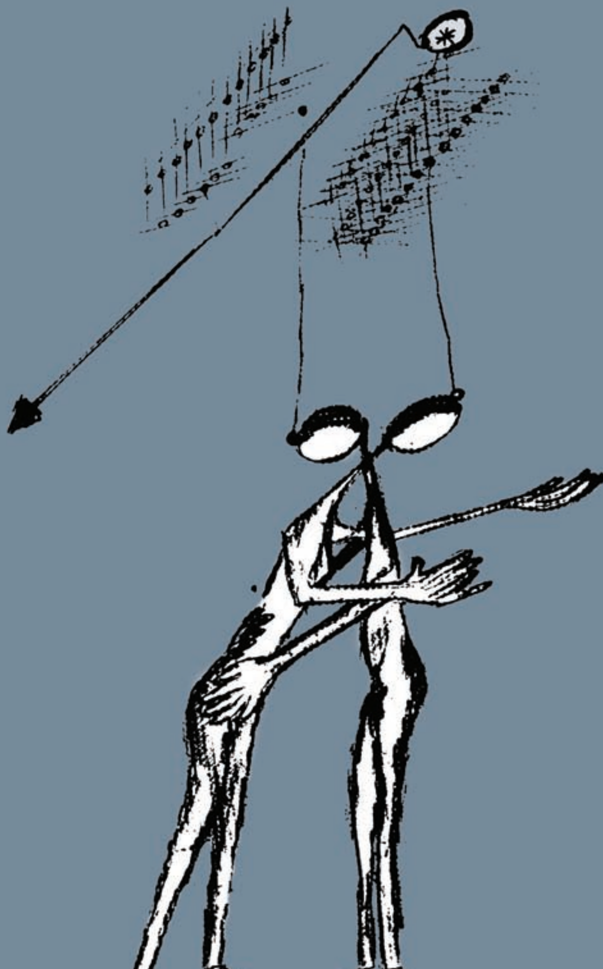
Notes on Einstein-Podolsky-Rosen (EPR) Paradox & Hamilton Optomechanical Analogy



Josh Yehoshua Shachar

"With the establishment of the statistical transformation theory the formalism of nonrelativistic quantum mechanics was completed in all its essential points. But a formalism, even if complete and logically consistent, is not yet a physical theory. To reach this status, some of its symbols have to be given an operationally meaningful interpretation (or epistemic correlation in the sense of Carnap's "phenomenal-physikalische Zuordnung"[44]). For unless a formalism is linked with certain data of sensory experience in such a way that both the beginning and the end of a chain of theoretical deductions are anchored in experience, it is not yet verifiable or falsifiable by experiment or observation and consequently not a physical theory."
Max Jammer, *The Conceptual Development of Quantum Mechanics*, 1966[45]

This monograph attempts to bring the formalism of quantum mechanics into the realm of a physical theory by postulating rules by which observable phenomena occur during the transition of a given wave packet from the entangled superposition state to the observable state. I propose a mechanism by which the energy transformation from the Schrödinger time-evolution state to the manifestable one is accountable by calculating the complete Hamilitonian and by avoiding the need to describe the collapse as a quantum jump. Modifying the 'master equation' utilizing Snell's Law provides for a wave packet reduction through the lensing effect. The reduction of the wave packet follows the Hamilton Optomechanical analogy enabling a full account of the energy transfer within the system. One interesting corollary of the optical conjecture is a possible solution to the EPR paradox.

NOTES ON THE
EINSTEIN-PODOLSKY-ROSEN (EPR)
PARADOX
&
HAMILTON OPTOMECHANICAL ANALOGY

A conjecture for a collapse theory;
Computational method for the transition from a quantum mechanical superposition state to its observable state, employing an optical-coupling operator and the reduction of the wave packet through a refraction Index model.

By Josh Yehoshua Shachar

First Edition:	September 2010
Author:	Josh Yehoshua Shachar
Editors:	Kathy Tran, Paladin Luboff , Henry Hertsel Corech
Production:	P A Art and Design www.pagraphicsonline.com

This edition published by Opticus
ISBN: 978-0-615-37806-0
Library of Congress Control Number: 2010930184
Book Design by Opticus
www.magnetecs.com
Printed and bound in the United States of America
M 9 8 7 6 5 4 3 2 1

*0. CONTENTS

*1. The quantum-mechanical view of the world may be summarized in the following manner: Physical situations are characterized by state functions; these in turn determine the probability distributions [20] of the eigenvalues of the various operators corresponding to the physical quantities that are associated with the situation. Our knowledge of how the situation evolves in time (i.e. the Schrödinger equation [1]) enables us to have the sufficient information for associating particular eigenvalues with certain physical quantities [13]. If so, what is the problem called "interpretation" within the framework of quantum-mechanics?

In this paper we shall present the above problem, namely: *Is quantum mechanics formalism is a complete description of the system?* This question was formulated by the Einstein, Podolsky and Rosen paper (1935) [2].

The problem, assuming the possibility of stating it in a generalized form, seems to be rooted in the fact that quantum-mechanics offers theoretical internal conditions for the determination of a system's values, if and only if the particular eigenvalues which occur are either 0 or 1. The question to be asked is what are we to say in regard to those quantities for which the state function is not an eigenfunction, but rather, a superposition of eigenfunction [10] (See (1) p. 6-13, p.16). This problem presents us with what is called "the dilemma of interpretation" of the quantum-theory, i.e., either we complete the assignment of values to those quantities, or give up the space-time picture of the world. Without such completion, we have no means by which to determine the momentum and the position of a particle. The uncertainty principle and the formalism of matrix mechanics [4] prohibit non commuting variable from having a precise value [12] .

*2. Einstein ((2) p. 169) in a letter to M. Born presented the problem of interpretation in the following manner:

"*…I consider a free particle described at a certain time by ... function <u>completely described – in the sense of quantum-mechanics</u>. According to this, the particle possesses neither a sharply defined momentum nor a sharply defined position. In which sense shall I imagine that this representation describe a real individual state of affairs? ...*"

In EPR's article (3) we are given the problem in a formalized manner, let us now present it: If Ψ is an eigenfunction of the operator A, $\psi \equiv A\psi = a\psi$.

Hence, the physical quantity A has with certainty the value a.

If, for example,

(2) $\psi \equiv e^{(2\pi^4 / h)P_o x}$,

where x is the independent variable, since the operator which corresponds to the momentum is,

(3) $P = \left(h/_{2\pi i}\right)\partial/_{\partial x}$,

this we apply to the first equation (in EPR's paper) and obtain

(4) $\psi \equiv P\psi = \left(\dfrac{h}{2\pi i}\right)\partial\psi/_{\partial x} = P_o\psi \cdot$

We may therefore conclude that the momentum has with certainty the value P_{o} (i.e. with probability equal to unity). If, for example, the first equation does not hold, we are unable to talk about the particular physical quantity A as having any particular value (see *1). According to quantum-theory if we know the momentum (Equation 4), we can only say that the relative probability that the measurement of the coordinate will give a result lying between a and b is (5) $P(a,b) = \int_a^b \overline{\psi}\psi\, dx = \int_a^b dx = b - a$. Since the probability depends only on the difference *(b-a)*, all the values of the coordinates are equally probable… ((3) Equations #5 & # 6 p.778)

From the above we infer that if the momentum is known, the position, in order to be known, must be measured. Such measurement, however, results in the disturbance of the system, and hence the system will not be in the state described by equation #2. The measurement will provide us with a new value for the system in which the particle has a new wave function. It thus follows that we cannot know the position AND the momentum, but rather only ONE of the two [12].

*3. The duality [5] to which we have arrived does not belong only to the particular variables of momentum and position, but rather to an infinite number of variables. In the context of measurement theory, the above is discussed in the following manner:

"…this latter dualism is only part of a more general pluralism…which refers to infinity of non-commuting measurable quantities…" (para.*4. & (4), pp. 155-156)

Einstein suggested two hypotheses regarding para. *1-*2; we shall examine the arguments in the context of the article itself, i.e. EPR, (3).

Hypothesis 1: The free particle has a definite position AND a definite momentum, hence, Ψ function represent an incomplete description of the real state of affairs.

Hypothesis 2: In reality, the particle has neither a definite momentum nor a definite position, hence, in principle, *a complete description*… ((2) pp. 169-170)

Hypothesis 1 and 2 inquire into the question presented very sharply by Arthur Fine (5):

"… just what is the problem over completeness? It is the state of the theory undetermined the values of the various quantities, leaving value gaps. (The quantities are only partial functions on the set of the states). The problem then is whether one can consistently interpolate values so as to fill the gaps, and one wants to do this in a way consistent with the assignment of values quantum-theory does make, consistent with experiment, and consistent with other plausible constraints, whether derived from physics or from metaphysics embodied in one or another 'interpretation' of quantum theory…"

EPR's argument is intended as a support for hypothesis 1. i.e. that quantum-mechanics supply only an *incomplete* description of the real state of the free particle. EPR claim that hypothesis 1 is true; therefore, they offered an experiment which may prove hypothesis 2 to be false. The following argument offered by D. Bohm (6) and Y. Aharonov is similar in structure to the one offered by EPR; let us now present it.

Consider a pair of spin one-half particles, formed in the singlest state, and moving freely in opposite directions. By the Stern-Gerlach magnets [6], it is possible to perform measurement on selected components of the spin $\vec{\sigma}_1$ and $\vec{\sigma}_2$. If the measurement of $\vec{\sigma}_1 \cdot \vec{a}$, yield the value +I, then, according to quantum-mechanics, the measurement of $\vec{\sigma}_2 \cdot \vec{a}$, will yield the value –I. (These results are possible only if Einstein's "separability" is kept, in which case the Stern-Gerlach experiment of "separability" means the orientation of one magnet does not influence the magnetic field of the other, and the potential energy v for the total system must be 0, hence:

$\underline{v(\sigma_1,\sigma_2) = v(\sigma_1) + v(\sigma_2) + v_{12}(\sigma_1,\sigma_2) = 0}$, and where v is equal to 0.

(Note that this is the core of the Furry's hypothesis regarding the Hamiltonian complete description of the system after separation, and the answer to this description is a central theme of the collapse theory which we advocate in this paper).

The argument follows by stating that the result of measuring any chosen component of $\overrightarrow{\sigma_2}$ by previous measurement of the same component of $\overrightarrow{\sigma_1}$ in the correlated system.

It logically entails that the result of any such measurement must be predetermined and since a quantum-mechanical wave-function does not determine the result of an INDIVIDUAL measurement, the predetermination implies that there is a possibility to arrive to a more complete description of the real state of affairs of the free particle, a result which contradicts hypothesis 1.

EPR, by following a similar argument to the one we have presented above, concluded the following: either (a) the quantum-mechanical description of reality, given by the wave function, is incomplete, or (b) when the operator corresponds to two physical non-commuting quantities the two quantities cannot have a simultaneous reality. (EPR p.126)

Remark: *The answers given by EPR in their article contain other issues which we did not yet examine. I choose to postpone their presentation to a later stage in the paper, so as to confine them with D. Sharp's (7) criticism and thus eliminate repetition.*

*4. The conclusion arrived by D. Sharp (7) in his article is identical to the one arrived at by N. Bohr in 1935 – Bohr (31) objections to EPR's hypothesis 1, relies on the knowledge that quantum mechanics formalism for the correlated system is based on Born's density function, which describes the probability of assigning an eigenvalue to a specific observable in a system by the use of Schrödinger equation while the system is in a *superposition* state, further mandating that any property of the system exist *not* only in one state, but all possible states at once. Due to this property, to completely describe a particle one must include a description of every possible state and the probability of the particle being in that state. Since the Schrödinger equation is linear, taking into account all possible states will be a linear combination of each solution [20]). Sharp centers his arguments against those of EPR in his technical-mathematical representations which further distinguish (his solution) from Bohr's by claiming that *"it is of interest because it does not rely on the epistemological presupposition of N. Bohr…"*

It is not my aim in this paper to examine Bohr's position in his article "Discussions with Einstein on the epistemological problem in atomic physics" (8), however the relevant discussions made by Sharp in his article ((7) p. 135-232) will be examined in the following paragraphs. It is essential to distinguish between Bohr's solution, centering on the definition of "physical reality", and Sharp's solution, based on the techno-mathematical claims which are either verified or falsified by an experimental means and are based on the "fact" that the Hamiltonian of the system after separation violates the canonical description of quantum mechanics. In section *3 we demonstrate that through the proposed experiment we employ a Stern-Gerlach apparatus (similar in structure to that of EPR's arguments but by employing a spin-half particles, instead of photons).

EPR employs the criterion of "completeness" and "reality", thereby arriving to their conclusion that, either the quantum-mechanical description given in terms of the wave function Ψ is incomplete, or non-commuting observables have a simultaneous reality.

In addition to what we have stated above, EPR offered two additional conclusions:

C_1: To one of the subsystems several inequivalent descriptions can be assigned, and:

C_2: The eigenfunction describing this subsystem could have belonged to the operators of non-commuting observables, a contradiction within the formalism of matrix mechanics and violation of the experimental data.

Conclusions C_1 and C_2, taken with respect to the "reality" and "completeness" criteria, constitute the "EPR paradox", i.e. the view that quantum-mechanics is essentially an INCOMPLETE DESCRIPTION OF NATURE (Sharp p.226).

4.01 In order to clarify those arguments which serve as the "building-stones" of the EPR paradox, it is important to first define certain concepts, i.e. concepts having a "rooted fuzziness" that complicate the interpretation of the paradox, e.g. "no interaction", a construct which in our review weakened the strength of the arguments given by EPR and led to Bohr's criticism in 1935 and later to Sharp's comments in 1961.

"No Interaction": The two systems do not interact if and only if the potential energy of the total combined system in $V_{12}=0$. If this condition is fulfilled, the systems S_1 and S_2 are separable.

Based on the definition of "no interaction", let us now measure some physical quantity A in system S_1. We know that for every measurable physical quantity A, there correspond an Hermitian Operator [13], i.e. an operator for which the eigenvalue problem can be solved ((1) p.16), therefore, the wave function $\psi_1(\bar{r}_1)$ will be presented as $\psi_1(\bar{r}_1)=\sum_n a_n\psi_n(\bar{r}_1)$ - this step is called "preparation".

4.02 After the step of preparation, the single eigenfunction for S_1 is $\psi_k(\bar{r}_1)$ and the whole system, immediately after the measurement, can be presented as S_{12}: $\Psi_b(\bar{r}_1,\bar{r}_2)=\psi_k(\bar{r}_1)\psi(\bar{r}_2)$, where $\psi(\bar{r}_2)$ is as yet a purely arbitrary function.

4.03 S_1 and S_2 are correlated systems so that the measurement of the physical quantity A can be regarded as a measurement of the WHOLE correlated system S_{12}. (This conclusion is built within equation 7 in Sharp's paper and is represented by $\Psi_b(\bar{r}_1, \bar{r}_2)$).

4.04 Two results may be obtained from 4.03:

a_1: $\Psi_a(\bar{r}_1, \bar{r}_2)$ may be considered as the state function <u>prior</u> to the measurement. (See 4.02), and

a_2: $\Psi_b(\bar{r}_1, \bar{r}_2)$ is the state function <u>after</u> the measurement.

Let us now make a comparison between equation 6 (where $\psi(\bar{r}_2)$ is a purely arbitrary function) in Sharp's paper and equation 7, also in Sharp's paper (where $\psi(\bar{r}_2)$ has a <u>definite value</u>) – the results are the following:

b_1: $\psi(\bar{r}_2)$ may be determined by Eq. 7

b_2: $\psi(\bar{r}_2)$ may be an eigenfunction of some quantity in S_2

4.05 From 4.01-4.05 we are able to conclude that the measurement of the physical quantity A (with the corresponding Hermitian Operator A operating on the elements of the vector in Hilbert space [25]), will yield the predication of the definite value of A's measurement (called the state function Ψ of the measurable A in the system S_{12}), in the correlated system S_{12}, $\Psi_b(\bar{r}_1, \bar{r}_2) = \Phi_k(\bar{r}_2)\psi(\bar{r}_1)$, where ψ_k is an eigenfunction of the observable in system S_1, and Φ_k is an eigenfunction of an observable in S_2.

4.06 However, $\Psi_a(\bar{r}_1,\bar{r}_2)$ (the wave function prior to the measurement) does not contain sufficient information for describing the state function of each system S_1 and S_2 separately, but rather, the state of the whole correlated system.

4.07 Following *3 (i.e. the Stern-Gerlach experiment), where we have demonstrated that if a measurement is performed on one of the sub-systems (spin component $\vec{\sigma}_1$), enough information is being acquired for determining which eigenstate is to be assigned to $\psi(\bar{r})$. According to quantum-mechanics, if measurement is to be performed on a system S_2, the eigenfunction will be $\Phi_k(\bar{r}_2)$. This result will be predicted with certainty and therefore, according to Einstein's "Reality Criterion", there is an element of physical quantity measured in S_2.

4.08 Let us now instead of measuring quantity A in S_1, measure quantity c with the eigenfunction $c-\zeta_\eta(\bar{r}_1)$, by a syllogism identical to that in 1-8 in EPR's paper, the conclusion to which we'll arrive is that S_1 is described by the eigenfunction $\zeta_k(\bar{r}_1)$, and S_2 is described by the eigenfunction $\eta_k(\bar{r}_2)$.

4.09 It is assumed that generally $\eta_k(\bar{r}_2) \neq \Phi_k(\bar{r}_2)$.

4.10 It thus follows that S_2 will receive two different descriptions. The two descriptions $\eta_k(\bar{r}_2)$ and $\Phi_k(\bar{r}_2)$ would depend on the measurement performed on S_1.

4.11 The next step taken by EPR is the exploration of the possibility that $\eta_k(\bar{r}_2)$ and $\Phi_k(\bar{r}_2)$ could belong to the operations of non-commuting observables.

*5. In the following paragraph, we present the pair-concept "uncertainty relation" and that of "the operators of non-commuting observables" as defined by matrix mechanics. That is to say, there is a certain level in which both philosophers and physicists agree regarding that "fact", i.e. raw experimental data; our intention in this paper is to present this consensus and to examine through it the solution given by EPR and Sharp, and by further separating the notion of 'separability' and the Hamiltonian of the system, as it is the center of disagreement which lead one to a state of paradox, while the other describes the state of affairs as a mere confusion in utilizing the canonical machinery of quantum mechanics. The conceptual and techno-mathematical problem in quantum-mechanics results mainly from the formal necessity of describing the elementary particles in terms of both wave and particle (Louis de Broglie 1924, E. Schrödinger 1925). Hypothesis 1 and 2 (*3) examine whether or not the situation described by quantum mechanics is actually the real state of the particle in nature. In the following discussion, we'll present certain facts that will clarify our later criticism and the root of the disagreement between EPR and Bohr (or, between all the supporters of the Copenhagen School and those who are supporters of determinism, which in turn is supported by algebraic constructions of local hidden variables theories[8]). The Copenhagen School regards the situation where the particle does not possess a defined momentum AND position, as the adequate description of the particle (see hypothesis 2 and para. *3), they argue against the claims given by EPR (3) and Bohm and Aharonov through the usage of the following analysis:

5.01 In "reality", the particle has neither a definite momentum nor a definitive position, the description given by the Ψ function is, in principle, a complete one, i.e. quantum mechanics formalism is a complete description and it is the real state of affairs.

5.02 Since, according to the Copenhagen School interpretation [3] the wave particle duality is a fundamental one, the numbers yielded by the machinery of quantum mechanics must be generated through the use of some calculations techniques that consider both field theoretic and particle theoretic data. (See (8)(9) p. 234-235),.

5.03 In that respect, EPR's paper may be viewed as a manifestation of the 'hope' to discover some analytical error in calculations within the quantum mechanics (by the suggested system). Such discovery will prove that the description given by quantum mechanics is INCOMPLETE. The hope is based on the classical notion that in reality the theory can be revised by introducing hidden variables which will complete the description, while the fundamental duality of the wave particle, under the uncertainty relation, is due to the formalism of quantum mechanics but the natural state of the physical reality is inherently classical, hence the wave particle does possess a simultaneous reality of position and momentum that is hidden, and thus is intuitively plausible! The measurement problem declared under the non commuting variables doctrine and Dirac matrix representation is a theoretical limitation, not the natural state of affairs, according to the EPR's assumptions.

In order to prove the above point, EPR resorted to determinism, completeness, and causality. The hope for such a discovery is to be found in Einstein's article "Physics and Reality" (9):

"...To believe this (quantum-mechanics) is logically possible without contradiction, but it is so very contrary to my scientific instinct that I cannot forego the search for a more complete description."

This is the motivation behind EPR's arguments against the present semi-completeness of quantum-mechanics.

Let us now present the arguments which demonstrate the reasons why the Copenhagen School considered the above hope to be impossible within the framework of quantum-mechanics. Quantum mechanics considers the state of entanglement[10] a fundamental property of a correlated system, as it is in a superposition state and it is forbidden that any of the infinitely conjugate non commuting variables (such as momentum or position in the S_{12} system) be measured without a violation of the Schrödinger equation (which itself describes how the quantum state of a physical system evolve in time).

5.04 According to Dirac's operator calculus (10) which consists of the non-commutative relation between particular parameters (i.e. position and momentum, or time and energy), the most we are able to arrive at in our knowledge of the micro particle is its partially defined state. This view is sharply contrasted with the classical one, which assumes that physical reality of non commuting variables and their properties exist without the act of measurement of the observer. We shall examine the content of the classical conception in the conclusion and as it was established by the fact that, maintaining a local hidden variable theory in light of Bell's Theorem [9] and its experimental data space, is inconsistent with the EPR hope as the corollary to such efforts will violate the special relativistic axiom of the finality of speed of light, leading to 'spooky action at a distance'.

5.05 The manner by which Dirac's conclusion is contrasted with the requirement of classical determinism is seen in the following:

Given that a particle is in location x, y, z with time t, we can, according to the classical view such as that of EPR's paradox, completely defines all the parameters. This causal syllogism cannot be given in quantum theory.

