On the extended Stochastic Electrodynamics Interpretation of Quantum Mechanics

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Abstract. An extended version of Stochastic Electrodynamics (SED) which provides an interpretation of Quantum Mechanics free of its preternatural aspects is reviewed briefly. In addition, recent simulations of the hydrogen ground state based on SED which have been inconclusive are criticized for having employed only a restricted understating of the physical consequences of the hypothetical underpinning of SED.

1. Introduction
Quantum Mechanics presents an extraordinarily exasperating challenge. As a Physics theory it is at once both the most encompassing and useful theory ever developed, while at the same time arguably providing the least instinctively reasonable association with familiar physical processes. Efforts to fathom the essential fundamental content of the theory have led to such counter intuitive and non-physical notions such as signal propagation backwards in time (transactional interpretation) and virtually infinite duplication of the observed universe (many-worlds). Of course, there are also many less extravagant proposals, but in the end none of the most discussed, and very few if any of the obscure alternatives, present a picture of nature compatible with Classical Physics, Formal Logic and macroscopic experience. This situation for many practicing physicists has induced an attitude of deliberate rejection of, often even denying the possibility in principal of, an intuitive understanding of quantum phenomena. One oft hears the admonition: “shut up and calculate,” in other words, apply the known-to-be-successful recipes and prescriptions and abandon all efforts at ‘Natural Philosophy.’

Nevertheless, instinct and intuition based on accumulated experience with natural phenomena play an ineluctable role in science. “Science” is that intellectual pursuit of certain knowledge initiated, as the best historical records seem to indicate, by the ancient Greeks and denoted “Natural Philosophy.” In turn, Natural Philosophy in the course of the following centuries spawned both Science and Theology. Although the pursuit of certain knowledge is central to both disciplines, within science the sub discipline of Formal Logic has deduced the limits of obtaining certain truth by reasoning. What was therewith found is that, given the necessary inputs, that within what is known as a “logical structure,” statements can be adduced that are demonstrably free of contradiction with respect to the set of inputs, and can thus be regarded as being “certain” in a limited sense. An example of such a structure is Euclidean Geometry for which the inputs comprise 1) a set of “primitive elements” (point, line, plane, etc.) and 2) an axiom set. Once these two sets are at hand, then syllogisms, i.e., rigorous proofs of additional statements concerning the relationships among the primitive elements, can be found...
almost mechanically. While this final process results in statements of unimpeachable verity (with respect to the axiom set), the first two steps, namely selecting primitive elements and axioms, are, as it were, ‘alogical;’ they are selected on the basis of intuition garnered from common experience. This is the venue within which ‘interpretations’ of theories play an essential role in the advancement of science.

Herein the aim is to review a particular minority-developed and minority-supported interpretation of Quantum Mechanics which arguably presents the least conflict with intuition and common experience: an ‘extended’ version of Stochastic Electrodynamics (SED).

2. Stochastic Electrodynamics
After the development and widespread acceptance of Quantum Mechanics in its sophisticated variant: namely Quantum Electrodynamics (QED), which is largely specialized to cover the interaction of matter, in particular in the atomic state, with light (actually electromagnetic interaction generally, but found most useful for high frequencies) it was found possible to plausibly explain many matter-light phenomena without the conceptions of QED. The theory doing so was denoted ‘semiclassical’ insofar as its input was standard Quantum Mechanics for matter (atoms) and classical electrodynamics for radiation fields. This scheme worked well for many, and with tricks for virtually all matter-light interaction phenomena, and had the appealing virtue that the implicit, intuitive interpretation for the fundamental processes was vastly less abstract than that associated with QED. The main obscurity intrinsic to QED is the physical identity of radiation (‘photons’): is it particulate, wave-like, both, etc.? Photons, as envisioned in QED terms, have turned out to be particularly obscure. In textbooks one can find suggestions ranging from photons being the ground state of the free electromagnetic field (which could stretch from one end of the universe to the other, but still be absorbed at a point (?)) to bullet-like so-called wave-packets resembling electromagnetic pulses. Philosophers of Science, i.e., those who pay as much attention to the internal, logical consistency of the vocabulary used as theoretical physicists pay to the mathematical consistency, have been unsuccessful at even identifying the ontological subjects of QED.

