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Original Paper

Resolving Collapse of Wavefunction and Quantum Foundational Paradoxes via Integrating New Physics of Particle Instability with Gravity

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Abstract: The missing physics behind the quantum measurement problem entailing collapse of the wavefunction or objective reduction (OR) has been a major unresolved problem leading to the well-known weirdness and foundational paradoxes of quantum mechanics. This paper describes the new relativistic physics of a spontaneously self-decaying or self-forming quantum particle and its spontaneous complementary wave-particle behavior representing the spontaneous mass-energy equivalence principle. The new physics is integrated into a physical/mathematical description of the Objective Reduction or collapse process including the quantitative effects of gravity and kinetic energy (anti-gravity) that govern the instability of a quantum particle. A Relativistic Wave Particle (RWP) model is developed that extends the de Broglie model to include the new relativistic physics predicting wave-particle behavior over the entire range of dynamic states (V=0 to C). The RWP model predicts the coherence and de-coherence boundary or collapse of the wave function. When gravity effects dominate the antigravity governing the instability of the particle, the quantum state or wave function collapses to classical state of mass or particle and vice versa. In addition, the process of collapse caused by interference by a measurement device or observer's consciousness is also explained. RWP model also describes the inner workings of other well-known quantum phenomena related to non-locality and Heisenberg's uncertainty, explaining that the measurement uncertainty may not be a fundamental universal reality. The new physics is then integrated also into a Relativistic Universe Expansion (RUE) model that is vindicated by recent empirical observations of the universe expansion and resolves paradoxes of current mainstream cosmology theories, such as dark energy/matter, Hubble Tension, cosmological constant problem, black hole singularity, and massive galaxies observed in early universe etc. The RWP and RUE models reveal the non-local hidden variables explaining the inner workings of quantum mechanics predicting non-locality or entanglement without violating the Bell's theorem based on local hidden variables. A potential framework for an integrated universal model for matter-mind-consciousness is proposed entailing the observer and the observed.

Keywords: Measurement Problem; Nonlocality; Wave-particle Duality

INTRODUCTION

Quantum mechanics theory, despite its successes, has remained enigmatic and paradoxical [https://en.wikipedia.org/wiki/List_of_unsolved_problems_in_physics] because of a lack of understanding of its inner workings. Scientists are still puzzled over its features such as wave-particle duality, entanglement, "spooky action at a distance" and whether uncertainty is a fundamental universal reality. The behavior of the small or quantum versus the classical large objects shows uncommon features that remain unexplained by existing theories. Even within quantum domain, massive versus massless particles are treated differently in their mathematical descriptions lacking a cohesive universal model integrating quantum versus classic behavior. Quantum Mechanics (QM) is founded on quantum uncertainty or indeterminism as a fundamental nature of reality or an artifact of the measurement problem. Einstein disagreed with this view stating that "God does not play dice with the universe" pointing to the incompleteness of quantum mechanics theory. Common human experience does not support the intuitions of quantum mechanics. Freeman Dyson, an eminent physicist, expressed this strangeness by saying- "I understand now that there isn't anything to be understood." Even Richard Feynman, known for his mastery of the subject, raised the question: "How does it work? What is the machinery behind the law…We have no ideas about a more basic mechanism from which these results can be deduced." Roger Penrose [7] has made the following remarks regarding the quantum measurement problem-

"What we do not have is a thing which I call OR standing for *Objective Reduction*……It is a missing theory….."I am going to regard the superposition of the one state plus the other as an unstable state – it is a bit like a decaying particle or a uranium nucleus or something like that, where it might decay into one thing or another and there is a certain time-scale associated with that decay. It is a hypothesis that it is unstable, but this instability is to be an implication of the physics we do not understand…..The thing is that, in the superposed state, you have to take into account the gravitational contribution to the energy in the superposition. But you cannot really make local sense of the energy due to (quantum) gravity and so there is a basic uncertainty in the gravitational energy…That is just the sort of thing which one gets with unstable particles."

The relativistic mass-energy behavior can affect not only space-time, but also the fundamental fabric of the universe in terms of non-locality and action at a distance. This paper investigates the inner workings of quantum mechanics via developing and integrating a new Relativistic Wave-Particle (RWP) model of an unstable particle (spontaneous mass-energy conversion) as an extension to the existing de Broglie model, depicting the physics of the relativistic mass-energy effects and wave dynamics governing the quantum behavior. The RWP model provides mathematical formulations of the natural limits of quantum behavior and transition boundary between classic and quantum behavior including the effects of gravity at quantum scales. The model also provides a physical understanding and resolution of the well-known and as yet unresolved paradoxes related to the measurement problem or the observer (role of consciousness) paradox leading to the collapse of the wave-function, spooky action-at-a-distance or non-locality, Heisenberg's uncertainty, and parallel universes. The new physics is then integrated into a Relativistic Universe Expansion model that is vindicated by recent observations of the universe resolving paradoxes of current physics and cosmological theories such as dark matter/energy, cosmological constant and quantum vacuum energy problems, Hubble Tension, big bang singularity etc.

RELATIVISTIC WAVE-PARTICLE (RWP) MODEL

Bohr's "Copenhagen interpretation" described the wave-particle duality as the basic puzzle of quantum mechanics since both classical and quantum conceptions of reality are required to make predictions of the observed reality. While the particle nature of light was discovered by Max Planck in 1900 and later clarified by Einstein (1905) in explaining the photoelectric effect, French physicist Louis de Broglie, in his doctoral thesis in 1924, discovered that every particle of matter also acts as a wave that guides its motion in space. Under proper conditions of size and motion of the particle and geometry of interacting bodies (such as slits), a particle will produce an interference or diffraction pattern just like a wave. Louis de Broglie proposed the following relationship between the effective wavelength and momentum of the body:

$$\lambda_{dbr} = \frac{h}{mV} \tag{1}$$

Where λ_{dbr} is de Broglie wavelength, m is the mass and V is the velocity of the body. Louis de Broglie derived the above equation based on classical motion of a fixed mass without any consideration of the relativistic effects. The mass of the body was assumed to remain constant irrespective of the magnitude of its velocity. The need to enhance the existing well-known de Broglie model is realized because it is unable [1 thru 4] to resolve quantum paradoxes such as non-locality, collapse of the wave-function or the measurement problem, Heisenberg's uncertainty, and parallel universes etc.

Using the relativistic models of spontaneous mass-energy conversion described in ref. [5 & 6], a set of relativistic relationships governing the dualistic wave-particle behavior as per the mass-energy equivalence principle can be derived as follows. A quantum particle such as a photon is also described as a quantum wave packet with an energy *e* given by the following equation:

$$e = hf \tag{2}$$

Wherein h is Planck's constant and f is the frequency of oscillation of the wave packet. Now, from Einstein's theory of Special Relativity (SR), a mass m has an equivalent energy given as follows,

$$e = mC^2 \tag{3}$$

Combining the above two equations gives,

$$f = \frac{mC^2}{h} \tag{4}$$

The wavelength λ of the wave packet is related to the velocity V as follows,

$$\lambda = \frac{V}{f} = \frac{hV}{mC^2} \tag{5}$$

As part of the SR theory, Einstein derived the famous law governing conversion of mass to energy: E = m C^2, wherein E and m represent equivalent changes in energy and mass respectively. Unstable particles are known to decay instantly and simultaneously (without any time delay) exist as waves of energy as per well-established wave-particle complementarity.