5.06 Dirac's calculus proved that the wave function description can be transformed into an equivalent matrix description and vice versa, since neither the wave nor the particle approach the elementary processes with high significance, thus symmetry has been reached. This symmetry was taken as an argument against the possibility of EPR's experiment, which reasserted the fundamental and irreducible nature of the wave-particle duality and the overwhelming experimental data that followed.

5.07 In this paragraph, we will formulate the reason behind the impossibility to realize the hope expressed in 5.03 within the framework of quantum-mechanics. We'll also cover the reasons behind the position expressed in 5.01 – 5.02 and Dirac's conclusion expressed in 5.04 – 5.05 which serve as an argument against the viewpoint of EPR. It must be noted that the description we shall supply is technically incomplete and is a schematical account of the subject, imposed by the framework and limitation of the present paper. The aim is to present the pragmatical as well as principal considerations assumed to be essential to the ortodox interpretation of the Copenhagen School in order to prove their claims; i.e. that the quantum-mechanical "world picture" is a complete one, and that any attempt to supplement the theory will violate the actual state of affairs of the system. We shall further demonstrate the reason why this position is contradicted within the deterministic picture offered by classical physics and maintained by EPR in their attempt to supply a "more complete description of the system S_{12}.

Suppose that an electron e, described in the Schrödinger manner (i.e. cluster of interference or wave group ((1), p. 15, 21, 62)) is to be located. To "locate that electron" as a classical "point mass" of the intersection by the coordinate x, y, z and time t, would require the introduction of an infinite number of waves, and infinite number of varying amplitudes and frequencies. These conditions must be fulfilled in order to "Squeeze" the wave packet into a "vertical line" ("points-mass") – (this requirement is part of the mathematical description of the calculation in Hilbert space [25]). The above theoretical move will render our knowledge of the electron's energy, as unknown (conceptually, the energy is linked with the amplitude and frequency of the wave in that particular configuration space). The link makes it impossible to determine which of all the different waves is to be identified with the energy level of the electron.

5.08 Suppose we were to determine the energy of the electron e; we should perform an opposite step to the one described in 5.07, i.e. decrease the different phase wave in order to reach a monochromatic result with respect to the configuration space. The above move permits the physical entity to occupy an infinite number of possible positions. EPR describes this phenomena in the following manner: $P(a,b)=\int_a^b \overline{\psi}\psi\, dx=\int_a^b dx=b-a$ and thus, the whole interval of infinite continuous and distinct values lies in the difference 'b-a' which are the possible values of the coordinate of the particular particle e.

5.09 In explaining the phenomena described in 5.07, we are confronted with "nature itself". This in turn presents us with an elementary particle that is an insolvable pair of wave and/or particle. Taking the operational definition of the "uncertainty relation" and Dirac's calculus with the conclusions it entails, that the Copenhagen School, mainly Bohr, treats hypothesis 2 as not a mere technical truth (see argument in *3). In Tarsky's usage of the notion "truth", i.e. a predicate which fulfills certain recursively defined conditions), but rather as a truth in the classical sense, i.e. adequate for the picture of reality given through "empirical experiments". Hypothesis 2 is supported by an additional rule, namely, "the irreducibility of statistics":

"There is no property in any system which specifies in advance the result of an observation of a quantum mechanical dynamical property more precisely then does the quantum-state of the system itself".

ERP expresses their position with regard to hypothesis 2:

"... while we have thus shown that the wave function does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe however, that such a theory is possible.." (EPR p. 780)

5.10 As we examine the Copenhagen School's conviction as to the impossibility of describing simultaneously the position and momentum, we find that their stand on this matter is not a pragmatical one, i.e. a matter of insufficient apparatus and primitive devices for measurement of simultaneous properties of non commuting variables, but rather it is a consequence of their fundamental premises which they consider as built-in within the basic formulation of quantum-theory (Dirac's operator calculus). If metaphysics is to be embodied in this factual discipline, it is to be structured within the basic formalization in the following way: from the lower order of factual information up to the higher order inferences, the same patterns of inference rules can be applied to the organization and interrelationship of the data (e.g. Dirac's operator calculus with respect to the existence of a joint probability distribution for position and momentum at a given instance). From Von Neumann and Bohr's proof, we find it to be unacceptable to have elementary processes which are at once deterministic and yet have certain hidden variables beneath the surface of the performed observation. As a result, the EPR's expression of the following is MEANINGLESS according to quantum-mechanics;

"The exact state of the electron e is exactly at position x,y,z at time t with precisely the energy v…".

Paraphrasing on a positivist interpretation of this state of affairs based on quantum mechanics use of its formalism, the above sentence is clearly not a well formed expression within the syntax or semantical denotation of quantum mechanics formalism as Dirac's calculus would entail. (It is noted that subsequent review of the von Neumann's proof, by Bohm et al. (38) pp. 460-462 demonstrates that *the "proof is circular and that the conclusion is tacitly assumed in the premises on which the argument is based"*,)

With respect to the "Uncertainty Relation" expressed by Dirac's operator calculus, demonstrating the impossibility of having the non commuting variables as noted above, such a statement of the above type is virtually un-grammatical within quantum-mechanics. Again, we will assume that the impossibility imposed by the Dirac's matrix representation of conjugates-non commuting variables is inherently related to the matrix representation and its diagonal limitation.

It is noted that the *pilot wave theory* with a revised formalism and assumptions enable the derivations of such variables by analytical methods, as the first derivative of the position under the pilot wave formalism will result in computing the velocity and momentum when the results are expressed in spherical coordinates within the Lagrangian matrix.

In the following sections of the arguments we will try to explain why EPR's experiment is not a grammatical expression from the stand point of quantum-mechanics (we assume here that it is known that a WFF (well-formed formula) is a sentence, if it fulfills the mathematical requirements defined by Dirac's operator calculus). This explanation will be given jointly with the representation of Sharp's suggestion and Putnam's criticism as their assertions and criticism follow the logical arguments of Dirac's calculus and the inherent uncertainty relationship established by the matrix results relative to non commuting variables.

*6. The hypothesis examined in Sharp's article is to be found on page 229 of EPR's argument against the completeness of the quantum-mechanical description, it follows that the argument is relevant only if the formulation which it uses <u>is the most complete one available within the framework of quantum-mechanics.</u> Sharp considered the description used by EPR to be incorrect, i.e. the formalization of the correlated systems "*especially in describing the state of the system after measurement*" (p.229). Sharp's first argument is similar in structure to an argument given in 1936 by W.H. Furry, known as "Furry's hypothesis." Furry's hypothesis claims that from the point of view of quantum-mechanics the correlated systems S_1 and S_2 are best described, after they are spatially separated and have ceased to interact effectively, assuming their wave function is no longer a <u>pure state</u>, but rather <u>a mixture</u> of simple product states, in a manner by which each element of the mixture is in a definite state. The predictions for "joint measurements" (that of $\pm S_1$and $\pm S_2$ respectively) which are based upon a mixture, are different from those given by EPR's assumption, i.e., the assumption that a measurement of S_1 brings S_2 into a pure state. Since Furry believed quantum-mechanics to be correct, he inferred that a state, similar to equation (7) in EPR's paper, does not evolve automatically into a mixture of the Ψ function when S_1 and S_2 are separated from each other. (A detailed explanatory discussion is to be found in (12), on the topic of "Furry's Hypothesis", appendix 1 p. 191-192, and Furry's Note on the quantum-mechanical theory of measurement (30)). Therefore, step 7 is not the most complete description available within quantum-mechanics. Sharp claimed that two assumptions in equation 7 and 8 serve as the basis of EPR's formalization by which they arrive to their first assumption:

"That formula (7) is precisely correct before the measurement".

According to Sharp, the above assumption seems to be correct although he never actually explained why he considered "Furry's Hypothesis" [11] to be the possible direction by which to prove that Eq. (7) is not the accurate description of the system. A more systematic account on the problem can be found in (1) p. 211-224. Furry's conclusion is supposed by a different aspect of measurement theory, as it appears in the article "The problem of Measurement";

"It follows that it is not compatible with the equations of motion of Q.M. to assume that the object plus apparatus is, after measurement, a mixture of states each with a definite position of the pointer. It must be concluded that measurements which leave the system object plus apparatus in one of the states with a definite position of the pointer cannot be described by the linear laws of quantum-mechanics" (see (4), p. 163-164)

Let us now examine Sharp's argument against the formalization given by EPR:

6.01 Sharp's arguments against EPR's representation of the correlated systems S_{12}, after the measurement are the following:

(a) EPR assign separate states to parts of correlated systems (after the measurement of a component of S_1)

(b) (a) is incompatible with the most exact quantum-mechanical account (see (1) p. 85, with respect to "non-seperability")

(c) If (a) is false, it follows from the quantum-theory that only the entire system possesses a state-function.

(d) If (c) is a true statement within quantum-theory, it follows that separate components of the whole system, S_{12}, will not be represented by pure states after the measurement.

(e) If (a) – (d) are true, we are to interpret the measurement performed on S_1 only as a measurement of the whole correlated system S_{12}. This measurement places the whole system in a pure state.

(f) If (e) is true, then it is false to consider the measurement of S_1 as throwing S_2 into a pure state.

(g) From (a) – (f) we may conclude that EPR's argument (paradox), i.e. the claim that system S_2 possesses two different descriptions (state functions) $\Phi_k(\bar{r}_2)$ and $\eta_k(\bar{r}_2)$ is refuted.

(h) From (g), we are able to infer Sharp's conclusion, i.e. that the two different values (descriptions) of S_2 $\eta_k(\bar{r}_2)$ and $\Phi_k(\bar{r}_2)$, are simply a result of two different measurements of the whole correlated system S_{12}.

6.02 Sharp does not provide a proof showing why ERP's assumption that "the exact measurement of observable A in S_1 is possible" is correct (assumption noted in (8) p. 229). Instead of a proof, Sharp's notes employ E.P. Wigner's conclusion (1952) which showed that in a closed system, including the measured object and the measuring apparatus, the only quantities capable of being measured with exactitude are those which commute with all conserved quantities; this excludes position as long as the total momentum is conserved. (Wigner Z. Physik 133, 1952). The semi argument given above is not sufficiently strong, as it is dependent on the assumption that the observables or non-commuting operators cannot have a simultaneous reality. This assumption is precisely the one proved as incorrect by employing the EPR's formalization. Using Eq. 9 – 18, where EPR claimed that it is generally possible for Φ_k and η_k to be the eigenfunction of two non-commuting operators corresponding to physical quantities, we are able to conclude that the proof described in 6.02 is irrelevant to our present discussion, since EPR's aim at proving that *"it is possible for Φ_k and η_k to be eigenfunction of two non-commuting operators…"* ((3) p. 780). But, we can accept Sharp's view of the matter discussed above IF we assume Wigner's proof to be true. Wigner claimed (with the help of von Neumann's formalization) that the above "unrealizable" description is "unreal" from a physical point of view and is further in violation of Heisenberg uncertainty principle[12] as it assumes the fundamental view that the "real" nature of a particle/wave duality governed by $\Delta X \Delta P \geq \hbar/2$ is irreducible. John von Neumann initiated the hidden-variable program and gave an impossibility argument which was proven to be incorrect. In fact, his argument is now known to use too-strong assumptions (Bell (13a), 1966). It is the modern impossibility results of Bell (13), and Kochen-Specker (22), 1967 that are now considered decisive. Still, von Neumann's position was clear, as in the often-quoted statement: "The present system of quantum mechanics would have to be objectively false, in order that another description of the elementary processes than the statistical one [i.e., in order that a hidden-variable description] be possible" ((23), 1955, p.325).

6.03 Sharp's last argument is the most complex and controversial. The argument intends to contradict assumption (b), i.e. that the exact measurement of quantity "A" must throw the whole correlated system S_{12} into a state represented by the expression $\phi_k \psi_k$ (where $_k$ represents a factorization of the whole system after the exact measurement on the physical quantity "A" was made). According to Sharp, this factorization means that S_1 and S_2 are separable, and therefore that the potential energy of the whole system S_{12}, represented by $r_{12} = (\bar{r}_1 - \bar{r}_2) = 0$, is a true description. He claimed that <u>this representation of the whole system S_{12} is simply contrasted with the factual situation described by quantum-mechanics.</u>

6.04 Sharp's arguments against Einstein's principle of seperability of mechanically isolated systems are the following:

(a) The representation of the "Seperability principle" in EPR's experiment holds, if and only if the equation $r_{12} = (\bar{r}_1 - \bar{r}_2) = 0$ is true. This result, according to Sharp, is contrary to the "fact". He therefore infers that $r_{12} = (\bar{r}_1 - \bar{r}_2) \neq 0$.

(b) The argument in (a) according to Sharp is true, since he assumes two forms of interaction between charged particles (that are in an infinite distance apart) which can never vanish, consisting of (i) gravitational interaction and (ii) electrostatic interaction.

In (1) p. 76-81 d'Espagnat presents a definition for the "Seperability Principle", thus Sharp's problem, as it is presented in (b), goes through a certain modification:

"If a physical system remains, during a certain time, <u>mechanically</u> (including electro-mechanically etc...)

isolated from other systems, then the evolution of its properties during this whole time interval cannot be influenced by operations carried out on other systems". ((1) p. 81b)

The above form of presentation minimizes the problem involved in Sharp's arguments which were presented earlier.

(c) If interactions 1 and 2 are included in the Hamiltonian [7], i.e. the total energy of the whole correlated systems S_{12}, the wavefunction is no longer represented by the product $\Psi_b(\bar{r}_1,\bar{r}_2)=\psi_k(\bar{r}_1)\phi_k(\bar{r}_2)$. (This result is also supported by assumption (b) in 6.03.

(d) If (c) is true, then it follows from the considerations presented in 6.03 and 6.04 (a) – (c) that EPR's formal mechanism does not hold any longer. *('separability', hence completeness of the Hamiltonian is an essential element in the logical soundness of EPR's conclusion!)*

(e) EPR's assumption regarding the separability principle is violated by Sharp's inclusion of assumptions b(i) and b(ii), i.e. electrostatic and gravitational interaction. Therefore, the energy of the whole system will not be represented by the Eq. $r_{12}=0$ (see 4.01). As we have already established, the definition of separability simply means "no interaction", assuming that the Hamiltonian description $H=-\frac{h}{2m_1}\nabla_1^2-\frac{h}{2m_2}\nabla_2^2+r_{12}(\bar{r}_1,\bar{r}_2)$ is not the complete description of the potential energy of the whole system since the value of the total energy is $r_{12}\neq 0$, as a result of external influence which must be presented by a new potential r_g (gravitational influence) and r_s (electrostatic influence). These two potentials r_g and r_s are not part of the correlated system S_{12}, and must be regarded as external sources, which are by definition subjected to quantum-mechanical jump out of pure state of the time evolution state of the system. Following Sharp's article, we say that the Hamiltonian description does not represent the situation on which EPR based their calculations, i.e. their assumption of <u>isolation</u>, or no interaction does not hold and the system is not in a superposition state but a mixture states. This description simply means that the forces acting on the component systems are not <u>conservative</u>. If we "open" the correlated system to these unknown potentials, the system can no longer be represented by the product $\Psi_b(\bar{r}_1\bar{r}_2)$ and therefore the *"formal mechanism by which EPR reach their conclusion collapses"* (Sharp, 230). Hence, <u>conclusion</u> (e) <u>confirms Sharp's resolution of the paradox.</u>

6.05 The argument offered by Sharp is of the type called "Epistemological Consideration", since it does not present any possible experiment for verifying its statements. The above limitation placed on Sharp's argument does not contradict the fact that his argument is compatible with the findings of quantum-physics. (See mainly (12) article, paragraph 7.4, and p.1921). Although Sharp does not say it explicitly, it seems evident that the general conclusion arrived at in his paper is the following:

The seperability principle, (no interaction $r_{12} \neq 0$*, etc…) in spite of being characterized by apparent self evidence, must be abandoned. The operative conclusion, from the non-separability point of view, is that we should consider the whole system as ONE system rather than two. In spite of the possible separation of the corresponding wave packets, we must consider each spin as forming only one system, e.g. in the Stern-Gerlach magnet experiment.*

*7. Clauser J.F. & A. Shimony (12) conclude the following in their article:

"The argument of EPR is powerful, since their conclusion surely follows from their plausible premises…" The above conclusion would have been true, if and only if it was possible to find an experiment which fulfills the requirements described by the "Separability Principle" in such a way so as to make the description given by EPR to S_{12} a correct physical description of isolated systems; i.e. the formalization which describes the isolated system would have the form $\Psi(\bar{r}_1,\bar{r}_2)=\psi_k(\bar{r}_1)\psi(\bar{r}_2)$. In this manner the paradoxical conclusion of EPR would have been a rather valid one. Since one of the most basic phenomena in quantum-theory is the <u>possibility of prediction</u> with a certain probability of the future occurrence of some event rather than a <u>deterministic prediction</u>, i.e. "that the event will either happen or it will not", it follows that the function can describe the elementary particle in a probabilistic manner; i.e., the possibility of finding the particle at any given point is proportional to the square of the wave function[20] at that point (see Healy's (24)). This approach represents a 'semantical' way out, so as to 'plug' the logical incongruence between the subatomic transition and the classical/observable description of the collapse. The problem as I state in my arguments that follow is not the issue of how do we establish a coherent picture of the wave particle duality, as an observable phenomena, (see the double-slit experiment), but how do we to account for the transition from the micro state - A pure state of the time evolution function - to its mixture state, i.e. the Schrödinger's cat paradox.

We need a description of the system's Hamiltonian that represents the wave packet reduction as an *energetic event*, not a mathematical construct with semantical overlays that mask the conundrum represented by the EPR's paradox. The transition from superposition to its mixture as advocated by Sharp's arguments does not provide an energetic account of the total energy while employing the Hamiltonian total energy account as a reason for rejecting EPR's conclusion. Sharp does not explain the collapse of the wave to its mixture state, he is only stating such event an without accounting for it.

Let us suppose that the elementary particle is actually detected. An interesting epistemological question arises at this point: "did the particle have a definite position all along, i.e. even before the measurement was made"? This point brings us back to our starting point, as it presents us anew with the disjunction between hypothesis 1 and 2. In order to answer the above question and save the hypothesis, EPR offered their experiment. We have seen earlier in our discussion that EPR's solution does not satisfy the standard Hamiltonian description/requirements of quantum-mechanics, i.e. the requirement that a system is "isolated" was found as lacking a full description of quantum-mechanics' Hamiltonian under the conditions given in the experiment, (Furry's conclusion). As noted in their article (12), EPR's conclusion follows consistently from their premises, however one of the crucial assumptions on which they base their conclusions rests on the "Separability Principle", which is further based on the assumption that S_1 and S_2 are two systems which have interacted in the past, but at the time of the experiment these systems were spatially separated from each other. We have observed that the "Separability Principle", i.e. that there is no space which is like propagations of influences, crates a conceptual and technical problem with respect to the predictions and representation of the state function of the system according to conventional quantum-mechanics. We have thus arrived to the conclusion (following Sharp, Putnam, d'Espangat) that the principle of saperability as it appears in EPR's paper is false. d'Espangat on page 147 states the following:

"On the other hand the very ease with which we find these apparent counter examples to the seperability principle should make us doubtful about their real validity as such. Obviously, none of the facts we have just listed were unknown to Einstein; that he could nevertheless give credence to the seperability principle should induce us to try to be critical in the use of our conceptual framework as we are accustomed to be in the case of our mathematical formalism..." ((1) p.146-147). In the arguments that we posits we will demonstrate that although the EPR's paper does not account for the proper Hamiltonian in assuming the state of the system $S_{12,}$ it does not follow from the critique of Sharp and his contemporaries that the master arguments of the EPR's authors is wrong; on the contrary, the conclusion that follows from their arguments is a valid one, stating that quantum mechanics is not a complete description of the system $S_{12,}$ as it does not address the fact that the transition from the pure state to its collapse cannot be described by the probabilistic Boher's interpretation, as the mechanism of the collapse cannot be a semantical/ mathematical tools. (EPR's authors were clearly aware of the Boltzmann statistical interpretation of an ensemble of particles.

7.01 It is important to distinguish between the argument presented by Sharp (and the continuation of this line of argument given by Putnam (11)), from the one presented by Bell in 1964. The difference between these arguments lies in the fact that we do not use non-locality of many wave function particles as an argument against separability, e.g. the experiment suggested by Kasday, Ullman and Wu in 1971, or the cascade photon experiment suggested by Freedman and Clauster in 1972 (see (12) p. 1903-6). In the context of our discussion we must consider the <u>interpretation of the wave function</u>, described by Sharp and Putnam, to be the locus of the disagreement between EPR and Sharp. The line of arguments we follow are centered on the Hamiltonian description, not as an afterthought by the EPR's authors, but as the fundamental issue that quantum mechanics must account for the transition between micro state and the subsequent "emergence' of the macro-state. Not as a mathematical trick, or a complex gymnastics in verbal-descriptive adjectives (such as noted by the use of 'emergence' in the decoherence approach, or the large number statistical emergence as in GRW's theory). A physical description of 'How do we account for the transition between the states', so as to resolve the Schrödinger's cat paradox, within the existing formalism of the standard QM is still pending an explanation. The 'quantum jump' from the linear Schrödinger time evolution equation to its preferred basis (an eigenvalue) is a 'jump', hence we conclude that the paradox is unresolved.

