

# QUANTUM THEORY

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# **Shall we climb on the shoulders of the giants to extend the *reality* horizon of Physics?**

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**Abstract.** After a very successful flurry of activities for a few decades to maximize the benefits of the formalism of Quantum Mechanics to connect the micro and macro universe, the applied physics community has successfully engineered sustained technological innovations for human social advancements. However, a significant segment of the theoretical physics community put their endeavors essentially in inventing realities that are esthetically pleasing to our human logics (epistemology) rather than staying focused on discovering the actual physical realities in nature driven by cosmic logics (ontology). The purpose of this paper is an attempt to formulate a Reality Epistemology that can leverage our enormous successes in science to re-focus our attention to discovering nature's realities by understanding the physical processes behind all natural interactions that collectively make the cosmic evolution progressing forward. We underscore the deviation from seeking reality to justify the key premise of the paper. We can "see" (measure) the universe only through the "eyes" of the various sensors (detectors). None of these sensors are completely known to us as yet. All sensors also have inherently limited capabilities to respond to input signals and limited capabilities to "report" only a part of all that it experiences. We are thus forced to develop our mathematical theories mixing our human logics and incomplete information and hence they are all provisional and incomplete since they are predicting only correctly measured but limited report by the detector. Thus, we should be careful not to jump into conclusion that we have captured all the necessary cosmic logics behind the interactions involved. We dissect the measurement process in a generic way along with well defined steps to apply Reality Epistemology, which will jointly allow us to develop a scientific methodology of iteratively refining our "successful" human logics that can evolve towards our goal of capturing the cosmic logics. The core content of this paper was first presented at the 2007 QTRF-4 conference at the Vaxjo University [1].

## **1. Has physics really deviated from seeking reality of nature?**

Newton is still considered the giant of all physicists who was constantly seeking actual reality and explicitly admitted that he does not understand what light is, just as Einstein did almost three hundred years later while underscoring the necessity of seeking reality of nature's processes [1-7]. The title of the paper derives from one of Newton's sayings: "If I have seen further than others, it is by standing upon the shoulders of giants." Today we are both fortunate and confused because our guiding giants have been divided among themselves for many many decades, if not for a couple of centuries after developing more than half a dozen successful theories that we have been failing for many decades to synthesize into one system, the way the cosmic universe appears to be. So, we are forced to choose giants of our own choice and develop our own path. QTRF-4 is a welcome collective effort in the right direction that is formally questioning the direction of evolution of physics. The recently published books by, Smolin [8], Laughlin [9] and Penrose [10] give us more impetus to question the current epistemology that equates the finality of a theory based more on the mathematical elegance and correctness of predictions for measurements, and less and less whether it is capable of mapping the actual processes undergoing in nature. The quality "elegance" has been raised to such a level that even measurements have become secondary to various "successful" string theories [8]. If we carefully analyze the 50 years' of contributions of classical physics before the birth of QM, we can observe that a faithful adherence to discover the reality (physical processes behind interactions) and the culture of pushing the boundary of theories beyond their limits, have actually nurtured the birth of QM. However, QM over the last 82 years, by insisting on the completeness of the theory, has effectively stifled the cultural process of giving birth to the next higher level theory.

Nature has yielded an enormous amount of its working rules through our organization of diverse observations into coherent systems using logical mathematical modeling (theories). This implies to us that nature works using causal rules. Our logical premise is that causality in a large system cannot emerge if the component sub-systems are essentially non-causal; inverse is logically more acceptable. The emergent causal and logical behavior of the evolving cosmic system is essentially built out of sum of diverse interactions between the stable elementary particles - protons, neutrons and electrons. All these elementary interactions cannot be non-causal, as QM philosophy claims

to be. If "...nobody understands Quantum Mechanics", yet the formalism works, then we ought to tell the next generation that there is something fundamentally wrong with the interpretations of the formalism. After overriding Ptolemy's geocentric vision, we are back on imposing homocentric vision on all the enquiring minds by re-directing them to solely rely upon our human mathematical logic, instead of attempting to visualize the actual processes in nature. Being stifled by the quantum philosophy, we are emulating the 'invention culture' from our technological successes and imposing that on to physics. We are now deeply engaged in inventing realities rather than discovering the actual realities behind nature's evolutionary processes. Since QM formalism works so well, it must contain more realities than so far we have acknowledged. Our Reality Epistemology will help extract such realities and eventually facilitate the evolution of higher order theories by finding the limitations of QM.

