therefore do not exist; they are local manifestations of real scalar quantum waves. As a result, the Doppler effect and wave interference play a central role in physics. Moreover, the dependence of quantum wave velocity (speed of light) on medium density provides the energy exchange mechanism that is central to physics because all physical phenomena, including observation, concern energy exchange, or interaction. The conceptual simplicity of the model of physics proposed in this paper is shown to clarify a series of paradoxes and ill-understood phenomena at the fundamental level of physics such as wave-particle duality, the twins paradox, and the double slit experiment. As to entanglement, superposition, and nonlocality, the model implies that only weak versions of these properties exist.
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Résumé: La réponse se trouve juste en face de nous, mais nous refusons de voir. Nous proposons une modification des deux piliers de la physique fondamentale, la théorie quantique et la théorie de la relativité, afin qu'en plus de décrire les phénomènes physiques, elles les *expliquent*. Cela permet d'éliminer toutes les incohérences actuelles qu'elles entretiennent. Notre modification porte sur l'ajout d'un milieu (l'énergie potentielle) dans l'espace à trois dimensions. Ce milieu joue le rôle d'un système de référence, selon le principe de Mach. En conséquence, la vitesse de la lumière n'est plus absolue, mais relative au milieu et donc à l'observateur. Elle dépend aussi de la densité du milieu. Les ondes quantiques deviennent des ondes scalaires réelles qui se propagent dans ce milieu d'énergie potentielle et ne sont plus des probabilités de présence de particules. Les ondes quantiques scalaires réelles dans l'espace à trois dimensions constituent tous les phénomènes physiques représentant l'énergie tangible. Les particules n'existent donc plus, ce des manifestations locales des ondes quantiques scalaires réelles. L'effet Doppler et les interférences d'ondes jouent alors un rôle central en physique. De plus la dépendance de la vitesse des ondes quantiques (la vitesse de la lumière) à la densité du milieu constitue le mécanisme d'échange de l'énergie qui est au cœur de la physique. En effet les échanges d'énergie ou les interactions sont mis en jeu dans tous les phénomènes physiques, y compris l'observation. Nous montrons que la simplicité conceptuelle du modèle de la physique présenté ici permet d'élucider plusieurs paradoxes et phénomènes mal décrits par les fondements de la physiques, en particulier la dualité onde-particule, le paradoxe des jumeaux et l'expérience de la double fente. Notre modèle implique aussi que seules des versions faibles des propriétés d'intrication, de superposition et de non localité.

Key words: Relativity Theory; Quantum Theory; Galilean Relativity; Black Box Models; Wave Structure of Matter.

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I. INTRODUCTION

How should we explain or understand antimatter annihilating matter? How should we explain or understand wave-particle duality? How should we explain or understand vacuum fluctuations? How should we explain or understand wave propagations through empty space? How can the speed of light be absolute in relativity theory? These are five questions revealing there is something seriously lacking in our understanding of fundamental physics. On the other hand, mathematical models of fundamental physics, representing relativity and quantum theory, calculate associated physical phenomena very accurately. But when trying to *understand* fundamental physics through these models one encounters paradoxes.

Being system scientists, this state of affairs is familiar to us. The current models of fundamental physics we call "black box models" because they very well reproduce fundamental physical phenomena but without explaining them. To system scientists, it is well known that different model structures can describe identical relations between causes and observable effects. A model that produces the observed results from known or observed causes, but has a different structure than the system it describes, is called a black box model. Because the structure is different, black box models are *unsuitable* to explain the systems they describe. As we will argue in this paper, relativity and quantum theory are currently both black box models. As to quantum theory, this is most obvious since the system state within quantum theory has no clear physical interpretation. The system state not having an interpretation is the exact criterion for a black box model within system science.[1]

In Sec. II, the proposed modifications of both relativity and quantum theory are obtained through appropriate inspection of relevant events in the history of physics. That is all that is needed. Section III shows that the proposed modifications of both relativity and quantum theory can be found, but only separately and in parts, in the existing literature. Among others, the modification of relativity clearly shows why the Michelson–Morley experiment does not disprove the existence of a medium. In Sec. IV, the modified versions of relativity and quantum theory are combined. This provides the very simple mathematical model of physics proposed in this paper. Section V goes on to reveal how the conceptual simplicity of the model clarifies a series of paradoxes and ill-understood physical phenomena. Among others the conclusions consider consequences our proposed model of physics has for future research and education.