7.02. Our attempt in this paper is to describe the considerations which led to the paradox, and the considerations behind those who did not accept it. In part, we have given pragmatical considerations rooted within quantum-mechanics as results of certain relevant experiments, and we tried to demonstrate the common line taken by all those who have rejected EPR's conclusion as it is presented by the correlated system after the measurement of component A in System S_1. Principal considerations taken from the uncertainty relation demonstrated the impossibility of performing measurement identical to the one described by EPR. More than that, such measurements are <u>inconceivable</u> within the framework of quantum-mechanics. We have dealt with the concept "Isolated System", and the conclusions advocated by Sharp and Putnam regarding the impossibility of describing the system as if the interactions can be accurately expressed by a Hamiltonian equal to: $r_{12}(\bar{r}_1, \bar{r}_2) = 0$, as external influences violate such representation. Sharp and Putnam concluded that EPR's paradox is "no longer a paradox", but rather an error in the representation of the correlated system, i.e. an error that rests on the concepts of "Reality" and "Separability". Applying some concepts of semantics, we may say that EPR agree as to matters of fact and in their "meaning" in the "surface structure", i.e. as a starting point they assume that the statistical predictions of quantum-mechanics are correct, but in their "deep structure" they use a set of considerations which result in the discovery of the "incompleteness" of quantum-mechanics, or its inconsistency if it is complete description of the system after separation, (See (3) Eq. 9, Eq. 18, EPR p. 129-130). From Wigner's conclusion (see sub Para. 6.02) and Dirac's operator, it is derived that the EPR's proof is shaky due to its logical and theoretical inconsistency, (non commuting operator cannot be calculated using Dirac' matrix mechanics as conjugate variables are subject to the Hiesenberg uncertainty principle), as viewed from within the framework of quantum-mechanics. This is why Bohr and Sharp demonstrate that EPR's experiment is ungrammatical in the syntax of quantum-mechanics. The arguments we have presented show that the fundamental assumption called "Separability" does not stand the test of physical reality as it follows from the experiments and proof of Bell (13) in 1964.

To conclude we may also say that EPR's argument (including the paradox) WOULD have been valid if the separability principle was satisfied. The physical situation described by EPR is of immense importance in the examination of the philosophical implications of the quantum-mechanical view of the physical world. As Putnam puts it: the situation in quantum mechanics is parallel to that of the foundation of calculus in the 18th century, i.e. when its foundations were yet undecided.

"…but quantum mechanics, has not, up to date, been grounded in a consistent and, in principle, mathematically rigorous theory…" (Putnam IIa p.2). EPR's paradox is a pictorial projection of the above fact, i.e.*"That is usual, quantum mechanics provides no rigorous contradiction-free account at all"* (see Putnam, 11,11a).

In this work I have ignored the findings and experimental support generated subsequent to Bell's theorem. I limited myself to earlier critiques and positions held by the parishioners of QM and set the discussion by adhering to the historical context of the authors. The discussion of the EPR's paper up to January 1964 is summarized by paragraphs *1-*7, while Bell's article which was published in November 1964 (13), represents a new framework by which to examine the assumptions and conclusions of the EPR's paradox.

*8 Decoherence and the collapse theory arguments.

Following the arguments shown in *1-*7, we established a logical set of supporting links that addresses the plausibility of Furry's hypothesis and Sharp's resolution of the EPR's Paradox as to the fact that 'separability' criteria which is the foundation of this paradox might be the reason that the paradox is an intellectual disagreement on the nature of what a scientific theory should accept to its truth collection, as opposed to the claim made by the EPR's authors that quantum mechanics is not a complete description of physical reality.

The crux of the matter is the question whether the Hamiltonian is complete, or after separation the system's total energy is not properly accountable, hence the description suggested by EPR is incomplete. The arguments following paragraph *8 will address this topic and provide a new conjecture as to the wave packet collapse, by introducing a method and accountability to the proposed incompleteness of the system's Hamiltonian. In our attempt to reconcile such incongruity of the system's total energy, we will follow the wave packet collapse theories as noted by the modern approach of decoherence theorist Ghirardi, G.C., Rimini, A., and Weber, T., in their paper "A Model for a Unified Quantum Description of Macroscopic and Microscopic Systems" .(15).

8.1 The 'collapse' as it is defined by the proponents of decoherence theory, is outlined in this paper and its arguments are annotated for the purpose of demonstrating that any decoherence theory or hidden variable theory which attempts to solve the transition state from the subatomic to the classical state must account for transition in terms of its energetic value, in order to preserve the Hamiltonian. The mechanism by which the states of quantum systems become effectively classical is the subject of the arguments we present in section *9. In the past five decades it has become increasingly clear that many of the symptoms of wave collapse can be induced in quantum systems by their environments. Thus decoherence is caused by the interaction in which the environment in effect monitors certain observables of the system, thereby destroying coherence between the *pointer states* corresponding to their eigenvalues. This leads to the question of '*what is the energetic transition exchange which enables such selection?* By stating that the transition is environmentally-induced, as it is posited by the decoherence theorist, we are faced with a circular argument which provides very little information on the mechanism that coerce such a transition. We bring this question to the forefront of our discussion as the subject of the total energy of the system, as the presentation by Sharp's and Furry's hypothesis is centered on the fact that the EPR's paradox is invalid since the authors (EPR), did not account for the influences of the environment i.e. electrostatic and gravitational. But Furry and Sharp do not provide any explanations as to how the transition from pure time evolution state of the system is transitioned to a mixture.

The following set of arguments will form a *conjecture*, which will attempt to reconcile the transition of the wave packet reduction to the macro observable state, and will further attempt to identify the missing energetic value of the Hamiltonian, as the transition from subatomic to the macroscopic state occur.

Decoherence stipulates that the einselected pointer states are stable and retain correlations with the rest of the universe in spite of the environment is a given, and is classically observed. That the einselection enforces classicality by imposing an effective ban on the vast majority of the Hilbert space, eliminating especially the nonlocal "Schrödinger-cat states" (which is an observable), is derived from classical structure of phase space and is also a trivial assertion. The advocates of decoherence state that such an event '*emerges*' from the quantum Hilbert space in the appropriate macroscopic limit. We then ask the question: *What constitute an appropriate macroscopic limit*? The theory further stipulates that combination of einselection with dynamics leads to the idealizations of a point and of a classical trajectory as it is formulated by tensors formalism, the results of such combinations is a direct consequence from the derivation of the theory. Finally, the problem of measurements is relegated (by the decoherence theory) to the use of einselection, replacing the notion of quantum entanglement between the apparatus and the measured system with a semantical a substitute, and this process is justified by inserting an obvious correlation with the classical state. This effort results in the effective "collapse of the wave packet", and the process of wave packet reduction is now subject to rearranging the description of the discontinuity with semantical overlay, masking the transition from time evolution state to its classically observable state. This approach does not account for the *energetic event* that accompanies such reduction and provides us with *no* accountability of the Hamiltonian. The description of the decoherence postulates are best summarized by Wojciech Hubert Zurek, which outlines the fundamental views of the theory: *".....Spreading of the correlations with the effectively classical pointer states throughout the environment allows one to understand "classical reality" as a property based on the relatively objective existence of the einselected states. Effectively classical pointer states can be "found out" without being re-prepared, e.g., by intercepting the information already present in the environment. The redundancy of the records of pointer states in the environment is a measure of their classicality. A new symmetry appears in this setting. Environment-assisted invariance or envariance sheds new light on the nature of ignorance of the state of the system due to quantum correlations with the environment and leads to Born's rules and to reduced density matrices, ultimately justifying basic principles of the program of decoherence and einselection*" (see Wojciech Hubert Zurek, (26)).

This poetic representation of the transition from micro state to its observable classical description is no more then restating that 'reality' is present. No new informative data are provided by this description but a long semantical 'plugs', which followed by a complicated statistical arguments. But this 'explanation' is lacking, as the fundamental constitutes of reality, i.e. physical processes, are simple transformations of energy, and as long as you did not account for the Hamiltonian, you did not explain the event!

8.2 The notion of the *decoherence* and its ability to redefine the concept of "What is Real" in a manner commensurable with Popper's refutation and verifiability of scientific hypotheses, will set the arguments which supports the view that the bridge between the quantum's world description and classical world view can be reconciled in spite of the fact that a quarter century after my initial attempts at USC's symposium to describe the arguments of the EPR's seminal paper, we were able to identify the core of the disagreements as to the proper description of the Hamiltonian. This followed by sorting the competing and irreconcilable differences between Bohr and his school vs. EPR and their followers. The general differences leading to the paradox' conclusion and its main thesis *is still unresolved*: "what is Real" is still an open question!

The hypothesis that a probabilistic definition of the transition particle/wave nature must be anchored in some meaningful physical theory, and that the transition must be continuous and that such transition shall obey the standard machinery of QM theory, was advanced by the accumulated experimental data following Bell's Experiments, which led to the development of robust theoretical advancement under the doctrine of Quantum Decohertence. As noted above, decoherence's final observation relay on the notion of 'emergence', an *unsatisfactory* construct which assumes that the observational reality is present and is due to some statistical arguments and time domain allocations of physical events. But decoherence, according to our approach, does not account for the physical attributes essential in describing the transition,(the wave packet reduction), as an energetic event.

The review of decoherence description of the wave packet collapse is not a historical commentary, as the arguments we advance in this paper will lead to a possible and general outline for an '*optical transition*' operator in phase space enabling the wave packet collapse as a measure for the complete accounting of the Hamiltonian. The description outlined in the following paragraphs will describe the considerations which led to the formation of an alternative description of the collapse in terms of energetic event. The argument will demonstrate a classical continuous transition from the time evolution equation to an observable state. The arguments are supported by some observations which can now be reconciled by the theory without resorting to complicated set of solutions associated with statistical machinery. We do not doubt the veracity of the decoherence approach advocated by GRW and their statistical derivations, but we consider the use of statistical arguments as a way to explain the transition from the micro state to its macro/observable state as ornamental, as the final results indicate in their theory. The use of a construct such as 'Emergence', a concept devoid of *any* physical meaning and frankly stated, is at best a place holder for the problem of 'why the reduction occurs', rather than providing a plausible solution within the framework of classical dynamics.

8.3 We start by assuming that the criticism launched by the authors noted above, (as to the incomplete description of the EPR's representation of the system, see arguments noted in Para.*1-*7), which centered on the Hamiltonian description, as an incomplete and in violations of the system after separation. In summary, Furry and Sharp contended that EPR's paradox is the results of incompatible description of the state function, which does not meet the quantum mechanical formalism due to the reasons and arguments noted above. It is further clear that these observations will lead to several theories which have now been devised so as to supplement such description, and to further bring the paradoxical results derived by the EPR's paper to agree with the fundamental tenets of quantum formalism. The alternatives to the EPR's description assumed different paths whether by adding to quantum formalism a set of conditions, such as the family of hidden-variables theories, or by modifying the system's transition through dynamical-collapse theories. The best-known are pilot-wave (or de Broglie-Bohm) theory and Ghirrardi, Rimini, and Weber theory, (GRW). In this paper we will outline a physical theory which meets the requirements of the standard quantum formalism and will enable the transition of the wave collapse without the discontinuity associated with the problem of measurement. In addition, the proposed solution will eliminate the need for a semantical overlay, which is the hallmark of the decoherence theory or the Everettian counterpart, since this one necessitates a many word interpretations so as to reconcile the problem of two kinds of dynamical evolutions in quantum mechanics with classical Lagrangian as well as relativistic dynamics.

8.4 During the year 1984, I presented a paper during the symposium on Quantum Mechanics at the USC school of Philosophy in support of my Fulbright research grant. The topic of my talk was titled: "Notes on EPR's Paradox and Sharp's Resolution*"*. The presentation centered on the formal aspect of the notion of "Separability", which is one of the critical assumptions made by the EPR's authors. The formalization of this aspect by the EPR's argument led to an intense intellectual deliberation and resulted in a dramatic reexamination of the main thesis of Quantum Mechanics and its interpretation relating to fundamental views associated with the concept "What is Real", and with emphasis on its testability criteria for establishing as well as employing such concepts in daily use by the working scientist.

In my presentation on the EPR's Paradox I focused on the underlying assumptions as well as the formal apparatus of the arguments, by exposing persistent aspects of the proof provided by the paper so as to demonstrate that the EPR's paradox is still an *unresolved* intellectual challenge. This position is not assumed because Quantum mechanics is not a theory that satisfies *all* its predications, and definitely not because QM is not enabling a complete understanding of the subatomic word, such as quantum chemistry and molecular biology. But in spite of its monumental successes, QM provides us with a clear separation between the microscopic and the classical observable universe, and this dichotomy and dyslexia between these two world descriptions is the reason why the EPR's paradox is still looming over the intellectual edifice. Which 'Physics' (capital 'P'), is still representing as "Quantum Mechanics Problem of Interpretation".

8.5 The commentary on the separability criteria presented by Sharp's paper (7) is one element within multiple theories that were debated by the community of scientists and philosophers, while reviewing the topics associated with concepts of 'separability', 'causality', and 'locality'. The 'separability' is the main topic that guided the developments of the pilot-wave theory, de Broglie-Bohm theory, the Bohmian mechanics, Causal interpretation, ontological interpretation and the phenomenological 'emergence' description presented by the decoherence theory, all of which attempts to reconcile and justify the *discontinuous* nature, and the use of two distinct descriptions of the physical world. by the use of time-independent Schrödinger equation on the one hand, and the macroscopic classical description of the point like mass after the wave packet collapse on the other. None of the above theories provides us with contradiction-free accounts for the collapse associated with the inseparable de Broglie pair.

8.6 When emphasizing the role of the Hamiltonian in rebating the EPR's paradox, I intended to drive the fact that 'separability' construct and its physical meaning, is the center piece of the debate, and the arguments that support such claims are the beginning of a solution by which the quantum mechanical word's view and the classical interpretation of "what is real" are to be reconciled with our intuitive, (it is the underlying motivation which drove the EPR's paper and its arguments), perception and its formal description of the observable reality.

The historical sequencing of the arguments presented in paragraphs *1-*7 and the criticism employed by the practitioners of QM, such as the ones discussed partially in my presentation, were supported by the active debate conducted by the founding fathers of QM as they formed the newly established Atomic Science. The luminaries of this newly founded science, such as de Broglie, Bohr, Born, Hiesenberg, Pauli, Schrödinger, Wigner, Bohm et al, had to resolve the fact posed by the EPR's paper, employing a simple and robust logic in a *Gedankenexperiment* manner so as to highlight the incongruence of the competing views of classical vs. subatomic interpretation of "what is real".

In this presentation we did keep the arguments pros and cons within their historical context, and confided the reasoning to their era. we deliberately organized the discussion on the paradox and its arguments within the intellectual frameworks of the founding fathers of quantum mechanics. We maintained a clear separation of the discussion and its participants to be limited to the publication dates up to the insightful publication of Bell's Inequality and Bell Experiments papers.

The reasons for the ortodox use of historical demarcation in the description of the EPR paradox is due to the arguments for and against the EPR's formulation of the criterion defining "Physical Reality". Those were set during 1935-1964 period, and were due to discussions during that period which assumed philosophically, heavily-laden arguments with context-dependent approach. This was later freed from this intellectual scope, mainly due to the publication of Bell's Inequality theorem and its effective use of experimental setting in arguing the merits of such arguments.

The notion of "What is Real" with its Kantian's overtones prior to Bell's theorem, was reformulated after the era of Bell, by following a deliberative approach to strip the metaphysical-halo associated with the notion of "What is Real". A halo reminiscent of Aristotelian and scholastic metaphors, this approach was redefined by a Popperian's doctrine emergent subsequent to Bell's inequality publication, and the experimental setting and the demonstrations by Aspect's 1981 paper (see (25) & (25a)).

As shall be clear from the argument presented, and the motivation for separating EPR's paper (1935) from the subsequent publication of Bell's inequality paper (1964), this had nothing to do with the need to preserve "historical integrity", but was rather due to the problem of Quantum Interpretation being radically devoid from its philosophical bend, and the deliberations associated with Kantian categorical separation of the notion "What is Real". The new arguments were channeled to a Popperian's scientific model, whereby operational meaning of the notion "Physical Reality" was reformulated under a doctrine of a decision algorithm, followed by an experimental model capable of refuting or affirming the question "what is real". The use of ideological scaffolding within the theoretical framework and machinery of the Standard Quantum Mechanics formalism, as fashioned by Bohr and his followers, was minimized to its operational narrow interpretation.

8.7 As the argument is advanced by the commentary in the paper, we will introduce a set of questions relating to efforts which attempt to reduce the paradox to its possible resolutions with the aid of W.H. Furry's approach and H.D Sharp's presentation. The arguments advanced by Furry and Sharp are central to the definition of the 'complete

Hamiltonian' which we postulate as the basis for re-interpretation of the wave packet collapse. We further point to the treatments of the Hamiltonian, by highlighting the facts that what is currently postulated as perturbations in quantum mechanics transition states, are the source for the wave packet collapse, and such description must be reduced to transition by the use of optical operator, and as such transition is due to 'energetic event' countable by classical formalism. We further employ the use of Snell's law of refractive media to describe the transition from a superposition state to its mixture, without any assumptions of *discontinuity or quantum jumps*.

We titled this conjecture after the **Hamilton optomechanical analogy**. (See appendix I,II, & III for the detail on the origin of the analogy).

Some of the early arguments against the EPR's thought experiment were no more then a *semantical overlay* on the problem of "What is Real", suggesting that the paradox is a mere confusion of terms associated with the wave packet collapse. The notion that the system conceived as "pure state" is not a true representation of the system, as it is violated by the facts that after "Preparation", or the system "Separability" is not preserved, hence the system according to these arguments is no longer in a pure state. This commentary was due to the "no interaction" rule and is breached by 'additional influences', and therefore the edifice of the impeccable logic of the EPR's arguments tumbles under the loads of external influences which are not accounted for by the formalism of EPR.

8.8 The main proponents of the "separability" violation's argument were centered on the notion that the Hamiltonian description $H=-\frac{h}{2m_1}\nabla_1^2-\frac{h}{2m_2}\nabla_2^2+r_{12}(\bar{r}_1,\bar{r}_2)$ is not a complete description of the potential energy of the whole system. Since the potential energy of the system S_{12}

is defined by 'r', and is represented by violation of the Hamiltonian inequality ($r_{12} \neq 0$), this according to Sharp is due to the system not being closed under the Hamiltonian. By further incorporating external influences such as: r_g for *gravitational influence* and r_s for the *electrostatic influence,* it follows that r_g, and r_s were not accounted for in preserving the Hamiltonian of system S_{12}. This argument entails that the assumption of Schrödinger's time evolution setting the system S_{12} in "pure state" (undisturbed) is violated. The arguments presented by many of the objectors to the EPR's will invariably center on some formal representation of the system and the characterization of the system S_{12}, before and after the preparation and or 'measurement' of one of the components of the correlated system in violation of the non commuting variables.

This line of argumentation advocated by some of the contenders objecting to the EPR's paper conclusion were given in the 1936 paper by W.H. Furry, and collectively defined as the "Furry Hypothesis", claiming that from the standard formalism of quantum-mechanics the correlated systems S_1 & S_2 are best described after they are spatially separated and have ceased to interact effectively. All this while assuming that their wave function is no longer a pure state, but rather a mixture of simple product states, in a manner by which each element of the mixture is in a definite state.

8.09 Our presentation on the EPR's Paradox avoided the subsequent development of multiple variations on the probable solution employing the 'Pilot Wave theory', which was the first known example of a hidden variable theory presented by Louis de Broglie in 1927 with its modern reincarnation titled the Bohm interpretation. Pilot Wave theory is based on Hamilton–Jacobi dynamics [16] (a comprehensive treatment of the formalism and the origin of this calculus is addressed in (28)), which avoid the Bohr necessary conditions to derive the conjugate non commuting variables such as momentum and position as mutually exclusive. This procedure is achieved by the use of the geometrization of the space as defined by a derivative to the action (defined as '*S'*), within the theory, and by eliminating the needs for Bohr's interpretation, which requires a conjugate of non commuting variables, (position, momentum) to be computed by the Pauli matrices, and were momenta is known by the theory as derivatives of *S*. The formalism of the wave collapse in the pilot wave theory is a tangential topic to the argument we advocate in this paper. The elimination of the Pauli matrix in obtaining the position coordinates is based on the wave theory with geometrical and time independent considerations, which were ignored in this paper, as the problem and the discussion associated with the theory *will not alter* our conclusions on the nature of the transition as an 'energetic event' in describing the wave packet reduction.

My discussions in sections *1-*7 were supplemented by historical accounts of the original paper presented in the philosophy colloquia in 1984, and it was set in such a manner so as to address the central theme of the EPR's paradox in answering the question of "What is real", within the context of QM's formalism. While we recognize the findings and observations of Bell's inequality's refutation of the possibility of constructing a meaningful and scientifically credible Hidden-Variable theory, the paper with its arguments advocates a possible explanation for the wave-packet collapse by relying on the central tendency of the decoherence hypothesis as the attempt to unify the subatomic and the classical observable worlds' descriptions without violation of the standard QM formalism, and by avoiding the ortodox interpretation associated with the measurement problem.

8.10 The aim of the *decoherence* theory is to redefine the concept of "What is Real" in a manner commensurable with Popper's refutation and verifiability of scientific hypothesis. This attempt is also the roots of the arguments presented by this paper, supporting the view that the bridge between quantum's world description and classical world view can be *reconciled*. In spite of the fact that a quarter century after my initial attempts at the USC symposium to describe the EPR seminal paper, I did find that by sorting the competing and irreconcilable differences between Bohr and his school vs. EPR and their followers, the paradox's main thesis is unresolved: "what is Real" in the contexts of the wave collapse is still an open question!

The hypothesis that a probabilistic transition of the wave particle and the nature of such transition is the effort associated with the theory of decoherence. This aims to reconcile the apparent incongruity of the Schrödinger equation linear evolution with the quantum jump into the macroscopic state. This transition must be anchored in some meaningful physical theory, which further stipulates the following conditions that:

A transition from the micro to the macro observable must be linear and such transition shall obey the standard machinery of QM theory. It is further assumed that such transition from the Schrödinger time evolution state must follow the correspondence principle.

These views were held and advanced by the accumulated experimental data following Bell's Experiments, which eventually led to the robust theoretical advancement under the doctrine of Quantum Decohertence.

The conceptual framework of quantum decoherence is so foreign to the founding fathers of QM, that any attempt to connect the reasoning-line of arguments advanced by Bohr (1936) to such arguments as advocated by Ghirardi, G.C., Rimini, A., and Weber, T. (1985) is best classified as 'categorical error'.