Spontaneous birth and decay of particles from and into the vacuum of space involves a dynamic spontaneous (acausal) mass-energy creation and dilation process that plays an important role in the evolution dynamics of the universe. In order to represent a kinetic field equation establishing the spontaneous mass-energy transformation, it is hypothesized that the energy released during a spontaneous conversion of mass to energy manifests as relativistic kinetic energy of motion. This hypothesis is tested and vindicated by recent observations of the expanding universe in a follow on paper [5].

Let us now consider a spontaneously decaying mass M_o at rest (V=0) representing a total relativistic energy, $E_0 = M_0 C^2$. The transformation energy, TE, of decaying mass, Δm, can be described according to the specific theory of relativity as follows:

$$TE = \Delta m\, C^2 = (M_0 - m)\, C^2 \qquad (6)$$

This energy is assumed to propel a radial expansion of mass m with a radial velocity V. The momentum is conserved via a spherically symmetric radial expansion of the remaining mass. The relativistic kinetic energy (KE) is given by the special relativity (SR) theory as follows:

$$KE = mC^2\left(\frac{1}{\sqrt{1-(V^2/C^2)}} - 1\right) \qquad (7)$$

In the absence of any gravitational force or energy, equating this kinetic energy to the energy from mass transformation given by eqn. (1), we obtain the following:

$$(M_0 - m)C^2 = mC^2\left(\frac{1}{\sqrt{1-(V^2/C^2)}} - 1\right) \qquad (8)$$

Simplifying the above provides the following equation governing spontaneous decay of mass:

$$m = M_o\sqrt{1-(V/C)^2} \qquad (9)$$

Eqn. (9) contrasts with the SR equation: $m = M_o/\sqrt{1-(V/C)^2}$, wherein m increases infinitely as V approaches C during an externally implied force to accelerate a non-decaying mass or particle such as in a particle accelerator. Please note that eqn. (9) makes the total mass energy (M_0C^2) invariant in all frames of references irrespective of their velocity V.
Also note that SR predicts similar relationships for space and time dilation as follows:

$$s = S_o\sqrt{1-(V/C)^2} \qquad (9a)$$
$$t = t_o\sqrt{1-(V/C)^2} \qquad (9b)$$

Substituting eqn. (9) into equations (4) and (5), we obtain the following **Relativistic Wave Particle (RWP)** model expressions for the frequency f_{RWP} and wavelength λ_{RWP} for an unstable particle's spontaneous mass-energy conversion during the wave-particle behavior,

$$f_{RWP} = \frac{M_o C^2\sqrt{1-(V/C)^2}}{h} \qquad (10)$$

$$\lambda_{RWP} = \frac{hV}{M_o C^2\sqrt{1-(V/C)^2}} \qquad (11)$$

COMPARISON BETWEEN DE BROGLIE AND RELATIVISTIC WAVE-PARTICLE (RWP) MODELS

Equation (1) gives the de Broglie wavelength for a rest mass M_0 as follows:

$$\lambda_{dbr} = \frac{h}{M_0 V} \tag{12}$$

Using this, de Broglie frequency can be calculated as follows,

$$f_{dbr} = \frac{V}{\lambda_{dbr}} = \frac{M_0 V^2}{h} \tag{13}$$

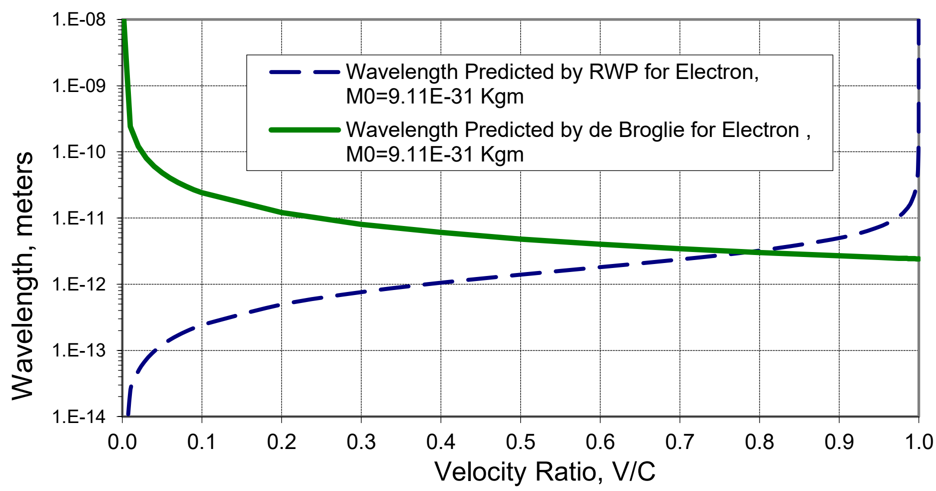
Dividing equations (10) and (11) by equations (13) and (12) respectively, we obtain:

$$\frac{f_{RWP}}{f_{dbr}} = \frac{\sqrt{1-(V/C)^2}}{(V/C)^2} \tag{14}$$

$$\frac{\lambda_{RWP}}{\lambda_{dbr}} = \frac{(V/C)^2}{\sqrt{1-(V/C)^2}} \tag{15}$$

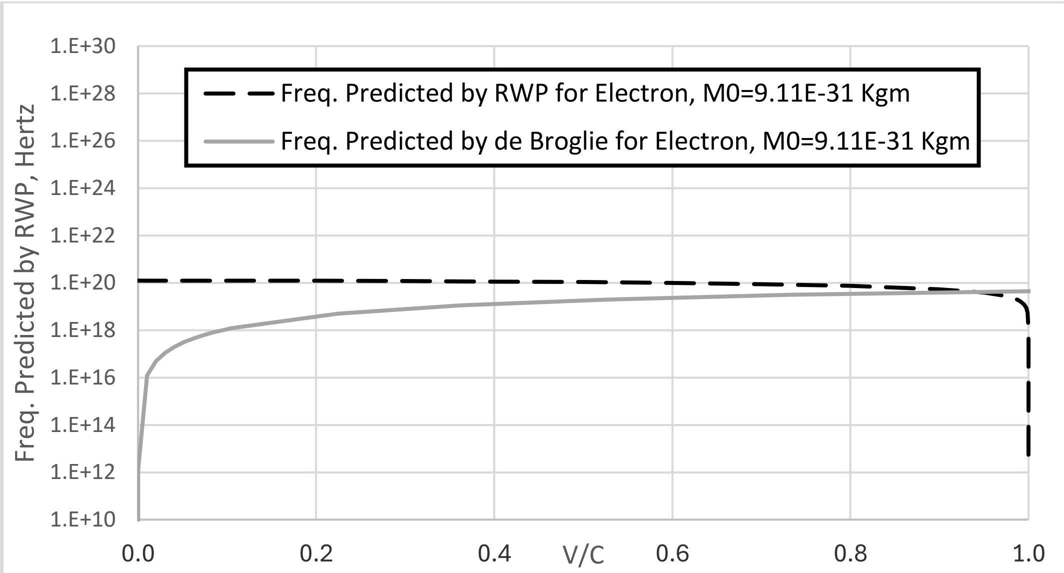
Figure 1 shows wavelengths of an electron mass ($9.1\text{x}10^{-31}$ kg) calculated by RWP equation (11) and de Broglie equation (12) as a function of velocity ratio V/C. At V=0, the wavelength calculated by de Broglie model is infinite, while RWP calculated wavelength is 0. As V increases to equal C, the de Broglie wavelength decreases to reach a minimum value of 2.42 x 10^{-12} meters while the RWP wavelength increases indefinitely because of a total mass dilation. Close agreement is seen between the wavelengths predicted by two models around V/C of 0.8. Figure 2 shows frequencies of an electron mass ($9.1\text{x}10^{-31}$ kg) calculated by RWP equation (10) and de Broglie equation (13) as a function of velocity ratio V/C. At V=0, the frequency calculated by de Broglie model is zero, while RWP calculated frequency equals 10^{20} hertz. As V increases to equal C, the de Broglie frequency increases to reach a maximum of 10^{20} hertz, while the RWP calculated frequency decreases to zero because of a total mass dilation. Again, close agreement is seen between the frequencies predicted by two models around V/C of 0.8.

