Co-existence of Continuous and Discrete Physical Behavior

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Abstract Louis de Broglie conjectured that massive particles exhibit three fundamental behaviors, namely corpuscular, oscillation and wave behavior, which are revealed in different types of experiments. Although de Broglie spent many years to develop a theory describing the origin of those behaviors, he ultimately remained unsuccessful. Recent theoretical developments indicate how those fundamental behaviors can be unified in a single non-linear continuous oscillating process which possesses a discrete time period and demonstrates the existence of dynamically emerging space. This report provides a summary overview of the main results.

Louis de Broglie conjectured that a massive particle performs a process which exhibits co-existing corpuscular, undular and oscillatory behavior [1]. The full extent of those ideas has hardly been explored since they were proposed, although various people such as David Bohm have made some attempts in this direction.

The corpuscular property of massive particles is exposed in collision experiments. Wave or undular behavior is revealed in interference phenomena such as Young's interference experiment with electrons. de Broglie's wave is created upon particle motion. Oddly enough, in contrast with a classical wave of which the speed increases, the wavelength of de Broglie's wave reduces upon increasing particle speed. Lastly, de Broglie also considered the presence of internal oscillatory behavior in massive particles, which would be present regardless of the state of motion of the particle. Accordingly, a stationary electron performs an oscillation with a frequency equal to

$$\nu_0 = m_0 c^2 / h \qquad (1)$$

where m_0 is the rest-mass of the electron, c is the speed-of-light and h is Planck's constant. Electron oscillation has been observed indirectly [4].

Since the measured mass of electrons is constant, (1) indicates that the oscillation frequency of an electron must be extremely stable. Therefore, a fundamental notion of discrete time or quantum beat period Δt_0 can be introduced by defining

$$\Delta t_0 \equiv 1/\nu_0 \qquad (2)$$

which is equal to the oscillation period of the stationary electron and can also be referred to as the quantum of time. For an electron, it follows that $\nu_0 \approx 10^{20}$ Hz. Since the internal motion is very small, see (3), and detailed oscillation behavior is unknown and in general highly non-linear,[1] this rescinds the need to introduce an even shorter notion of discrete time to describe the unceasing evolution dynamics of the oscillator.

Using (2), evolving time can be measured by counting the number of oscillation periods that have passed since counting was initiated. In practice, evolution of discrete time can be approximated by mathematically continuous time t, since Δt_0 is much smaller than any currently measured time interval.

Unfortunately, despite extensive research, de Broglie was not able to provide a satisfactory explanation for the co-existence of all three mentioned massive particle behaviors in a single physical process. More recent investigations by Andrei P. Kirilyuk demonstrate the co-existence of all three behaviors in a single, spatially random, quantum beat process, which unifies quantum and relativistic behavior of massive particles [3]. These considerations also show that, although discrete time dynamically emerges from an unceasing oscillation process, the oscillation process itself, the motion and the de Broglie wave of a massive particle are all continuous phenomena.[2]

The quantum beat process that unites all three particle behaviors requires the existence of two mutually attracting fundamental fields, referred to as electromagnetic protofield and gravitational protofield. Four fundamental interactions are observed in nature. Of those interactions, electromagnetic interaction and gravity have a long-range character. Weak interaction and strong interaction are short-range interactions. In order to match the observed types of interactions with the protofields, while relying on minimal assumptions, it must be conjectured that the electromagnetic protofield facilitates electromagnetic and weak interaction, and the gravitational protofield mediates gravity and strong interactions.

From observations, it is known that the long-range electromagnetic interaction is much stronger than gravity. Therefore, in order to match particle interaction behavior mediated by the protofields with observed interaction strengths, the electromagnetic protofield must be much more mobile compared to the gravitational protofield [2,3].[3] The very different protofield mobilities means that a perturbation in both fields, caused by protofield attraction, will be primarily observable within the electromagnetic protofield. The speed of a perturbation in the electromagnetic protofield must be constrained by its attraction to the gravitational protofield and be fixed due to the extreme stiffness of the latter.

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[1] Analogous to the highly non-linear internal motion of a pendulum clock.

[2] Oscillatory processes and periodic phenomena are prevalent in nature at all physical scales. Examples are the motion of electrons in atoms, electronic crystal oscillators, mechanical clocks, rotation of planets, motion of moons around planets, and the path followed by planets around stars. The conjectured existence of oscillating quantum beat processes would be yet another example. As demonstrated by the considerations in the remainder of this report, their existence appears to be required in order to consistently describe nature at all physical scales.

[3] This can be understood by considering the mutual attraction of the protofields. Upon their attraction, the mobile electromagnetic protofield, as it were, falls into the stiff gravitational protofield. Consequently, long range interaction between particles must be stronger via the electromagnetic protofield than facilitated by the gravitational protofield.