We bring this topic to the forefront of the arguments which follow, as I see a clear advantage in anchoring the technical considerations that led to the notion of 'emergence' and the experimental data generated by Serge Haroche[14] and his co-workers at the École Normale Supérieure in Paris in 1996, a direct consequence of an evolutionary form which define the 'collapse theory' within a theoretical boundary , (albeit wrong under my review), but the fact that decoherence re-engineered the foundations of such transition from the superposition state to its eigenvalue, (by the use of arguments accountable by measurable means), was a step foreword in redefining the EPR's paradox under operational structure and where experimental set up can be designed to test the hypothesis.

We further consider the context-free description advocated by some, including the topics of '*causality*' and '*separability*' *before* and *after* Bell's era, as 'categorical error', as it ignores the radical shift in treating the problem of interpretation during the 50 years, which elapsed since the EPR's paper of 1935, and the publication of Bell's paper 1964. The Bell's inequality and the subsequent GRW's formalism of 1985 is a direct rejection of the strong ideological tendencies practiced by academic community before Bell's paper and was due mainly to the fact that quantum mechanics' overwhelming predictable success could not be questioned. The conservative adherence to standard quantum mechanics and the authoritarian ortodox influence of Bohr, were additional constraints for the academic community in rejecting new interpretations. But QM's success does not provide a satisfactory solution for the problem of measurement, as well as *quantum jump,* or in terms of the state, the collapse of the wave-function, onto one of a large number of wave-functions that were previously superposed, a fact that continues to divide the classical word from its subatomic counterpart. These are some of the roots that preserved the description of the collapse as discontinues, by continuing to advocate two incompatible descriptions of physical reality.

The arguments we propose in gapping the schism between classical and quantum transition is centered on a possible mechanism of "*how do we operationally employ the "wave packet reduction" concept and separate this construct from its probabilistic root of interpretation as defined by the decoherence theory, while preserving the standard theoretical structure of QM as the transition occurs*? This task is essential as QM predictions and experimental data are not in question, but its explanation of the *transition* from the subatomic domain to the macroscopic reality carries an unsatisfactory luggage associated with the notion defined by the theory as "emergence". Following a *probabilistic* decision mechanism so as to enable the wave packet reduction to occur without a clear physical mechanism to support it, cannot be considered a solution, as physical models of any natural processes must account for the energy content of the event, i.e. the Hamiltonian. (The thermal bath of the environment and its statistical agitation as in Brownian motion could not be the only reason for the collapse, as the selection of the preferred basis or the privileged state of an eigenvalues are not randomized sets of events. The regularity of our visible world reemerged time and time again, thus the reason for the collapse is energetic in nature and its appearance is measurable)

The task of providing a physical meaning with an experimental footings for the phenomenological "*emergence*" of a macroscopic event measurable by our sensory apparatus is a challenge as the 'wave function collapse' under the decoherence theory happens *spontaneously*. We need to form a classical and physical explanation to the notion of 'emergence', and further provide for consistent description satisfying Bell's inequality, which mandates that any hidden variable theories necessarily violate locality as well as special relativistic limitation set by 'action at a distance' with signal travelling faster than the speed of light. These are the boundary conditions we operate under: The *Bell's inequality*, and further accounting for the wave packet collapse as an *energetic event*, its transition must be continuous and its formalism shall be compatible with *standard quantum mechanics*. It's a tall order (these boundary conditions) that must be satisfied if we are to attempt a solution to the conundrum posed by the EPR's paradox.

8.11 In its simplified and schematic form, decoherence theory can be formalized by the expression where the system Hamiltonian H is the sum: $H = H_c + H_e + H_1$, where H_c is an operator acting in the relevant Hilbert space, H_e is the environment operator, and H_1 is a coupling term. As shall be suggested by this paper's conjecture, H_1= is the coupling term describing the energy transition between the environment interacting with the Schrödinger evolution of the wave/particle. This coupling transition term assumes the form described by Hamilton optomechanical analogy and in this paper it is formulated with the use of Snell's law of optical refraction in phase space with permeability operator which acts on Hilbert space.

The decoherence theory was originally proposed by Hans Dieter Zeh in the 1970s to solve the problem of macroscopic interference. Several authors further developed it and in 1996 came the experimental observation of this effect, the decoherence effect by a group headed by J.M. Raimond and S.Haroche (16). A detailed and systematic rendition of decoherence is outlined by R. Omnes (36), which describes the basic solution introduced by Zeh H.D. in solving the Schrödinger's cat paradox, and by further redefining the notion of Schrödinger evolution and the coherence of the wave packet into its de-coherent state, as it interacts with the environment.

Decoherence assumes that macroscopic bodies also obey the laws of quantum mechanics. Then the state of such a body is given by a wavefunction. Also according to the principle of superposition of states, such a wave function of the macroscopic body shall be a superposition of several wavefunction. When waves superpose on each other, interference occurs. But in practice we never observe such interference.

A simplified representation of the wave function is given by: $\psi(x) = c_1\phi_1(x) + c_2\phi_2(x)$,where $\phi_1(x)$ is the wave function centered at point x_1, and $\phi_2(x)$ is centered at point x_2. The transition from micro state to macro state is the non linear quantum jump, addressed by Bell's monograph "Are there quantum jumps?", where Bell frames the discussion on the nature of quantum entanglement by stating that "*There is nothing in this theory but the wavefunction. It is in the wavefunction that we must find an image of the physical world, and in particular of the arrangement of things in ordinary three-dimensional space. It makes no sense to ask for the amplitude or phase or whatever of the wave function at the point of ordinary space. It has neither amplitude nor phase nor anything else until a multitude of points in ordinary three-space is specified.*"

Omnes (36) comments on the subject of the transition from the micro with the environment as an interference between the superposition state to its datum indication, i.e. the pointer by asserting that the system transition of the wave function resembles two different states, $\psi(x, y) = c_1\phi_1(x, y) + c_2\phi_2(x, y)$, and where " *One may thus* *expect that the two final functions,* $\phi_1(x,y)$ *and* $\phi_2(x,y)$ *are very different in their fine y dependence,….*" Omnes proceeds to assert that such impact of the environment will result in a selection of the form, $\int \phi_1^*(x,y)\phi_2(x,y)dy = 0$

whereby " *the outcome of such a complete lack of phase coherence cannot be other than orthogonality of the environment part of the two wave functions*." ((36) p.74).

It is clear from the above comments by Omnes that his description of the final state of the wave function is nested in the unavoidable landscape of 'reality', whereby the state function after the collapse is a orthonormal selection by the environment. What is to follow is clearly the phenomenological representation of the eigenvalue out of spectrum of infinite probabilities associated with the energy, position and phase possibilities available to the linear wave function. No solution is obtained from the conundrum of the "quantum jump". We are back to Born's rule of interpreting the selection from the superposition state to its new environmentally induced state. Born's rule of finding the wave energy or position of infinitely non commuting variable are still nested in the probability function $p = \int_V |\psi(x,t)|^2 d^3x$, and its outcome (its orthonormal vector) as a manifested state is $\int |\psi(x,t)|^2 d^3x = 1$. This is subject to *selections* defined by either GRW's formulation, based on Gaussian distribution of energy contents, phase space and a set of constants to placate the complete Hamiltonian, etc.

Our final comments relating to the proposed solution of the wave packet reduction is that without defining the transition in classical terms associated with a complete description of the Hamiltonian, as a predictable element of the theory and not as set of constants added to the master equation by fiat , we did not resolve the ' EPR paradox'.

8.12 In our arguments, supporting the transition as an 'energetic event', we introduced a physical measurable constants such as *permeability* and *relative permittivity of space,* as these elements when combined with phase space formalism will provide a physical explanation of the transition from quantum mechanical micro state to its classical observable state via the phase space, without the use of concepts such as *'emergence'*, '*spontaneity'* and the statistical overtones that employ the statistical machinery of 'Gaussian distribution' as a physical cause of action. We consider the machinery of statistical measure to uncover the nature of energetic events, but statistical description *is not* to be construed as cause of action!. (Statistical explanations are inherently turning into ontology, where a symbol manipulation is substituted for a cause of action. In the physical description we assume transformation of energy as the only measure of explanatory mode. GRW's description of 'emergence' is an example of a theory that turned statistics into ontology which by strict theoretical measures set by the EPR's paper on 'what is real', will invariably represent GRW's arguments as the logical fallacy under the category of "*assertum non est demonstratum*".

The energetic event transition mechanism will explain the wave function collapse as it is realized under continuous, classical terms, and further by accounting for the energetic exchange (Noether symmetry) of such a transition. The conjecture presented by this paper will assume a full account of the Hamiltonian.

This is the Hamiltonian argument that we advocate in supports of the 'reduction' as a classical event. The origin of the argument associated with the energy transfer (Hamiltonian) is due originally to Furry's hypothesis, which in his treatment he cites the r_g term for *gravitational influence* and r_s term for the *electrostatic influence,* as the reasons why the system S_{12}, cannot be considered as a complete description of the systems energy.

The main theoretical foundations of our conjecture are historically connected with the Hamilton optomechanical analogy which we detail in our appendices.

The argument we propose in supports of a revised theory of decoherence is based on the energy transfer argument due to the Hamiltonian H_0 stipulated by the EPR's paper not being a complete description of the system S_{12}. After separation we stipulate that the transition is consistent with quantum effects and shall include the effects of the transition from pure state to its macroscopic observable state with the added term of decoherence as shown in para. 8.11, where $H_{total} = H_c + H_e + H_1$ includes the effect of such transition in phase space. With the assumptions made by GRW (15), we stipulate that the transition occurs under the Snell's refraction coefficient, and on the time order of optical domain with frequency range of $v=10^{15}$ Hz.

These efforts of identifying the transition for the wave function collapse in phase space cannot assume the path of *semantical attributes,* such as assumed by the statistical description of GRW and defined as 'emergence', so as to plug the intellectual gap associated with the transition from micro state to the observable one. Rather it provides a testable mechanism so as to enable the interpretation to follow a *rigorous* description of the physical constants which enable the wave function to collapse. The fact that such event is based on the notion of "emergence", as advocated by the decoherence theory, reasserts the motivation that led the EPR's authors to construct the logical arguments associated with the recursive definition of 'what is real'.

GRW with their article (15), established a version of the decoherence theory and its conclusion represents the given results by assuming a high ranking solipsistic argument (statistical emergence), if one ever was developed! as all collapse theories want to reconcile the mathematics of quantum mechanics which suggests that subatomic particles exist in a superposition of two or more states. With the measured results which only ever give us one state, the phenomenological emergent qualia of the observable is than explained in terms of time domain and statistical probabilities in phase space. The fact that we can easily prepare an electron to have a spin that is mathematically *both* up *and* down for example is evident, but any experimental result will yield *either* up *or* down and never a superposition of both states. The standard model, or Copenhagen interpretation of quantum mechanics, posits a wave-function collapse every time one measures any feature of a subatomic particle. This would explain why we only get one value when we measure, but it does not explain why measurement itself is such a special act, as noted earlier by the remark of Bell's paper ”Speakable and unspeakable in quantum mechanics” where he states,”…. *Now in my opinion the founding fathers were in fact wrong on this point. The quantum phenomena do* not *exclude a uniform description of micro and macro world…system and apparatus. It is* not *essential to introduce a vague division of a world of this kind*. ((14) p.171).

More importantly, the standard interpretation doesn't define what counts as "measurement". GRW originated as an attempt to get away from the imprecise talk of “measurement”, which plagues the standard model. By suggesting that particles *spontaneously* collapse into stable states, GRW escapes the ideas that measurement is a special act or that some specific part of measuring a subatomic particle causes the particle's wave function to collapse.

The notion that a selection of spectrum of probabilities are available to the particle or ensemble and are selected by a mechanism defined by decoherence theory as “emergence”, smacks as all other "spooky action” constructs, (which the EPR's paper alerts us, so as to avoid this chimeras of metaphysical constructs, not befitting within the scientific doctrine). It demands that any explanation shall provide a possible experimental setup for such a transition by further demonstrating the mechanism in terms of what is measurable at the macroscopic reality. GRW's arguments suggesting that particles spontaneously collapse into stable states under statistically random chosen state (out of a probabilistic spectrum). Supplementing such argument, by introducing a process guided *exclusively* by Gaussian distribution is interesting and creative, so as to avoid the needs for an observer and the Bohr's legacy of interpretation. But it is also a 'trick' that pushed the problem of the wave packet collapse to an effect guided by the hands of probability operator, and GRW don't explain the collapse in terms of the total energy of the system. Furthermore GRW do not explain how is it that a selection occurs, such that no physical event escape the scrutiny of the Hamiltonian!

In summarizing the approach taken by the decoherence theory with all its genus and species varieties, all are in accord with the basic intuition declared by Hans Dieter Zeh (37), stating that the 'environment' has a roll in the wave packet reduction, and where interference destroys the linearity of the time evolution process. This paper argues against decoherence theories as it classified such attempts of solving the wave collapse by the use of formalism of 'Phase space and einselection' while wrapping the theory with Dirac's notation, or by mapping such transition on diffusion constants built within the space time manifolds. All the above highly formal theories are asserting the *ad hoc* nature of the transition. It is clear that without consistent classical definition of the energetic event associated with such transition, the Hamiltonian is not accounted for. Hence 'decoherence' as a theory did not solve the Schrödinger's cat Paradox. Bell's paper "Are there quantum jumps", sets the pragmatic merits of GRW's proposal by stating"…*The cat is not both dead and alive for more than a split second. One could worry perhaps if the GRW process does not go too far*. ((14) p. 204). Timing of the unfolding of the state probability matrix to form the wave packet collapse through random selection is clearly an out, so as to eliminate the 'observer' problem. J.S. Bell further addresses this question regarding the "*artificial distinction that quantum phenomena do not exclude a uniform description of micro and macro worlds…system and apparatus."...(*14) p. 171.

J.S. Bell's (14) "Introduction to the hidden-variable question" defines the motivation for such theory by stating that ..."*Now nobody knows just where the boundary between the classical and quantum domains is situated."* (p.29). In formulating an objective measure of the "switch", the theory must attempt to disclose the relationship between the subatomic and macroscopic transition with "reality" that is, be measurable under the same theoretical criteria associated with the notion of what we termed in this paper following Furry's hypothesis as "energetic event".

This "event" or *switch* shall be part of the Hamiltonian so as to account for the transition, as the collapse of the wave is assumed to meet the classical notion of "*work*"!

8.13 In addition to the criteria associated with 'energetic event', enabling the phase transition from the micro to the macro state, we must stipulate that this effort, (of incorporating the *permeability* constant to the space time manifold), *must not* depart from the standard quantum mechanical formalism, but will offer a possible link that anchors the probabilistic nature of the wave packet collapse by stipulating a measurable physical mechanism for the transition. Hence it explains the *physical nature* of this transition and the selection of the preferred state out of the Born's probability matrix.

The proposed ‘energetic event’ approach employing an optical operator will cause the ‘collapse of the wave packet’ so as to satisfy an objective criteria for what J.S. Bell in his paper (14) “Are there quantum jumps”, is echoing Schrödinger’s concern by citing (1952) ”*If we have to go with these demand quantum jumps, then I’m sorry that I ever got involved*”, which Bell proceeded to define as the biggest drawback of QM due to the fact that “…*the erratic behavior of the picture by which “ no sharp definition of such a scale could be made*”, between the smoothly evolving time evolution and the ‘interrupted’ wave packet collapse. We assume that regardless of the successful predictive power of QM we are faced with two distinct world’s views which beg the question: where do we draw the line that separates between the subatomic and its observable manifestation, as it is further exemplified by Schrödinger’s cat paradox.

8.14 The second argument in accounting for the wave packet reduction is outlined by using classical dynamics formalism, a method which enables the separation of the non commuting variables without violating the standard quantum mechanical description. The momentum and position of the wave packet are preserved as the time evolution function transition through the optical refraction operator, under the *Snell’s law of refraction,* and the residual energy of the transition can be expressed by Fresnel's equations which give the intensities of the reflected and transmitted as (1-R). A detailed discussion of such formalism is shown in the preceding paragraphs and in appendices I & II. The proposed solution for the collapse is enabled by the space time manifolds and its space permeability operator, which describes the mechanism of how the collapse occurs as an ‘energetic event’. The transition from the micro state to the macroscopic state is *continuous* as the transfer mechanism depends on the optical characteristic of a space time manifold. The trigger, (or the “Switch” as noted by Bell), of the collapse *is subjected only to the refractive indices of space permeability,* and the residual energy content of the transition defined by the Hamiltonian is accounted for by correlating such energy with the experimental anomalies defined by the current description as ‘perturbation. As it turns out it is very difficult to find exact solutions to the Schrödinger equation for Hamiltonians of even moderate complexity. The Hamiltonians for which we know exact solutions, such as the hydrogen atom and the quantum harmonic oscillator, are too idealized to adequately describe most systems. Using perturbation theory, the current theory uses the known solutions of these simple Hamiltonians to generate solutions for a range of more complicated systems. For example, by adding a perturbative electric potential to the quantum mechanical model of the hydrogen atom, the theory calculates the *tiny shifts* in the spectral lines of hydrogen caused by the presence of an electric field (the Stark effect).

8.15 Before we proceed with the formal arguments in support of the Optical operator triggering the collapse, I would like to bring to the discussion the arguments against the possible construction of hidden variable theory in light of Bell’s inequality. As the proposed solution will invariably trigger the automatic citation of the form “Aren’t you aware of Bell’s inequality theorem?,” which I bring and cite Bell’s commentary on the subject of ‘hidden variable theories’. Bell discusses and addresses the ‘pilot wave’ solution proposed by de Broglie-Bohm …”*Absurdly, such theories are known as ‘hidden variable’ theories. Absurdly, for there it is not in the wavefunction that one finds an image of the visible world, and the results of experiments, but in the complementary ‘hidden’ Variables. For no sharp definition of such a scale could be made”….*

(14 p. 201). We cites this paragraph as the issue of ‘hidden variable’, as the solution proposed by this paper does not alter the standard formalism of quantum mechanics. It employs the space time manifold with the already assumed grid of the permeability operator, this constant being an inherent element of the space fabric, and when the transition to a definite state occurs that transition is based on the principle supported by classical and relativistic observations of quantum optics, stating that:

The tangential components of any electromagnetic wave are *discontinuous* regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums.

*9 The first set of arguments advanced by the paper follows the trails of the Hamiltonian which must be accounted for as it is a proper measure of any physical system description. By further questioning the validity of the EPR’s formalism describing the system $S_{12,}$ the authors conclude that the proper description of the Hamiltonian must account for all external influences, hence they had concluded that the system is not in a *pure state* but a *mixture*, which invalidates the separability principle of isolated system. Therefore EPR’s conclusion does not follow the standard quantum mechanical description and *the paradox according to Sharp is no longer an issue* but rather an error in formal representation of the state function.

As outlined by arguments noted in paragraphs *1-*7, whereby Sharp’s criticism and Furry’s hypothesis questioned the validity of EPR assumptions, their commentary and proposed solution is centered on the Hamiltonian. But the arguments presented by the insertion of r_g for *gravitational influence* and r_s for the *electrostatic influence* are invalid due to both force fields being symmetrical under special relativity and thus are governed by an invariance under translations and rotations transform. (A detailed formal argument for this view is shown, by referring to the definition of Poincaré group[16], which states that such influences as defined by r_g and r_s cannot be counted as the reason that the 'seperability' condition set by the EPR's authors is violated). It follows that 'separation' conditions for the system S_{12} is not violated, as these forces are invariant to such influence. The distance and the conditions for the separability were preserved by the proposed apparatus and were shown by the experimental set-up devised by Bohm and Aharonov (29).

9.1 We postulate the following conditions for the wave function reduction; these conditions are formulated in terms of classical optics and are revised so as to satisfy relativistic optics.

i) The transition from the micro to the macro state or from the Schrödinger time evolution equation to the macro observable is accounted for by the *Hamiltonian.*

ii) By introducing the space time manifold *with* its permeability constant we will able to compute the tiny shifts in the spectral lines currently calculated by perturbation theory, (an important tool for describing real quantum systems), as it is very difficult in practice to find exact solutions to the Schrödinger equation for Hamiltonians of even moderate complexity.

iii) By introducing the permeability constant, we will be able to compute and predict the tiny shifts in the spectral lines, due to optical decoherence of the wave packet associated with the opacity broadening of spectral lines: Electromagnetic radiation emitted at a particular point in space can be absorbed as it travels through space. This absorption depends on wavelength. The line is broadened because photons at the line wings have a smaller reabsorption probability than photons at the line center.

iv) The transition is demonstrable without any assumptions of *discontinuity* between the time evolution of the wave function and the macro state, with the exception of the optical shift defined by Snell's law of refraction.

v) Based on our earlier assumption noted above, a set of correlations between the *spectral line shifts* can be mapped onto the respective *Snell's law transition angle* and Fresnel's equations for refractivity. To determine this energy, (which under the current formulation of quantum mechanics is calculated by employing the perturbation theory method), we use the Fresnel's equations, defining the intensities of the *reflected* and *transmitted* energy of the wave trajectory in phase space; consequently the fraction of incident energy that is transmitted is (1-R), and this residual energy is represents the Snell's shift due to the permeability constant coupled with the phase space manifold.

vi) The transition from micro state to the macro state, defined by the wave packet reduction, is a representation of the tangential components of any electromagnetic wave which are *discontinuous,* regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums.

vii) An energetic 'event' or '*switch*' between states shall be counted as part of the complete Hamiltonian, so as to define the transition, (the collapse of the wave packet), within the classical notion of "*work*" performed.

viii) The Snell's shift causing the reduction is related to the kinetic energy.

9.2 The argument proposed will be set first as a classical case where a simple and intuitive example along the lines of classical optics theory is proposed, and where Snell's law of refractive index is employed in interpreting the transition from coherent superposition state through the transition state. Decoherence is associated with the first derivative of the geometric translation or rotation of the wavefront due to velocity change in phase space. This example will demonstrate and visualize the model in two dimensional grids, as the relativistic Snell's law formulation will tend only to obscure the validity of the solution. Extending the solution to three dimensional grids or a vectorial or tensorial geometry is accomplished the fact since optical translation or rotation in phase space is linear phenomenon.