Figure 1: Comparison of wavelengths predicted by RWP and de Broglie models for an electron.



It should be noted that at small velocities (V~0), de Broglie model predicts very large wavelength even for a large mass, which is counter to the physical experience since large classical objects moving at zero or very slow speeds do not act or appear as a wave or quantum objects. Hence, de Broglie model does not represent physical reality at low values of V. This discrepancy is understandable since this model was originally intended for quantum particles of small masses moving at large velocities close to C. At V=0.8C the predictions of de Broglie model and RWP are fairly close as shown in Figures 1 and 2.

Figure 2: Comparison of frequencies predicted by RWP and de Broglie models for an electron.



RWP MODEL PREDICTS PHYSICAL LIMITS OF QUANTUM VS. CLASSICAL BEHAVIOR

A quantum particle is an elusive entity that can appear from or disappear into nothingness or vacuum, and exhibits unexplained behavior that follows weird rules involving strange properties. The quantum behavior or properties are so far different from those of the real-life objects that there appears to exist separate worlds or universes for the ordinary real-life objects versus the quantum objects. There still exists a big gap in the fundamental understanding of the duality of wave and particle behaviors. Roger Penrose [7] states- "… I believe that the normal view of physicists is that, if we really understood quantum physics properly, we could deduce classical physics from it. …... In practice, one does not do that – one uses *either* the classical level *or* the quantum level."

In the previous section, the wave-particle behavior was mathematically described ignoring gravitational effects. In the following, we will derive mathematical expressions of the physical limits that govern transition between quantum and classical behavior including gravity. Equation (16) below representing a relativistic model of a self-decaying mass can be obtained by adding the gravitational energy term to eqn. (8) describing conservation of relativistic mass-energy, kinetic energy and gravitational energy,

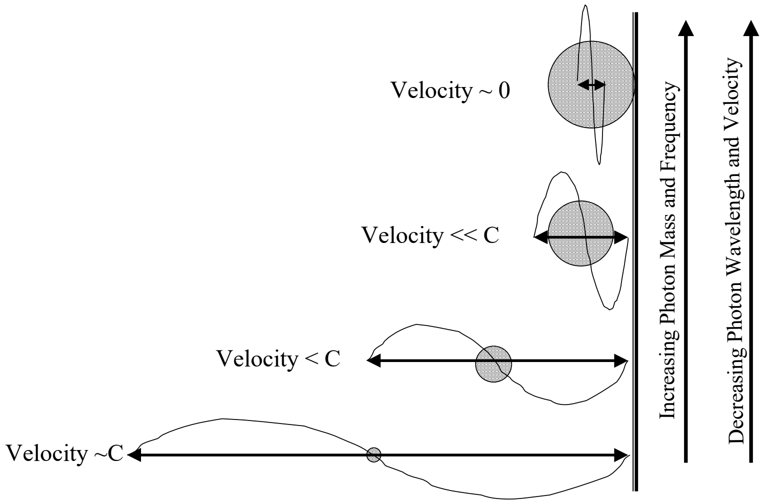
$$(M_0 - m)C^2 = mC^2\left\{\frac{1}{\sqrt{1-(V/C)^2}} - 1\right\} + \frac{Gm^2}{R} \qquad (16)$$

Equation (16) above represents the Relativistic Universe Expansion Model (RUE) depicting the explicit physical/mathematical description of the Cosmological Constant and vindicated by the observed universe expansion as described in references [1, 3, & 5]. The fundamental characteristic of quantum behavior is the wave-particle complementarity, which allows a quantum entity to act as a wave or particle depending upon its environment. When a particle travels uninhibited in free space, it generally acts or exists as a wave, and when it is intercepted via a measuring device or an obstruction it appears to act as a particle. Such spontaneity of converting from a particle (mass) to wave (energy) is built into the observed wave-particle behavior in a variety of experiments involving quantum particles such as electrons, atoms or molecules. From equation (16) above, it is evident that the spontaneous mass to energy conversion, represented by equation (9), exhibiting the wave-particle behavior can occur when the gravitational energy is much smaller compared to the kinetic energy amplifying the kinetic or wave aspect rather than inertial (mass) or particle aspect:

$$\frac{Gm^2}{R} \leq mC^2\left\{\frac{1}{\sqrt{1-(V/C)^2}} - 1\right\} \qquad (17)$$

Further, it is hypothesized that quantum entity acts as classical when its wavelength is larger than its classical material size or diameter. Figure 3 provides a physical picture of a quantum particle behavior as a spontaneously self-decaying mass travelling as an uninterrupted wave in empty space at V close to C. When a measuring device interrupts the free motion decreasing its velocity V, the wavelength decreases progressively until it decreases to match the boundary condition velocity V~0 of the measuring device. During this process, when the wavelength decreases to less than the size (diameter) of the particle, the quantum nature collapses to the classical pass behavior leading to the collapse of the wave function or the objective reduction.

Figure 3: Wave-particle behavior of a quantum particle before during a measurement process.



Hence, radius R in equation (17) can be approximated by half of the wavelength given by equation (11),

$$R = \frac{\lambda_{sdm}}{2} = \frac{hV}{2\, MoC^2\sqrt{1-(\frac{V}{C})^2}} \qquad (18)$$

Substituting equations (9) and (18) into equation (17) and simplifying leads to the following:

$$M_{oq} \leq \left(\sqrt{\frac{hC}{G}}\right)\left[\sqrt{\frac{V\left(1-\sqrt{1-(V/C)^2}\right)}{2C(1-(V/C)^2)^{3/2}}}\right] \qquad (19)$$

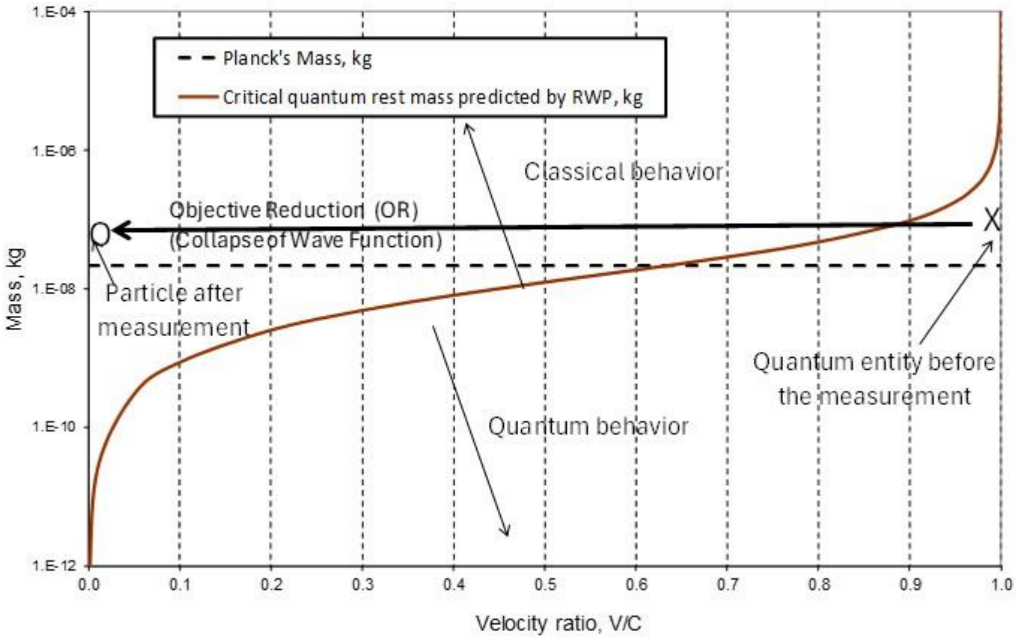
Wherein, M_{oq} represents the maximum or limiting rest mass that exhibits the wave-particle duality or quantum behavior for a given V/C. Masses greater M_{oq} would be expected to behave as classical rather than quantum due to significant gravitational effects opposing spontaneous mass-energy conversion.