But, what is reality? Whatever I can measure (record) reproducibly under controlled (similar) conditions, are my reality related to the interactions between the identified interactants (sensor-sensee or detector-detectee) however minute amount of reality may that be compared to the vast cosmic ocean of unknowns. Since I know not any of the interactants and all the applicable forces and their separate and joint, linear and non-linear influences completely, I am obliged to use extend my rational imagination to visualize the processes undergoing between the interactants and develop some "limited" hypotheses congruent with the immediate observations. The best choice I have in modeling the interaction and the follow-on transformations experienced by the interactants, is to assume natural processes to be causal and logical.

We believe that we have created impediments towards our scientific progress by ignoring our eternal ignorance forced on us by nature the way we can gather information about nature. We can "see" (measure) the universe only indirectly through the "eyes" of the various sensors (detectors). None of these sensors are completely known to us as yet. All sensors also have inherently limited capabilities to "see" (respond) to input signals and limited capabilities to "report" only a part of all that it experiences. They all "see" through vision-limiting "goggles" and "speak" to us through band-limited "channels" which are characteristically unique for each of them and not quite known to us. We are forced to develop our mathematical theories mixing our human logics (hypotheses) and incomplete information and hence they are all provisional and incomplete since they are predicting only correctly measured but limited reports by the detectors. When we succeed in constructing an equation to model and predict a set of observations using human logic and limited information, we are automatically limiting our progress to integrate new behaviors of nature that are not logically congruent with the "limited" equation! Mathematics being human invented pure logic, it has to be logically "complete" and "closed", based on the original set of hypotheses, for it to work. Therefore, for any successful equation (theory) to work for a small segment of the undivided universe, by definition, it must have ignored many other potential interactions due to other forces and/or under logically very different contexts. Thus, the only way to integrate multiple successful theories, or partially solved jig-saw-puzzles of the universe, is to break them apart and try to re-assemble them as one bigger jig-saw-puzzle by selectively rejecting and/or modifying some of the human logics towards infallible cosmic logics. Therefore, we should be careful not to jump into conclusion with any working theory that we have captured all the necessary cosmic logics behind the set of interactions represented by the theory. We need to dissect the measurement processes in a generic way along with well defined steps to apply Reality Epistemology (RE), which will jointly allow us to develop a scientific methodology of iteratively refining our "limited successful" human logics into evolving cosmic logics that we are really after. It may be an indefinitely iterative process for us to find the ultimate theory of everything.

A correct approach needs to incorporate some validating or anchoring steps. Could that be integrated with our desire and need to design our sustainable evolution? It is the technologies that we have been discovering and inventing by emulating nature's various processes since the beginning of our emergence as bi-peds with enormous number of neural nets that are far more than the necessity of our survival against competition with the other species. Therefore, nature is our best peer. She is a creative system engineer undergoing logically self consistent steady evolution through innumerable processes of interactions between all possible entities in all possible ways creating galactic and biological technological marvels by utilizing only a small set of (four) interaction forces (or, potential gradients) to the extent we understand so far. It is interesting to note that we build large jig-saw-puzzles for our children by using only a few set patterns, which easily leads them to make many un-integrate-able little "solved" puzzles. Scientific history is replete with multiple theories correctly predicting the same measurements, some of which have been shown to be mathematically equivalent to each other and some are not.

It is wise for us to take the roles of creative reverse-system-engineers and then emulate some of the selected processes of nature to create beneficial technologies that are congruent with our sustainable evolution, for we need a long long time to understand the purpose of the cosmic evolution and our roles in it. Our theory driven technologies can become the anchoring points with nature's actual working rules (or, realities). Thus, the Reality Epistemology that we are proposing could be capable of integrating materialistic science and spiritualistic philosophy into one working system to accelerate our intellectual evolution. Such a wholistic vision can guide us more robustly through

our innumerable successes and failures. History tells us that even our great thinkers have been extracting nature's working rules only in piecemeal and we have been successfully integrating them through ages into deeper and higher levels of working knowledge, but with a lot of ideological straggles amongst ourselves, which is healthy. Science has always been a "work in progress". Declaring the tentative *working rules* that are evolving with the evolution of our knowledge as the *laws* of nature imposes serious psychological impediment on the growth of the naturally enquiring minds of the young students. Science is not like building a pyramid by discovering the right fitting stones for we do not yet know the ultimate working structure of the universe!