We start by introducing an ensemble of electrons transitioning through the permeability operator μ_0 represented by the space manifolds forming a '*spatial lens*'.

The *lensing* effect, constituting the energetic event's transition, is based on the Snell's law' formalism coupled by the observation that the tangential components of any electromagnetic wave are *discontinuous* regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums.

We represent the relationships between the space time manifold and the transition due to the refractory nature of a 'spatial lens' and further defining such a 'lens' by the identity $\mu(\omega)\cdot\varepsilon(\omega) = n^2(\omega)/c^2$. The index is expressed by the terms of permittivity $\varepsilon(\omega)$ and permeability $\mu(\omega)$. In its simplest form the law states that the relative angles of wave propagation in one media through the boundary of the second media depends on both the dielectric and magnetic properties of each media, jointly defining the index of refraction coefficient *n(ω).* The speed of the electromagnetic wave is given by c, thus the speed of electromagnetic wave propagation in the media is inversely proportional to the index of refraction. This index expressed in terms of permittivity $\varepsilon(\omega)$ and permeability $\mu(\omega)$ where the permittivity and permeability of the mediums are related to the index of refraction by the relation of Snell's law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$.

A classical example of the use of such 'lensing' of electromagnetic propagation is presented with a boundary conditions set first in a static case $(\omega \cong 0)$ and where the general relation describing the magnetic field relative to the permeability is: $\frac{B_{1t}}{\mu_1} = \frac{B_{2t}}{\mu_2}$ if $J_s = 0$, where subscript *1t* and *2t* stands for the tangential components of the B field on both sides of the boundary. The tangential components of B are *discontinuous* regardless of any current density at the interface. This discontinuity is related to the permeability of the two mediums. As a direct consequence of the above interface conditions, the magnetic field (either H or B) is refracted at the interface. We use *an example* from optics where permeability μ_1=>1000 and air with permeability μ_2=1. Rearranging and substituting we obtain $\tan\theta_1 = \frac{H_{1t}}{H_{1n}}$ and $\tan\theta_2 = \frac{H_{2t}}{H_{2n}}$, where *t* stands for tangential component and *n* for normal component. Substituting $H = B/\mu$ and $B_{1n} = B_{2n}$ we obtain $\frac{\tan\theta_1}{\tan\theta_2} = \frac{\mu_1}{\mu_2}$.

The above equations correspond to a common interpretation of relativistic wave propagation dynamics and its salient case of a non-relativistic static perspective. The static solution for the example noted above is calculated as follows:

$$\theta_1 = 80°,\ \ \mu_1 = 1000,\ \ \mu_2 = 1, \tan\theta_2 = \frac{\mu_2}{\mu_1 \cdot \tan\theta_1},$$

thus $\theta_2 < 1°$

The resultant optical displacement associated with the discontinuity of the medium due to permeability difference on the transition boundary is best described by the use of phase space, as the transition through the 'spatial lens' is defined by the boundary and by the Hiesenberg uncertainty principle relation. The energetic event can now be derived as the sum of the velocities *before* $|v_1-v_2|$ and *after* the transition from the pure state to a mixture state. This energetic event is due to the classical first derivative of the position coordinates of the system, and can assume the formulation of quantum mechanics as defined for example by the 'pilot wave' theory formalism.

Employing the Hamilton optomechanical analogy in formulating a suitable solution to the collapse it follows that the geometrization of the space is associated with the decoherence coupling term $H_{1,}$ and the translation or rotation within a phase domain is recursively dependant on the first derivative of the position coordinates after the coupling operator acts on the wave-packet ensemble.

The observational value of the collapse is set at the optical region as the transition revolves at the reduction of wavefront velocities of the ensemble relative to the permeability of space (constant).

9.3 The wave packet transition from 'pure state' governed by Schrödinger time evolution equation to its definite state selected out of the Born's probability density function, can be separated out of the probability spectrum. This is achieved by the use of the first derivative from the position coordinate, so as to account for the velocity of the system transition and possibly. Related to the cause of the selection of the privileged basis of the eigenvalue out of the spectrum of the density matrices probabilities. This description is due to the rules defining the observed phenomenon described by Snell's law, which states that: *The tangential components of any electromagnetic wave are discontinuous regardless of any value of energy density at the interface*. This discontinuity is related to the permeability of the two mediums. The 'event' is calculated as the system is transitioning through phase space via the optical operator. We posit such condition as *the reason for the collapse of the wave packet* and the loss of coherence. The ensemble's velocities and trajectories, are transitioning through the space time manifold and the permeability of space, while the collapse is an event associated with the refractive index governed by Snell's law of refraction. Such selection out of the 'pure state' of superposition is further enabled by positing the energy level of the ensemble relative to Fresnel's equations, i.e. the Born's probability density function is reduced to the preferred state basis, based on the energy value of the wave packet relative to phase space and permeability constant.

Under this description we define the transition and its Hamiltonian by accounting for the energetic event of velocity change across the newly defined phase space with its permeability constant as the 'selector operator' out of the Born probability density function. All descriptive elements in this approach assume *only* energetic terms for the collapse, as there are no elements of time dependence in this description ('energy' is time invariant in static case). The transition from pure state to its observable state is defined by energy transfer due to the tangential components of any electromagnetic wave transition in phase space and the permeability of space constant. The advantage of such energetic event transition is clear, as it behaves and obeys the pilot wave formalism by avoiding the transition from the micro-subatomic state to its macroscopic observable state without the use of semantical constructs such as 'emergence', and where the mechanism of collapse is a function of energy transfer in accordance with the classical Hamiltonian evolution.

We are further able to derive the value of the transition state, by calculating the derivative of the position coordinates, so as to account for the systems Hamiltonian. By integrating the "permeability" constant as a member of the space/time manifold, we provide the Schrödinger's time evolution equation with the *necessary physical operator*, enabling the transition in phase space without the discontinuity of the wave packet reduction. We further provide an *objective measure* for the arbitrary definition of the *border* between the macro and micro worlds description.

The quantum mechanical "observer" is now being replaced with an "energetic event" as continuous transition from the Schrödinger time evolution to its observable state. This is governed by a classical Lagrangian description over an optical operator, (with the notable limitations associated with the Hiesenberg uncertainty principle as well as the restriction on the ability of non commuting variable to be simultaneously present during measurement). The probabilistic nature of the wave particle as described by Born's rule is preserved by this construction as the selection of the preferred basis (of the eigenvalue for the system) is based on energetic preference of the system's Hamiltonian. This fact is not in violation of the Born's rule, but an explanation that the *selection* of the probability or privileged basis of the eigenvalue is a dependent variable associated with the energetic value of the ensemble velocity or its position, as it is transitioning through phase space under the optical operator described above.

9.3.1 This description is an adequate definition for the notion coined by J.S. Bell in the article '*introduction to the hidden-variable question'* (13a) where he contemplates the notion of where is the '….boundary between the classical and quantum domain..'. The physical 'switch' that demarcates the quantum mechanical state from its classical counterpart is one of the motivation he lists, "…it is this possibility, of a homogeneous account of the world, which is for me the chief motivation of the study of the so called 'hidden variable' possibility." (p.30). The incorporation of energetic value, associated with the preferred basis or the eigenvalue, (or the einselection as coined by the decoherence theorist), that leads the process of the transition from the micro-world description to its manifestable observable state as an energetic process. This process results from the geometrization of the transition under the optomechanical analogy we presented above, hence the "switch" contemplated by Bell's motivation is accounted for by the analogy.

9.4 The following sections will describe a possible account for the wave packet collapse under standard optical description. This mechanism depicted by the classical description of the wave transition via the space/time manifold is not altered. The only variation on the wave equation is the change of velocity |v|, relative to the permeability of space μ_0. Identifying the transition from the time evolution state, (pure state), to the collapse (mixed state), is a *continuous* energetic event. The transition through space time manifold, occurs due to the *refractive* media of the space manifold. It is associated with the energy exchange while translating, e.g., the momenta associated with the spin angularity, as the ensemble is transitioning from its time evolution to its classical observable state.

It follows that the wave packet reduction problem and the proposed solution noted above depends only on the consideration of the small deviation (H) of the Hamiltonian as a perturbation to the Hamiltonian (H_0) is identified by *slight shifts* on the spectral line visible by the experimental apparatus. This shift from the projected value, defined by quantum formalism for such transition, is proportional to the tangential value defined by Snell's law and relative to the permeability constant. Snell's law enables us to determine the paths of optical rays passing though a *discrete* boundary between regions of constant refractive index, but Snell's law doesn't explicitly tell us the path of the wavefront in a medium of *continuously* varying refractivity.

The image associated with phase space and Wigner distribution is reinforced by the fact that such correlation links the wavefunction that appears in Schrödinger's equation to a probability distribution in phase space, and it is used in this paper as an analogous correlation between such probability of the observable out of Born's rule, (the 'preferred basis' or the eigenvalue out of the eigenfunction), which is the expected value predicted by Wigner correlation of such observable in phase space).

To determine this correlation under the optomechanical analogy, we refer to Fresnel's equations, which give the intensities of the reflected and transmitted electromagnetic waves as a consequence relating the fraction of incident energy that is transmitted; this relation is measured as (1-R) by Fresnel's equations,:

$$R = \frac{I_{reflected}}{I_{incident}} = \frac{1}{2}\left[\frac{\sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)} + \frac{\tan^2(\theta_1 - \theta_2)}{\tan^2(\theta_1 + \theta_2)}\right]$$

We then summarized and conclude that the transition from the superposition state to its observable state in accordance with Born's rule of finding the wave energy or position probability as defined by the function $p = \int_V |\psi(x,t)|^2 d^3x$, results in its outcome, (its orthonormal vector), and by its manifested state, and is described by the expression $\int |\psi(x,t)|^2 d^3x = 1$.

As stipulated above, we don't propose any change to the standard quantum mechanical description and its inherently statistical nature, governed by Born's probability rule and its density matrix, but we are stipulating that the time evolution of the wave function must account for the transition by a modification to the *master equation* noted by our final arguments in this paper.

We propose that the master equation shall measure the complete Hamiltonian, as the 'transition' is the result of the wave packet reduction in the *optical domain.*

Futhermore the emission from the energetic event shall be counted by the photons emission, with energy proportional to the angle of deflection associated with the first derivative of positional change and or the reduced rotation in spherical coordinates The wave packet transition out of the superposition pure state to a mixture state is governed by Snell's law of refractive medium.

9.5 In re-establishing the basic intuitive conjecture of Furry's Hypothesis (see argument in para. *6) we postulate that a state vector is not an attribute of a single electron, photon, trapped ion or a quantum dot, but a value of an observable assigned to a physical system, and it has only a meaning in a context of a particular physical experiment. Furry's rebuttal of the EPR assumptions leading to a "paradox" is avoided, because the reduction of the state vector in the measurement process is a passage from a description of the whole ensemble of the experimental results to a particular sub-ensemble of these results.

This paper asserts the position advocated by Furry in that the system or ensemble of particles after separation *cannot* be defined by the formalism of 'pure state' and it differs from Furry's hypothesis on the *nature* of such transition.

By questioning the process of *Why is the transition from pure state to a mixture occurs, and how can such transition be accounted for relative to the Hamiltonian?* we postulate that such transition is represented by the *geometrical displacement* defined by Snell's law and can be described by the first derivative of a geometric translation and rotation due to the permeability constant of space. How else can we justify the selection of the preferred basis a-*priori*, as the Born's rule provides us with no hints on the selection from a spectrum of infinitely many possible eigenvalues!

9.6 Our discussion of How the preferred state is selected follows the basic tenet of the decoherence theory but differs in a fundamental way, as the decoherence conjecture does not for the actual wave function collapse, but provides a mechanism for the appearance of wave function collapse. Salman Habib et al. (33) present evidence that decoherence can produce a smooth quantum-to-classical transition in nonlinear dynamical systems [22]. The authors describe a high-resolution tracking of quantum and classical evolutions which reveals differences in expectation values of corresponding observables. Using the solutions of the *master equations* [23] demonstrates in their analysis that decoherence destroys quantum interference in Wigner distributions, as it reduces the Born probability or density matrix to the selected eigenvalue in phase space, (analogous to classical density matrix), and is modified by the limitations imposed under the uncertainty principle due to non commuting variables. This process washes out the fine structure in classical distributions, hence bringing the two closer together. Habib et al report that correspondence between quantum and classical expected values is also re-established. Similar observations are reported by [14] Serge Haroche and his co-workers at the École Normale Supérieure in Paris in 1996. Their approach involved sending individual rubidium atoms, each in a superposition of two states, through a microwave-filled cavity. The two quantum states both caused shifts in the phase of the microwave field, but by different amounts, so that the field itself is also put into a superposition of two states. As the cavity field exchanges energy with its surroundings, however, its superposition appears to collapse into a single definite state. Haroche and his colleagues measured the resulting decoherence via correlations between the energy levels of pairs of atoms sent through the cavity with various time delays between the atoms. In both cases Salman Habib et al and Serge Haroche et al, the observed wave packet collapsed as it emerged under the environmental apparatus of the experiments in terms of decoherence explanatory doctrine, but neither provides a causal and energetic accounts underlining the selection of the collapse as a measure predicted by classical machinery defining the system's Hamiltonian. Finally, neither described the mechanism of the emergence of a preferred basis for the eigenfunction so as to account for the eigenvalue observed.

9.7 We have to address the fact that the preferred state (a mixture), must be influenced by some physical; measurable process, where an energetic exchange is part of this transition. The use of snell's law in describing the transition from pure state to a mixture is based (in this paper), on the predicate that the preferred basis for the collapse is solved by employing the rule [19] as conceived by Bohr (31), and the doctrine of the "correspondence principle", so as to explain the radiative behavior of an atom as it approach the classical radiation from accelerated charges in high quantum states. Certainly the observed line spectra from atoms differ radically from classical behavior. Beiser (32), gives an example of calculating the radiation frequency of an atom for quantum number n=10,000 and states that it differs from the classical result by only 0.01%. The correspondence between quantum mechanics and classical physics is to the transition from pure state to a 'mixture'. The conjecture using Snell's law to account for the collapse amounts to stating that the transition occurs due to the geometric displacement associated with the first derivative of the position in phase space, which satisfies the conditions set by the theory as it provides for the full accounting of the Hamiltonian. This conjecture further describes the transition from the states as an 'energetic event', without the immediate reliance on the computational machinery of perturbation theory, as a means by which we account for the anomalous *small* *spectral shifts* observed in our experimental results. This conjecture supports the notion and explains the fact associated with the selection of a preferred basis without violation of the quantum mechanical formalism and without resorting to notions of 'emergence', to describe the selection of a mixture out of the Unitarian state, which is mandated by the Schrödinger's equation. Dynamical Collapse Models offered by the decoherence theory is motivated by the fact that some who do not like the idea of collapse due to observers, try to rig the wavefunction evolution so as to favor reduction of the state vector in a well defined way. One way is to say that the wavefunction, or at least a part of it, gets "hit" periodically in such a way so as to cause localization in the position basis. Another way is to add a nonunitary term into Schrödinger's equation, the extra term in the equation adds some low level universal noise. The end result is a tendency to collapse into energy eigenstates with probabilities consistent with Born's law [20].

The importance of decoherence theory is that it brings some understanding about the process of wave collapse by describing the tendency of a system to fall out of quantum superposition, but decoherence does not explain the automatic selection in terms of preferred state out of the Born's probability density function. The conjecture of geometrization the phase space by the use of Snell's law of optical displacements, an equivalent event to the wave collapse reduction, is the main thesis proposed by this paper, and its conclusion is that the wave collapse transition from the time evolution 'pure state' to a 'mixture' is the result of classical energetic event, measured by the transition under the rule: The tangential components of any electromagnetic wave are *discontinuous* regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums.

9.7.1 This intuitive picture of the Hamilton optomechanical analogy is supported by the experimental phenomenon observed by the Stark effect[21] , defined classically as the shifting and splitting of spectral lines of atoms and molecules due to the presence of an *external* static electric field. The amount of splitting and or shifting is due to the pressure broadening (Stark broadening) of spectral lines by charged particles. When the split/shifted lines appear in absorption, the effect is called the inverse Stark effect. The Stark effect is the electric analogue of the Zeeman Effect where a spectral line is split into several components due to the presence of a magnetic field. These effects and others will serve as a basis for our attempt to provide a collapse theory that explains the wave packet reduction in phase space as an energetic event that completes the Hamiltonian account of the energy as the transition occurs.

The symmetry structure underlying the ray and wave approaches to paraxial optics are explored in our appendices I, II, & III. Optics and mechanics have long shared many key conceptual ingredients and elements of mathematical structure. These include not only the statements of their laws in the form of variational principles but also the exploitation of appropriate canonical formalisms. A major landmark in their mutual development was the discovery by Hamilton (1828) of the *optomechanical analogy*; this analogy later played an important role in Schrödinger's discovery of wave mechanics.

The example provided by the argument shown in para. 9.2 demonstrates the simplicity and clarity of this event. The Hamiltonian is accounted for and the transition mechanism from subatomic to the classical observable is defined. Further corollaries can be drawn by simply postulating the "emergence" of a definite state out of the Born's probability density function as a result of 'energetic events' within a phase space-computation model. This is based on energy and phase of the wave packet to its mixture state without resorting to time domain considerations, as advocated by decoherence theory and by relaying solely on the energy transfer associated with the tangential components of any electromagnetic wave in phase space. Note that paraxial optics provides us with a clear insight on the nature of the formal structure similarities associated with the behavior of wave mechanics in the time domain and the Helmholtz equation in the frequency domain. These similarities reinforce our use of the basic tenets of Hamilton optomechanical analogy in providing an adequate explanation to the nature of the collapse. Specifically it shows that the transition from the time evolution unitary operator to its observable state preserves linearity of such processes.)

9.8 Concluding remarks and observations.

9.8.1 In their paper Chung-Hsien Chou et al. "Exact Master Equation and Quantum Decoherence of Two Coupled Harmonic Oscillators in a General Environment" (39), the authors demonstrate the decoherence effect on the system $S_{12.}$ Using the exact master equation for two coupled quantum harmonic oscillators interacting via bilinear coupling with a common environment, we bring this example to indicate the environmental influence on a system where the preparation of the system is controlled and the correlated system is in a superposition state. Furthermore the coherent state of the entangled two or more oscillators can be altered by small induction of noise, which alters the system's coherence through the unitary evolution of the entangled system into a mixture. This effort leads us to conclude that the intuitive assertion made by Furry's hypothesis is grounded by the experimental data noted by (39). We outlined in para. 6.04, following Furry and Sharp's comments, that the EPR description of the system after preparation cannot be represented by the superposition formalism, i.e. 'the total energy of the whole correlated system S_{12}. Thus the wavefunction *is no longer* represented by the product $\Psi_b(\bar{r}_1, \bar{r}_2) = \psi_k(\bar{r}_1)\phi_k(\bar{r}_2)$. This assertion followed by noting that the Hamiltonian *is not* defined by the equality $r_{12} = (\bar{r}_1 - \bar{r}_2) = 0$. Hence we have re-established Furry's hypothesis, employing additional supporting arguments and therefore we conclude that the EPR paradox was the result of *improper representation* of the system after 'separation' due to influences that could not be accounted for by EPR's formalism.

9.8.2 We further employed formal arguments such as the Poincaré group [17] stating that due to symmetry and homogeneity of the space manifold, the reasons provided by Furry as to the external influences such as gravitational as well as electrostatic, are not the reason for invalidating the EPR paradox. The reason for such invalidity is grounded by the fact that the Gedankenexperiment designed by the authors of the EPR paper assumed symmetrical conditions where the homogeneity of the space manifolds in establishing the ground for their conclusions are invariant to such influences. However, their intuitive conjecture of the EPR's improper representation the system S_{12} *is the correct approach* to the EPR's paradox solution. We note the direct influence of Furry's ideas to the subsequent by H. Dieter Zeh with the publication of his seminal paper "On the Interpretation of Measurement in Quantum Theory"(37), which led to the development of decoherence theory.

9.8.3 The introduction of Bell's inequality [9] and Bell's experiment, followed by (25) & (25a) with its experimental realization of Einstein-Podolsky-Rosen sets up the simplification introduced by D. Bohm, Salman Habib et al. (33) Chung-Hsien Chou et al. (39), and the direct measurements conducted by Serge Haroche [22] and his co-workers at the École Normale Supérieure in Paris in 1996. These were all a direct evidence to the newly defined experimental doctrine conceived by H. Dieter Zeh (37), again an expansion on Furry's hypothesis, as to the assertion that the environment with a calibrated sets of boundary conditions is the reason for the collapse from the pure state of coherent ensemble to its mixture state.

9.8.4 The paper proceeded by introducing the decoherence theory that established many variation on the theme of the environmental influences (associated with the use of different boundary conditions) on the transition from a superposition state of the Schrödinger evolution equation $i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$ to its macro observable state, by incorporating the coupling operator.

9.8.5 The use of a modified Schrödinger equation coupled with a set of constants in phase space assumed multiple formalization in the fast evolving development of decoherence theory. The multiplicities of formalization is due to the introduction of various boundary conditions assumed in accounting for the energy, which influenced the transition or the collapse outcome from the linear time evolution to its classical state. As shown by Chung-Hsien Chou et al. a small energy value is the cause for the collapse.