Almost simultaneous with the development of QED, there arose a parallel theory in which it was envisioned that Quantum Mechanics for matter might be unnecessary if it was taken as an alternate hypothesis that, in addition to any thermal electromagnetic field, there is always present a statistically independent background field. A distinction between these two fields, while being somewhat artificial and dependent on the particular chosen model for the electromagnetic interaction, can be made on the basis that, this extra field is distinct from thermal radiation and does not lead to friction forces or, in other words, a means to empirically distinguish “privileged” inertial frames. These two desiderata can be met by supposing that, the background signals are statistically independent of thermal radiation, i.e., uncorrelated; and that, their physical manifestations are distinct. Thermal radiation, obviously, has to affect those physical characteristics of matter that can be measured in terms of a ‘temperature,’ i.e., such as macroscopic and mesoscopic motion, while the background primarily interacts with either internal or hyper microscopic motion. Indeed, the theory is discussed largely in terms of hypothetical oscillators having Zitterbewegung frequencies while free to also move ‘macroscopically’ as do molecules of a gas, where only the latter relatively large scale motion substantially contributes to the measured temperature of the gas.1

In order for such high frequency oscillation to avoid contributing to the thermal energy of elementary charges, it seems sufficient that first, its ‘signals’ be uncorrelated (statistically independent) of signals in the thermal range; and secondly, be isotropic and statistically frame independent—or, as oft expressed: “have a Lorentz invariant energy spectral distribution.”

1 Extensive and accessible reviews of the historical literature pertaining to SED can be found in: [?].
In fact, this latter condition has been used to formulate a derivation of the required functional form. The argument goes as follows. For electromagnetic signals, the energy is the fourth (time) component of the Lorentz 4-vector with momentum expressed by the three space components; i.e., for a bundle of elementary signals, we may write:

\[ P = \gamma \vec{k} f(\omega), \]  

(1)

where \( f(\omega) \), the distribution over frequencies, is not also a function of \( \vec{k} \), i.e., of direction, as it is \textit{ab initio} taken that the background is isotropic. This quantity is expressed in a moving frame as:

\[ P' = \gamma (P - \beta \vec{k} \cdot |\vec{k}|) = \gamma (\vec{k} f(\omega) - \beta |\vec{k}| f(\omega)) = \gamma (\vec{k} - \beta \vec{k}) f(\omega) = \vec{k}' f'(\omega'). \]  

(2)

Thus, if the condition of invariance is imposed on:

\[ f(\omega) = f'(\omega'), \]  

(3)

then \( f \) must be a constant, so that for such a background signal it is concluded finally that,

\[ E = \text{constant} \cdot \omega. \]  

(4)

This conforms with the ‘quantum ground state’ of the free electromagnetic field when the constant is set equal to \( \hbar/2 \).\[1\]

The considerations given here thus far constitute the essential hypothetical input for the interpretation for Quantum Theory denoted ‘Stochastic Electrodynamics’ (SED). It was hoped that the phenomena so well quantitatively encoded by the mathematical methods deduced from Quantum Theory could also be \textit{quantitatively} described in terms of the methods used for stochastic mechanics. These efforts were rewarded with many successes, but seemingly confined to phenomena described by ‘Second Quantization,’ which excludes the wave-like aspects encompassed by the Schrödinger Equation.

This situation, promising though it was, begged for additional structure.

3. Extended SED

A direct consequence of Eq. (4), apparently unnoticed by early developers of SED, follows from the same fundamental, hypothetical input, namely that, an elementary charged particle, taken first order to be a high-Q oscillator in its own rest frame, will interact with its resonant mode of the invariant, non-thermal, background to establish an energetic equilibrium such that:

\[ m_0 c^2 = \hbar \omega_0. \]  

(5)

This statement is virtually tautological insofar as it is essentially the definition of a particle’s resonant frequency, \( \omega_0 \), which will turn out to be immaterial (i.e., immeasurable) \footnote{\textit{Note:} This statement is virtually tautological insofar as it is essentially the definition of a particle’s resonant frequency, \( \omega_0 \), which will turn out to be immaterial (i.e., immeasurable). Now, with respect to an arbitrary direction in space, this resonance state results from background signals coming from both directions and on the average constituting a standing wave with an antinode at the particles location.}.