Manifest and emergent material universe is real and causal. It is subtle, complex and *elusive*, but it is neither mystical nor a *non-causal illusion*! We need to appreciate that there are real ongoing physical processes behind the emergence of both the irreducible and stable elementary particles as well as the most complex systems built out of these elementary particles. Let us consider an elegant yet simple example that we have all experienced – a colorful rainbow, say, visible inside a man made fountain in Sun light. We know that photons do not possess any colors; neither do the water droplets inside the fountain! If you enter inside the fountain, you will not find the rainbow. Yet, it is an emergent reality in nature and not an illusion. It can be observed only by color-interpreting frequency sensitive sensors and only at the focal plane of an imaging system looking at the fountain and only when the Sun is behind the imaging sensor (observer). There is no real rainbow inside the fountain. The emergence of the mystical beauty of a rainbow is elusive but causal, and definitely not an illusion! The specific dispersive refracting property of the water droplet, which is at the root of rainbow color separation, is itself an emergent property of the spherical water molecules in bulk. Understanding the processes behind its formation help us understand the local weather conditions, besides enjoying its esthetic beauty, while advancing the optical sciences by validating a good number of optical principles through a single emergent phenomenon!

Even the elementary particles may be emergent undulating entities in the cosmic field rather than some immutable "material" particles. After all, mass is inter-convertible to energy and Schrödinger's equation "maps" them as some form of harmonic undulations in the cosmic field [11, 12]. It is worth noting that unlike Maxwell's wave equation for EM "waves" that equates second derivative of the field strength with time and space coordinate, Schrödinger's equation equates first time-derivative of the "particle" field strength with that of the second space-derivative of the field strength. Seeking reality will be elusive!

## 2. DISSECTING OBSERVATIONS AS "SUPERPOSITION EFFECTS AS MEASURED TRANSFORMATIONS (SEMT)" AT THE CORE OF DOING PHYSICS

Creating science out of methodical observations generally require appreciation of the following universal steps in nature. (i) We can scientifically measure only re-producible quantitative *transformations* that are experienced by our interactants (or detector-detectee, or sensor-sensee). (ii) Any transformation in measurable physical parameter requires *energy exchange* between the interactants. (iii) The energy exchange must be guided by at least one *force of interaction* between the interactants and it must be strong enough to facilitate the exchange of energy, which are usually constrained by unique characteristic of each interactant. (iv) All force rules being distance dependent, energy exchange between the interactants requires that they must experience each other as locally present or *physically superposed* entities (experience each other within their sphere of influence).

Therefore, all observations constitute measurable superposition effects. Interactants must be physically *superposed* within the range of the *interacting force* that will allow some *energy exchanger* followed by some *transformations* that is measurable for us. Superposition effect is thus an *active causal and local process*, not a passive mathematical principle! Interpretations of successful mathematical formulation must recognize this *Reality Epistemology* (RE). The objective of physics is to map and visualize the physical interaction processes that facilitate the energy exchange followed by transformations in the interactants.

### 2.1. Re-visiting SEMT in view of the four force rules we understand, so far!

(i). *Gravitational force (GF)*: All cosmic entities, from galaxies, stars, planets, atoms and elementary particles, the entire observable material universes is effectively superposed on each other as far as GF is concerned. GF is weak; its range is long.

(ii). *Electromagnetic force (EMF)*: Stability of atoms, molecules and their all possible transformations, including their interactions with electromagnetic waves (light, etc.) are all dictated by this force. A dominant part of the biospheric evolution is driven by this force. EMF is relatively stronger than GF, but the range is shorter. The superposition effects due to the EMF from the molecules of two different human bodies are essentially negligible (un-entangled) on a first order analysis.

(iii). *Weak Nuclear force (WNF)*: Radioactivity and related isotopic nuclear transmutations are a by product of this force. The range of WNF is of the order of the size of the atomic nuclei. The superposition effects due to two radioactive atomic nuclei within the same bound molecule are negligible within the first order analysis.

(iv). *Strong nuclear force (SNF)*: Our slow physical evolution relies on the stability of an array of nuclei held together by this SNF, built into stable atoms and molecules by the EMF and held on the surface of the Earth under the atmosphere by the GF. Different atoms within the same molecule are superposed as far as electromagnetic force is concerned, but their nuclei are not superposed as far as SNF is concerned within the first order analysis.

While the observable material and light based universe may generically appear as *non-local*, a careful analysis of SEMT tells us that all measured phenomena are necessarily *local* since all forces of interactions have a finite physical range! Entanglement is operative within the operating range of the force.