Figure 4a shows the critical quantum rest mass predicted by RWP equation (19) describing the limits governing the quantum versus classical behavior. For velocities close to V/C = 0.6, the predicted critical or maximum quantum rest mass is of the order of Planck's mass, $2.1767\text{x}10^{-8}$ kilograms. For very small velocities, the critical rest mass decreases and for higher velocities close to the speed of light C, it increases by several orders of magnitude. Hence, at small velocities the quantum behavior is experienced only by very light particles and at higher velocities even a lot heavier mass can exhibit quantum properties or wave particle duality. Such behavior is not predicted by de Broglie model lacking the relativistic physics of spontaneous mass-energy conversion exhibited during the wave-particle behavior. Figure 4b shows the limits of classical versus quantum behavior for four different particles – Planck's mass, electron, neutrino, and God particle as described later, eqn. (21). Please note that masses greater than roughly Planck's mass mostly behave as classical over the range 0<V<<C as observed in everyday life. Also, even the well-known small mass quantum particles could behave as classical at very small velocities, V<<<C.

RWP RESOLVES THE OBJECTIVE REDUCTION (OR) - QUANTUM MEASUREMENT PROBLEM (COLLAPSE OF WAVE FUNCTION)

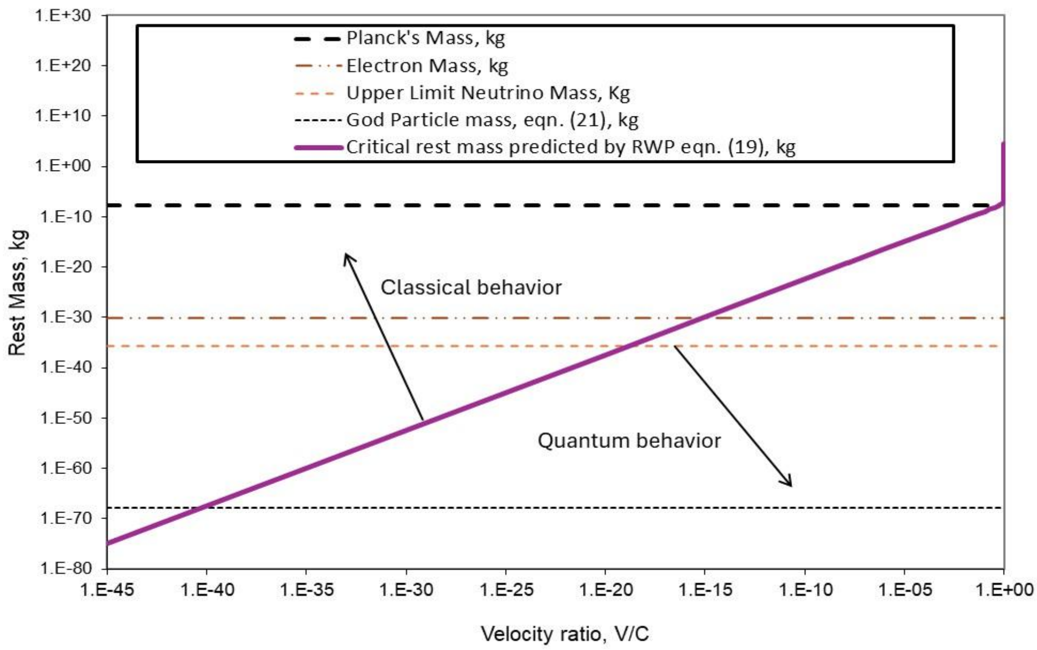
The **OR problem** is also known as the **Quantum Measurement Problem or Observer's Paradox (Collapse of the Wave Function)**. At the quantum level, the state of a system is described by a complex-number weighted superposition of all possible alternatives. The time-evolution of the quantum state or the SchrÖdinger evolution is obtained by the linear superposition of all possible states. Each of the individual states are assumed to evolve independently but are superposed together with complex number weightings that are invariant in time. This linearity is built into the widely accepted formulation of quantum mechanics in SchrÖdinger's wave equation, which represents a deterministic and quantitative description of quantum reality. However, as Roger Penrose [7] points out, the rules change when a measuring device or observer looks into the quantum reality and in the process converts it into a classical reality. This process of conversion from quantum to classical reality is defined as the *Collapse of the Wave Function* or *Reduction of the State Vector.* An example of this is the observation of an electron wave as a dot when it hits the screen. Following this process, the two alternatives are no longer superposed linearly. Instead, the squares of the weighting complex numbers become the ratio of the probabilities of the two alternatives. The reality that was fully deterministic before the collapse, all of a sudden becomes non-deterministic or probabilistic after the collapse of the wave function caused by the process of measurement or observation by a conscious observer. This paradox or mystery of quantum mechanics theory is also known as the *Measurement Problem*.

Figure 4a: Critical quantum rest mass and Objective Reduction (Collapse of Wave Function) of quantum to classical behavior predicted by RWP.



The mathematical formulations of RWP account for the missing physics identified by Roger Penrose [7], namely the effects of gravity on the stability and spontaneous decay of unstable particles, in explaining the physical basis behind the quantum measurement problem. First of all, RWP equation (16), (17), and (19) describe the limits of classical versus quantum behavior of particles accounting for the contribution of the gravitational energy as suggested by Roger Penrose [7] eliminating the uncertainty caused by the so-called quantum gravity absent from existing quantum mechanics theories. Secondly, equation (9) properly treats the energy conservation involving spontaneous decay of a mass. In addition to the gravitational potential energy, the kinetic energy and the mass energy are properly accounted for in RWP. This provides for a proper superposition of the mass/energy movement or conversion between various space/time states that a particle can experience before, during or following a measurement is made. In summary, RWP model integrates the missing physics in formulating and resolving the mysterious collapse of the wave function or Objective Reduction (OR) paradox of the quantum mechanics.

Figure 4b: Objective Reduction (Collapse of Wave Function) of quantum to classical behavior predicted by RWP for Quantum Particles.



Measurement Induced Objective Reduction or Collapse of the Wave Function

Figure 4a shows a schematic of the physical process that happens during measurement of a quantum event and how a quantum wave changes to a particle for the *Objective Reduction* to occur. Let us assume that there exists a quantum entity moving at close to the speed of light in free space as depicted by the right tail end of the arrow in Figure 4a. When this quantum entity existing dominantly as a wave in the free space, as depicted by eqns. (10) and (11), is interrupted by a classical measuring device or obstruction, its velocity changes or could practically drop to zero (V/C ~ 0), as depicted by the left end of the arrow in Figure 4a. As is evident, the process of measurement or any obstruction/barrier causes a sudden change in the dynamic quantum state leading to a *collapse* of the quantum wave (wave function) into the region of non-quantum or classical behavior. The Objective Reduction occurs because of this sudden decrease in the quantum wave velocity leading to the collapse of the wave-function. RWP thus explains the physical process involved in the *Objective Reduction* or *Collapse of the Wave Function* that occurs during the *Measurement problem* in quantum mechanics.