Analysis of the state function equation that describes attraction of the protofields shows that it gives rise to a continuous unceasing non-linear state function pulsation (oscillation) of fixed period Δt_0. The analysis of the general state function that describes this oscillation behavior also demonstrates that two distinct types of dynamic transitory states exist; a single intermediate state and multiple reduction states. These states are mutually exclusive in the dynamic sense, i.e., they can only occur one at a time and any two subsequent reduction states are always interposed by the intermediate state [2,3].

The single intermediate state corresponds with temporary weak binding of the interacting protofields. The reduction state, of which in general multiple exist, is a dynamically evolving pulse caused by strong attraction of the two protofields and results in a temporarily existing highly local space point, which is observed as corpuscular behavior in collision experiments. The observed three dimensions of space may dynamically emerge from the protofield interaction and the possible existence of three degrees of freedom in the observable electromagnetic protofield. Another possibility is that the two protofields and their interaction lead to the three spatial dimensions.

For a stationary particle, the discrete space points are created in a small dense region, see Δx_0 in (3). The unceasing sequence of both types of states results in non-linear protofield oscillation and, consequently, dynamically emergent discrete time (as the oscillation period).

A particle in motion has reduction states which tend to be more spatially aligned in the direction of motion. Consequently, a series of intermediate state appearances, which are interposed between reduction states, behaves more coherently compared to a stationary particle. The average spatial coherency of the series of intermediates states is equal to de Broglie's wave, of which the wavelength reduces with increasing speed of the particle.

Dynamic transitions from one reduction state to the next (via the intermediate state) are necessarily probabilistic, since observation of the highly non-linear dense behavior of the state function does not allow prediction which of the reduction states is 'dynamically chosen' next, and all reduction states have to appear frequently as part of the general state function behavior. The probabilistic transitions between reduction states to the next explains that time appears 'now' and is asymmetric, because any knowledge of the previously traversed reduction state is lost. Most equations in physics, such as Schrodinger's wave equation and Maxwell's equations, are 'time symmetric' in the mathematical sense, since they do not take into account the underlying probabilistic character of the reduction state transitions.

The speed of a perturbation in the electromagnetic protofield should be constrained by its attraction to the gravitational protofield and be fixed due to the extreme stiffness of the the latter, and is denoted as *c*. After further development of the theory, and comparison with current physics, it turns out that *c* is equal to the speed-of-light.

The distance Δx_0 covered by a protofield perturbation[4] over a single quantum beat period Δt_0 between two space point can be expressed as

$$\Delta x_0 = c \Delta t_0 \tag{3}$$

From these observations, it can be concluded that massive particles exhibit an internal motion at the speed-of-light and that the externally observed particle motion can never exceed the speed-of-light. This is the reason that the expressions for relativistic energy and momentum of a massive particle contain the speed-of-light as a parameter (see also discussion of equation (4)).

State functions with multiple reduction states are identified with massive particles, because they exhibit internal random motion giving rise to inertia. State functions with zero reduction state and one reduction state lack internal randomness and thus perform linear motion with a speed equal to the speed-of-light. Based on observed particles, it seems natural to identify those state functions with photons and neutrinos, respectively.

Since all electrons and positrons have the same mass, it follows that they have the same quantum beat frequency and thus the same quantum beat period, see (1) and (2). The only remaining degree of freedom that could distinguish electrons and positrons is the oscillation phase. In order to consistently explain the observed two types of electric charge, the quantum beat processes of all electrons must be phase-synchronized and electrons and positrons must have an opposite oscillation phase. Hadrons likely consist of a bound aggregate of two or three in-phase or out-of-phase quantum beat processes [2,3].[5]

The different mobilities of the protofields, their mutual attraction, and the unceasing quantum beat oscillation together must give rise to a continuous rotation which corresponds to particle spin and which is primarily observable as an effect in the electromagnetic protofield.

The quantum beat process of a free massive particle (electron) can be described in terms of Kirilyuk's physically rationalized quantum condition, which holds relative to an assumed displacement frame (see below for this notion)[6]

$$h = \boldsymbol{P} \cdot \Delta \boldsymbol{X} \tag{4}$$

where $\boldsymbol{P} = \left(E/c, p_1, p_2, p_3 \right)$ and $\Delta \boldsymbol{X} = \left(c \Delta t, \Delta x_1, \Delta x_2, \Delta x_3 \right)$ are the particle's

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[4] As mentioned, a protofield perturbation is primarily observable in the electromagnetic protofield.

[5] The quarks that are detected in particle experiments could be identified with a dynamically emerging space point during the oscillating quantum beat period.

[6] Notation used by current author. The quantum condition can also be written less formally as $-h = -E \Delta t + \sum_{i=1}^{3} p_i \Delta x_i$. In this case, the left-hand side indicates the quantum of action $\Delta A = -h$ and the quantum condition as a whole has a similar form as used in current physics with discrete action replaced by continuous action, and with continuous time *t* and location *x* instead of discrete time Δt and displacement Δt , respectively.