### 3. PROPOSED METHODOLOGY FOR REFINING WORKING HUMAN LOGIC INTO OPERATING COSMIC LOGIC [CC-LC-(ER)<sup>2</sup> EPISTEMOLOGY]

**3.1 Defining CC-LC-(ER)<sup>2</sup> epistemology.** For centuries Physics has been synonymous with seeking *Conceptual Continuity (CC)* among a group of diverse but related set of observed phenomena by iteratively and creatively constructing *Logical Congruence (LC)* among all of them to find a higher level of organization leading to a coherent map or theory for the selected set of observations. Our *belief* in this CC-LC epistemology and intuitive *faith* in one continuous and logically functioning universe have been paying off enormously. Our cumulative successes indicate that nature's evolutionary processes do consist of logical patterns & organizations. Thus far, the CC-LC-epistemology has helped us "solve" several separate little pieces out of the giant cosmic jig-saw-puzzle. But we are having trouble in integrating them into one coherent puzzle.

As articulated earlier, all of our "successful" theories are constructed based on limited information about the set of phenomena it is modeling. But however limited, the very success implies that it has captured some cosmic truth, but not all. Thus, we must systematically apply the (ER)<sub>1</sub> epistemology, which is maximization of *Extracting* and *Extrapolating Realities* out of a given theory (equation). While the practices of successful predictions by any new theory are examples of (ER)<sub>1</sub>, we have been neglecting the power of this component of the proposed epistemology chain by not focusing on finding the limitations of a theory. The case in point, we are considering QM as complete, rather than explicitly looking for its limitations that would pave the way for discovering higher level theories.

We believe that the "trouble" is not with physics [8], but lies with our epistemology. Current physics has been developed based essentially on reductionism, matter into elementary particles and radiations into photons. We have neglected to develop a methodology of thinking that would help appreciate the emergence of new complex properties and rules when a complex system is formed out of very many simpler elements. We now need to add another iterative feed back loop of (ER)<sub>2</sub> - *Emergentism and Reductionism* on to CC-LC-(ER)<sub>1</sub> and create a higher level of methodology, CC-LC-(ER)<sup>2</sup> epistemology. This reality seeking epistemology will help us iteratively refine reject re-define some of the founding human logics behind our current "successful" puzzle pieces (theories) and let them evolve closer and closer to the actual operating cosmic logics. Thereby, make the various theories more congruent (amenable) to each other towards unification, CC-LC epistemology but at a higher level. As we have underscored earlier, logically closed equations mapping successfully different subsets of cosmic phenomena based on incomplete knowledge of the universe will necessarily require modifications on their original fundamental premises (hypotheses) before they can accommodate, or amalgamate into, different cosmic logics of interactions. We do not have options but to start with human logics (epistemology) to start making small maps of nature. Then we use CC-LC-(ER)<sup>2</sup> epistemology to iteratively refine the human logics to become closer and closer to the cosmic logics, evolving towards grand unification of different theories.

**3.2 An elucidating example.** Some 2500 years ago Gautam Buddha of India gave the best allegorical story on how to apply CC-LC-(ER)<sup>2</sup> to visualize and understand the subtle and elusive "material" universe. How would a group of people, blind from birth, describe and visualize an elephant? It applies equally well to us today as we are trying to describe and visualize the cosmic elephant. First we need to recognize that as far as scientific vision is concerned, we are literally blind. We never see or sense the world directly. Even our human vision is essentially a set of interpretations created by our brains that is convenient for our evolution, not what the actual image is on the retina. We see vivid colors in bright light and we recognize the same colors even in faint light, even though the photons do not have any colors at all. The images we "see" are erect, even though the actual image on the retina is always inverted! In seeking reality about the elephant, the blind people have to search for conceptual continuity (CC) among all their individual sensory inputs by iteratively applying all possible logical congruence (LC) among

them. Even then they will only get the outer shape of the elephant. A deeper level of understanding about how such a shape can be a conscious living being requires the blind people to iteratively refine the model of elephant by first applying (ER)<sub>1</sub> - extracting and extrapolating their perceived realities to become commensurate with models of other living species. Then they need to apply (ER)<sub>2</sub> – *emergentism and reductionism*, to delve deeper into understanding the emergence of elephant’s living behavior out of many parts and organs. Today, we “scientifically” understand the *emergence* (E) of any living being out of molecules and DNA’s that are highly *reduced* (R) constituents, but we still do not fully understand the emergence of consciousness. Buddha’s story also underscores that the existence of the elephant is real, irrespective of whether the blind people sensed it at all or understood its existence in the strict sense. So, philosophies giving serious credence to questions like, “did the tree fall if nobody heard of it?” is a useless diversion if we want to seriously explore the realities of the emergent cosmic universe. The bacteria in the woods are fully cognizant of the availability of lots of food from the fallen tree! Human philosophy cannot hinder their evolutionary physical needs.