RWP Resolves *SchrÖdinger's Cat* paradox

Another famous example of the quantum measurement problem is the so-called *SchrÖdinger's Cat* paradox in which a cat can exist in a state of being both dead and alive at the same time. A cat, which is a classical object, is never seen to exist in such a quantum state in real life experience. RWP model resolves this apparent paradox as follows. While Schrodinger's cat may be interpreted as paradoxical macroscopic superposition of compound states of two separate subsystems – a live and a dead cat, RWP describes it as a non-local superposition of correlated states of the subsystems via eqn. (9), wherein an undecayed mass state is correlated with "live cat" and a decayed state is correlated with a dead cat. These two end states are correlated by the physics represented by eqn. (9) that prohibit the two states appearing as simultaneous realities. Thus, the eqn. (9) physics allows the various states to be nonlocally coherent, which is central to the process of the Objective Reduction or the nonlocal collapse of wave functions.

Framework For Observer's Consciousness Induced Objective Reduction or Collapse of the Wave Function

Eqn. (16) and (18) describe all possible correlated states of a given mass M_0 in terms of relativistic parameters of mass m and V/C (denoting kinetic energy) including the effects of gravity. Since the human mind is an intermediary between the observations (recoded by the brain) and conscious experiences of the physical world, it is imperative to understand the physical basis of the mind for a complete understanding of the role of consciousness during and observation process. The well-known physicist Freeman Dyson during an interview with meaningoflife.tv alluded to the evidence of three levels of mind - the human mind, the mind residing at the micro level the atomic subatomic level, and then at the very macro levels the mind of the universe. The manifestations of the way the subatomic or quantum world acts lead one to think that mind is a reasonable way to describe what's going on. Dyson states - "Well simply that it (quantum particle) seems to make choices…. the fact is that you have an atom of uranium; it sits there on the table and then tomorrow it's gone…….. So the atom seems to have a freedom to choose, that's something, which characterizes quantum processes that they seem to just occur spontaneously. We call that spontaneous decay. So it is spontaneous; that to my mind implies that the thing makes a choice. ……So that this freedom that the individual atom has to have…. seems to be an indication of some rudimentary form of mind." This freedom of choice allows the particle to have any value of V between 0 (no decay) and C (full decay). Hence, V represents **V**olition (limited free will), while **C** represents Choice (free will) to be free from bondage of space, time, or inertia (mass) since all these dilate to zero in state V=C. V/C thus represents a relative degree or fractional level of free will or consciousness [8].

While the particle has Volition or sort of free will to choose a state V, the human mind consisting of thoughts and experiences of the observations represented by brain waves/particles also follow the same physics that allows a conscious observer to choose a state of Volition V or free will. As suggested above by Freeman Dyson, the two most fundamental aspects of the spontaneous decay of atoms are the spontaneity or the free will without any external causation and the decaying process wherein the fixed stationary mass transforms into the radiative kinetic energy in the form of alpha particles moving close to the speed of light. Thoughts in a contemplative or meditative human mind can be compared to the quantum particles that can decay at the free will of the person. This provides a common basis for the human mind and the micro-mind suggested by Dyson. The brain waves measured via EEG during various mental activities point to the wave-particle nature of the human brain/mind processes following eqns. (16) thru (19).

During the measurement induced collapse of the wave function, a non-sentient measuring device (V/C ~ 0) is involved that truncates most quantum states (V/C > > 0) from the observational field of the device leaving access to only limited probabilistic classical states (V/C ~ 0). Now, let's consider an absolute sentient or conscious observer with V=C (V/C =1) representing an observer moving at the speed of light (a fully enlightened observer) looking at the states of M_0. As per eqn. (19) or Figure 4a, such an observer would experience NO collapse and perceive the total reality of all states as they exist naturally or uninterrupted wavefunctions. However, an observer who chooses to be in a state V/C < 1, would experience collapses according to eqn. (19) or Figure 4a. V/C thus represents the level or degree of consciousness of the observer.

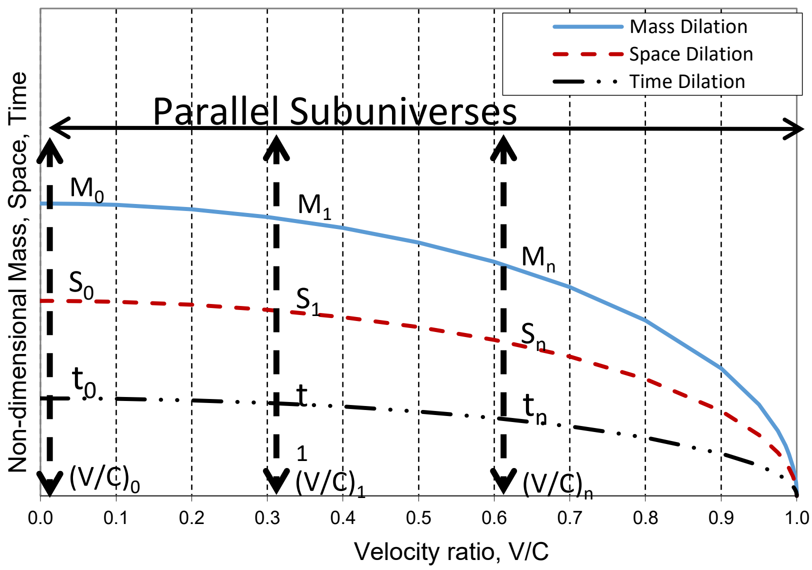
In conclusion, a collapse could occur either via an inanimate measuring device (V/C ~ 0) or a sentient observer in a state V/C < 1. Further, the collapsing process truncates part of the reality, only an enlightened observer (V/C = 1) could witness the whole (all inclusive) of un-collapsed reality as is in a fully dilated mass, space, time state. Whatever is measurable via classical measuring devices is collapsed reality, the un-collapsed reality (V/C=1) is immeasurable as it exists in eternal zero-point state of fully dilated mass, space, and time.

RWP Explains Theory of Parallel Universes

The theory of parallel universes (or many worlds) has been advanced by its proponents to explain the mysterious collapse of the wave function consisting of infinite number of states to one classical solution experienced by the observer. Each of the infinite number of universes corresponds to a probable classical outcome that can occur when an observer looks at the quantum system. The parallel universes coexist but are not quite parallel in the strict sense, since they are considered to communicate with each other at the quantum level supposedly through a common space and time. An observer cannot experience them all and can detect them only indirectly via their impact on the observed or collapsed events in space-time.

The proponents argue that the theory of parallel universes is by far the simplest explanation of the observed quantum experiments since it involves the fewest additional assumptions. When an observation is made, it is presumed that the whole ensemble of parallel universes partitions in two groups with different outcomes. The observer happens to experience only one of the outcomes in his own universe. The other dilemma solved by this theory is the so-called observer paradox in quantum cosmology. In a classical quantum observation, the observer is outside the quantum system and looking at it causing the collapse of the wave function. However, when the observer is within or part of the quantum system itself, such as in the case of observations of the universe by an observer within it, the standard interpretation of the quantum theory fails. Hence, the quantum cosmological observations cannot be explained by the standard interpretation of quantum theory. The theory of parallel universes eliminates this dilemma. A third point forwarded as an advantage of this theory is that it does not require the strict definition as to who the observer is. The definition of an observer relative to the quantum system is an open question in the standard interpretation, and probably involves a definition of the consciousness, which is not an easy problem to resolve. The theory of parallel universes eliminates the observer and mind from interpretation of the observed reality. However, the key weakness of the theory is that it cannot be tested and involves many open questions regarding the properties and nature of mass-energy-space-time interactions among many universes.