Thus, any remaining signals constituting a node at its location will be ‘invisible’ to a localized charge.

These standing waves in a particle’s rest frame will appear to be traveling waves in moving inertial frames, say, in a frame with a diffraction slit in a plane barrier. Eq. (6) expressed in the moving frame using Lorentz transformations is

\[ 2 \cos (k_0 \gamma (x - c \beta t)) \sin (\omega_0 \gamma (t - c^{-1} \beta x)). \]  

(7)
Here it is clear that the wave vector of the second or modulation factor, $\gamma \beta k_0$, can be identified as the DeBroglie wave vector of the particle in the frame of the supposed slit. Further, the Lorentz transformation of Eq. (5):

$$\gamma m_0 c^2 = \hbar \gamma \omega_0$$  \hspace{1cm} (8)

leads directly to:

$$\vec{p} = \hbar \gamma \beta k_0.$$ \hspace{1cm} (9)

Thus the imagery supported by this conception is essentially that the DeBroglie wave associated with an atomic level particle is not something originating within or attached to the subject particle, rather it is the pattern in the those background radiation signals with which the particle is in energetic equilibrium. The oscillations involved are those which in the conventional quantum theory have been designated Zitterbewegung (trembling motion) as found by Dirac to be implicitly captured within the mathematical formalism of relativistic quantum theory. The actual mechanical effect on charged material particles is envisioned as being realized by radiation pressure; and this has the consequence that, the mechanical effect is proportional to the square of the deBroglie wave intensity.\(^2\)

It remains, of course, to show how this conceptual complex relates to the Schroedinger Equation. There exists a quite direct connection if it is taken at the start that, the effects of a high frequency background, like those of thermal radiation but more so, cannot be individually measured or modeled. The only description practically available is, therefore, statistical. The fundamental equation for the statistical time evolution of ensembles of like entities is the Liouville Equation:

$$\frac{\partial \rho(\vec{x}, \vec{p}, t)}{\partial t} = -\nabla \rho \cdot \vec{p} + (\nabla \rho \cdot \vec{F}) \rho + \sum_{i=x,y,z} \frac{\partial}{\partial p_i} \nabla_p \rho.$$ \hspace{1cm} (10)

Now, insofar as the momentum, $\vec{p}$, an independent variable, satisfies Eq. (9), one may take $(2 \vec{p})/\hbar$ as a kernel for a Fourier transformation:

$$\hat{\rho}(\vec{x}, \vec{x}', t) = \int e^{i \frac{\vec{p} \cdot \vec{x}'}{\hbar}} \rho(\vec{x}, \vec{p}, t) d\vec{p},$$ \hspace{1cm} (11)

for which the similarly transformed Liouville Equation is:

$$\frac{\partial \hat{\rho}}{\partial t} = \left( \frac{\hbar}{i 2m} \right) \nabla' \nabla \hat{\rho} - \left( \frac{i \hbar}{2} \right) \left( \vec{p}' \cdot \vec{F} \right) \hat{\rho}.$$ \hspace{1cm} (12)

Solution for equations of this form are sought by first separating variables using transformations of the form

$$r = x + x', \quad r' = x - x',$$ \hspace{1cm} (13)

to get:

$$\frac{\partial \hat{\rho}}{\partial t} = \left( \frac{\hbar}{i 2m} \right) (\nabla^2 - (\nabla')) - \left( \frac{i \hbar}{2} \right) \left( \vec{p}' - \vec{p} \right) \cdot \vec{F} \left( \frac{\vec{r}^2 - \vec{r}'^2}{2} \right) \hat{\rho}.$$ \hspace{1cm} (14)