**3.3. Objective vs. subjective.** We also need to be aware regarding how to distinguish between the objective presence of the cosmic universe that has been evolving for billions of years, well before the appearance of human specie, and the inherently subjective manner by which we are for ever challenged to gather information about this universe. Personally, I really am not totally objective about the outside universe. I simply cannot be! I “see” what is really functionally important for my survival in the real world with my limited number of sensors, which themselves are limited in both sensing and “reporting” to me. My thinking and interpretations are also colored by my brain, my 100 trillion symbiotic microbes and bacteria, my family and social training and my personally acquired knowledge, politics and ego driven by my own successes and failures! By being consciously aware of the methodology of CC-LC-(ER)<sup>2</sup> epistemology, I can iteratively refine my subjective sensor inputs and the organizing human logics into higher and higher levels of objective truth and cosmic logics behind the evolving universe.

**3.4. Why elegant mathematics is not enough?** Although it is obvious from the prolonged stagnant state of physics that elegance and symmetry of mathematics is not sufficient guide to explore nature, we present two simple examples to underscore the necessity of constantly applying CC-LC-(ER)<sup>2</sup> epistemology. First, let us revisit why we have rejected Ptolemy’s geocentric model. It required several free parameters to allow Ptolemy to construct “epicycles” for each planet separately to accommodate relative “wobble” motion relative to our Earth. Kepler, based on Copernicus’ suggestion, showed that Helio-centric model fits the observations more coherently and logically without many free parameters except a central force of attraction by the Sun. Over the following centuries, Newton formalized the “central force” as gravity, Einstein generalized it to “curvature of space” and we are still at dilemmas as to how to accommodate the measured velocities of the stars in the outer periphery of the galaxies. The point is we need continuous refinements in our modeling based on discovering actual realities rather than inventing mathematically elegant ones. But, if we take the example of today’s “successes” of various String Theories using many dozens of free parameters, Ptolemy’s geocentric model can be revived with much less numbers of free parameters than the String Theories.

Let us look at another example with elementary mathematics. Pythagoras’ relation can be replaced by a pair of relations that I discovered in my 7<sup>th</sup> grade school from a particular example of a right angled triangle with sides 5, 4 and 3, as many other students must have:

$$\left[ c^2 = a^2 + b^2 \right] \quad \text{vs.} \quad \left[ c = 2a - b \text{ where } (b/a) = (3/4) \right] \quad (1)$$

Even though Pythagoras’ quadratic relation can be derived from the pair of linear relations suggested above, which makes the two relations mathematically equivalent, my teacher favored the visualizing power or the geometric value of Pythagoras’ relation. Because, one can literally construct the unit squares on each side of a right angled triangle and see for himself why Pythagoras’ relation makes sense, which is not so obvious from the other approach based on geometric ratio of the sides. Advanced physics is replete with many such examples like (i) the equivalency of Heisenberg’s matrix formulation vs. Schrödinger’s “wave” equation and (ii) equivalency of Feynman’s “path-integral” vs. Tomonaga-Schwinger’s “variational method”. (iii) Sudarshan showed that Wolf’s classical coherence formulation is equivalent to Glauber’s QM representation. Can one of the mathematical constructs guide us better than the other in seeking and visualizing the actual interaction processes in nature? This is a relevant question from the stand point of the epistemology we are proposing. The key point is to recognize that not all “working” human logic has a unique one-to-one relation to the cosmic logic. Thus we must develop a methodology of rational iteration process that can keep on refining our working human logic towards the “nirvana”, the cosmic logic.

**3.5. Imposing realities on the symbols and mathematical operators of successful equations.** Even in pure mathematics, equations to be correct, the meaning and operation of all the symbols and the connecting operators must be clearly defined. Based on our discussion in Section-2, on dissecting observations as “superposition effects as measured transformation” or SEMT, we must acknowledge that any equation that successfully predicts the

outcomes of a wide set of interactions between different interactants, all the symbols must represent the states of the interactants and the operators must represent actual interactions (operations) between them. This is an essential component of the reality epistemology we are promoting.