Figure 5: Depiction of RWP sub-universes or many worlds within a single universe model.



RWP model provides a physical understanding of the many possible outcomes signifying parallel worlds or sub-universes within the umbrella of a single whole universe, of an observation in terms of qualitative degree/level (V/C) of consciousness of the observer. According to RWP, the mass-energy-space-time state of a system is directly dependent upon the relative velocity ratio (V/C) between the observer and the observed. Figure 5 shows RWP predicted mass-space-time states as a function of the velocity of the observer as well as the progressions of manifold outcomes of the parallel sub-universes or many worlds. At low velocities, the mass-space-time (M_0, S_0, *and* t_0) act as fixed or classical as assumed in the Newtonian mechanics. However, different events and outcomes (M_n, S_n, *and* t_n) can exist as per eqns. (9, 9a, & 9b) for different observers moving at different speeds $(V/C)_n$. For a given rest mass M_0, the total energy remains invariant or constant equal to M_0C^2 maintaining coherence between all states at various V/C values. However, at large velocities when V approaches C, the mass-space-time dilate to zero and hence the outcomes or events/phenomenon observed by different observers experience quantum entanglement becoming completely coherent with each other in a Zero Point State. In summary, RWP provides a qualitative physical understanding of the theory of parallel sub-universes within a unified single universe correlated via different relativistic mass-space-time states of different observers' frames of references moving at various speeds.

RWP Contrasts with Roger Penrose's Objective Collapse Theory

Penrose's objective collapse theory presumes that a wave function collapse occurs as a physical process, with observers or measuring devices not having any special role. The hypothesis is that the wave function cannot be sustained in superposition beyond a certain energy difference between the quantum states approximately equal to a Planck mass, which he calls the "'one-graviton' level"[16]. This energy difference causes the wave function to collapse to a single state, with a probability based on its amplitude in the original wave function, as per standard quantum mechanics procedure. Penrose's "'one-graviton' level" criterion forms the basis of his prediction, providing an objective criterion for wave function collapse [16].

Penrose points out that particles, atoms and electrons, warp space-time due to gravitational effects as modelled in GR. An entangled particle in two locations at the same time, should yield two superposed gravitational fields, which according to Penrose's theory, takes energy to sustain. The higher the energy required to sustain a system, the less stable it is. Over time, an unstable system tends to settle back to its simplest (collapsed), lowest-energy state: in this case, one object in one location producing one gravitational field [17].

While the RWP predicted collapse could be either measurement induced or observer's consciousness interpreted/perceived, Penrose collapse happens due to instability caused by lack of energy required to sustain the superposed state's two gravitational fields. RWP depicts a continuous smooth transition boundary, shown in Fig. 4b, between the classical and quantum states of a single particle based on relative magnitudes of gravitational (Newtonian) and kinetic energy (antigravity or Cosmological Constant [5]), while Penrose theory addresses sudden collapse due to instability of entangled states of two gravitational fields.

Nonlocality or entangled state of a single photon has been observed when a photon impinges on a balanced beamsplitter [18].

TESTABLE PREDICTIONS OF RUE/RWP AND EXPERIMENTAL VALIDATION

While it is extremely difficult to make direct experimental measurements of parameter V/C and wavefunctions since classical measurement devices interfere and alter the measured quantum event, RUE and RWP predictions are testable and validated against several scientific observations as described below.

SR theory provides a direct relationship between V/C and redshift Z as described below,

$$z = \sqrt{\frac{1+(V/C)}{1-(V/C)}} - 1$$

Cosmic observations of the universe expansion and mass evolution are often made using the measured redshifts of stars and galaxies. These observations do not disturb the cosmic phenomena and hence provide a reliable and useful data to validate RUE/RWP predictions on cosmic scale. Reference [5] provides a detailed description of successful experimental validations of RUE/RWP against various cosmic observations including Hubble, Supernova, and mature galaxies in the early (far-field) universe that are not predicted by the Standard Model – Lamda Cold Dark Matter (^CDM). One key successful RUE/RWP validation entails accurate prediction of Hubble and Supernova expansion observations **resolving the well-known Cosmological Constant problem** wherein the vacuum energy density predicted by Quantum Field Theory (QFT) is up to 120 orders of magnitude higher than observed expansion rate (known as the worst ever prediction of science). This is also known as the **Dark Energy problem** within ^CDM formulations that constitutes about 70% of the universe contents. The second significant prediction of the RUE is its predicted **presence of mature galaxies in the early far-field universe** that point to some fundamental missing physics from the current Standard ^CDM model. Thirdly, RUE **resolves the Hubble Tension problem** afflicting ^CDM via providing the new physics of the cosmological constant that depicts a relativistic nonlinear rather than linear Hubble expansion denoted by V=HR, (H=Hubble parameter). The success of the RUE/RWP is further solidified via resolution of other current known paradoxes [5] **eliminating the need for inflation, run away space expansion propelled by unknown dark energy, black hole singularity, repulsive gravity (an oxymoron), cosmic horizon problem, and violation of the fundamental mass-energy conservation laws of the universe** etc. Many of these paradoxes are shown to be artifacts of foundational issues within ^CDM formulations.

RWP RESOLVES OTHER KEY FOUNDATIONAL QUANTUM PARADOXES

RWP model also resolves some other well-known and yet unresolved paradoxes related to quantum entanglement or non-locality and whether Heisenberg's uncertainty is a fundamental reality of the universe as described below.

RWP Solution to Quantum Entanglement or Action-at-a-distance or Non-locality

Another famous mystery of quantum mechanics is the *Action-at-a-distance* or *non-locality* caused by *Quantum Entanglement*. Einstein and his colleagues, Podolsky and Rosen, first highlighted the physical problem involved in this paradox. Subsequent experiments performed by Alan Aspect [9] and Anton Zeilinger at the Vienna Centre for Quantum Science and

Technology [10] have confirmed the correctness of the predictions of quantum mechanics. In Aspect's experiments photon pairs are emitted at a source in an entangled state and travel in two different directions to two detectors located at about 12 meters apart from each other. The decision to measure the direction of polarization of the two separated photons was made after the photons were in full flight from the source to the detectors. The results of the measurements showed that the two photons do not behave as two separate and independent classical objects. Instead, the observed states of the two photons were observed to be in the entangled state that matched the predicted joint probabilities of quantum mechanics. Similar experiments [11] have been performed to verify action-at-a-distance or non-locality over distances of several hundred kilometers. Quantum entanglement of macroscopic mechanical systems was observed [14] with high degree of correlation that they no longer be described separately indicating that quantum mechanics presumably applies to objects of larger sizes. Entanglement at high energy scales in top-antitop quark events produced at Large Hadron Collider [15] with the ATLAS experiment. Highlighting this unexplained mystery, Roger Penrose [7] states- "…They are entangled in such a way that there is no way of using that entanglement to send a signal from A to B – this is very important for the consistency of quantum theory with relativity." However, the information contained within the entangled particles is available at both locations simultaneously.

The mystery of the *Action-at-a-distance* or *Non-locality* is explained by RWP eqn. (11) based on spontaneous mass-energy conversion that can induce a very large wavelength as the mass decays to small values at velocities close to C as shown in Figure 1. The spatial extent of the wavelength determines the distance over which the entanglement or non-locality of a particle is expected to occur. The correlation or coherence over this spatial extent is instantaneous and not subject to the locality caused by the finite speed of light, which limits the speed of travel of a signal. RWP eliminates the shortcomings of the De Broglie equation that fails to predict large wavelengths at V~C and ensuing non-locality. Wavelengths of a quantum particle with a rest mass of M_0, can be calculated using equation (11). Since the wavelength is inversely proportional to the rest mass, the wavelength for the lighter rest mass is proportionally longer than the heavier one.