This equation in turn can be separated for forces, $\vec{F}$, for which there exists a quadratic potential ($\vec{F} = -\nabla V$) so that we may write

$$\hat{\rho}(\vec{x}, \vec{x}', t) = \psi^*(r', t) \psi(r, t),$$ \hspace{1cm} (15)

\(^2\) Historical references to the extension of SED include: [?]. Actually, in that this so-called extension requires no additional hypothetical input, it is better denoted perhaps a ‘revelation’ or ‘discovery’ within SED. Physics theories, moreover, are products of human enterprise and therefore dominated by societal conclaves not always disinterestedly involved; thus, the ideas supporting this extension too are ignored by many SED proponents.
which finally gives
\[ \frac{i\hbar}{\partial t} \frac{\partial \psi}{\partial t} = \frac{\hbar^2}{2m} \nabla^2 \psi + V\psi, \]
(and its complex conjugate) the Schroedinger Equation.\(^3\)

So, what does all this offer? The answer is: a line of reasoning starting with classical physics with the addition of the SED background to the essence of Quantum Theory based on evident, physically motivated considerations. In this form its implicit interpretation is free of the preternatural aspects afflicting the current popular interpretations.\(^4\)

Note that a modification to the more common conceptions deduced from the assumed existence of an SED background considered here, is the introduction of an additional deduced effect, namely, the idea that the SED background provides a menu of signals to which an individual material entity (particle) ‘tunes’ preferentially so as to select signals describable as standing waves with antinodes at the particle’s position in its rest frame. It is envisioned that the particle is induced to follow or dwell in such nodes and troughs of the energy pattern of these selected signals by the mechanical action of radiation pressure. In detail, the image depicting the total physical situation is that, a particle’s interior oscillator tunes to those standing wave signals in the SED background corresponding to its Zitterbewegung frequencies. Such standing waves in moving inertial frames are modulated by the particle’s deBroglie wave length so that when the particle passes through a slit, say, it essentially finds itself ‘surfing’ on a diffracted or modulated deBroglie wave. Again, the mechanical work done on the particle to modify its trajectory to conform with the deBroglie wave’s diffraction pattern (stochastically, of course) is radiation pressure from the modified Zitter waves.

As an illustration of the utility of this interpretation, consider the perennial quantum conundrum: diffraction at slit. Entities considered particles are envisioned to ‘surf’ on the pattern provided by the background signals with which they interact. On the other hand, beams more intuitively (or in some classical limit) simply diffract passing through a slit as considered in classical physics, but then when observed at very low intensity, ignite just one photo detector atom which happens to be randomly itself in a hyper sensitive state. Thus, such a detection gives the impression it was granular when in fact it was the detector granularity responsible for this impression.

This just described ‘modified’ SED interpretation for Quantum Mechanics is not endorsed by all who are proponents of some form of SED for its own sake or as an alternative to Quantum Theory. Thus, criticisms which have been found on the basis of the conceptions held by such proponents do not pertain to the extended version.

To efficiently explain the technicalities of the differences, let us first review some pertinent mathematical background.

4. Mathematical Structure Technicalities

From the very conception of a rationalization for Quantum Theory based on SED, the central impulse appears to have been given by Born’s interpretation of the squared modulus of a wave function as a probability density of presence. This led apparently to the supposition that the fundamental underlying physical mechanism responsible for quantum phenomena could be some sort of statistical (or stochastic) mechanical process. The time evolution of such processes in classical Statistical Mechanics is governed by parabolic diffusion differential equations characterized by a first order partial derivative in time. Solutions for differential equations of this sort are generally exponential growth or decay equations and are time irreversible. The processes they describe increase entropy, in contrast to the fundamental equation for Quantum

\(^3\) For further analysis for the incorporation of potentials other than quadratic see ref.\([6]\).

\(^4\) Spin is included in extended SED as a manifestation of the polarization of background signals; see: \([6, 7]\).
Mechanics, namely, the Schroedinger Equation, which is a time reversible, hyperbolic differential equation.

