Scientific Research Publishing

Journal of High Energy Physics, Gravitation and Cosmology, 2023, 9, 301-352
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

History Lessons from the 5th Solvay Meeting, 1927

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How to cite this paper: Beckwith, A.W. (2023) History Lessons from the 5th Solvay Meeting, 1927. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 301-352.
https://doi.org/10.4236/jhepgc.2023.91023

Received: October 31, 2022
Accepted: January 28, 2023
Published: January 31, 2023

Abstract

Largely drawn from "Quantum Theory at the Crossroads: Reconsidering the 1927 Solvay Conference" by Guido Bacciagaluppi and Antony Valentini, but also from several books by Pais ("Inward Bound" and "Subtle is the Lord"), plus other sources, we examine some of the very contemporary themes as to quantum measurement which were debated in the 5th Solvay meeting. In addition, we also discuss some issues given by Roland Omnes in "Understanding Quantum Mechanics" as to the problem of classical and quantum properties, which is at the forefront of the Quantum Gravity issues of how to reconcile semi classical physics with the presumed bridge between Planckian physics (presumably quantum in nature) with the rest of cosmology. The issues argued in part by the Solvay meeting as to Quantum measurements and the competing Pilot theory, as brought up by De Broglie, and how that plays out as to the later Hidden Variables and the alleged determinism foundations of an embedding structure for Quantum physics, still are with us, and make the Solvay meeting, 1927 a stellar event, still worth revisiting 90 years later.

Keywords

The 5th Solvay Meeting, Quantum Measurement, Quantum Gravity

1. Introduction

In our review of what to expect from this paper, we will be making several analogous inquiries as to the history and its consequences for the development of physics.

a) First of all we go into how both the Matrix (Heisenberg) and (Schrodinger) wave equation versions of quantum mechanics both have fidelity with respect to each other, and can and do have historical inputs into the Heisenberg Uncertainty principle. More to the point, they in terms of larger physical systems, than the usually small scale quantum domain of applicability both fulfill the requirements of the Correspondence principle, as of the mean both systems duplicate classical behavior. In the case of the Heisenberg principle, as outlined by Omnes, in both of his volumes [1] [2] this correspondence principle, is built directly into that formula structure explicitly. In the case of Schrodinger's equation, this correspondence with Classical behavior is seen directly in Ehrenfest's theorem, as seen in Bacciagaluppi and Valentini [3], as well as in Gasiorowitz's elementary QM textbook [4]. Needless to say, this is elementary, but at times overlooked, and the consequences of this blending into the classical regime of physics, are outlined thoroughly in the fourth volume of Mehra and Rechenberg's historical rendition [5] of how Heisenberg built up his "matrix model".

b) The contrast with the Pilot Model of De Broglie, as given in [3] is sobering and stark. The Pilot model sought to use a single-particle "trajectory' as a way to avoid the use of the probabilistic interpretation of Quantum mechanics, but in doing so, the particle trajectories become so complicated that later, as mentioned in both [6], and [7] that probabilistic interpretations of the hyper complex particle trajectories, become essential. In addition, the De Broglie version of the Pilot model used what De. Broglie called U waves, which failed, as brought up by Pauli, allegedly failed basic criteria of adherence to the necessary phenomenology observed with the physics of Inelastic scattering.

De Broglie eventually dropped his initial version of Pilot theory, although it was re-resurrected by both Bohm and Schrodinger, and the revised version, still had the defect of single particle trajectories, having such complexity that probability was deemed essential in their analysis and evaluation.