Please note that nonlocality of a particle predicted by RWP is limited over its wavelength only and not over the entire universe. In order to demonstrate the non-locality of a very light mass particle due to its dramatically large wavelength, we will calculate the ratio of the wavelength of a self-decaying mass given by equation (11) to the radius (R) or size of the universe predicted by Hubble Model (V=HR), equation (20) below:

$$\lambda_{sdm} = \frac{hV}{M_o C^2 \sqrt{1-(V/C)^2}} \qquad (17)$$

$$V=HR, \text{ or } R=V/H \qquad (18)$$

Wherein, H is the Hubble Constant. Combining the above two equations and simplifying gives the following,

$$\frac{\lambda_{sdm}}{R} = \frac{hH}{M_o C^2}\left[\frac{1}{\sqrt{\{1-(V/C)^2\}}}\right] \quad (19)$$

The minimum value of the ratio of the wavelength to the radius R is given by the above equation as follows,

$$\frac{\lambda_{sdm}}{R} = \frac{hH}{M_o C^2} \quad (20)$$

Using the above equation, we can now calculate the maximum value of the rest mass of a particle, defined here as the God-particle, for which the wavelength is equal to the size or radius of the universe as follows,

$$M_o = \frac{hH}{C^2} \quad (21)$$

For a Hubble Constant of 2.27×10^{-18} sec.$^{-1}$, the rest mass of a God-particle is calculated to be 1.66×10^{-68} kilograms. As is apparent from equation (19), the ratio of wavelength to Hubble radius for an electron (mass equal to 9.11×10^{-31} kilograms) is several orders of magnitude (10^{-38}) smaller than the ratio of 1 for the God-particle. The God-particle has 100% probability to be at all points in the universe, satisfying an ideal non-locality, as compared to an electron, which will be located or confined to a much smaller region of its wavelength. Hence, God-particle will appear to be in perfect coherence and entanglement all over the universe because of its wavelength encompassing the entire universe. In summary, RWP provides a mathematical and physical understanding of the observed Quantum Entanglement and Action-at-a-distance or non-locality.

RWP Explains Heisenberg's Uncertainty Not a Fundamental Universal Reality

The Heisenberg Uncertainty principle describes an inherent and irreducible uncertainty in prescribing both the position (Δx) and momentum (Δ mV) of quantum particles. Such uncertainty is related to the observed dual behavior of photons and other small particles such as electron, proton etc. in the microscopic world that act both as particles as well as waves. This uncertainty is often presumed to occur due to the direct and unavoidable impact of the measuring device or process on the motion or spatial location of the measured entity itself. In classical physics and Quantum Mechanics, mass, space and time are fixed (Newtonian frame of reference) and independent entities, which are used to define velocity and momentum of the particle. Detailed calculations by Heisenberg determined the following mathematical form of his uncertainty principle,

$$(\Delta x)\{\Delta(mV)\} \geq \frac{h}{2\pi} \quad (22)$$

Since the Planck's constant, h, is very small, the uncertainties at macroscopic level or for scales of everyday large objects are negligible. However, at microscopic level wherein we deal with small particles such as electrons, protons and atoms, the uncertainty becomes significant. For particles with higher speeds approaching the speed of light, such as electrons and photons, the relativistic effects become significant, and the assumption of fixed space and time does not hold. Heisenberg's principle, known as the fundamental basis for probabilistic formulation and calculation of Quantum mechanical behavior, does not specify as to how does the uncertainty get impacted by these relativistic effects.

In the following, we will use RWP model to reevaluate the Heisenberg's principle and calculate physical parameters and conditions under which the principle may hold and vice versa. The wavelength of a particle, λ_{sdm} , describes the region in space over which the particle resides, hence it represents the spatial uncertainty in the position of the particle.

$$\Delta x \approx \lambda_{sdm} \qquad (23)$$

Using equation (9), the uncertainty in momentum mV can be calculated as follows,

$$\Delta(mV) = M_o\left(\frac{1-2\left(\frac{V}{C}\right)^2}{\sqrt{1-\left(\frac{V}{C}\right)^2}}\right)(\Delta V) \qquad (24)$$

Substituting equations (23) and (24) into (22) and simplifying, the following is obtained,

$$(\Delta x)\{\Delta(mV)\} \geq \frac{h}{2\pi}\left[2\pi\left(\frac{V}{C}\right)\left\{1-\frac{\left(\frac{V}{C}\right)^2}{1-\left(\frac{V}{C}\right)^2}\right\}\Delta\left(\frac{V}{C}\right)\right] \qquad (25)$$

Let us define a Heisenberg's Uncertainty Factor (HUF) as follows:

$$HUF_{sdm} = \left[2\pi\left(\frac{V}{C}\right)\left\{1-\frac{\left(\frac{V}{C}\right)^2}{1-\left(\frac{V}{C}\right)^2}\right\}\Delta\left(\frac{V}{C}\right)\right] \qquad (26)$$

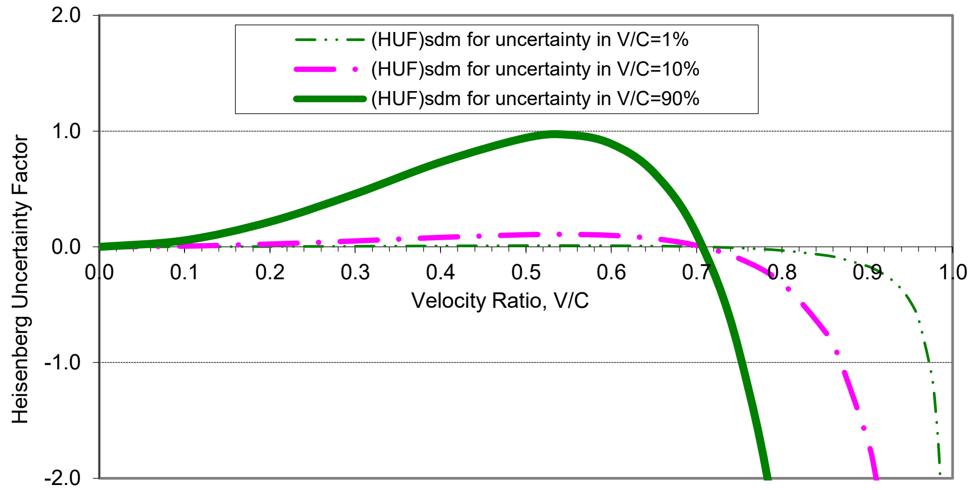
Substituting the above into eqn. (25) gives the following:

$$(\Delta x)\{\Delta(mV)\} \geq \frac{h}{2\pi}(HUF_{sdm}) \qquad (27)$$

Comparing the above against the Heisenberg's principle, equation (22), the principle is satisfied when $|HUF| \geq 1$ and violated when $|HUF| < 1$. It is apparent from equation (26) that HUF depends directly upon the value of velocity V and its uncertainty ΔV. **If the uncertainty ΔV is zero, HUF will be zero and hence, the Heisenberg's principle will be violated**. For non-zero ΔV, predicted values of the HUF for a self-decaying mass are shown in Figure 6. It is to be noted that for velocities less than approximately 70% of the speed of light C, the $|HUF|$ is less than 1 and the Heisenberg's principle is violated even for an uncertainty in velocity V being as high as 90%. For smaller uncertainties in V, the principle is satisfied only for much larger velocities. For 1% uncertainty in V, the minimum value of V has to be greater than 95% of the speed of light C for the principle to hold true.

