The Real/Virtual Exchange of Quantum Particles as a Basis for the Resolution of Wave-Particle Duality and Other Anomalies of the Quantum Phenomena

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A hypothesis based on the exchange and the inter-conversion of the "real" and the equivalent "virtual" particles of the quantum vacuum can resolve the contradiction of wave-particle duality, the "spookiness" and the other conflicting properties of the quantum particles. It can be shown using simple mathematics that the extent of the wave or the particle nature of a quantum particle depends on the rate of this "real/virtual" particle exchange, the velocity and the rest mass of the exchanging "real" particle.

The revolutionary quantum phenomena has posed both ontological and epistemological problems for natural science and philosophy; that remains unresolved even after more than a century of its discovery. The wave-particle duality, the characteristic non-locality, the prevalence of the interplay of chance and necessity among other things distinguish the quantum phenomena, from hitherto anything previous epistemology could even conceive of. The great intuition of Democritus that matter is composed of some elementary particles or atoms more or less holds true and has been vindicated even at the subatomic level; but the contrary nature of matter as a wave at quantum level has also now been well established.

This has given rise to conflicting and mutually exclusive philosophical claims of the objective reality, ranging from positivist and subjective idealism to the realist views of a deterministic, unchanging and a permanent objective reality, to a mechanistic measurement problem as expressed by the Heisenberg's uncertainty principle, But however much wildly differing interpretations of the quantum phenomena are, the rationalist notion of a certain, deterministic and inherently unchanging reality (knowable or not) as the basis of epistemology is widely accepted. At the quantum level this amounts to assuming that the stable quantum particles like protons, electrons, photons, etc., retain their unique and singular identity on a permanent basis; or at least since the creation of the universe, through a Big Bang or otherwise. The only recognized change of the stable and the everlasting fundamental particles is their fusion at the core of the stars to form higher elements.

Albert Einstein, who was a pioneer in the development of the quantum theory, rejected the "spooky" quantum phenomena for its lack of certainty and causality. He (and many others) also opposed the generally accepted but confusing and opportunistic interpretation of the Copenhagen consensus. Einstein tried to avoid the quantum conundrum by adopting a notion of physical reality based on a "continuous field" rather than material particles, particularly in his theory of general relativity (GR). In Einstein's own words, "Since the theory of general relativity (GR) implies the representation of physical reality by a continuous field, the concept of particles and material points cannot play a fundamental part and neither can the concept of motion. The particle can only appear as a limited region in space in which the field strength or energy density is particularly high" [1].

The popularity of "continuous field" based GR have been responsible for the undermining of the original particle based orientation of quantum electrodynamics (QED); as "field" based theories like quantum field theory (QFT) now dominate quantum mechanics and the related domains of cosmology. The fact that the quantum vacuum is seething with ghostly virtual particles that pop in and out of existence has been very well established after the discovery of the Lamb Shift [2], with a precision that is unmatched by any other physical measurements. The Casimir Force is also generally attributed to be due to the presence of virtual particles. These virtual particles can be made real using various well-known techniques [3]. Yet except for being a mere nuisance for creating infinities in the quantum mechanical equations, the virtual particles has so far received little attention from an ontological and epistemological point of view. A new theoretical and experimental re-evaluation of the intuitively derived uncertainty principle of Werner Heisenberg suggest that, the uncertainty does not always come from the disturbing influence of the measurement, but from the more fundamental quantum nature of the particle itself [4]. This points to a possible role of the virtual particles in the uncertainty relation.

All the experimental evidence and technological experience so far, suggest that the virtual particles of the quantum vacuum may play a significant role in determining the attributes of the quantum phenomena, namely the wave-particle duality, its non-locality, its uncertain nature and influence (based on chance and necessity) on the macroscopic biochemical and astrophysical processes etc., than hitherto appreciated.

In opposition to the view of a static objective reality, where the stable and fundamental quantum particles retain their permanent and unique identity; it is assumed in the present hypothesis that the objective reality is dynamic, where there is perpetual exchange of position and identity between the real quantum particles with their respective and reciprocal virtual counterparts; such that no permanent and unique iden-

tity of "real" quantum particles is possible. This exchange is mediated by Heisenberg's uncertainty relation:

$$\Delta E\,\Delta t \geqslant \frac{h}{4\pi}\,,$$

where ΔE is the energy gained by the virtual particle during the time interval Δt, that is equivalent to the mass/energy of the real particle that would exchange with it, and h is the Planck constant. It is clear that the time Δt required for this exchange is extremely small compared to the time of the change in position or the velocity of the real quantum particles that must be within the limit of the velocity of light (c) according to Einstein's theory of special relativity (SR).