Holding in view the fact that the goal or purpose of our considerations is to interpret Quantum Theory, i.e., not to analyze Nature for as yet unknown or ill understood phenomena, it can be asserted that fundamentally stochastic processes, and their mathematical rendition employing parabolic statistical processes, or their underlying mechanical equations of motion with random inputs, will not be at the core of the physical processes exhibiting 'quantum' characteristics.

Further, hyperbolic differential equations are in a class (Sturm-Liouville p.d.q.) for which the solution space has the structure of what has become designated a “Hilbert space.” This structure admits Fourier decomposition of solutions in terms of sets of orthogonal functions. Of particular consequence here is the fact that while every function in such an orthogonal set is a solution of the equation, it is in general not a particular solution for any given problem; it typically does not satisfy the initial or boundary conditions appropriate for the particular problem.

The fact that eigen vectors of the Hilbert solution space (when it exists) for an equation are only in exceptional cases also valid particular solution for the problem is an old issue. When Fourier first proposed expanding solutions to such equations in terms of trigonometric (eigenfunctions) functions it was vehemently argued that, the trigonometric eigenfunctions must be meaningless insofar as these very functions as Fourier components for, as an example, a single pulse restricted in time, themselves are not so time restricted. Were they, they would violate causality as they are finite into the future before the pulse itself is even generated! In the end this controversy was resolved as it was effectively noticed that, these Fourier components, while solutions to the equation, are not particular solutions suitable for the specific problem; i.e., they do not satisfy either the relevant initial or boundary conditions; only their sum does.

5. SED Verification failures: A Critique
Attempts have been made to verify SED by simulation of what is intended to be an electron in the ground state of a hydrogen atom but subject to the effects of exposure to the SED background. At least two such studies have been made. The first one, a 2-dimensional simulation, came to seemingly positive results for the ground state in that it appeared to be time stable.[8] However, no excited states led to such results; either the electron was seen to escape (ionize the atom) or impact the nucleus. A recent 3-dimensional simulation of much greater both numerical precision and physical reality has been reported.[9] In it the electron’s orbit as a function of time is calculated from an equation of motion alternately labeled the Abraham-Lorentz or the Brafford-Marshall (after the researchers who first employed it in the context of SED studies):

$$m \ddot{r} = - \frac{Ze^2}{4 \pi \varepsilon_0 r^3} + \frac{e^2 \dot{r}^2}{6 \pi \varepsilon_0 r^3} - e \left[ \vec{E}(\vec{r}, t) + \dot{\vec{r}} \times \vec{B}(\vec{r}, t) \right],$$

(17)

where the first term on the right is for Coulomb attraction, the second for radiation damping and the third for identified incoming electromagnetic, including thermal, signals and, in particular, SED signals. Again, integration of (rather: simulation based on) this detailed equation of motion led to ionization, not stability in a hydrogen like ground state. This result, as it stands, might be taken for being strong contrary evidence to the possibility of an SED interpretation for Quantum Mechanics.

Arguably, however, a number of fundamental considerations tend to negate this conclusion. These include:

a.) Equation (17) supports the calculation of mechanical phenomena determining individual orbits of the electron in hydrogen; as such it is parallel to the implicit underlying laws describing Brownian motion of individual molecules. In standard Statistical Mechanics or Thermodynamics
there is no theoretical route from orbital equations to a hyperbolic (vice parabolic) differential equation for the time evolution of densities on phase space. If the goal is to rationalize Quantum Theory, then this approach can be judged to be illinspired *ab initio*.

b.) When, as mentioned above, the eigenstates of a hyperbolic differential equation—here the Schroedinger Equation—are not actually particular solutions of the problem, then, even in conventional Quantum Theory also they may not satisfy the boundary requirements for a particular solution. This, in turn, implies that electron trajectories are not actually sorted or individually occupied in physically distinct orbits corresponding to the set of eigenfunctions; physically acceptable solutions, i.e., those we may imagine to be ontologically existing, would have to be a sum of eigenfunctions that do meet the initial or boundary conditions. One such possible initial condition for a density function would be that it is everywhere positive-definite. In fact, it is well known that coherent functions and thermal states meet this requirement. That particular eigenfunctions, actually their eigenvalues, are correlated with observables, mostly spectral lines, is perhaps more a consequence of the observing instrumentation than of the ontic structure of atoms. With these circumstances in mind it imagined that the parameter values used in the simulations were irrelevant to the actual problem, thus, the reported simulations would be inconclusive relative to the modified version of SED.