4-momentum and 4-displacement, respectively, and the dot indicates the Minkowski inner product [4]. In the latter expressions, E corresponds to the particle energy, the p_i are particle momentum components, Δt is the discrete quantum beat time period of the particle in motion (which is equal to Δt_0 for a stationary particle) and Δx_i is the displacement of the massive particle over a single quantum beat period Δt along the i-th displacement axis, i=1,2,3.

Planck's constant h in the quantum condition indicates the existence of the electron oscillation [2,3]. The quantum condition quantifies co-existing corpuscular behavior (by E and p_i), oscillation behavior (by Δt) and wave behavior (by the relation $\lambda_B = h/p$, where λ_B is de Broglie's wavelength and p is the momentum in the direction of motion) [3,4].

Quantum condition (4) is not tied to a particular coordinate frame of reference, but holds relative to a given displacement frame. A displacement frame is a set of orthogonal axes with respect to which particle motion (not location) is observed.[7]

Equation (4) also embodies unification or co-existence of quantum behavior and relativistic invariance[8]. The latter follows from the fact that Planck's constant is the same relative to all displacement frames. Therefore, it is not surprising that the quantum condition yields all fundamental quantum and relativistic equations of current physics for a free particle. Examples are the time dilation expression, the equivalence of mass and energy, relativistic equations for energy and momentum, and Schrodinger's wave equation (which describes de Broglie's wave). All those equations are provided with a natural physical interpretation in terms of dynamically emergent oscillation, space and time. In addition, the notion of particle mass obtains a clear physical meaning: it is the consequence of the quantum beat oscillation, see (1), and internal spatial randomness.

Relativistic invariance of quantum condition (4) yields exactly the same mathematical expression for the Lorentz transformation L as in current physics, yet must be described as

$$\Delta \boldsymbol{X}' = L(\Delta \boldsymbol{X}) \tag{5}$$

where the regular space-time 4-vectors are replaced by the particle displacements $\Delta \boldsymbol{X}$ and $\Delta \boldsymbol{X}'$, which are constrained by (4) relative to different displacement frames K and K' respectively [4].[9]

[7] The fact that a displacement frame is used (which consist of three directions of motion) instead of a coordinate frame, makes the description more 'relative'.

[8] In Special Relativity, an event corresponds to a coordinate tuple (t, x_1, x_2, x_3), essentially with zero duration. In contrast, as demonstrated in this report, any physically measured event must have a minimal duration equal to the proper time $\Delta t_0 > 0$. The physical existence of events of non-zero and fixed duration makes relativity theory and quantum theory compatible and allows unification into a single theory.

[9] In contrast with (4), the explicit expression of the Lorentz transformation does not contain Planck's constant.

Interactions between particles arise as a consequence of the dynamic behavior of particles, which exerts attractive or repulsive tension between particles mediated by the protofields [2,3]. The long-range electromagnetic interaction and short-range weak interaction are facilitated by the electromagnetic protofield. Long-range gravity and short-range strong interaction are exerted through the gravitational protofield. Consequently, the protofields and their interaction gives rise to both the existence of particles and their interactions such that they both have a quantum origin. Quantum condition (4) can be generalized to include (long-range) electromagnetic interaction between particles through the electromagnetic protofield, resulting in

$$h=(\boldsymbol{\Pi}-q\,\boldsymbol{A})\cdot\Delta\,\boldsymbol{X} \tag{6}$$

Where $\Delta\boldsymbol{X}$ is the 4-displacement of the particle, $\boldsymbol{\Pi}=(H/c\,,\Pi_1\,,\Pi_2\,,\Pi_3)$ is the generalized momentum, $\boldsymbol{A}=(\phi/c\,,A_1\,,A_2\,,A_3)$ is the electromagnetic 4-potential, ϕ is the scalar potential, $(A_1\,,A_2\,,A_3)$ is the vector potential and $\boldsymbol{\Pi}=\boldsymbol{P}+q\,\boldsymbol{A}$. In the latter expression $\boldsymbol{P}$ is the 4-momentum as in (4).

From (6), the approximation of particle motion as piece-wise free motion, and the Lorentz transformation (5), all main results of classical electromagnetic theory can be derived, such as relativistic potential transformations, relativistic electromagnetic field transformations and Maxwell's equation [3].

Gravity is a inherently quantum phenomenon, since it is caused by particle oscillation induced long-range tension in the gravitational protofield. The effect of gravity is described by approximating particle motion in terms of 4-displacement segments and by introducing the physically rationalized metric g_{ij} and the invariant interval Δs as

$$\Delta s^2=\sum_{i=0}^{3} g_{ij}\Delta x_i\Delta x_j \tag{7}$$

where the interval Δs is equal to $c\Delta t_0$ and the particle displacements Δx_i over a single quantum beat cycle are constrained by (4). The metric equation yields the geodesic equation of General Relativity, which describes the continuous motion of particles subject to gravity [3].