The simplest example comes from the photo detection [13-15] process that requires careful attention to match the mathematical symbols representing actual physical process of light matter interactions, but not underscored in most of the books. Well formed optical beams (beyond near field diffraction zones), light beams simply pass through each other without modifying each others spatial and temporal energy distribution unless we insert detecting material dipoles within the volume of superposition which are quantum mechanically responsive to the frequencies of all the beams [3-7, 16-31]. If this were not true, we could not have discovered the unique and characteristic Hubble Doppler shift of light beams coming from trillions of individual stars residing in billions of galaxies whose beams are necessarily crossing through (being superposed) as they travel to the Earth. This has enormous consequences both in the classical quantum optics that we have been neglecting at an enormous cost to progress in physics!

Superposed or not, we “see” visible and higher frequency light beams only through the “eyes” of detecting material dipoles each one of them wearing unique “quantum goggles” [20]:

$$\text{Field: } E(t) = a(t)e^{i2\pi\nu t}; \text{ Stimulation: } \psi(t) = \chi_{(1)}a(t)e^{i2\pi\nu t}; \text{ Transformation: } D(t) = \langle \psi^* \psi \rangle \quad (2)$$

$D(t)$ , the measurable transformation due to real physical superposition of the EM field and the detecting dipoles is a QM prescription that “works” and has two built in steps, taking square modulus of the dipole stimulation and the ensemble average. The susceptibility to polarization of the dipole  $\chi_{(1)}$  contains all the quantum response properties of the molecules. Note that while normally we use only the linear (first order susceptibility), in reality all EM fields induce all possible linear and non-linear susceptibilities. We “blissfully” neglect this higher order effects until we encounter molecules with strong nonlinear polarizability that are becoming more and more common. In reality, the dipole stimulation should be written as:

$$\text{Stimulation: } \psi_{(n)}(t) = \sum_n \chi_{(n)} E^n(t); \text{ Transformation: } D(t) = \langle \psi_{(n)}^* \psi_{(n)} \rangle \quad (3)$$

While Eq.3 already looks complex for general situations, it is even more complex in reality, because both the susceptibility and the EM field are vectors and accommodating the angle between them is quite complex [33]. For multiple EM fields superposed on the detecting molecules, taking the simple linear case of Eq.2, we have:

$$\text{Stimulation: } \psi(t) = \sum_{q=1,2} \vec{\chi}_{(1)} \cdot \vec{a}(t - \tau_q) e^{i2\pi\nu(t - \tau_q)}; \text{ Transformation: } D(t) = \langle \psi^* \psi \rangle \quad (4)$$

We have introduced the vector notation on the dipole susceptibility and the EM field to underscore the absence of interference fringes due to orthogonally polarized light is due to the fact that the same dipole cannot carry out dipolar undulations into two orthogonal directions at the same time; it will chose to undulate to one or the other EM vector [12, 20, 25].

This simple recognition of the physical process of “seeing” light through the “eyes” of dipoles has many remarkable implications. First, any time light passes through any material and/or reflected or scattered by some material surface, some of their intrinsic physical properties (frequency, phase, amplitude, polarization) very likely will change. This is built into Maxwell’s wave equation when one applies the “boundary conditions”. Thus, if we think in terms of propagating photons, most of the time the re-directed photon is no longer the same photon that originally impinged on the surface of the medium.

Accordingly, the Bell’s theorem [33] to be relevant at all for interference experiments, it has to be re-derived for each interferometer in terms of physical dipole undulations of not only the detector molecules but also of those of dielectric or metal coating boundary molecules of beam splitters and mirrors that introduce differential  $\pi$ -phase delays for “internal” vs. “external” reflections and the states of polarizations [34], etc. Generally, this  $\pi$ -phase factor is “accommodated” within the physical path difference between the different arms of an interferometer, which is equivalent to ignoring the physical processes that we want to underscore as doing real physics. This approach is benign as long as the Poynting vectors of the two light beams are non-collinear and of different wave front curvatures. When the Poynting vectors of the two collimated beams of equal amplitudes are collinear on a beam splitter [parameters are not explicitly introduced in the above equations], the total energy of both the beams (for same frequency only) will be re-directed in one of the two directions depending upon the coordination of the optical path delay and the  $\pi$ -phase delay between the “external” and “internal” reflections introduced by the boundary dipole molecules of the beam splitter. These boundary molecules cannot collectively redirect the wave front energy in one preferential direction without experiencing the simultaneous but differential  $\pi$ -phase stimulations from both the sides [27, 28] Measurable superposition effects are always due to simultaneous stimulations of the dipoles and hence the phenomenon is necessarily *local* [20].