II. HISTORY

By appropriately selecting key moments in the history related to relativity theory, the proposed modifications of relativity theory will be deduced first in this section. Next in a similar manner modifications of quantum theory will be deduced. The history list of relativity theory does not contain general relativity, because it builds on special relativity and that is where our modifications come in. Before we present the lists, we first introduce notations in Table I.

TABLE I. Notation.

Symbol/shorthand	Meaning
E	Energy
E_p	Potential energy
E_p^d	Potential energy density
c	Quantum wave/light velocity
h	Planck's constant
f	Frequency
λ	Wave length
m	Mass
p	Impulse
x, y, z	Spatial coordinates
t	Time
Φ_m	Scalar wave amplitude
G-relativity	Galilean relativity
G-transformation	Galilean transformation
G-physics	Classical physics
E-relativity	Einstein relativity/special relativity

A. History list revealing modifications of relativity theory

Galilei 1638. Classical physics (G-physics), G-relativity for inertial systems. c infinite.

Maxwell 1865. Maxwell equations, not G-relative because c is finite and supposed to be a fundamental natural constant, thus absolute (independent of inertial system).

Mach 1883. Principle of Mach: All, seemingly absolute appearances, such as inertia and centrifugal forces, are effects with respect to all mass in the universe (fixed stars).

Michelson 1887. Interferometer, no medium detected, c finite and absolute confirmed.

Lorentz 1904. Lorentz transformation. Contradictions between Maxwell equations and G-relativity resolved, i.e., G-physics and Maxwell equations invariant under the Lorentz transformation with c finite. Interpretation Lorentz transformation: time/length contraction.

Einstein 1905. Special relativity (E-relativity). When all physical laws *including* c are assumed absolute, the Lorentz transformation comes out as a consequence of the finite velocity of light (considered infinite in G-relativity). No medium, space and time no longer independent, simultaneity lost.

Galilei introduced relativity (G-relativity) with respect to inertial systems implying that the physics in any two such systems is governed by the same laws (G-physics). Time in any two inertial systems is identical (simultaneity). Space coordinates are different but follow from a simple transformation (G-transformation). Inertial systems are fundamental to relativity. They are systems in which objects on which no forces act move with constant (possibly zero) velocity. Mach's principle gives a physical account of inertial systems. According to Mach's principle, they are all those systems not accelerating with respect to all mass in the universe (fixed stars). In this way, all mass in the universe (fixed stars) becomes an absolute reference system.

Before Mach, Maxwell devised equations meant to fully describe electromagnetism. But Maxwell's equations were not G-relative because c in his equations was supposed to be a natural constant, i.e., absolute (independent of the inertial system). If c is not, Maxwell's equations lose their mathematical beauty and generality. Physical arguments for c to be absolute in any inertial system oppose the idea that in space there is a medium that enables propagation and acts as an absolute reference system. In trying to settle this issue, Michelson and Morley performed their famous experiment that seemed to deny the presence of a medium. Next Lorentz devised a transformation, different from the Galilean one, that would make c absolute in different inertial systems. Applying this transformation resolved contradictions between Maxwell equations and G-relativity. But as opposed to the G-transformation, the physical interpretation of the Lorentz transformation implies length and time contraction. Finally, Einstein showed that when postulating an absolute c in every inertial frame the Lorentz transformation comes out as a consequence. In G-relativity c is considered infinite. Postulating an absolute c in every inertial system leads to a new space-time concept in which there is no medium, i.e., an absolute reference system. Moreover, time and space are no longer independent and simultaneity in different inertial systems is lost. To further motivate an absolute c, Einstein referred to the Fizeau experiment which seemed to confirm this.