In short, the Pilot theory, albeit not necessarily wrong, appears to use probability to have a single particle trajectory approach observed experimental conditions, which is actually the reverse of the quantum case.

c) Finally, it is worth noting that as brought up in [8] [9] that the Pilot model has a hard time ever generalizing to special relativistic conditions, a jump done in QM within 2 years due to the intervention of Dirac [3] [10]. *I.e.* even now, as brought up by [8] [9] that physicists struggle to obtain via the Bohmian Pilot model, to do what Dirac did so cleanly in [10] [11] [12] [13].

d) It is also seen in Omnes [1] [2] that the eventually "improved" version of the Pilot model has a modified Hamilton-Jacobi expression, with an action S, acted on its left hand side. Also, the right hand side has a new term often called Q, as a "quantum potential", which is not necessarily going to easily go away.

e) In terms of the Quasi Newtonian expression, for the Pilot model, the left hand side is F = mass times acceleration, but the right hand side is negative 1 times the gradient of the (standard potential, V, plus the Quantum potential Q).

This means that we do not have an averaged out Ehrenfest's theorem [3] [4] [5], as in the QM case, but that we hope we can have (V + Q) act, effectively as a classically behaving right hand side of F = Mass times acceleration.

f) Is that guaranteed to happen? *I.e.* in e? Not necessarily. In theory yes, but in practicality, not always.

So, in terms of Oscam's razor [14], it appears that the Pilot model runs into trouble with a neat correlation to the Correspondence principle.

The take away here, is that if you wish to have a comparatively clean delineation between classical and Quantum effects, that the Pilot model has difficulties.

But wait, what about the main clash in the 1927 Solvay meeting? Between Bohr and Einstein as to the Heisenberg Uncertainty principle? Here, Bohr and Einstein in 1927 argued initially as to the correctness of quantum mechanics, *i.e.* as seen in [3] [15]:

We shall in our text develop other issues with respect to the Uncertainty principle, as related by [15] [16] [17] [18] and one of the most startling, is the suggestion in [18], which has extremely important implications, for the inter relationship between classical and quantum models, that a three body system, as described in their article could imitate much if almost all of the phenomenology of the double slit experiment.

Next, by 1930, in the failure of the 2nd Bohr-Einstein debate, in Salvoy, Einstein turned to the alleged incompleteness of Quantum Mechanics and came up with the startling EPR publication, which lead to quantum entanglement [19].

From Wikipedia [20].

quote:

The Einstein-Podolsky-Rosen paradox or EPR paradox [1] of 1935 is an influential thought experiment in quantum mechanics with which Albert Einstein and his colleagues Boris Podolsky and Nathan Rosen (EPR) claimed to demonstrate that the wave function does not provide a complete description of physical reality, and hence that the Copenhagen interpretation is unsatisfactory; resolutions of the paradox have important implications for the interpretation of quantum mechanics.

End of quote

g) We will in our discussion of the EPR, and then Entanglement, highlight a potential cosmological application area, as brought up by the author, in [21] where the author writes as of the reference:

Quote

We review Vuille's generalized Schrödinger equation with its Ricci scalar inclusion, in curved space-time. This has a simplified version in the pre-Planckian regime, which leads to comparing a resultant admissible wave function with Bohmian reformulations of quantum physics, a radial distance given by a modified Poisson's equation and a minimal graviton mass. Finally, we look if Bohmian mechanics has a role in our formulation.

End of quote

If the radial distance, as analyzed goes to zero, and we cannot refer then to Bohmian mechanics, we then may have to reduce our inquiry, especially if there is a pre Universe structure, to post universe starting expansion structure to be linked by some variant of entanglement, if we wish to connect the Pre Universe physics constants, to the present universe physics constants, like as an example, $\hbar$. This methodology will be brought up in the next section, *h*.

h) In addition we will say more about the Pilot model, plus its limitations, and the Correspondence principle, and how that could influence certain issues as of quantum gravity.