We summarized the GRW and the decoherence (15) proposal, and the analysis of the reduction process which employed *ad hoc* considerations (albeit well grounded in its formal representations by phase space effective dimensionality). The original system's wavefunction *can be expanded arbitrarily as a sum of elements in a quantum superposition*. Each expansion corresponds to a projection of the wave vector onto a basis. The basis *can be chosen at will*, which is the reason why the decoherence conjecture provides us with multiple equivalent descriptions. Let us choose any expansion where the resulting elements interact with the environment in an element-specific way. The boundary conditions are a function of *matching the total Hamiltonian,* so as to satisfy the conditions *before* and *after* environmental interaction, and in particular to the vanishing of quantum interference terms after decoherence has occurred. Such elements will with overwhelming probability, be rapidly separated from each other by their natural unitary time evolution along their own independent paths. After a very short interaction there is almost no chance of any further interference. The process is effectively irreversible. The different elements effectively become "lost" from each other in the expanded phase space created by coupling with the environment. The original elements of the dynamical system investigated are said to have *decohered*. The decoherence conjecture might be correct as to its **descriptive model**, but lack any physical intuitive evidence as to its *predictive* power. Whether we employ the Dirac notation to describe the system's dynamics as it evolves from the unitary time evolution $|\psi\rangle = \sum_i |i\rangle\langle i|\,\psi\rangle$ and where the $|i\rangle$ s form an einselected basis (**e**nvironmentally induced selected eigen basis). The system S_1 $|before\rangle$ evolves into $|after\rangle = \sum_i |\epsilon_i\rangle\langle i|\psi\rangle$. It is clear from the description noted above that the transition from the superposition to its mixture state indicates that the system collapses into decoherence, but this is a *phenomenological* description of the reduction without any accounting of the energetic conversion of the process which coerces such a transition. The decoherence theory describes the energy associated with thermodynamically induced equilibrium, involving statistical and time considerations, as the set of environmental constants are organized to satisfy the total energy required to induce the reduction of the wave packet into its manifestable state.

Wojciech H. Zurek, (26) has defined einselection as follows: "Decoherence leads to einselection when the states of the environment $|\epsilon_i\rangle$ corresponding to different pointer states become orthogonal: $\langle\epsilon_i|\epsilon_j\rangle = \delta_{ij}$

It is clear from the descriptions provided by the different versions of the decoherence conjecture that the basic intuitive foundations of the theory's are sound but the multiplicities of boundary conditions satisfying the collapse phenomenon are not unique, an indication of the theory immature state. We can derive the same results by introducing different heat-bath conditions, and obtain similar results. Newtonian and Hamiltonian dynamics with its relativistic versions enable a unique and predictable solution once the initial boundary conditions are defined. GRW theoretical foundations are best described as a model with full reliance on *fitting the data* to account for the phenomena. We term this argument, as "*assertum non est demonstratum*".

9.8.6 Our proposed hypothesis relating to the wave packet reduction assumed that the collapse is the result of decoherence associated with the environmental influences in phase space, while preserving the Brownian nature of the ensemble, and without stipulation that the statistical description is the cause for the collapse itself. Born's rule states that, given a wave function $\psi(x, y, z, t)$ for a single structureless particle in position space, is further reduced to stating that the probability density function *p*(x,y,z) for a measurement of the position at time t_0 will be given by *p*(x,y,z), and is = $|\psi(x, y, z, t_0)|^2$ Hence the basic tenets of the standard quantum mechanical description is preserved. But the transition from the coherent superposition state to its manifestable classical state, is governed by the use of the permeability operator in phase space due to energetic conversion. It is also represented by velocity change defined as the rotation or translation of the ensemble coerced by the permeability operator in phase space. This process is further described by the formalism of Snell's law of refraction.

9.8.7 The wave packet collapse, under our conjecture, assumes the use of classical wave mechanics in the optical domain. This process is governed by Snell's law of refraction, which states that: *The tangential components of any electromagnetic wave are discontinuous regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums*.

9.8.7.1 Refraction of electromagnetic waves take place at the interface between two media of different refractive indices, with $n_2 > n_1$. Since the velocity is lower in the second medium ($v_2 < v_1$), the angle of refraction θ_2 is less than the angle of incidence θ_1; that is, the wave in the higher-index medium is closer to the normal. Snell's law states that the ratio of the sines of the angles of incidence and refraction is

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

equivalent to the ratio of velocities in the two media, or equivalent to the opposite ratio of the indices of refraction. We assumed this rule under the Bohr Correspondence principle. We further stipulate that relativistic modifications to Snell's formalism will enable the decoherence effects and can accounts for the Stark and Zeeman effects and other spectral small shifts in spectral analysis, which currently are assumed as part of the perturbation phenomenon's.

9.8.7.2 In summery we provide an outline for the use of permeability operator in phase space which forms the *coercive force* that causes the transition from coherent superposition state into its observable. It also addresses the energy transformation so as to account for the complete Hamiltonian, and it relates such transition to its intuitive geometric counterpart by Snell's law and by accounting for the energetic transformation by employing the Fresnel's equation $R = \frac{I_{reflected}}{I_{incident}} = \frac{1}{2}\left[\frac{\sin^2(\theta_1-\theta_2)}{\sin^2(\theta_1+\theta_2)} + \frac{\tan^2(\theta_1-\theta_2)}{\tan^2(\theta_1+\theta_2)}\right].$ This resolves the value of such transition relative to the intensities of the *reflected and transmitted* electromagnetic waves. This solution relates the fraction of incident energy that is transmitted shift as a consequence of the geometrical. We propose that a similar mapping to Wigner distribution be applied to Born's rule so as to correlate the intensity of the value derived from Fresnel's 'R" term to the probability matrices. The correlation between Fresnel's Intensity values and Born's probability $\|\Psi\|^2$, will assume the same structure of Wigner distribution function as it is correlated by such probabilities with phase space.

***10** Summery and observations:

We employ this section as an executive summary in order to elucidate the arguments that led us to form a new species of decoherence collapse theory fashioned under the Hamilton optomechanical analogy.

What we aimed at with this thesis was to examine and elaborate on the specific assumptions that lead the EPR's authors to their conclusion. The analysis we conducted centered on the fact that the system after separation must be scrutinized as to the energy summation of the system, the complete Hamiltonian.

EPR's arguments that lead to its paradoxical conclusion that quantum mechanics is an incomplete description of the state of the particle, were based on the logical syllogism that either the system after separation possesses two different eigenvalues or that the system violates the canonical representation of quantum mechanics, which mandates that non-commuting variables do not possess simultaneous reality.

In that case, the conclusion and hope of the EPR's authors asserted that quantum mechanics is an *incomplete description of the natural state of affairs*, and as a corollary to that assertion they (EPR) introduced the hope that a complete description and a radical revision of the subatomic theory be found, and where the 'hidden variable' classically defined by Lagrangian mechanics be restored to our view of the physical world.

We stated our deliberations by analyzing the fundamental assumptions made by the 1935 paper (3). We set the locus of our criticism on the notion of "Separability" and its operational definition while employing the basic insight of Furry's hypothesis. Furry introduced the fact that secondary influences such as gravitational as well as electrostatic forces should be counted as one computes the Hamiltonian. Our criticism of the arguments presented by Furry and Sharp were based on formal structural definition of the space manifold, and are summarized by the Poincaré symmetry group.

The basic insights of Furry's hypothesis were further developed so as to account for the complete Hamiltonian in light of the seminal work of H. Dieter Zeh expressing the notion of *Loss of Coherence* in the domain of subatomic dynamical system as corelated environmental influences.

In our treatment of the “separability” concept employed by the EPR’s authors, we found the pivoting lever that enabled the introduction of a novel collapse theory, which explains the transition from the coherent-superposition state of the wave particle pair to its manifestable and observable state, under the doctrine introduced by Hamilton (1828), formulated under the title “the optomechanical analogy”.

Hamilton optomechanical analogy, as it relates to loss of coherence after the interaction with the environment and the basic tenets of our conjecture are summarized in these concluding remakes, stating that a system of particals in an entangled state (superposition) in the quantum regime, is subject to influences from the environment, and that such loss of coherence occurs in the optical domain.

As to the historical relevance and use of analogical formal structure to describe dynamical systems, we adopted the Hamilton optomechaqnical analogy to describe the environmental phenomenon and influences between waves acting on a physical object. We found that Johannes Kepler had observed and describe the tails of comets to be deflected by what he believed was a kind of “solar breeze”. This was the first reported observation of radiation pressure acting on a physical object. Subsequently, Kepler suggested building “ships and sails proper for heavenly air” in his “Dissertatio com Nuncio Sidereo” (Venice, 1610)

We further presented a quantum-mechanical treatment of an optical model to describe the collapse of the wave packet as the result of geometrical optics in the electromagnetic spectrum, utilizing the formal machinery of Snell’s law of refraction and the subsequent energetic event of the collapse from pure state to its mixture in terms of the intensity value ‘R’. Fresnel’s equation was correlated with Born’s rule for mapping the probability spectrum of the eigenfunction with its preferred basis or its privileged state.

The elegant solution to the optical collapse theory will eventually employ the Wigner function as it properly conveys that a given state can be calculated from its density matrix. For each quantum ensemble there exists a Wigner function. Just like the classical phase-space probability density, it too is real and normalized.

If we are to state the *Hamilton optomechanical analogy* in its simplest form, we first postulate that the collapse theory is governed by a transition from the Schrödinger time evolution state (a linear process) to its observable state. We supplement the coupling term to the Schrödinger equation with the use of an optical operator $i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi + c$, where $"c"$ is the coupling constant associated with displacement in the form of Snell's Law, (Geometrical displacement (9)). The relation between the elements forming the collapse are governed by geometrical dependency as noted by $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$, and where the transition from a Brownian collection of an entangled state to its observable state follows the Born's rule $\|\Psi\|^2$, and where the specific variable or property observed $P(a)$ is represented by $P(a) = \sum_j P_j \|E\Psi\|^2$. Such selection of the preferred basis is governed by the energetic value as defined by Fresnel's equation for the intensity, so forming the preferred basis from Born's rule $\|\Psi\|^2$, is correlated with function of R value, such that

$$R = \frac{I_{reflected}}{I_{incident}} = \frac{1}{2}\left[\frac{\sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)} + \frac{\tan^2(\theta_1 - \theta_2)}{\tan^2(\theta_1 + \theta_2)}\right]$$

We then characterize the entire transition from Schrödinger linear time evolution to its observable state as a geometrical displacement due to velocity change in the ensemble coherent state (superposition) by the use of Snell's Law, where $|V_0 - V_1|$ represents the interference decoherent state which lead to the collapse in phase space.

We further stipulate that the energy (the Hamiltonian) is complete if we add the photonic emission with its appropriate energy value defined by (1-R) out of this process, where the total Hamiltonian is accounted for by the constant "c", which we term by this paper as the optical operator (or H_1, the coupling operator in the form of decoherence formalism).

The last assumption in our decoherence conjecture is the fact that the preferred basis of the eigenfunction is generated due to the energy level of the process being the proportional value of "R" relative to the probability density matrix (Born's Rule) and where R is related to $\bar{\mathbf{v}}$ as $|V_0 - V_1| = R$ and where R is related to the velocity V as $\frac{n_2}{n_1}$, the first derivative of the position $(\dot{q})$ of the ensemble.

We then conclude our arguments relating to the EPR's paradox by stating the following:

a) The system S_{12} after separation is not a true representation of the complete Hamiltonian.

b) The complete Hamiltonian is a summation of the Hamiltonian with the coupling operator "$\mathbf{c}$ ".

c) The transition from coherent state (superposition) to its correlated state is followed by geometrical displacement due to the medium permeability (μ_0)change in phase space.

d) We stipulate a coupling operator (Snell's Law) defining the transition from coherent (pure state) to its observable state due to velocity change of the ensemble.

e) We further stipulate that the geometrical displacement calculated by Snell's Law is represented by the first derivative of the new position $(\dot{q})$.

f) The displacement of (q) within the transition is an energetic event defined by Fresnel's equation and represented by the value (1-R).

g) The value of the geometrical shift is represented by the energy and the residual emission of photons, relative to the relation noted by I $_{Refracted}$ / I $_{incident}$ ratio, defined by Fresnel's equation.

h) The preferred basis out of the probability density matrix $p = \int_V |\psi(x,t)|^2 d^3x$ (Born's Rule) is selected due to energy distribution of the ensemble and it is based on statistical rules such as described by Poisson function.

i) Such selection is the result of the collapse from coherent/entangled state due to velocity change of the ensemble in its transition from superposition state to its observable state.

j) Hence, EPR's Paradox is resolved by the fact that in phase space, small change in the Hamiltonian (H_0) in the superposition state (due to velocity change associated with the geometrical shift in Snell's law region) leads to a new Hamiltonian where $H = H_c + H_e + H_1$ and where H_1 is a coupling operator which acts on the ensemble, during the collapse.

We then conclude that EPR's paradox is in error due to improper accounting of the Hamiltonian and that a new optical operator (the coupling H_1) is to be supplemented in order to eliminate the paradox.

***11** Appendix I

a) Appendix 1 describe the notion of discontinuity associated with the transition from the Schrödinger time evaluation state, a linear description of the Hamiltonian and its transition to its observable state, a process qualified under the standard canonical Heisenberg matrix mechanics as a "Quantum Jump."

b) According to matrix mechanics, an atom can jump suddenly from a state 2 to a state 1 with a photon emission. At $t_1 = |2 >< 2|$holds (Omnès 19949 Section 5.8 and 11.1), if we map the transition to $\mathrm{t}_1 = |2 >< 2|$ by assuming that $t_2 - t_1 \gg \Delta t \equiv t_2 - t_1 \gg \Delta t \equiv \hbar / (E_2 - E_1)$, and where $E_1$and E_2 represent the atom energies in the states 1 and 2, respectively. This transition is defined as the "Quantum Jump," a discontinuous non-linear event.

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H}\Psi + c$$

c) The transition from the Schrödinger *linear* time evolution process (a form of Lagrangian dynamics modified by the introduction of the wave-particle duality) is an example of the energetic event we stipulate as a *modification to the master equation* as a necessary condition for the transfer from the subatomic, non-observable state to its observable state. The dynamic of such transitions is currently described by the Quantum Jump, leading to two independent representations: a *classical* and *quantum mechanical* description of the physical world. The wave packet is described by the Schrödinger evolution and the classical are represented by Lagrangian or Hamiltonian dynamics with its relativistic versions. The transition in the Heisenberg Matrix mechanics is a jump. We classify this jump as a genus for all energetic events transforming out of the Schrödinger state to its observable state, unless we assume that the transition can be assumed to conform to an optical operator in phase space, where the reason for the transition is inherently dependent on the space time manifolds with its permeability constant, as it is an integral element of the abstract space of time/position and frequency/momentum.

d) We then re-introduce Furry's Hypothesis, by positing two different values to the system S_{12} after 'separation'. Whereby the question raised by the EPR's paper is introduced again: which descriptions shall be adapted?

i. Description of the system after separation as noted in para. 4.02, (pure state in superposition), or

ii. Description noted in para. 4.05 (mixture of states with two different eigenvalues corresponding to the density matrix, or Born's rule, but in violation of the Dirac matrix mechanics excluding the ability of non commuting variables to be measured simultaneously).

This is the question which we assume to be in need of an answer, so as to resolve the assertion made by Furry and Sharp in their critique of EPR's assumptions.

e) This is the intellectual juncture which this paper is investigating, and which led to GRW and variety of collapse theories, culminating with the decoherence conjecture, that the environment with controlled set of parameters influences the reduction of the wave packet from its coherent state to its mixture state.

f) We classify the transition as an energetic event and where the transition from pure state (superposition) to observable is characterized by classical optical operator, coupling the energy of the state transition by the use of Snell's Law. We further describe the transition from its pure/coherent linear evolution to its observable state by the use of Born's rule and the density matrix, while computing the probability of such observable (property), by introducing the Fresnel's Intensity formalism. The use of Fresnel leads one to determine the underlying energetic cause for the *preferred basis* of the eigenvalue observed.

g) Let us now formalize these steps, so as to summarize the arguments presented by this paper. In our deliberations we introduced EPR's arguments as well as the criticism of Furry and Sharp. The observations we collected were centered on the main topic of 'what is real'. The EPR's authors set boundary conditions for the notion of what is real, within the framework of what they perceived as canonical descriptions of the system S_{12} after 'separation'. The main criticism of Furry was his attack on the proper description of the system S_{12}, as he contended that the description provided did not account for 'outside influences' such as gravitational as well as electrostatic components. We summarize Furry's hypothesis by the arguments set in para. 4.05 or 4.06 above. Furry further stipulated that the system S_{12} cannot be described as noted by EPR's paper, as there is not sufficient information in the system to deduce the EPR's paradox, due to the incomplete Hamiltonian matrix.

h) Using formal arguments identified by symmetry considerations as defined by Poincaré group algebra, we conclude that gravitational as well as electrostatic influences attributed by Furry to EPR's description of system S_{12} are not valid , as gravitational/electrostatic elements are universal and invariant as is assumed within the EPR paper; we noted that it is surely Einstein, with his keen sensibility to the space manifold construction, that such error wouldn't have committed by Einstein; as invariance noted by para. *9 carefully laid within the paper (3)). Hence, we concluded that the reason for the improper description of the system S_{12}after 'separation' cannot be the logical error that tumbled the foundation of EPR's arguments.

We then followed Furry and Sharp's arguments relating to whether the EPR's arguments defining the complete Hamiltonian are the correct accounting of the system S_{12}energy. The argument posited by this paper is substantially different from Furry and Sharp's arguments regarding the outside influences, as it relates to the quantum state of the system S_{12}, whether there are outside influences that might merit <u>two different</u> descriptions relating to the eigenvectors and represented by two eigenvalues such as the correlated system S_{12}, $\Psi_b(\bar{r}_1,\bar{r}_2) = \Phi_k(\bar{r}_2)\psi(\bar{r}_1)$, where ψ_k is an eigenfunction of the observable in system S_1 and Φ_k is an eigenfunction of an observable in system S_2.

i) This observation is due to the fact that the system after separation is a mixture, (see para. 4.08 and 4.10).

j) Furry's Hypothesis captures the intuitive insight where outside influences of secondary forces impact delicate and low energy event associated with the wave packet collapse. The fact that outside influences are not accounted for by the Hamiltonian was the only argument which might eliminate the EPR's conclusion, that Quantum Mechanical description is *incomplete*, hence a revised theory (hidden variable) is needed so as to account for the fact that there exists a theory with classical attributes which shall identify and predict the observable properties of a physical event. (EPR's arguments never undermined the validity of the statistical nature of Born's rule, as it is consistent with Boltzmann mechanics).

k) The complete Hamiltonian description or its constituents was the subject of study by Hans Dieter Zeh. With the hope to restore a classical view across the physical world description, he introduced the conjecture stating that the dynamical influences of the environment are responsible for the wave collapse from superposition to an observable state. He postulated that such influences might explain the nature of the transition from the superposition state to the observable reality. Hans Dieter Zeh formed the foundation for the notion of decoherence, a phenomenological theory, which attempted to reconcile the micro world description with its observable, classical world view. The intuitive idea that the collapse or the transition state might be explained by physical properties such as temperature, pressure, and Boltzman's thermodynamical considerations, led to a variety of collapse theories under the general headline of 'decoherence'. It was clear from phenomenological considerations that superposition is a coherent state where the ensemble or its single element (particle) with infinitely many of amplitudes (the ensemble in a superposition state) is best described by its linear notion of the time evolution equation. It was further conjectured by Hans Dieter Zeh that the environmental influences impacted the Hamiltonian and the "Quantum Jump" with its nonlinear character might be explained through classical mechanisms. At the time, Hans Dieter Zeh was aware of the prohibition established by Von Neumann, so his attempts avoided the direction of Bohm pilot wave approach, and his arguments were centered on what we later termed as the 'master equation'. Hans Dieter Zeh further exhibited the same attitude, shared by many working scientists, which shows the monumental success of quantum mechanics as an indication that the Copenhagen Interpretation is the true theory, and such orthodoxy was coupled with the argument about the irreducibility of statistics as an additional safeguard from deviation from the canonical formalism of quantum mechanics.

1) The background of the work stated above led us back to the notion of the complete Hamiltonian, or Furry's Hypothesis, reformulated by Hans Dieter Zeh conjecture, which introduced the environment as the cause for the collapse so as to transition the wave packet (observed by the 2-Slit experiment), from its coherent state to its observable state. The selection of the preferred basis, from the pure state to its mixture, is governed by Born's rule$\|\Psi\|^2$, which stated that the probability of an observable event is described by $P(a) = \sum_j P_j \left\| E\Psi_\mathrm{j} \right\|^2$, and

where(a) is the property observed by the selection, or the preferred basis.

Furry's hypothesis relating to the fact that the complete Hamiltonian is not accounted for by EPR's formalism, is then the starting point for the argument relating to the following:

- After separation the system S_{12} cannot be represented simply as a pure state. $r_{12} = (\bar{r}_1 - \bar{r}_2) \neq 0$.
- After separation, the system S_{12} is no longer in a superposition state as the correlated system $S_{12}$is represented by two different eigenvalues. ηk (r_2) and

  Φk (r_2).
- The collapse of S_{12}into a mixture involves additional 'energy,' not accounted for by the complete Hamiltonian. $r_{12} \neq 0$.
- We then concluded that the paradox might be resolved by accepting the intuitive argument of Furry and subsequently the proposed solution of Hans Dieter Zeh, incorporating the environmental influences as the cause for the collapse from pure state to its preferred basis. $H = H_c + H_e + H_1$
- Decoherence, or the reduction of the wave packet to its observable state was followed by genus and species arguments describing the collapse or transition from its coherent state to its mixture through the influence of the environment, mimicked by the Wigner function in phase space, and where probability is the governing rule by which the wave packet collapsed 'energies' are distributed accordingly, so as to obtain the selected eigenvalues as the preferred basis. (See GRW arguments.).This description is captured by the decoherence theory in its mature state, by supplementing the Schrödinger time evolution equation with classical/macro-environmental constants (the master equation). The 'einselection' is now being triggered by a complex constant which enables the collapse in a time

domain dependence, coupled with the Schrödinger equation as the master equation;

$i\hbar\frac{\partial}{\partial t}\Psi = \widehat{H}\Psi + c_k^{ij}$. The term c_k^{ij} is a form of a tensorial structure incorporating a variety of environmental influences depended on establishing 'realistic' boundary conditions so as too satisfy the complete Hamiltonian.