Let us take stock. Historically, there were essentially three arguments to shift from G-relativity to E-relativity:

A. to take into account the finite velocity of light
B. to uphold the beauty and generality of Maxwell's equations by assuming an absolute c
C. experiments that either measure c to be absolute or acknowledge the nonexistence of a space medium which is considered equivalent

Argument A is a clear physical argument and constitutes the positive contribution of E-relativity. Argument B is a mathematical argument, not a physical one. Argument C only appears to be a physical argument. This is because the Michelson–Morley and Fizeau experiments (and all similar ones) do not truly measure c, but a related quantity that is generally constant, as we shall see and explain in the next section. Therefore, the required modification of E-relativity is *to abandon the assumption that c is absolute,* i.e., a fundamental natural constant independent of the inertial system. As we shall see in Sec. III, doing so we allow for a medium in space that:

1. acts as an absolute reference in accordance with Mach's principle
2. allows for wave propagation through space
3. can explain vacuum fluctuations which also require a medium
4. restores independence of space and time and simultaneity in different inertial systems

As a consequence, c is only approximately constant with respect to the medium because it depends on medium density. Also the Lorentz transformation as well as Maxwell's equations need modification.

B. History list revealing modifications of quantum theory

Clifford 1870. Matter is waving.

Planck 1900. Spectrum black-body radiation explained if radiation energy is quantized by units $E = hf$, with h being the Planck's constant and f being the frequency of radiation.

Einstein 1905. Explanation photoelectric effect by postulating that light consists of particles (photons) having a single Planck unit of energy $E = hf$. Discovery $E = mc^2$ raised wave-particle duality.

Bohr 1913. Model of atom structure explaining energy quantization.

De Broglie 1924. All matter has a wave character, $\lambda = h/p$. Matter waves, wave-packets.

Born 1925. Matter waves are probability waves of particle presence at different locations.

Schrödinger 1927. Schrödinger equation. Solutions can be matter or waves.

Bohr 1927. Copenhagen interpretation. Matter waves are probability waves of particle presence at different locations. Complementarity principle, observer-object connection, entanglement, nonlocality.

Dirac 1928. Relativistic version of Schrödinger equation. Solutions reveal electron spin and predict the positron.

As found by Lorentz and Einstein, respectively, black-body radiation and the photoelectric effect could only be explained by assuming energy of radiation is quantized by units $E = hf$. Together with Einstein's famous relation $E = mc^2$, this raised wave-particle duality. Bohr built the first model of atom structure that explained quantization of energy exchange. Already in 1870 Clifford proposed that all matter is manifestation of waves. Given wave-particle duality, De Broglie suspected that all matter has a wave character which seemed somewhat later to be confirmed by experiments on electrons. De Broglie introduced matter waves that represent particles by wave-packets. Wave-packets are waves that only cover a very small region in space. This small region of space may be identified with an associated particle. So wave-packets comprise and therefore explain wave-particle duality. Mathematical calculations, however, showed that wave-packets which initially cover only a very small region in space spread very quickly to cover very large regions in space no longer representing particles. To circumvent this problem, Born proposed to not interpret matter waves as physically real but instead as probability waves of particle presence. Next Schrödinger developed his famous, though nonrelativistic, wave equation determining quantum wave propagation. A little later Dirac developed a relativistic version. This version incorporated electron spin, which had been mysterious until then, and correctly predicted the positron.

Around the same time, Schrödinger developed the wave equation, Bohr extended Born's interpretation of quantum waves as probability waves into what became known as the Copenhagen interpretation of quantum theory. This interpretation was dominant for a long time and possibly still is. The consequences of this interpretation are, however, very hard to understand from a physical point of view because they involve complementarity, collapse of the wave function to represent observer-object connection (observation), entanglement, and nonlocality. Therefore, the Copenhagen interpretation also faced severe opposition, like from Einstein and Schrödinger. Despite the opposition, the Copenhagen interpretation remained predominant. The opposition also continued leading to a series of different interpretations of quantum theory and the associated quantum waves. None of these, however, considers quantum waves as just *real physical scalar waves in a medium having only three dimensions*. This is the interpretation we propose which has the following important characteristics:

1. It is conceptually very simple and therefore free of paradoxes.
2. It is very easy to understand physically.
3. It allows for wave-packets that comprise and explain wave-particle duality.
4. It removes inconsistencies with relativity theory when the modification of E-relativity in Section II is applied.