c.) The modified SED underpinning for Quantum Mechanics as presented herein, leads not to a description of the electron orbits as determined by classical electrodynamics, but a description of the topology of the standing waves in the background over which the electron moves. By analogy with Alpine skiing, one might say that, it provides a topographical specification of the “moguls” upon which a skier (electron) navigates passively under the influence of radiation pressure. In the case of the extended interpretation, we see that a solution to Schroedinger’s Equation provides only the topography of the moguls, not the navigation, however realized, of the electron. Rather, it is just taken as a consequence of what amounts to the Born interpretation of wave functions, that “electron-skiers” will tend to spend the most time avoiding high and steep energy moguls and less time at or near high energy zones.

In this context, it seems conceivable that, the simulations referenced above implicitly assume that the electron in hydrogen sees a broad spectrum of SED background signals, whereas in the extended interpretation the signals with nodes at the position of the electron do not interact or affect the electron. That is, only a filtered set of signals would be involved, thereby reducing the total energy of the set of effective signals. It would be unnatural to take such an energy reduction into consideration within the conceptual formulations of the cited simulations; and consequently, they would attribute excess work to be done done on a simulated particle’s trajectory leading to ionization.

Thus, in conclusion, calculations or simulations of possible electron orbits need not be expected to conform to stratified images fostered even by conventional Quantum Theory. The failure of the above cited simulations to fulfill expectations based on the original SED, constituting essentially a diffusion (parabolic) based paradigm, cannot be taken as faithful evaluation of the utility or rectitude of the extended (hyperbolic) conceptual complex.

6. A Vexation
A point of consternation found both in the current version of Quantum Mechanics, as well as in all SED interpretations, is the current understanding based on General Relativity of the divergence of the energy in either the ground state of the free electromagnetic field (per Quantum Theory) or the SED background field, i.e.:

\[
\frac{\hbar}{2} \int_{0}^{\infty} \omega \, d\omega \longrightarrow \infty.
\] (18)

In the literature developing SED, the energy spectral density, \(\hbar \omega/2\), per normal mode is
deduced by two lines of argumentation. Both are motivated on the grounds that, this background must be such that it does not distinguish a particular inertial frame—considered an empirically justified desiderata. One argument is that outlined above (§2) and based on direct, elementary employ of Lorentz transformation. The second argument is an application of Einstein’s deduction of the force resulting from radiation pressure on moving mirrors. Here the idea is to find an expression for the radiation pressure and then deduce the energy spectral density for which this force as a function of the velocity vanishes, i.e., does not offer a means of distinguishing inertial frames. Sometimes this Einstein argument is phrased in terms of seeking an energy density for which the recoil from stimulated emission compensates the directional drag or friction from Lorentz abborred spontaneous emission.

Einstein’s calculation starts by considering the abstract Lorentz transformation of the expression for the radiation density of a signal, \( \rho(\omega, \psi) \), where \( \psi \) is the azimuth angle about the signal’s propagation vector, then expresses all quantities in terms transformed variables, integrates the result over all solid angles, expands everything in sight in terms of binomial or Taylor series, and finally retains terms linear in the velocity, thereby obtaining an expression of the form:

\[
F = \text{[Constants]} \left( \rho - \frac{1}{3} \omega \frac{\partial \rho}{\partial \omega} \right).
\] (19)

The terms in the curved brackets constitute a differential equation with solution \( \rho \approx \omega^3 \), from which, after factoring off the density of modes in 3-dimensional space, \( \approx \omega^2 \), one gets Eq. (4) by fixing the constant empirically equal to \( \hbar/2 \).