• In our paper, we then conclude that the crux of the EPR's argument must be revised by answering the basic intuitive conjecture of Furry's hypothesis, as to the complete Hamiltonian, where $H_{total} = H_c + H_e + H_1$ (see para. 8.11), and where H_1 is the coupling term, or operator.

• The coupling term H_1 is the physical operator in the transition from pure-superposition state to its observable state, and where the preferred basis, now described by $||\Psi||^2$ is occurring due to an observable event defined by $P(a) = \sum_j P_j ||E\Psi||^2$ as the preferred basis.

• This paper proposes a conjecture whereby the reduction from the superposition/coherent state of the de Broglie's wave/particle is a reduction associated with the first derivative of the position in phase space, and that such transition is governed by Snell's law formalism. We further stipulate that such reduction is principally associated with the permeability of space constant M_0 in phase space, as the reduction involves the velocity difference $|V_0 - V_1|$, and it is proportional to the geometric angle of translation and or rotation relative to Snell's law, by further mapping such transition as noted by the refractive index: $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$, and its characteristics is dependent on the index of refraction $[(n]i)$ in the phase space domain.

m) Since the only element in physical space that influences the medium (phase space) is the permeability of space μ_0 we posit the conjecture that the transition from pure state to its observable is dependent on the permeability value of μ_0,μ_1.... μ_n and the translation and rotation in phase space is related to the angle θ_i, Fresnel's intensity, I_j value is then represented by the proportional energy value of the term R , and where R is defined by Fresnel as: $R = \frac{I_{reflected}}{I_{incident}} = \frac{1}{2}\left[\frac{\sin^2(\theta_1-\theta_2)}{\sin^2(\theta_1+\theta_2)} + \frac{\tan^2(\theta_1-\theta_2)}{\tan^2(\theta_1+\theta_2)}\right]$ and where the transmitted energy observed is equal to $(1 - R)$.

We then conclude under the conjecture that the optical operator (permeability of free space) is the coupling operator H_1. We further correlate Born's rule of finding the relevant observable property as described by $\int_b^a |\Psi(x,t)|^2$ within the possible eigenvalues Ψ_1, Ψ_2...... Ψ_n so as to yield the preferred basis out of the probability spectrum $\int_b^a |\Psi(x,t)^2 c|^3 x = 1$ as a transition of energy from the pure state (coherent) to its observable state. This event is represented by the use of the first derivative of the position (translation, rotation in spherical coordinates) as representing the energetic value associated with the optical operator and H_1 as the coupling operator. This process demonstrated that the group velocity change impacted by the permeability value $\mu_0$in phase space governed by the energy $(1 - R)$is the reason for the wave collapse as an energetic event, hence accounting for the complete Hamiltonian, H_{total}.

n) We then proceed to resolve the EPR's paradox by answering the question posed by the EPR's authors 'what is real', by exploring the standard quantum mechanical formalism, with classical coupling operator, stating that:

n.i) the preferred basis out of the Born's density matrix is an energetic event mapped onto Fresnel's intensity value ‘R’.

n.ii) the energetic event is properly described by geometrization of the phase space transition as a function of permeability constant(μ_0).

n.iii) the transition or collapse is dependent on velocity change as the first derivative of $(\dot{q})$ of the position coordinates.

n.iv) We then relate the geometrical refractive index n of Snell's law to its energetic value by invoking the use of Fresnel's equation and its intensity value $(\mathbf{1} - R)$.

n.v) A correlation between $I =$ transmitted energy relative to the incident angle θ_0 is the operator coercing the coupling operator to enable the preferred basis (or the eigenvalue).

n.vi) We then conclude that the decoherence (phenomenological description) of the event titled as 'emergence', is consistent with Born's rule, as the transition from the superposition to its observable state, which occurs due to a coupling operator and that such operator is governed by an energetic event in classical terms.

Following EPR's criteria for 'what is real' is therefore established by the use of classical, intuitive and observable states accounting for the complete Hamiltonian, and such arguments are the solution to the EPR's paradox.

***12** Appendix II

The following is a predictable algorithm for computing the transition from Schrödinger time evolution functions to its observable state without a 'quantum jumps'.

The discussion and observations relating to the question weather the EPR's arguments lead to its paradoxical conclusion is examined by this paper relative to the question: Is the EPR's description of the system S_{12} a proper one, and does it account for the *complete* Hamiltonian after the separation ? We concluded, based on a modified Furry's hypothesis, that EPR's argument did not account for the total energy of the system after separation. Hence, the system description is either incomplete or the system after separation is represented by two different eigenvalues. (See para. 4.11, $\eta_k(\bar{r}_2)$ & $\Phi_k(\bar{r}_2)$)

The paper then introduced the optical conjecture as a measure of the wave packet reduction, describing the system transition from pure state to its observable one by incorporating the phenomenological assumption of decoherence theory whereby the transition is the result of permeability of space constant in the phase space domain. (para.8.12)

The transition from the superposition entangled state of the ensemble to its manifested observable is characterized by the introduction of a coupling operator. This operator translates the wave collapse as an energetic event in the phase space domain by employing the formalism of Fresnel's equation. (para. 9.04)

The paper then provides an answer relating to the standard representation of quantum mechanics by answering the question: How are we to account for the selection of the *preferred state* out of the Born's probability spectrum?.(para. 9.03)

The answer to the adoption of the Born's rule is identified as a translation or rotational angle generated by the velocity change, described by Snell's law and is proportional to the angle, described as the first derivative of the position coordinates of the system $S_{12.}$

The energetic equivalence between position during the optical shift is then measured by the Fresnel's equation where (1-R) represents the energetic value and is related to the eigenvalue selection, which then accounts for the preferred basis for the selection of the eigenfunction out of the Born's probability matrix.

The paper then concludes that the preferred basis or the eigenvalue selection out of the Born's probability matrix is closely aligned with the energetic value associated with the relative permeability in the phase space domain and the index of refraction.

The proposed solution to the collapse of the wave packet from its superposition to its observable state must answer a critical question: A dynamical system, described by the Schrödinger time evolution function, transitioning to its observable state, must be provided with a predictable algorithm so as to compute the preferred basis or the eigenvalue, by improving the convergence of expectation values predictability of such theory. This effort, which must account for such a description as the Lyapunov exponent [24], is a measure of the system's evolution from its dynamical pure state to its observable state. For simple dynamical systems, knowing the trajectory is often sufficient, but most dynamical systems are too complicated to be understood in terms of individual trajectories. In this paper we posit the fact that the trajectory of the ensemble at the transition from the entangled state of superposition to its observable state is governed by the formalism of Snell's law, and its energetic value is determined by Fresnel's equation. The rate of separation can be different for different orientations of an initial separation vector and in this paper it is postulated as a conjecture, i.e. that the collapse of the ensemble from its coherent state to its observable state is a form of a 2–slit apparatus. The apparatus which coerce the transition, the coupling operator H_1, is manifested by the permeability value in phase space, and its observable (out of the Born' probability spectrum), is the index of refraction, where Snell's refraction index is further associated with the first derivative of position coordinate due to velocity change due to the loss of coherence of the system. Thus, there is a spectrum of Lyapunov exponents equal in number to the dimensionality of the phase space.

The paper then concludes by stating that:

a) The EPR's arguments leading to the conclusion that quantum mechanics is an incomplete description and is incompatible with the standard quantum mechanical description of the system S_{12}, and hence the paradox, is in error due to the fact that the complete Hamiltonian is not accounted for after separation.

b) The insight of Hans Dieter Zeh Conjecture as to the coherence of the superposition vs. the observable state of the system does provide a reasonable solution to the paradoxical results derived by the EPR's authors, and that decoherence is associated with an environmental coupling operator.

d) This paper's conjecture in resolving the collapse of the wave packet transition from its pure state to its observable mixture by employing the coupling operator as an optical displacement in phase space and by defining the coupling operator as the permeability of space constant and its manifestation is demonstrated by using Snell's law formalism.

e) The preferred basis out of the Born's probability rule is linked with the energetic value of the $I_{\text{refracted}}$ vs. I_{incident} as exemplified by Fresnel's equation, and is a corollary the spectrum of probabilistic option in Born's matrix, is reduced to the energetic value of the first derivative of the position coordinate of the ensemble, where the velocity difference of the ensemble is no longer in a superposition state where the wave packet duality is collapsed due to loss of coherence.

f) Serge Haroche and Beiser's calculations of the loss of coherence results can be measured by the use of the optical operator posited by this paper, as decoherence is a measure linked to the observation that <u>The tangential components of any electromagnetic wave are *discontinuous* regardless of any value of energy density at the interface.</u> This discontinuity is related to the permeability of the two mediums.

g) That quantum mechanical description of the Schrödinger time evolution state of the system with its linear characteristics is preserved after decoherence by incorporating the optical coupling operator to the formalism by rearranging the master equation in the following manner:

g.i) Refraction of electromagnetic wave at the interface between two media of different refractive indices, with $n_2 > n_1$. Since the velocity is lower in the second medium ($v_2 < v_1$), the angle of refraction θ_2 is less than the angle of incidence θ_1; that is, the wave in the higher-index medium is closer to the normal. Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of velocities in the two media, or equivalent to the opposite ratio of the indices of refraction. We assumed this rule under the Bohr Correspondence principle.

g.ii) the use of permeability operator in phase space forms the coercive force which causes the transition from coherent superposition state into its observable while addressing the energy transformation so as to account for the complete Hamiltonian. By further relating such transition to its intuitive geometric counterpart under the Snell's law of refraction and by accounting for the energetic transformation by the use of Fresnel's

Equation, we thereby resolve the value of such transition relative to the intensities of the reflected and transmitted electromagnetic wave as a consequence relating the fraction of incident energy that is transmitted.

g.iii) The preferred basis or the eigenvalue of the state after decoherence is governed by the energetic value associated with the permeability constant in phase space and is the reason for the selection of the eigenvalue out of the probability matrix.

g.iv) 'Quantum jumps' are not the proper description of the system as the transition from superposition of an entangled ensemble to its decoherent state and is linear in nature. Its observable is the result of energy associated with the geometrical displacement of the ensemble as it is coupled with the permeability operator, hence the system can be described by the first derivative of the position coordinate in accordance with Snell and Fresnel's equations.

g.v) The system after loss of coherence must assume the form of a dynamical system governed by the formalism and predicable algorithm of Lyapunov exponent.

g.vi) The evolution function Φ^t is the solution of a differential equation of motion $\dot{\chi} = v(x)$.

The equation gives the time derivative, represented by the dot, of a trajectory x(t) on the phase space starting at some point x_0, during a transition from coherent state to its observable. The vector field v(x) is a smooth function which at every point of the phase space M provides the velocity vector of the dynamical system at that point. (These vectors are not vectors in the phase space M, but in the tangent space TM_x of the point x, and is the result of the geometrical transition due to the coupling operator as defined by Snell's law). Given a smooth Φ^t, an autonomous vector field can be derived from it by employing the equivalent value derived from Fresnel's formalism. Hence the transition is linear, governed by the observation that the tangential components of any electromagnetic wave are *discontinuous* regardless of any value of energy density at the interface. This discontinuity is related to the permeability of the two mediums.

We than conclude that the wave packet collapse is a geometrical translation or rotation in the phase space domain and where the transition is smooth, linear and obeys the Lyapunov exponent, and the master equation of the system dynamics is a coupling operator that describe the transition as the first derivative of the system's position coordinates while accounting for the complete Hamiltonian. $G(x, \dot{x}) = 0$

***13** Appendix III

This appendix is presented as a justification to the major assumption that this paper posits a conjecture that the wave packet reduction can be solved by employing the optical phase space and the optomechanical formulation of Hamiltonian mechanics as *analogous*. This assumption must be verified as it assumes that optical and mechanical dynamics are similar in their formal structure and the physical meanings of the entities reviewed are 'real'. Reality check is an important criterion as the EPR's arguments are centered on the notion that 'formalism' and accuracy of the algorithmic apparatus of quantum mechanics must conform to our basic intuitive understanding of the physical universe. A massive geometrization and a comprehensive statistical apparatus does not constitute reality. Paraphrasing on R. Omnes (36) …"*the word "dog" does not bite*." What one must ask of a theory is that it provide a notion describing what we see as fact and that nothing in this theoretical notion should conflict with what we observe as facts." (p 241.).

The analogy of optics and mechanics has long shared many key conceptual ingredients and elements of mathematical structure, as it is described by D. Gloge and D. Marcuse (41) ''Formal quantum theory of light rays''. These include not only the statements of their laws in the form of variational principles but also the exploitation of appropriate canonical formalisms. Arnol'd, V. I, (41), describes the optomechanical analogy, which arguably had a central role in the development of wave mechanics, and is usually expressed by describing analytical mechanics and geometrical optics separately, then pointing out a handful of similarities.

A major landmark in their mutual development was the discovery by Hamilton of *the optomechanical analogy*; (Hamilton 1828), this analogy, where wave and classical mechanics were seen to be related to each other in the same way as wave and ray optics. A historical account of Hamilton optomechanical analogy is described by L.M. Brown, page 1252-1259, as it is related to the conjecture posited by this paper. A detailed formalism of the analogy of employing a synthesis between ray and wave is outlined by R. Simon and N. Mukunda, (40), and an axiomatic definition of the optomechanical analogy is detailed by McKinsey, et al.(43) & (43a).

In summary, we assume that a wave collapse theory following the Bohr's correspondence principle, is a probable representation of the transition from coherent superposition state of the wave particle duality and that such transition takes the canonical form of the Hamilton optomechanical analogy as the substitution of the mechanical attributes to the optional domain, provides us with a transition from the subatomic to its classical manifestation with a contradiction free description by further avoiding the *quantum jump* from the linear Schrödinger time evolution state to its manifestable observable entity, and by accounting for the complete Hamiltonian.

The geometrization hypothesis presented by this monograph is an attempt to describe the physical nature of the wave-packet collapse and its solution is based on the Hamilton optomechanical analogy. Using this analogy, we postulate that the transition from coherent/superposition state to the observable state is governed by the Lyapunov exponent dynamics. The trajectory and separation from the entangled state is postulated as an energetic event defined by an optical coupling operator. The collapse is further described as transition of the wave-packet in phase space and its behavior is modeled by the use of Snell's law of refraction. The preferred (or the privileged) basis out of the eigenvector is represented as a probability spectrum which maps the energetic value of the ensemble relative to Fresnel's trigonometric identity.

We concluded our arguments by stating that the EPR paradox can be resolved by employing the Hamilton optomechanical analogy and as a corollary to the optical collapse conjecture we concluded that the EPR representation of the system after 'separation' did not comply with the rigorous definition of the complete Hamiltonian.

We propose, based on the arguments presented, that the paradox is resolved by stating that after separation the system is no longer in a superposition state, but instead in a mixture state with two different eigenvalues. We then reformulated the description of such 'separation' by introducing the optical coupling operator and by indicating that the dynamics of the collapse satisfies the system's energy transformation, as we have now accounted for the complete Hamiltonian.

***14** Glossary and Notes

The glossary to the article was added in support of certain terms of art, so as to render some of the arguments advocated by the paper to be self contained with its references. The definitions and comments were derived from multiple sources as further identified in the bibliography (*15)

[1]**Schrödinger equation**: $i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$ is an equation that describes how the quantum state of a physical system changes in time. Where Ψ is the wave function; $i\hbar\frac{\partial}{\partial t}$ is the energy operator, i is the imaginary unit, and $\hbar$ is the reduced Planck constant, and $\hat{H}$ is the Hamiltonian operator.

[2]**EPR (Einstein–Podolsky–Rosen) paradox**: Entangled "particles" are emitted in a single event. Conservation laws ensure that the measured spin of one particle must be the opposite of the measured spin of the other, so that if the spin of one particle is measured the spin of the other particle is now instantly known. The most discomforting aspect of this paradox is that the effect is instant, so if something happens in one galaxy it will cause an instantaneous change in another galaxy. But according to Einstein's theory of special relativity, no information-bearing signal or entity can travel at or faster than the speed of light, which is finite. Thus, it seems as if the Copenhagen interpretation is inconsistent with special relativity.

[3]**Copenhagen interpretation**: An interpretation of quantum mechanics. A key feature of quantum mechanics is that the state of every particle is described by a wavefunction, which is a mathematical representation used

to calculate the probability for it to be found in a location or a state of motion. According to this interpretation, the act of measurement causes the calculated set of probabilities to "collapse" to the value defined by the measurement. This feature of the mathematical representations is known as wavefunction collapse.

[4]**Matrix mechanics**: A formulation of quantum mechanics created by Werner Heisenberg, Max Born, and Pascual Jordan in 1925. Matrix mechanics was the first complete and correct definition of quantum mechanics. It extended the Bohr Model by describing how quantum jumps occur. It did so by interpreting the physical properties of particles as matrices that evolve in time. It is equivalent to the Schrödinger wave formulation of quantum mechanics.

[5]**Wave–particle duality**: The concept that all matter exhibits both wave-like and particle-like properties. Being a central concept of quantum mechanics, this duality addresses the inadequacy of classical concepts like "particle" and "wave" in fully describing the behavior of quantum-scale objects. Orthodox interpretations of quantum mechanics explain this ostensible paradox as a fundamental property of the Universe, while alternative interpretations explain the duality as an emergent, second-order consequence of various limitations of the observer. This treatment focuses on explaining the behavior from the perspective of the widely used Copenhagen interpretation, in which wave–particle duality is one aspect of the concept of complementarity, that a phenomenon can be viewed in one way or in another, but not both simultaneously.

[6]**Stern–Gerlach experiment**: Is an important 1922 experiment on the deflection of particles, often used to illustrate basic principles of quantum mechanics. It can be

used to demonstrate that electrons and atoms have intrinsically quantum properties, and how measurement in quantum mechanics affects the system being measured.

[7]**Hamiltonian**: H is the operator corresponding to the total energy of the system. Its spectrum is the set of possible outcomes when one measures the total energy of a system. It is of fundamental importance in most formulations of quantum theory because of its close relation to the time-evolution of a system.

[8] **Local hidden variable theory**: is one in which distant events are assumed to have no *instant* (or at least faster-than-light) effect on local ones.

[9]**Bell's theorem**: A no-go theorem, loosely stating that no physical theory of local hidden variables can ever reproduce all of the predictions of quantum mechanics.

[10]**Quantum entanglement**: A property of a quantum mechanical state of a system of two or more objects in which the quantum states of the constituting objects are linked together so that one object can no longer be adequately described without full mention of its counterpart—even if the individual objects are spatially separated. Quantum entanglement is at the heart of the EPR paradox. This interconnection leads to non-classical correlations between observable physical properties of remote systems, often referred to as nonlocal correlations.

[11]**Furry's Hypothesis**: A conjecture that a state vector is not an attribute of a single electron, photon, trapped ion or quantum dot, but a value of an observable assigned to a physical system which has a meaning only in a context of a particular physical experiment. The EPR paradox is avoided because the reduction of the state vector in the

measurement process is a passage from a description of the whole ensemble of the experimental results to a particular sub-ensemble of these results.

[12]**Heisenberg uncertainty principle**: $\Delta X \Delta P \geq \hbar/2$, states by precise inequalities that certain pairs of physical properties, like position and momentum, cannot simultaneously be known to arbitrary precision. That is, the more precisely one property is known, the less precisely the other can be known. In other words, the more you know the position of a particle, the less you know about its velocity, and the more you know about the velocity of a particle, the less you know about its instantaneous position. If an observable is measured and the result is a certain eigenvalue, the corresponding eigenvector is the state of the system immediately after the measurement. The act of measurement in matrix mechanics 'collapses' the state of the system. If one measures two observables simultaneously, the state of the system collapses to a common eigenvector of the two observables. Since most matrices don't have any eigenvectors in common, most observables can never be measured precisely at the same time. This is the uncertainty principle. If two matrices share their eigenvectors, they can be simultaneously diagonalized. In the basis where they are both diagonal, it is clear that their product does not depend on their order because multiplication of diagonal matrices is just multiplication of numbers. The Uncertainty Principle then is a consequence of the fact that two matrices A and B do not always commute, i.e., that A B - B A does not necessarily equal 0. The commutation relation of matrix mechanics: $\sum_k (q_{nk} p_{km} - p_{nk} q_{km}) = \frac{ih}{2\pi} \delta nm$ Shows that there are no states which simultaneously have a

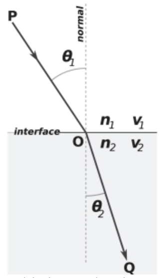
definite position and momentum. But the principle of uncertainty holds for most other pairs of observables too. For example, the energy does not commute with the position either, so it is impossible to precisely determine the position and energy of an electron in an atom.

[13]**Hermitian operator**: Operators in quantum mechanics are of a special kind called "Hermitian". An operator is called Hermitian when it can always be flipped over to the other side if it appears in a inner product: Hermitian operators have the following additional special properties: They always have real eigenvalues, not involving $\boldsymbol{i} = \sqrt{-\mathbf{1}}$. Physical values such as position, momentum, and energy are ordinary real numbers since they are Physical values such as position, momentum, and energy are ordinary real numbers since they are eigenvalues of Hermitian operators. Their eigenfunctions can always be chosen so that they are normalized and mutually orthogonal. In the linear algebra of real matrices, Hermitian operators are simply symmetric matrices. A basic example is the inertia matrix of a solid body in Newtonian dynamics. The orthonormal eigenvectors of the inertia matrix give the directions of the principal axes of inertia of the body.

[14]**Collapse** of a quantum superposition into a single definite state: Is an experimental support to the decoherence hypothesis ,which was quantitatively measured by Serge Haroche and his co-workers at the École Normale Supérieure in Paris in 1996. Their approach involved sending individual rubidium atoms, each in a superposition of two states, through a microwave-filled cavity. The two quantum states both cause shifts in the phase of the microwave field but by different amounts, so that the field itself is also put into a superposition of two states. As the cavity field exchanges energy with its

surroundings, however, its superposition appears to collapse into a single definite state. Haroche and his colleagues measured the resulting decoherence via correlations between the energy levels of pairs of atoms sent through the cavity with various time delays between the atoms.