Another implication of “seeing” light only through the “eyes” of detectors is how we use time-frequency Fourier theorem [18]. The theorem implies the possibility of synthesizing a pulse by superposing many Fourier frequencies as if the EM fields by themselves re-group their energy. But, we know that mode-locked lasers cannot function without the presence of intra-cavity saturable absorber or non-linear Kerr material [22, 24]. The dispersion theory based on this theorem also implies that dipoles of linear material medium must respond to the Fourier decomposed frequencies whenever it experiences a pulse irrespective of the shape and duration of the incident pulse that must always take a finite time to enter into the medium itself [19, 18].

The fourth implication relates to the coherence theory that is normally presented as “field-field” correlation even though the physical “correlation” comes from simultaneous response of the detecting dipoles to both the stimulations. Fortunately, for the current theoretical presentation in the normalized version, the square of the susceptibility factor  $\chi^2_{(n)}$  drops out and the “degree of coherence” appears as due to “field-field” correlation. This makes this elegant theory rather unphysical. We are in the process of re-writing the coherence theory in terms of detection processes, which considers the susceptibility of the detecting molecules to be inseparable [27, 18]. Eq.5 helps one appreciate our point. We loose access to visualizing the physical processes by eliminating the susceptibility term  $\chi^2_{(1)}$ :

$$\gamma_{dipole}(\tau) = \langle \psi^*(t)\psi(t-\tau) \rangle / \langle |\psi(t)|^2 \rangle = \langle a^*(t)a(t-\tau) \rangle / \langle |a(t)|^2 \rangle \equiv \gamma_{field}(\tau) \quad (5)$$

Obviously, if we can discover a detector whose molecules undergo transformation simultaneously utilizing its multiple (sum of) non-linear polarizability, such a simple equivalency as in Eq.5 will not be possible. Further implications will be published elsewhere.

**3.6. Applying CC-LC-(ER)^2 to model what a photon is.** First, we need to justify whether an attempt to re-define the photon is called for considering the current state of very broad acceptance of photons as indivisible quanta which “interfere only with itself”[35 Dirac]. “Self interference” (or, photons knows how to arrive only at the bright fringe locations) naturally dictates the acceptance of unusually strong non-causal concepts like, “non-locality”, “delayed superposition”, “multiple universe”, etc. A summary of these main stream views and related references can be found from these review articles [36, 37]. Our position is that the emergence of causal macro universe, being totally based on quantum interactions in the micro universe, the latter interaction must also be causal. So we should try to model a causal “photon” to bring back *reality* in physics (the title of the paper).

A Fourier monochromatic mode of the vacuum is not a starting causal model for a photon since Fourier modes are physically non-causal, existing over all time that violates conservation of energy. So, the “CC-LC” component of our epistemology demands a causal model for the photon and when we press to also apply (ER)<sub>1</sub> (*extract and extrapolate reality*) out of various classical and quantum optics theories and observations, we find the following model. Our proposed photon is a mode of the vacuum as QED claims, but with two caveats. First, it is a space and time finite packet of EM wave evolving and propagating out following the classical Huygens-Fresnel (HF) diffraction model from the moment the emitting molecule releases in the “vacuum” the quantum of energy  $\Delta E = h\nu$ , with a carrier frequency  $\nu$  under the space and time finite 3D envelope [23]. This far, our model is congruent with the correct demand of QM,  $\Delta E = h\nu$ . The next issue is to reconcile with the measured natural line width of spontaneous emission to be a Lorentzian. Classical physics (Lorentz) has solved the problem by proposing the emission envelope to be exponential whose Fourier transform is Lorentzian. We have analytically shown that the *time integrated* fringe broadening observed in classical spectrometers due to time-finite pulses do correspond to Fourier spectral intensity (square modulus of the Fourier transform of the temporal envelope) [31, 29, 21].

Let us now apply again (ER)<sub>1</sub> along with (ER)<sub>2</sub> (*emergentism and reductionism*). The HF diffraction model is holding out as a remarkably accurate model for light propagation from all the macro to nano photonic devices. So, it must have captured some cosmic logic in it. Its key proposition is that every single point on the wave front behaves as a new source point. We are proposing to accept this point to be literally true. This implies that the cosmic “vacuum” holds a stationary and uniform electromagnetic tension field (EMTF) everywhere in a state of equilibrium [11, 12]. The light wave (photon) is simply a propagating wave group that is an undulation of the EMTF induced by the released energy  $\Delta E$  by an excited molecule undulating at a frequency  $\nu$ . The photon is an emergent phenomenon out of the stationary EMTF. The model is quite congruent with all classical material based undulations that inherently propagate out with diffraction. The wave on the water surface is simply an undulation of the surface against the surface tension when displaced by an external energy source out of its state of equilibrium. Same is true for sound wave where the tension in equilibrium is the air pressure due to Earth’s gravitational attraction on the air molecules. The similarity between the Maxwell’s wave equation and the material based wave equation is remarkable. The displaced point out of the state of equilibrium, whether EMTF or water surface under tension, wants to comeback to its original state of equilibrium and delivers its “displacement energy” to the next domain