In so many words, this plus other ideas will form the basis of our review of the sort of physics which make their appearance in our document, as far as Salvoy lessons. And we will refer and elaborate upon each of these topics in our manuscript.

i) Quantum Geometrodynamics, as given in [22] will be given as a way to introduce the idea of the applications of the discussion of the nature of time, as brought up in Salvoy, [3], in particular a discussion of "time after quantization" as given in page 149 of [22] will be brought up in terms of a wave functional, and the Wheeler De Witt equation which does without an explicit time dependence as written up in Equation (5.18), Page 149 of [22], which actually parallels in its own way what was brought up by Schrodinger, in [3] about his view of the relevance of time in quantum microsystems, versus a contained closed quantum state. This also will be a way to introduce the ideas of quantum statistics, as given both by Schrodinger, in [1] [2], Einstein, in [15], and its links to present cosmological issues as arising in present research [22].

j) In this, a suggestion by Dr. Robert Baker, as to a difference in time flow, as far as the early universe, as a counterpart to the above suggestions, but well within the idea of quantum measurements, and quantum dynamics will be introduced [23].

k) In [24] we show how these ideas are pertinent as to the idea that Quantum mechanics maybe embedded within a deterministic super structure, [25] which is in itself an extension of the debate as to complementarity, and the use of quantum physics, as opposed to the Pilot model and hidden variables. Which was debated extensively in Solvay, 1927.

l) Finally, we will conclude with a review of the document given to the author by Corda and others as far as Torsion [26], *i.e.* extensive use of the ideas of using commutators, is used, and we will compare their suggested use of commutator algebra with the Heisenberg, Schrodinger, and also Dirac derivation of commutator algebra as given in [3] and [5], as far as giving insight as to the applications of correspondence, as was discussed in numbing detail in [13] and [15] by Pais, who actually knew several of the contributors to the Solvay conference.

In doing all this, we outline what is admittedly going to be a long paper, and in our conclusion, we will outline lessons learned from Solvay, as a conclusion as to the (a) to (l) topics brought up, with a closing suggestion as to what this portends for quantum gravity research issues. We also will briefly talk about more recent efforts to interpret quantum theory as a subset of a larger deterministic structure in our concluding remarks, with reference to [25] and its comparison with [27]. Secondly is a new HUP principle, as elucidated by the Author [28] and then the inflaton field used as a measurable datum, as brought up by Corda, in [29], plus the final supposition, as given by the author as that the new elucidated Heisenberg Uncertainty principle, may be linked to the start of the preliminary expansion of the Universe as given in [30].

a. This last supposition, as given in [30] will be actively compared to the Einstein-Bohr debates as given in the context of the 1927 and 1930 Solvay debate positions by Einstein and Bohr, with the author making some final concluding remarks on what if [30] is true, and what it pertains to, in the search for a robust version of Quantum gravity in the early Universe. Also, it is important to note what [31] brings to the discussion as to the correspondence principle.

2. First, Block of Review, How the Correspondence Principle, and Linkage of Quantum Formalism to Classical Physics Was Used to Construct the Heisenberg Equation; and the Alternate Protocol Used by Schrodinger via Ehrenfest's Theorem, to Obtain Linkage to Classical Physics for the Schrodinger Equation

To start this, begin looking at how the Correspondence principle was initiated as a way to simplify experimental connections from the laboratory with purported physical theories, and this is a take off of the discussion in [3]. In [32] there is a simple Fourier mathematical bridge which is presented with concludes as follows:

Quote from [32]

To summarize, the classical limit problem has been debated since the birth of quantum theory and is still a subject of research. In this paper, we present a simple mathematical formulation of Bohr's correspondence principle. We consider the simplest quantum system, the harmonic oscillator, and obtain exact classical results. We believe that this approach illustrates in a clear fashion the difference between Planck's limit and Bohr's correspondence principle. Finally, using this simple procedure we find corrections to the exact classical result as a series in the ratio $\hbar S$, *which is very small for classical energies but not zero. It would be interesting to test whether this energy dependence could be observed for the case of real quantum systems approaching the microscopic-macroscopic boundary.*

End of quote from [32]

The results referenced above, are in response to the very real struggle still going on today [33] [34], as to make linkage to the classical and quantum domains, of space-time and their formalistic connections. *I.e.* what we will do is to reproduce the simpler ideas brought up in the 1920s and 1930s which gives the physical essence of the problems debated, *i.e.* in the case of the Heisenberg equation derivations, we find that the QM commutation relations, as thought of by Heisenberg were used directly to make a bridge from the Matrix mechanics approach to obtain a classical equation.