Although very simple conceptually, computationally our real physical scalar waves are complicated. This is due to the nonlinearity caused by variations of medium density due to large wave amplitudes that occur, especially at the center of wave-packets. This causes waves to modulate one another and constitutes the energy exchange mechanism that underlies all of physics. Also this nonlinearity implies that quantum wave propagation is described by wave equations different from those of Schrödinger and Dirac that are linear.

Summarizing, proper inspection of the history related to relativity and quantum theory reveals that at some stage mathematical arguments took over from physical arguments in developing physical models of both. As to relativity, this led to the assumption of an absolute velocity of light irrespective of the inertial system and the idea that a medium in space is not present. As to quantum theory, this led to abandoning the idea that quantum waves are physically real. By:

1. reinstalling a medium in three-dimensional space that
2. propagates scalar quantum waves that are physically real

in Sec. IV we will build a conceptually very simple model of physics in which the scalar waves make up the whole of physical reality. In Sec. III, we will show that the ideas 1. and 2. have been proposed before in the literature, but separately. Only when they are *combined* our conceptually very simple model of physics is obtained, free of paradoxes.

III. LITERATURE

When assuming a medium, the velocity of light c is not independent of the inertial frame which seems to contradict experiments by Michelson–Morley and Fizeau. These experiments, however, all measure what is called the two-way velocity of light, i.e., the average velocity of light when it travels back and forth. The same holds for all other experiments of this type. The reason being that a single clock is always used to perform these experiments to circumvent the clock synchronization problem. Because solving the clock synchronization problem in turn requires knowledge of the one-way velocity of light which is to be measured. Due to the averaging that occurs during measurement, the two-way velocity of light always comes out constant in every inertial frame irrespective of the one-way velocity of light (the same holds for sound waves propagated by air). Einstein postulated the one-way velocity of light to be absolute irrespective of the inertial frame in E-relativity. Mansouri and Sexl[1–4] and Selleri[5] further described and explained this issue and derived transformations between inertial frames that may all replace the Lorentz transformation if the postulate of an absolute one-way velocity of light is abandoned. Using the Sagnac effect in which acceleration plays a crucial role, Selleri[5] singled out one inertial transformation, different from the Lorentz transformation, as the physically correct one. This transformation restores the existence of simultaneity in different inertial frames (called absolute simultaneity in the paper) and removes the twins paradox. Restoring simultaneity in different inertial frames basically restores independence of space and time. Still time and length dilation in different inertial frames occur but only as a direct consequence of the finite velocity of light. The situation has become fully compatible with the existence of a medium in space that propagates light/waves. It is another matter to establish the inertial frame associated with the medium. Here, relativity complicates matters.[1–4,6,7] As to the physical model proposed in this paper, establishing the existence of a medium is sufficient however.

Starting from the idea advocated by Clifford in 1870 that matter is waving, *mechanistic models* of fundamental physical particles were proposed by Battey-Pratt and Racey[8] and Wolff.[9] The mechanistic nature of these models relies entirely on the representation of fundamental physical particles by scalar waves. Wolff[9] also made the important suggestion that the nonlinear nature of the medium, especially near the center of wave-packets where the change of density is high, causes waves to modulate one another. This leads to shifts of frequency Δf corresponding to energy exchanges $\Delta E = h\Delta f$. So the modulation of waves provides a conceptually simple energy exchange mechanism. Note that in a medium with constant density waves do interfere but they do no change frequency. Therefore, they do not exchange energy while all physical phenomena are based on energy exchange or interaction. Later, Wolff[10] introduced the terminology "wave structure of matter" (WSM) which we find highly appropriate and will use from now on.