If we consider a point source for a "real" quantum particle at the centre of a sphere, then the particle could be any where (during a specific time interval) within this sphere defined by a radius which is proportional to the velocity of the particle. The particle will then have the possibility to exchange position and identity with equivalent virtual particles within this sphere; assuming that the real/virtual exchange does not affect the velocity of the real particle under consideration. This rate (R) of exchange of "virtual" particles par "real" particle par unit time, then will be directly proportional to the volume of the sphere and inversely proportional to ΔE, the energy equivalent of the mass (m) of the real particle that is exchanged with a corresponding virtual particle, according to the following equation:

$$R = \frac{\frac{h}{4\pi}\frac{4}{3}\pi r^3}{\Delta E} = \frac{\frac{h}{3}r^3}{\Delta E} = \frac{\frac{h}{3}kv^3}{mc^2}\,,$$

where h is the Planck constant, r is the radius of the sphere that is proportional to the velocity v of the particle, and k is a proportionality constant. For a particle with the velocity of light (c), the rate is

$$R = \frac{\frac{h}{3}kc}{m}\,.$$

Now, it is obvious from the above equation that for particles with zero rest mass like photons, neutrinos, gravitons etc. the rate of exchange will be infinite, hence the particle or a group of particles will have a wave character spreading in all three dimensions and also can act as long range force carriers.

With massive and stable particles like electrons, positrons, protons, etc., this exchange rate will be finite but much smaller and hence will be restricted around the direction (from the source) of the motion of the particle as a cylindrical or a conical wave front and like an arc in two dimensions; over a tangible distance. The arc-length of the wave packet in two dimensions will depend on the mass and the velocity of the quantum particle. The heavier the mass and slower the velocity, the shorter will be the length of the arc and the wave-packet. The rapid slowing down of the quantum particle along the original direction of its motion is likely to taper down the cylindrical wave-front into a cone shape. More massive and slow moving objects will demonstrate no wave character at all and follow the laws of classical mechanics. It is because a slower velocity will cover less volume of space in specified time and the greater mass will have exorbitant energy requirement for the uncertainty principle and hence lower exchange rate with the potential virtual particles. These aspects of the wave-packet for different quantum particles can possibly be verified with adjustable two slit experiments. This approach to the problem of the propagation of quantum particles very superficially compares with the "Path Integral Formulation" of quantum mechanics by Richard Feynman, where the integration over an infinity of possible trajectories is used to compute a "quantum amplitude" [5].

This real/virtual (and vice versa) exchange of the quantum particles explains their "spookiness", the wave-particle dual character and their non-locality within the limit of the speed of light. Whether all the properties of the quantum particles aside from their charge, such as parity, spin etc. are also conserved or whether their entanglement is affected during these exchanges; needs to be worked out. This hypothesis will be contrary to the generally accepted notions of causality and formal logic, or what G. W. F. Hegel termed as "the view of understanding". But it will be in conformity with the law of "the unity of the opposites" and the other laws of dialectics.

The "view of understanding" abhors contradictions and posits a sharp distinction between the opposites, based on Aristotelian doctrine of "unity, opposition and an excluded middle in between". This view assumes the presence (at least from the time of the creation of the world) of an objective reality that is essentially permanent, certain, unchanging, deterministic and continuous etc. Any change, motion or development in this view can only come from an "impulse" from outside; following the law of cause and effect. There is little wonder that the conflicting and the uncertain nature of the quantum phenomena has given rise to confusion and to mutually exclusive philosophical claims of the objective reality, ranging from the positivist and subjective idealism to the realist views of the "guiding waves" of a continuous and permanent objective reality on the one hand and to a mechanistic and simplistic measurement problem as expressed by the Heisenberg's uncertainty principle, on the other.

An exactly opposite view of the objective reality mainly attributed to the Greek philosopher Heraclitus and later developed by G. W. F. Hegel, Karl Marx and Frederick Engels posits "eternal change due to inner strife" as the permanent feature of the objective reality and the world. Any stability or apparent permanence is only relative and conditional. The world in this view is infinite, eternal and ever changing. This view follows from Hegel's elaboration of dialectics as the "Absolute Identity of identity and non-identity" — "the unity of the opposites" i.e., a simultaneous unity and conflict of the opposites residing together at the very element of a thing or a process in a logical contradiction. Any material existence is a

contradiction of the opposites and must eternally be resolved to a new "becoming" through a dialectical "negation of the negation", in a chain of processes in triads that give rise to the phenomenology of the world. At fundamental quantum level, the objective reality is a contradiction of "being" and "nothing", giving rise to "becoming" or existence. The QED established fact that the quantum vacuum seethes with virtual particles, the notion of an eternal real/virtual exchange and a dynamic equilibrium as the basis of the objective reality is in conformity with a dialectical view of the universe.

From a dialectical point of view, "being" and "nothing" must always exist together in contradiction, as a part of the objective reality of the universe. One cannot supersede or exhaust the other, so there can be no question of a beginning or an end of the universe. For dialectics, there is also no mega-leap (like Big Bang) in nature; precisely because nature is made entirely of infinite leaps of the "negation of the negation", mediated by chance and an iron necessity that is inherent in chance! In addition to real/virtual particle exchange, inter-conversion of real and virtual particles through quantum tunnelling and through yet other still unknown processes is possible. The energetic core of the galaxies are likely to be the favourable sites for the generation of new matter and anti-matter from the virtual particles This author had previously attempted to use these ideas to explain some cosmic phenomena [6], the origin, evolution and the structure of the galaxies [7] and other aspects of modern cosmology [8].

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