Insofar as this power spectrum leads to an elemental conflict between two basic theories, there must be a mistake, at least within the understanding of one theory or the other, if not an irreconcilable conflict in their essential foundations. Something about one theory or the other must be utterly wrong. If the defect lies with Quantum Theory, then it also lies with SED in any version.

Thus far, remedies have all been not only unsuccessful, but arbitrary in the extreme. The most straightforward proposal has been to insert a cut-off upper limit to the integration in Eq. (18). However, if a cut-off is set high enough to include the frequencies needed to explain atomic spectroscopy in quantum or SED theory, then it is up to 120 orders of magnitude above a limit set by the lack of observed gravitational effects as predicted by General Relativity. Introducing a ‘killing’ exponential decay factor, \( e^{-c \omega} \) into the integrand of Eq. (18) also renders the integral finite, but still without physical justification or comparability with General Relativity. A certain degree of hope might be justified in looking for a loophole in the derivation of Eq. (19) (with its many approximations); but, so far published ideas in this direction are vanishingly small.

Arguably, the resolution for this conundrum is more likely to be found in General Relativity, for which empirical support is much more sparse than for either Quantum Mechanics or SED.

7. Conclusions

Modified SED supports an interpretation for Quantum Mechanics parsimonious and sober in its hypothetical inputs. Perhaps its greatest advantage is that it slinks right past the need for those hypothetical assumptions made regarding Quantum Theory to the effect that, wave functions pertain directly to the objects being described. Instead in SED they portend a description of an electromagnetic environment affecting the orbits of the objects of interest by means of radiation pressure. This, in turn, precludes the need for the ‘Projection Hypothesis’ according to which a material entity is realized (or converted from an ethereal ‘wave function’ to a concrete entity) by measurement or other intervention of sentient beings. Consequently, there is no need for the notion of ‘entanglement’ to explain correlations among formerly coupled entities; all correlations
are seen to result from 'prior causes' inherited conventionally.\(^5\) On the basis of these considerations it can be hoped that the world “out there” is not ontologically a mystical circus.

References

[1] De la Pena, L. (1983) Stochastic Processes Applied to Physics and other Related Fields: Proc. of the Escuela Latinamerica de Fisica 1983, Singapore: World Scientific.
[2] De la Pena, L. & Cetto, A. M. (1996) the Quantum Dice, Dordrecht: Kluwer Academic Publishers.
[3] Boyer, T. (1985) The classical vacuum: Scientific American, Band 253, Heft 2, (pp. 70-78).
[4] De la Pena, L. & Cetto, A.M.; Valdes-Hernandez, A. (2015) The Emerging Quantum: Cham: Springer Int. Pub. Switzerland.
[5] Kracklauer, A. F. (1974) On the Imaginable Content of de Broglie Waves: Scientia, 109 (pp. 111-120).
[6] Kracklauer, A. F. (1992) An Intuitive Paradigm for Quantum Mechanics: Phys. Essays, 5(2), (pp. 226-234).
[7] Kracklauer, A. F. (1999) Pilot wave steerage; a mechanism and test: Found. Phys. Lett. 12(2), (pp. 441-453).
[8] Cole, D. C. & Zou, Y. (2003) Quantum Mechanical ground state of hydrogen obtained from classical electrodynamics: Physics Letters 16, (p. 14).
[9] Nieuwenhuizen, T. M. & Liska, M. T. P. (2015) Simulation of the hydrogen ground state in Stochastic Electrodynamics: arXiv:1502.06856v2 [quant-ph].
[10] Einstein, A. (1917) Zur Quantentheorie der Strahlung: Mittilungen d. phys. Zrich, Vers. 16 (pp. 47-62).
[11] Lehnert, B. (2016) On the Cosmic Zero Point Energy Density: J. Mod. Phys., 7, (PP. 1112-1119).
[12] Kracklauer, A. F. (2015) Entanglement: A Contrarian View: J. of Mod. Phy., 6, (pp. 1961-1968).

\(^5\) The concept of ‘entanglement’ is afflicted with serious difficulties independent of its appearance within Quantum Theory. See:[12]