IV. MODEL OF PHYSICS

The modifications of relativity and quantum theory presented in the previous two sections lead to a conceptually very simple model of physics that has real scalar waves in three dimensions as a basis. The scalar waves are represented using three-dimensional space and time that is independent of space. The dependence of scalar wave velocity on medium density provides the energy exchange mechanism that underlies all interaction. Despite the conceptual simplicity, the mathematical modeling is not straightforward because all physical phenomena, including space and time, emerge from potential energy. Therefore, we decided to leave the mathematical modeling to a future paper, except for the following formula:

$$\Phi_m(x,y,z,t) = E_p^d(x,y,z,t) - \bar{E}_p^d(x,y,z,t), \quad E_p^d, \bar{E}_p^d \geq 0. \qquad (4.1)$$

In the above equation, E_p^d represents potential energy density, i.e., the amount of interaction of the medium, and $\bar{E}_p^d$ average potential energy density. Furthermore, x, y and z represent three spatial coordinates with respect to a frame attached to the potential energy medium and t represents time which is independent of space, i.e., x, y, z. $\Phi_m(x,y,z,t)$ represents the wave amplitude. As to its propagation, several suggestions have been made in the literature. Wolff[9,10] suggested a scalar wave equation with wave velocity depending on medium density. The latter provides an energy exchange mechanism between the scalar waves. Battey-Pratt and Racey[8] show how Dirac's wave equation describes spherical rotation of part of the medium. Spherical rotation explains electron spin and is used by Wolff[9] to explain a scalar wave model of the electron that consists of a single scalar wave moving toward and out of the electron center. Spherical rotation explains the reversal of the wave in the electron center. Roychoudhuri[11] introduces space as a real complex tension field (CTF) as he calls it. In CTF, electromagnetic waves propagate according to Maxwell's equations while energy exchange occurs with particles that are conceived as material oscillators. CTF has the advantage that electromagnetic waves are naturally obtained whereas they should emerge from our model. On the other hand, CTF does not provide a fundamental energy exchange mechanism. So one could state that our physical model resides at a lower, more fundamental level than CTF.

V. EXPLANATORY POWER

Due to the conceptual simplicity of the model of physics, many paradoxes and ill-understood phenomena in physics disappear. Below a list is presented summarizing the ones that have already been mentioned in this paper as well as some that have not been mentioned yet. The latter will be shortly discussed subsequently.

A. List of resolved paradoxes and ill-understood phenomena in physics

1. Wave-particle duality
2. Energy exchange mechanism
3. Mach's principle
4. Action at a distance
5. Twins paradox
6. Electron spin
7. Electron radiation
8. Compton wavelength/Zitterbewegung
9. Annihilation particles and antiparticles
10. Vacuum fluctuations
11. Particle zoo
12. Schrödinger's cat
13. Heisenberg's uncertainty principle
14. Loss of simultaneity
15. Quantum tunneling
16. Renormalization quantum wave amplitude
17. Inconsistencies between relativity and quantum theory
18. Quantization of energy exchange
19. Double slit experiment, including "single photon" case
20. Continuous spectrum of Bremsstrahlung

As to "action at a distance," the medium propagates and reflects locally the presence of distant objects and phenomena. "Electron spin" is spherical rotation as explained by the model of Battey Pratt and Racey[8] that relies on WSM. "Electron radiation" could be explained[12] by a model similar to that of Wolff[9] that uses a scalar wave that moves toward and out of the electron center. The WSM models[8,9] also explain the "Compton Wavelength" and associated "Zitterbewegung." The "particle zoo" refers to the fact that the advance of quantum theory revealed many different "particles" which is in conflict with the philosophical argument that simplicity is expected at the fundamental level of physics. This is resolved by our model because these particles are all wave structures that are highly unstable (they exist only for a very short time) relevant only when considering stable wave structure transitions. The same holds for "vacuum fluctuations." "Schrödinger's cat" is not alive and dead at the same time because quantum waves are real instead of describing probabilities. So it is not the observer who decides "what becomes real," because there is no "collapse of the wave function" involved in observation. Observation is interaction too. "Heisenberg's uncertainty principle" follows from the fact that particles are spatially distributed wave structures that are observed through interaction with other wave structures.[8] "Quantum tunneling" is also explained by the spatially distributed nature of particles. "Renormalization of quantum wave amplitude" is a procedure needed to comply with the Copenhagen interpretation of quantum theory to make sure probabilities obtained from quantum waves add up to one. But our wave amplitude is real and need not be renormalized. "Inconsistencies between relativity and quantum theory" disappear because our real scalar quantum waves in the potential energy medium obey *locality and causality*.