making it the next (“secondary”) source of wave while generating propagating wave and also validating Huygens’ hypothesis over Newton’s “corpuscular” model, although a space and time finite wave packet (energy conservation) do imply the “corpuscular” existence of light! Propagating wave is an emergent and collective phenomenon. The root of the generation and propagation of all wave-like phenomena lay with a “field” (EMTF) or a material medium (water, etc.) under uniform tension in a state of equilibrium. Thus the cosmic space (EMTF) holds enormous amount of “static” energy, only a tiny fraction of which is manifest as propagating photon wave packets at any time whirling in every direction of the universe carrying the messages from distant atoms and molecules. EMTF itself quite possibly is the “Dark Energy” the astrophysicists have been looking for. No cosmic or local communication waves would have been possible without the existence of this EMTF in a state of quiet equilibrium! The next question is how to construct the stable particles out of it and then we will have a unified field theory inspired by the highly neglected classical hypothesis, the Huygens-Fresnel principle, supported by the various wave equations!

## SUMMARY AND CONCLUSIONS

We hope that we have demonstrated that QM formalism contains more physical realities than we have so far appreciated. Schrödinger’s  $\psi$  is not just abstract probability amplitude of an entity under study, but it represents the real physical dipole undulation stimulated by another undulating entity while physically present within each others range of the operating force of interaction [1, 20]. The purpose of physics is to visualize and understand the physical processes behind all interactions that have been keeping the “cosmic elephant” evolving logically and causally. Our description of the steps behind any measurement, SEMT (superposition effects as measured transformation), should convince the readers that measured interactions are causal and local. The logic is simple. The measurable state change or *transformation* (classical or quantum mechanical) require *energy exchange* allowed by an operating *force* provided the interactants are *local* to each other, implying that they are within each others force range. We have also provided a methodology of thinking that allows an iterative refinement of human logic (epistemology) towards cosmic logic (ontology). While all “working” theories definitely have captured some cosmic logics, none of them can claim to have definitely captured the ultimate cosmic logic because we are forced to construct any and all theories supported by measurements that can never gather complete information regarding: (i) all possible interactions capability between the interactants under study in any single experiment; (ii) it is impossible to be sure that we can collect all the information related all the transformations experienced by the interactants; (iii) this is further complicated by the fact that we do not know any of the interactants completely even today!

Based on these observations, we have developed a reality exploring epistemology, CC-LC-(ER)<sup>2</sup>, which can help us iteratively enhance our “working” human logics towards the cosmic logics that we are trying to map. We have given a powerful example by presenting a model for photons that while accommodates all the QED demands and classical causality, and at the same time, leads us to make a quite plausible hypothesis that the cosmic medium contains an enormous amount of reserved energy (“Dark Energy”) in the form of electromagnetic tension field (EMTF) in static equilibrium whose undulation induced by material dipoles manifest the space and time finite wave packets of light.

We believe that nature is a creative system engineer. So, our best hope to discover and understand nature’s reality is to approach her as reverse engineers. Our power to visualize the subtle and invisible processes behind all classical and quantum process will be significantly enhanced when we recognize that we are literally blind for everything we construct with our imaginations are based on subjective interpretations of the limited sensorial inputs by our brain, which has been necessary for our successful evolution. Thus framing the question with human logic dictates the answer we construct, which may or may not be conducive to iterative refinement we have proposed to advance towards cosmic logic. Thus, our epistemology providing guidance on how to eliminate hypotheses those are devoid of cosmic reality even though they may be “working” within a limited theory. If our starting premise is that light energy constitutes indivisible quanta, we will keep on imposing the quantum properties of the detectors on to EM fields for we can see them only through the eyes of the detectors. If alternate realities exist, they can be discovered only if we accept such possibilities, as some well known dissenters have tried to pave the way for [2, 38-41] but failed repeatedly. In the seventies, we unsuccessfully tried to present [42-51] to the community that in view of non-interaction (non-interference) between well formed light beams, the use of the time-frequency Fourier theorem as a principle of nature lies at the root of miss-representing many of the classical and quantum optical phenomena because Fourier “monochromatic” frequencies, existing over all time, are necessarily non-causal and the approach introduces non-causality in our physical theories.

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