All derived electromagnetic interaction equations and gravity interaction equations apply to the location of a massive particle as observed relative to a displacement frame. Extension of those results to 'free space' leads to results which are not supported by the theory (see Notes section).

From the previous considerations, it is clear that the original ideas of Louis de Broglie are still very relevant in order to accomplish unification of physics. The more fundamental conjectures made by Kirilyuk [2] (see [3] for a tutorial style expose) provide a mechanism by which the co-existence of three fundamental behaviors of massive particle and discrete space and time emerge from an unceasing continuous oscillatory process.

Notes

1. Many theories of physics presuppose the existence of space and time, or constrain the relation between space and time as space-time without ever providing a mechanism or source for their existence. Those kinds of theories are ultimately incomplete. In addition, any attempts to eliminate time from physics are futile, since this ignores the existence of quantum beat processes and thus discards dynamically emerging space, which must appear in conjunction with time.

2. The values of Planck's constant, the speed-of-light *c* and the period Δt_0 can be chosen as a smallest set to fix the internal displacement Δx_0 and the observed values of the energy *E*, momentum *p*, spatial displacement Δx, and time Δt of an electron.

3. In quantum condition (4) the energy and momentum of a massive particle are well-defined physical properties. Therefore, the quantum condition gives rise to 'uncertainty relations' $h=E\Delta\tau$ and $h=p\lambda_B$, in which the energy *E*, momentum *p*, time period $\Delta\tau$ spend on random behavior, and de Broglie's wavelength λ_B, are all well-defined physical properties and not uncertain at all [2,3]. Therefore, it appears that the current role of the uncertainty relations, which are often invoked to 'explain' physical phenomena, needs to be reconsidered in order to obtain a consistent unified theory of physics.

4. In the described quantum theory, the supposed collapse of the wave function upon measurement does not occur in the same fashion as in Quantum Mechanics. Upon every quantum beat period, the pulse-like reduction state dynamically emerges and subsequently collapses (dissolves), causing the state function to collapse at a fixed rate. On the other hand, the wave function (de Broglie wave), consists of the average of a series of intermediate state appearances and can only 'collapse' when the particle collides with another particle. However, a reduction of the wavelength (collapse) occurs only when the speed of the particle increases.

5. The electromagnetic interaction equations and gravity interaction equations that follow from the previous considerations only apply at the location of a massive particle as observed relative to a displacement frame [3]. This implies that any mathematical generalization of those equations to free space, where no massive particle resides, appear to be unjustified and therefore unphysical. Examples of such generalizations in current physics are the extension of Maxwell's equation and application of the gravity metric to free space. In the former case this yields unphysical wave equations. Instead, a physical 'electromagnetic' wave should be interpreted as an aggregate of individual photons, which may still be described in terms of some of the same equations as in Maxwell's wave theory. In case of gravity, the mathematical extension of the metric to empty space is a mathematical generalization which cannot be derived from the theory described in this report and appears to result in an unphysical description of a dynamically evolving space-time of the universe as a whole. Consequently, any supposedly

observed evolution dynamics of the universe remains to be explained in a different manner than current physics maintains.

6. Since the early 1900's there has been an increased tendency to formalize physics in an attempt to unify theories. For example, many theoretical physicists expect that separate theories can be unified into a single theory by choosing a sufficiently large mathematical space and by using symmetry principles to constrain the possible structures and behaviors in this space. Thus far, those attempts have mostly been unsuccessful because some fundamental quality seems to be missing.

7. The Standard Model of Particle Physics attempts to model particles and their interactions (electromagnetic, weak and strong interactions). This model incorporates many different parameters that are needed to match theory to observed particles and their interactions. Although it has been useful in predicting the existence of certain particles and the behavior of interaction processes, the Standard Model cannot be considered a fundamental theory of nature. The theory described in this report maintains that massive particles possess an extremely non-linear dynamic behavior. For this reason, it will always remain difficult to accurately describe internal particle behavior and short-range interaction processes between particles.

8. The theory developed in [2,3] does not address the confounding interference phenomena which appear, for example, in Young's interference experiment and the Mach-Zehnder experiment. This should not necessarily be considered a sign of incompleteness of the foundations of the theory. A relatively simple explanation for many quantum interference phenomena is provided in [5]. Under the assumption that optical devices and particle detectors perform a learning process, which determines particle arrival probabilities, it is demonstrated by means of simulation of networks of devices that many quantum interference effects are reproduced. Such a local optical or chemical learning process must ultimately originate from quantum behavior and fit within the theoretical framework described in [2,3].

References

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