B. Double slit experiment

To explain quantization of energy and with it the famous double slit experiment, including the case where "one photon at a time" passes the two slits, consider Fig. 1. The key to quantization of energy are properties of atoms which according to our model are stable wave structures (WSM). In physics, almost exclusively, atoms are both the energy emitters and energy detectors (absorbers/receivers). Their stability, however, dictates quantized values of wave length of the wave structures they are made of. These quantized values of internal wave lengths cause the quantized nature of energy emission by atoms through wave-packets. Also they cause

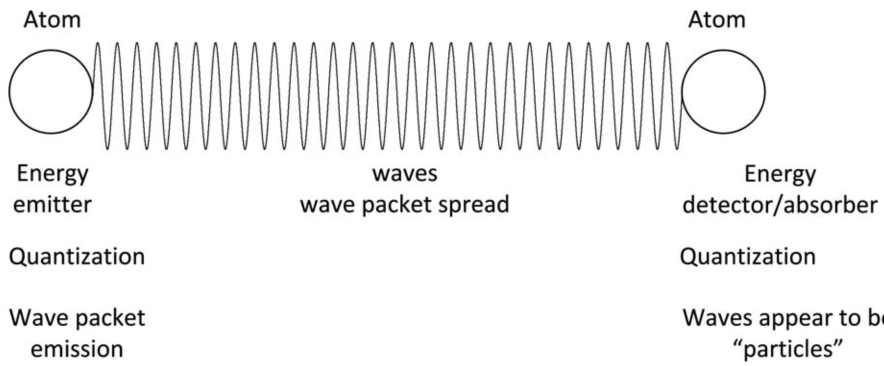

FIG. 1. Quantization of energy exchange and the WSM.

the detection (absorption) of wave energy by atoms to be quantized. Because of the quantized nature of energy that is emitted and detected, it appears as though particles realize the energy exchange. According to our model, they are ordinary waves that very quickly spread out in space. The latter provides us immediately with an explanation of the double slit experiment including the case where one photon at a time passes the two slits. The latter case is no different from the ordinary case because "single photons" do not exist when they reach the slits. They may be called single photons only near the emitter atom where they start as wave-packets (WSM) covering only a very small region in space. But these wave-packets very quickly spread out in space thus always going through both slits. Also, whenever a detector is placed at or near one of the slits, it prevents or partly prevents the waves from passing. This directly influences the interference pattern on the screen, as observed. The wave-packet spread implies that the energy received originates from several wave-packets that have been sent. As to the double slit experiment, our model shows the same capacity as that of Roychoudhuri[11,13] that also offers an explanation of the double slit experiment.

C. Bremsstrahlung

It is often stated that any energy exchange in physics is always quantized. According to Fig. 1 and the associated WSM, this is only so if stable more complicated wave structures, specifically atoms, are emitting and detecting (absorbing) energy. Compared with atoms, the wave structure of electrons is very simple. According to the "space resonance" model proposed by Wolff,[9] an electron is a scalar wave moving toward and out of the electron center. Together these make up a spherically symmetric scalar standing wave-packet. When two free electrons come close to one another, wave modulations, especially at their centers, affect the wave-packets and thereby the positions of the electron wave centers. This interaction is equivalent to the electromagnetic interaction of two free electrons which changes their kinetic energies. This energy exchange is associated with what is called Bremsstrahlung which is a type of energy exchange that is not quantized (Bremsstrahlung is known to have a continuous spectrum) in accordance with our proposed model of physics.