In summary, the RWP model provides the missing physics behind the Heisenberg's Uncertainty principle, its limitations and boundaries within which it holds true. The model accounts for the fundamental missing relativistic physics in the formulation of the Heisenberg's principle and reveals that there is no inherent uncertainty in nature insofar as the true relativistic nature of reality is realized and treated as such. It vindicates Einstein's assertion that "God does not play dice with the universe." One must remain aware of the inherent limitations of the measuring device, the observer, and the process of interpretation or observer consciousness as the root causes of the ensuing uncertainty.

Figure 6: RWP Predicted Heisenberg's Uncertainty Factor for a self-decaying mass.



RWP Explains Quantum Vacuum Catastrophe

The theoretical value of the Zero Point Energy density suggested by Quantum Field Theory (QFT) is about 120 orders of magnitude greater than the observed values of vacuum energy density (Cosmological Constant). This colossal disagreement is described by physicists as "largest discrepancy between theory and experiment in all of science" [12] and "probably the worst theoretical prediction in the history of physics" [13]. The energy of the quantum vacuum is not zero because of presumed quantum fluctuations or nonzero wavefunction. This deficiency is also known as the Cosmological Constant problem. RWP predicted vacuum energy density is very small at large velocities, V ~ C due to its predicted infinite wavelength and zero frequency. Further, the Cosmological Constant Problem is resolved via Relativistic Universe Expansion Model (RUE) depicting the explicit physical/mathematical physics description of the Cosmological Constant and vindicated by the observed universe expansion as described in references [1, 3, & 5].

RWP Describes Non-local Hidden Variables Explaining Inner Workings of Quantum Mechanics

Although Einstein had a strong role in the early development of quantum mechanics, he believed that it was incomplete and there must be a deeper deterministic physics that could describe its inner workings underneath its statistical or probabilistic predictions. He argued that quantum mechanics was incomplete and that there must be "Hidden Variables" – or missing deterministic physics needed to complete the narrative of probabilistic quantum reality. RWP formulations described in this paper vindicate Einstein's view and provide the mathematical and physical descriptions of the Hidden Variables, derived using SR theory, demystifying the "Spooky Action at a Distance" or non-locality. RWP also vindicates his view that Heisenberg's Uncertainty Principle can be violated, and uncertainty is not a fundamental reality. Bell's theorem has largely disproven the Local Hidden Variables theories with experimental tests supporting the idea that quantum reality is inherently non-deterministic and non-local. RWP is consistent with the quantum non-locality based on non-local variables (predicts large or infinite wavelength depicting quantum entanglement) rather than Local Hidden Variables. Hence, RWP does not violate Bell's theorem or quantum non-locality.

Philosophical Implications – Quantum Reality?

RWP model formulations provide seamless transition among a continuum of three categories of realities:

1. Classical Reality at macro level wherein locality prevails with masses having well-defined boundaries in fixed (Newtonian) space-time. Separated observer and the observed.
2. Quantum Reality at micro level wherein finite non-locality prevails with masses having complementary dualistic wave-particle behavior with no well-defined boundaries (probabilistic wavefunctions, fluctuations). The observer impacts the observed quantum event.
3. Zero Point Reality at the most fundamental level wherein mass, space, and time are fully dilated to zero and wavefunction dissolves to zero frequency and infinite wavelength representing One Eternal wholesome state of the universe. One wholesome fully integrated observer-observed state. This contrasts with the Zero Point Field of QFT that is full of particles, quantum fluctuations, and wavefunctions.

One of the key implications of the quantum Measurement Problem is that all physical measurements are destructive (due to the collapse of the wavefunction) and probabilistic limited to only one of the many potential aspects/outcomes of the deterministic reality. Since scientific method mandates measurements as the only vindicative proof of a scientific theory, it creates a dilemma whether quantum measurements represent a holistic convergence to one universal reality or divergence to many different hypothetical multiversal realities? Another key question is whether the Standard Lamda-CDM model predictions of the beginning and evolution/age of the universe have any meaning since many of the parallel universes have their own space-time and evolution/age with no synchronicity among them? Further, whether the quantum reality founded on non-zero fluctuations/wavefunctions and predicted vacuum energy being 120 orders magnitude larger than the observed Cosmological Constant (so called dark energy), represents the absolute fundamental reality - the true zero-point state of fully dilated mass-space-time as witnessed by an enlightened observer ($V/C = 1$) without any collapse? Last but not the least, whether Einstein's assertion of Quantum Mechanics as an incomplete theory is too humble as opposed to Roger Penrose's assertion that Quantum Mechanics is "Wrong"? Should physicists "shut up and calculate" to continue successful utilitarian applications of quantum mechanics or should they "shut up and contemplate" to fix the foundations of theoretical physics to represent the ultimate universal reality to achieve grand unification?

Should physics strive to solve the puzzle of consciousness to inject purpose and meaning into scientific method or continue its current path to maximize its utilitarian/commercial successes?

SUMMARY AND CONCLUSIONS

This paper describes the new relativistic physics of a spontaneously self-decaying or self-forming quantum particle and its spontaneous (no time delay) complementary wave-particle behavior. The new physics is integrated into a physical/mathematical description of the Objective Reduction process including the quantitative effects of gravity and kinetic energy (anti-gravity) that govern the instability of a quantum particle. A Relativistic Wave Particle (RWP) model is developed that extends the de Broglie model to include the new relativistic physics predicting wave-particle behavior over the entire range of existence (V=0 to C). The RWP model predicts the coherence and de-coherence boundary or collapse of the wave function. When gravity effects dominate the antigravity governing the instability of the particle, the quantum state or wave function collapses to classical state of mass or particle and vice versa. In addition, the process of collapse via a measurement device as well as the consciousness of the observer is also explained. RWP model describes the missing physics to explain inner workings of other well-known quantum phenomena related to non-locality and Heisenberg's uncertainty, explaining how uncertainty is not a fundamental universal reality. The new physics is then integrated also into a Relativistic Universe Expansion (RUE) model [1, 5, & 6] that is vindicated by the recent empirical observations of the universe expansion and removes many of the inconsistencies and paradoxes of current mainstream cosmology theories. The RWP and RUE models reveal the <u>non-local</u> hidden variables explaining the inner workings of quantum mechanics predicting non-locality or entanglement without violating the Bell's theorem based on local hidden variables.

RWP model describes the fundamental relativistic mechanism governing the quantum foundations and as to how gravity and measurement interference could affect the wave-particle nature of the observed collapse of the wave function to classic behavior. The limits of quantum versus classical behavior are predicted in terms of the rest mass and velocity of the self-decaying quantum particle. Non-locality observed in quantum phenomena is caused by the space-time dilation and/or the large wavelengths as expansion velocity V approaches to C. There is no inherent uncertainty built into natural phenomena; the observed uncertainty in quantum measurements results from the measurement error caused by the destructive nature of measurement that alters the relativistic mass-space-time of the measured event. The physical reality or state of a rest mass (or even universe) could be described as a set of infinite number of complementary relativistic mass-energy-space-time states as a function of varying velocity (V/C) of the frame of reference or level of consciousness of the observer. There is only one universe entailing multiple complementary or parallel sub-universes or many-worlds representing the infinite number of complementary relativistic mass-space-time states. This eliminates the need for fine tuning (or anthropic principle) for our universe to be unique as per multi-universes theory. RUE/RWP model consolidates and replaces many different interpretations of quantum mechanics into one coherent picture of reality within a holistic relativistic framework and model vindicated by the empirical observations of the universe as described in ref. [5]. A potential framework for an integrated universal model for matter-mind-consciousness is proposed entailing the observer and the observed.

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