[15]**Snell's law:** is used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media. The law says that the ratio of the sine of the angles of incidence and of refraction is a constant that depends on the media. In optics, the law is used in ray tracing $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$ to compute the angles of incidence or refraction, and in experimental optics to find the refractive index of a material. Refraction of light or electromagnetic wave at the interface between two media of different refractive indices, with $n_2 > n_1$. Since the velocity is lower in the second medium ($v_2 < v_1$), the angle of refraction θ_2 is less than the angle of incidence θ_1; that is, the ray in the higher-index medium is closer to the normal. Snell's law states that the ratio of the sine of the angles of incidence and refraction is equivalent to the ratio of velocities in the two media, or equivalent to the opposite ratio of the indices of refraction: v = velocity, SI units are m/s, n = refractive index, which is unitless.



This image has been released into the public domain by its author, Sawims.

[15.1] **Refractive index:** of a substance is a measure of the speed of light in that substance. It is expressed as a ratio of the speed of light in vacuum relative to that in the considered medium. The velocity at which light travels in vacuum is a physical constant, and is the fastest speed at which energy can be transferred. However, light travels slower through any given material, or medium, that is not vacuum. The speed of all electromagnetic radiation in vacuum is the same: approximately 3×10^8 meters/second, and is denoted by c. Therefore, if v is the phase speed of radiation of a specific frequency in a specific material, the refractive index is given by: $n = \frac{c}{v}$ or inversely $v = \frac{c}{n}$

This number is typically greater than one. However, at certain frequencies (e.g. near absorption resonances, and for X-rays), n will actually be smaller than one. This does not contradict the theory of relativity, which holds that no information-carrying signal can ever propagate faster than c, because the phase speed is not the same as the group speed or the signal speed. Sometimes, a "group speed refractive index", usually called the *group index* is defined: $n_g = \frac{c}{v_g}$ where v_g is the group speed. This value should not be confused with n, which is always defined with respect to the phase speed. The group index can be written in terms of the wavelength dependence of the refractive index as $n_g = n - \lambda \frac{dn}{d\lambda}$ where λ is the wavelength in vacuum.

[16]**Hamilton–Jacobi equation:** (HJE),is a reformulation of classical mechanics and, thus, equivalent to other formulations such as Newton's laws of motion, LaGrangian mechanics and Hamiltonian mechanics. The Hamilton–Jacobi equation is particularly useful in identifying conserved quantities for mechanical systems, which may be possible even when the mechanical problem itself cannot be solved completely. The HJE is also the only formulation of mechanics in which the motion of a particle can be represented as a wave. The wave equation followed by mechanical systems is similar to, but not identical with,

Schrödinger's equation, for this reason, the HJE is considered the "closest approach" of classical mechanics to quantum mechanics.

[17]**Poincaré group:** is the group of isometrics of Minkowski spacetime. The Poincaré group is a group extension of the Lorentz group by a vector representation of it. Its positive energy unitary irreducible representations are indexed by mass (nonnegative number) and spin (integer or half integer), and are associated with particles in quantum mechanics. Minkowski space is considered as a *homogeneous space* for the group. The Poincaré group is the full symmetry group of any relativistic field theory. As a result, all elementary particles fall in representations of this group. These are usually specified by the *four-momentum* of each particle (i.e. its mass) and the intrinsic quantum numbers J^{PC}, where J is the spin quantum number, P is the parity and C is the charge conjugation quantum number. Many quantum field theories do violate parity and charge conjugation. In that case, we drop the P and the C. Since CPT is an invariance of every quantum field theory.

[18] **Hamiltonians exact solutions:** such as the defined for the hydrogen atom, the quantum harmonic oscillator, are too idealized to adequately describe most systems. Using perturbation theory, we can use the known solutions of these simple Hamiltonians to generate solutions for a range of more complicated systems. For example, by adding a perturbative electric potential to the quantum mechanical model of the hydrogen atom, we can calculate the tiny shifts in the spectral lines of hydrogen caused by the presence of an electric field (the Stark effect). This shows up as a broadening of the energy spectrum lines, something which perturbation theory fails to reproduce entirely.

[19] **Bohr's correspondence principle**: demands that classical physics and quantum physics give the same answer when the systems become large. For example, Einstein's special relativity satisfies the correspondence principle, because it reduces to classical mechanics in the limit of velocities small compared to the speed of light. General relativity reduces to Newtonian gravity in the limit of weak gravitational fields. Laplace's theory of celestial mechanics reduces to Kepler's equations when interplanetary interactions are ignored, and Kepler's reproduces Ptolemy's equant in a coordinate system when the Earth is stationary. Statistical mechanics reproduces thermodynamics when the number of particles is large. The rules of quantum mechanics are highly successful in describing microscopic objects, atoms and elementary particles. But macroscopic systems like springs and capacitors are accurately described by classical theories like classical mechanics and classical electrodynamics. If quantum mechanics should be applicable to macroscopic objects there must be some limit in which quantum mechanics reduces to classical mechanics.

[20] **Born rule**: is a law of quantum mechanics which gives the probability that a measurement on a quantum system will yield a given result. Given a wave function $\psi(x, y, z, t)$ for a single structureless particle in position space, this reduces to stating that the probability density function $p(x,y,z)$ for a measurement of the position at time t_0 will be given by $p(x, y, z) = |\psi(x, y, z, t_0)|^2$

[21]**Stark effect:** is the shifting and splitting of spectral lines of atoms and molecules due to the presence of an external static electric field. The amount of splitting and or shifting is called the Stark splitting or Stark shift. The Stark effect is responsible for the pressure broadening (Stark broadening) of spectral lines by charged particles. When

the split/shifted lines appear in absorption, the effect is called the inverse Stark effect. The Stark effect is the electric analogue of the Zeeman Effect where a spectral line is split into several components due to the presence of a magnetic field.

[22]**Evidence of decoherence in experimental setting**: Habib, S et al. report: (Physical Review Letters, Volume 80, Issue 20, May 18, 1998, pp.4361-4365) states that decoherence can produce a smooth quantum-to-classical transition in nonlinear dynamical systems. High-resolution tracking of quantum and classical evolutions reveals differences in expectation values of corresponding observables. Solutions of master equations demonstrate that decoherence destroys quantum interference in Wigner distributions and washes out fine structure in classical distributions, bringing the two closer together. Correspondence between quantum and classical expectation values is also reestablished.

B. L. Hu, Juan Pablo Paz, and Yuhong Zhang, Phys. Rev. D 45, 2843–2861 (1992) describe the use of the functional path-integral method to derive an exact master equation for the quantum Brownian motion of a particle linearly coupled to a general environment (ohmic, subohmic, or supraohmic) at an arbitrary temperature and apply it to study certain aspects of the loss of quantum coherence

Hu, Paz and Zhang, Phys. Rev. D (1992) 2843] derived an exact master equation for quantum Brownian motion in a general environment via path integral techniques. Their master equation provides a very useful tool to study the decoherence of a quantum system due to the interaction with its environment. In this paper, an alternative and elementary derivation of the Hu-Paz-Zhang master equation, which involves tracing the evolution equation for the Wigner function was introduced.

[23]**Master Equation:** is a phenomenological set of first-order differential equations describing the time evolution of the probability of a system to occupy each one of a discrete set of states: $\frac{dP_k}{dt} = \sum_\ell T_{k\ell} P_\ell$ Where P_ℓ is the probability for the system to be in the state k, while the matrix T is filled with a grid of transition-rate constants. The notation $T_{k\ell}$ indicates an element from this matrix. It is the rate constant of change that corresponds to the transition from state k to state ℓ. Because T is square, the indices ℓ and k may be arbitrarily defined as rows or columns. Here, the first subscript is row, the second is column. The order of the subscripts, which refer to source and destination states, are opposite of the normal convention for elements of a matrix

[24]**Lyapunov exponent:** or Lyapunov characteristic exponent of a dynamical system is a quantity that characterizes the rate of separation of infinitesimally close trajectories. Quantitatively, two trajectories in phase space with initial separation δZ_0 diverge (provided that the divergence can be treated within the linearized approximation) $|\delta Z(t)| \approx e^{\lambda t}|\delta Z_0|$ and where λ is the Lyapunov exponent.

The evolution rule of dynamical systems is given implicitly by a relation that gives the state of the system only a short time into the future. The relation is either a differential equation, difference equation or other time scale. To determine the state for all future times requires iterating the relation many times—each advancing time a small step. The iteration procedure is referred to as solving the system or integrating the system. Once the system can be solved, given an initial point it is possible to determine all its future points, a collection known as a trajectory. For simple dynamical systems, knowing the trajectory is often sufficient, but most dynamical systems are too complicated to be understood in terms of individual trajectories. In this paper we posit the fact that the trajectory of the ensemble at the transition from the entangled state of superposition to its observable state is governed by the formalism of Snell's law and its energetic value is determined by Fresnel's equation. The rate of separation can be different for different orientations of initial separation vector and in this paper is postulated as a conjecture, that the collapse of the ensemble from its coherent state to its observable state is a form of a 2-slit apparatus. The apparatus, which coerces the transition, or the coupling operator H_1, is manifested by the permeability value in phase space and its observable, out of the Born's probability spectrum. The index of refraction (Snell's refraction index) is further associated with the first derivative of position coordinate due to velocity change due to the loss of coherence of the system. Thus, there is a spectrum of Lyapunov exponents which equals in number the dimensionality of the phase space.

[25]**Hilbert space:** formulation of quantum mechanics, and is a description of the possible states (more precisely, the pure states) of a quantum mechanical system. The states are represented by unit vectors (called *state vectors*) residing in a complex separable Hilbert space, known as the state space, and are well defined up to a complex number of norm 1 (the phase factor). In other words, the possible states are points in the projectivization of a Hilbert space, usually called the complex projective space. The exact nature of this Hilbert space is dependent on the system; for example, the position and momentum states for a single non-relativistic spin zero particle is the space of all square-integrable functions, while the states for the spin of a single proton are unit elements of the two-dimensional complex Hilbert space of spinors. Each observable is represented by a self-adjoint linear operator acting on the state space. Each eigenstate of an observable corresponds to an eigenvector

of the operator, and the associated eigenvalue corresponds to the value of the observable in that eigenstate. The time evolution of a quantum state is described by the Schrödinger equation, in which the Hamiltonian, the operator corresponding to the total energy of the system, generates time evolution. The inner product between two state vectors is a complex number known as the probability amplitude. During an ideal measurement of a quantum mechanical system, the probability that a system collapses from a given initial state to a particular eigenstate is given by the square of the absolute value of the probability amplitudes between the initial and final states. The possible results of a measurement are the eigenvalues of the operator—which explains the choice of self-adjoint operators, for all the eigenvalues must be real. The probability distribution of an observable in a given state can be found by computing the spectral decomposition of the corresponding operator. For a general system, states are typically not pure, but instead are represented as statistical mixtures of pure states, or mixed states, given by density matrices: self-adjoint operators of trace one on a Hilbert space. Moreover, for general quantum mechanical systems, the effects of a single measurement can influence other parts of a system in a manner that is described instead by a positive operator valued measure. Thus the structure both of the states and observables in the general theory is considerably more complicated than the idealization for pure states. Heisenberg's uncertainty principle is represented by the statement that the operators corresponding to certain observables do not commute, and gives a specific form which the commutator must have.

***15** BIBLIOGRAPHY:

(1)Bernard d'Espagnat: Conceptual Foundations of Quantum-Mechanics second edition, (1976) W.A Benjamin Inc.

(2)Born Einstein letters: Letter number 88, April 5th 1948

(3)Einstein-Podolsky-Rosen: Can Quantum-Mechanical description be complete? (EPR) In Physics Review 47,777 (1935)

(4)Wigner P. The problem of Measurement in American Journal of Physics Vol. #31, no.1 January 1963

(5)Fine A.: On the Completeness of Quantum-Theory. In Syntheses 29, 1974 p.257-289

(6)Bohr D. and Aharonov Y.: In Physics Review 108,1070. 1957

(7)Sharp H. D: The EPR paradox re-examined. in Philosophy of Science Vol. 28, no. 3. 1961. p.225-233

(8)Einstein A.: "Discussions with Einstein on Epistemological problems in Atomic Physics" by N. Bohr p.201-241

(9)Einstein A. Physics and Reality. In the "Journal of Franklin Institute" 221,349 (1936)

(10)Dirac P.A.M "The Principle of Quantum-Mechanics" third edition, Oxford and N.Y. 1947

(11)Putnam H.: Comments on the paper of D. Sharp. In Philosophy of Science Vol.28, No.3. July 1961 p.234-239

(11a)Putnam H.: Comments on comments on comments; A reply to Morgan and Wigner "Philosophy of Science" Vol.31, January 1964

(12)Clauser J.F & Shimony A.: Bell's Theorem, Experimental Tests & Implication. Rep. Vol. 41 Prog. Phys. 1978.

(13)Bell, J., "On the Einstein-Podolsky-Rosen Paradox," Physics, 1, 1964, 195- 200.

(13a) Bell, J., “On the Problem of Hidden Variables in Quantum Theory,” Reviews of Modern Physics, 38, 1966, 447-452.

(14)J.S.Bell, Speakable and Unspeakable in Quantum Mechanics, Cambridge, Cambridge UP, 2004.

(15)Ghirardi, G.C., Rimini, A., and Weber, T. "A Model for a Unified Quantum Description of Macroscopic and Microscopic Systems". Quantum Probability and Applications, L. Accardi et al. (eds), Springer, Berlin. (1985).

(16) Haroche, S. and Jean-Michel Raimond, (2006). Exploring the Quantum: Atoms, Cavities, and Photons, Oxford University Press

(17) Penrose, R. Road to Reality pp856-860

(18) Penrose R. Gravity and State Vector Reduction, in Quantum Concepts in Space and Time. Eds. R.Penrose and C. J. Isham (Clarendon Press, Oxford, 1986).

(19) Gregg Jaeger, Abner Shimony, Lev Vaidman, "Two interferometric complementarities", Phys. Rev. A, Vol. 51, 54 (1995)

(20) Berthold-Georg Englert, "Fringe Visibility and Which-Way Information: An Inequality", Phys. Rev. Lett., Vol. 77, 2154 (1996)

(21) Daniel M. Greenberger, Allaine Yasin ,"Simultaneous wave and particle knowledge in a neutron interferometer", Phys. Lett. A 128, 391, (1988)

(22) Kochen, S., and E. Specker, “The Problem of Hidden Variables in Quantum Mechanics,” Journal of Mathematics and Mechanics, 17, 1967, 59-87.

(23) Von Neumann, J., Mathematische Grundlagen der Quantenmechanik, Springer-Verlag, 1932.(Translated as Mathematical Foundations of Quantum Mechanics, Princeton University Press,1955.)

(24) Healey, R.., The Philosophy of Quantum Mechanics: An Interactive Interpretation. 1989, Cambridge: Cambridge University Press

(25) Aspect, 1981: A. Aspect et al., Experimental Tests of Realistic Local Theories via Bell's Theorem, Phys. Rev. Lett. 47, 460 (1981)

(25a)Aspect, 1982a: Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities, Phys. Rev. Lett. 49, 91 (1982).

(26) Wojciech Hubert Zurek, (2003), Decoherence, einselection, and the quantum origins of the classical, Rev. Mod. Phys. 75, 715–775

(27) Everett, H. (1957), .Relative State Formulation of Quantum Mechanics., Re-views of Modern Physics 29, 454-62.

(28) Michiyon Akane & Craig G. Fraser, The Early History of Hamilton- Jacobi Dynamics 1834-1837. Centaurus: Vol. 44: PP. 161-227 Munksgaard 2002. Centaurus ISSN 0008-8994.

(28a) Hamilton, W. R., Supplement to an Essay on the Theory of Systems of Rays, Transactions of the Royal Irish Academy 16, 1±61 (1830).

(29) D. Bohm, Y. Aharonov, Discussion of experimental proof for the paradox of Einstein, Rosen, and Podolsky Phys. Rev. 108, 1070-1076 (1957)

(30) W.H. Furry Note on the quantum-mechanical theory of measurement
Phys. Rev. 49, 393-399 (1936)

(31) Bohr, Niels (1976), Rosenfeld, L.; Nielsen, J. Rud, eds., Niels Bohr, Collected Works, Volume 3, The Correspondence Principle (1918–1923), 3, Amsterdam: North-Holland, ISBN 0444107843

(32) Beiser, Arthur, (1995) Concepts of Modern Physics, 5th Ed., McGraw-Hill.

(33) Salman Habib, Kosuke Shizume, Wojciech Hubert Zurek, (1998) Decoherence, Chaos, and the Correspondence Principle, Journal reference: Phys.Rev.Lett. 80, 4361-4365

(34) Guido Bacciagaluppi, The Role of Decoherence in the Foundations of Quantum Mechanics, QMLS Workshop, Vancouver, April 2003

(35) L. de Broglie, Recherches sur la théorie des quanta (Researches on the quantum theory), Thesis (Paris), 1924; L. de Broglie, Ann. Phys. (Paris) 3, 22 (1925). Reprinted in Ann. Found. Louis de Broglie 17 (1992) p. 22.

(36) Roland Omnès,(1999) Understanding Quantum Mechanics, Princeton University Press

(37) H. Dieter Zeh, On the Interpretation of Measurement in Quantum Theory, *Foundation of Physics*, vol. 1, pp. 69-76, (1970).

(38) D. BOHM and J. BUB, (1966) A Proposed Solution of the Measurement Problem in Quantum Mechanics by a Hidden Variable Theory, Rev. Mod. Phys. 38, 453–469 (1966)

(39) Chung-Hsien Chou1, Ting Yu and B. L. Hu, Exact Master Equation and Quantum Decoherence of Two Coupled Harmonic Oscillators in a General Environment. ArXiv: quant-ph/0703088v2 9 Dec 2007

(40) R. Simon and N. Mukunda, Optical phase space, Wigner representation, and invariant quality parameters, J. Opt. Soc. Am. A/ Vol. 17, No. 12/December 2000

(41) D. Gloge and D. Marcuse, Formal quantum theory of light rays, J. Opt. Soc. Am. 59, 1629–1631 (1969); D. Marcuse, Light Transmission Optics (Van Nostrand Reinhold, New York, 1972), Chap. 3.

(42) Arnol'd, V. I.: 1997, Mathematical methods of classical mechanics, Berlin, Springer.

(43)McKinsey, J. C. C., A. C. Sugar, and P. Suppes: 1953, Axiomatic foundations of classical particle mechanics, Journal of rational mechanics and analysis 2, 253-72

(43a) McKinsey, J. C. C. and P. Suppes: 1953, Transformations of Systems of Classical Particle Mechanics, Journal of rational mechanics and analysis 2, 273-89

(44) Carnap, C.F., “Uber die Aufgabe der Physik,” *Kantstudien* 28, 90-107 (1923)

(45) Jammer, M., The Conceptual Development of Quantum Mechanics, pp323, McGraw-Hill Book Company (1966)

Josh Yehoshua Shachar is an inventor and mathematician with over 20 years experience in the fields of advanced medical technologies and military systems. He has over 70 currently active patents and applications to his name and has held multiple executive management positions at high-technology companies. He is the principal owner and founder of Engineered Magnetics, Inc. (www.engineeredmagnetics.net), a military aerospace company, Pharmaco-Kinesis Corporation (www.pharmaco-kinesis.com), a smart medical device company, and Magnetecs Corporation (www.magnetecs.com), which creates robotically guided medical devices. He attended UCLA as a Fulbright scholar, then received his B.A. (University of Haifa) and M.A. (University of Southern California) in Philosophy.

NOTES ON EINSTEIN-PODOLSKY-ROSEN (EPR) PARADOX
&
HAMILTON OPTOMECHANICAL ANALOGY

The quantum-mechanical view of the world may be summarized in the following manner: Physical situations are characterized by state functions; these in turn determine the probability distributions of the eigenvalues of the various operators corresponding to the physical quantities that are associated with the situation. Our knowledge of how the situation evolves in time (i.e. the Schrödinger time evolution equation) enables us to have sufficient information for associating particular eigenvalues with certain physical quantities. If so, what is the problem called "interpretation" within the framework of quantum-mechanics?

The monograph presents the above problem, within the context of the EPR Paradox, by re-evaluating the question: Does quantum mechanics formalism provide a complete description of the system dynamics? The paper proposes a wave-packet reduction hypothesis, where the reduction from the superposition/coherent state of the de Broglie wave/particle pair can be formulated as a refractive event in optical domain-coupling in phase space. Further, we propose that the transition from superposition to decoherent state is governed by Snell's law.

Furry's hypothesis examines the EPR Paradox and the authors' inquiry on the nature of 'what is real'. The hypothesis undermines the EPR Paradox's description of the system after separation. Is it a pure or a mixture state? By scrutinizing the treatment of the complete Hamiltonian, Furry derives a resolution for the paradox.

Following the work of H.D. Zeh and the decoherence theory, we then propose to reformulate and resolve the EPR's Paradox by introducing an optical coupling operator (by way of a 'master equation'), redefining the boundary conditions that lead to the wave-packet collapse.

The analogy of optics to mechanics has long shared many key conceptual ingredients and elements of mathematical structure. A major landmark in their mutual development was the discovery of structural similarities summarized by Hamilton in Supplement to an Essay on the Theory of Systems of Rays (1830). The analogy states that wave and classical mechanics are related to each other in the same way as wave and ray optics.

We conclude the paper by stating that the EPR Paradox can be resolved by employing the Hamilton optomechanical analogy approach to the wave-packet collapse. Snell's law of refraction and Fresnel's formalism in phase space provide for a simple and intuitive account of such physical events. This geometrization hypothesis of the wave packet reduction enables a selection of the preferred ("privileged basis") eigenvalue out of the spectrum of Born's probability matrix without resorting to a set of ad-hoc constants in describing the collapse from the Schrödinger time evolution state to the observable state.

Following Bell's criticism of "Quantum Jumps", we close by proposing an optical conjecture that describes the wave packet collapse as a linear transition using terms of an optogeometrical method.

$12.95
ISBN 978-0-615-37806-0
51295>
9 780615 378060