D. Weak and strong properties

Comparing our model of physics with the current mathematical formalism of quantum theory, *weak and strong versions* of nonlocality, entanglement and superposition must be distinguished. The weak versions are properties satisfied by our proposed model of physics. The strong versions are properties satisfied by quantum theory. They are associated with the Copenhagen interpretation. These weak and strong properties are listed below together with their meaning.

Weak properties satisfied by the proposed model of physics

- weak entanglement: Everything depends on everything through causal local interactions.
- weak nonlocality: There is nonlocality but not instantaneously.
- weak superposition: Things can co-exist in a wave interference sense.

Strong properties satisfied by quantum theory (Copenhagen interpretation)

- strong entanglement: Everything depends on everything, instantaneously.
- strong nonlocality: There is instantaneous nonlocality.
- strong superposition: Things can co-exist. Observer decides what becomes real.

Experimental results at the quantum level[14–16] seem to indicate that strong properties exist. According to our proposed model of physics, they do not. It must therefore be possible to explain the experimental results using only weak properties. Although it is outside the scope of this paper to provide these explanations, we believe that these can be obtained by including properly the effect of macroscopic objects that are part of these experiments, such as the measurement equipment. Also the process of generating entangled particles (e.g., by parametric down conversion) must be included properly. This process is not at all well understood. Together with the effect of macroscopic objects it is totally ignored, or at best very much simplified, in the current explanations that rely on strong properties. And last but not least the interpretation of observations *depends* on the physical model choice.

VI. CONCLUSIONS

After modifying both relativity and quantum theory, the resulting model of physics proposed in this paper becomes almost analogous to acoustic waves mediated by air. Instead of air we have potential energy as a medium. The scalar acoustic waves are replaced with scalar quantum waves. Acoustic waves are all there is in the air like quantum waves are all there is in physics. From a scientific and educational point of view, this is of great significance because it leads to a proper and simple understanding of the fundamentals of physics that has been very much lacking. Physics, i.e., wave propagation, occurs in a medium in three-dimensional space and is causal and local. Time is independent of space. The velocity of light is not absolute but dependent on the observer and medium density. The latter creates the energy exchange mechanism causing wave frequency shifts equivalent with energy transfer. Electrons are represented by stable spherical symmetric standing wave-packets created by a single spherical wave moving toward and, after spherical rotation, out of the center.[8,9] Atoms comprise significantly more complicated stable wave structures. Their stability admits only quantized values of wavelength of parts of the structure. This causes the quantized nature of energy release and absorbance by atoms. This in turn makes the energy exchange between atoms look like mediated by particles. They are actually waves that very quickly spread out in space implying that photons only appear to exist. The latter allowed for a simple explanation of the famous double slit experiment, including the case where one photon at a time passes the two slits.

Computationally, the proposed model of physics is complicated due to the spatially distributed nature of the model and the nonlinearity caused by the dependence of wave propagation on medium density. This nonlinearity is vital because it provides the energy exchange mechanism in physics. To obtain quantitative results, the wave propagation must be mathematically modeled and the nonlinearity must be quantified. They depend on properties of the medium. This delicate issue is left for future research since it involves emergence out of potential energy of manifest energy as well as space and time and, in the end, all physics. It should also provide insight as to why the current black box models of physics often give excellent numerical results matching observations. Some results that have already been published may be regarded contributions in this area.[2–6,11,13,17–22]

Historically, it appears that at some stage during the development of physical models mathematical arguments took over from physical arguments. This applies to the strange postulate of an absolute one-way velocity of light in special relativity. At the quantum level, this resulted in highly complicated mathematical models, lacking a proper interpretation while incorporating ever larger numbers of "fundamental particles" and properties such as strong nonlocality and strong entanglement. According to our proposed model of physics, these particles are not truly fundamental while only weak versions of entanglement and nonlocality exist. One could say that during the last century physics has been heavily mathematized. As to obtaining accurate quantitative results matching observations this is fully justified. But when it comes to *explaining and understanding physics* this is not.

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