The closest to this Heisenberg idea, ironically, is mentioned in [34] which is a classical version of the Quantum Fock spaces, which is further amplified in [35] where the idea is to use a mean field theory approach, leading to:

Quote:

We present a semi-classical approach to many-body quantum propagation in terms of coherent sums over quantum amplitudes associated with the solutions of corresponding classical nonlinear wave equations. This approach adequately describes interference effects in the many-body space of interacting bosonic systems.

The main quantity of interest, the transition amplitude between Fock states when the dynamics is driven by both single-particle contributions and many-body interactions of similar magnitude, is non-perturbatively constructed in the spirit of Gutzwiller's derivation of the van Vleck propagator from the path integral representation of the time evolution operator, but lifted to the space of symmetrized many-body states. Effects beyond mean-field, here representing the classical limit of the theory, are semi-classically described by means of interfering amplitudes where the action and stability of the classical solutions enter. In this way, a genuinely many-body echo phenomenon, coherent backscattering in Fock space, is presented arising due to coherent quantum interference between classical solutions related by time reversal.

End of quote

The Heisenberg approach was in a sense very different, in that one used in Matrix mechanics, which will be outlined, a space in the derivations, where Quantum versions of commutation relations are inserted directly in order to bridge to a known classical result. This is in essence a 180 degree reversal from the program indicated above, and it is novel in its clever use of the imperative to use quantum commutation relations. To obtain a classical result in the mean, one has to use quantum mechanical reasoning.

From [1] [2] [3] we can say that Heisenberg started off with looking at

$$\begin{aligned} \nu_{n,m} &= \text{frequency change from } |n\rangle \text{ to } |m\rangle \text{ atomic states} \\ &= (E_n - E_m)/h \end{aligned} \tag{1}$$

This Equation (1) especially as given in [1] was directly inserted into what Heisenberg considered as a "resonating quantum quantities to consider/evaluate which we write up as

$$X_{nm}(t) = X_{nm} \exp\left[-2\pi i \nu_{n,m} t\right] \tag{2}$$

By the correspondence principle, the classical analog of Equation (2) is $X(t)$.

Note that Equation (1) and Equation (2) were thought of by Heisenberg as in the case of an atom in an electric field. And this classically to QM transformation would be denoted by

$$\text{Classically} \leftrightarrow qE(t)x(t) \xrightarrow[\text{Heisenberg substitution}]{} \text{QM} \leftrightarrow qE(t)X_{nm}(t) \tag{3}$$

We can then summarize that any classical quantity to QM would be linked by

$$\text{Classically} \leftrightarrow a(t) \xrightarrow[\text{Heisenberg substitution}]{} \text{QM} \leftrightarrow A_{nm}(t) \tag{4}$$

The linkage to commutation relations is later given by, in [1] page 26 of that reference by the following treatment of the time derivative of Equation (2) to read as

$$\begin{aligned}&\frac{\mathrm{d}X_{nm}(t)}{\mathrm{d}t}=V_{nm}(t)=\frac{-2i\pi}{h}(E_m-E_n)X_{nm}(t)=\frac{i}{h}(E_nX_{nm}(t)-X_{nm}(t)E_m)\\&\Rightarrow\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{i}{h}[H,X]\ \&\ H=\frac{P^2}{2m}\\&\Rightarrow\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{i}{h}[H,X]=\frac{i}{2mh}\cdot(P\cdot[P,X]+[P,X]P)\xrightarrow[{[P,X]=\frac{\hbar}{i}I}]{}\frac{P}{m}\\&\text{i.e. }\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{P}{m}\\&\text{iff }[P,X]=\frac{\hbar}{i}I\end{aligned}\tag{5}$$

The executive summary is that judicious application of $[P,X]=\frac{\hbar}{i}I$ allows us to retrieve the classical equation of motion, *i.e.* in the Heisenberg picture of matrix mechanics, the above argument allows a linkage of $\frac{\mathrm{d}X_{nm}(t)}{\mathrm{d}t}$ to $\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{P}{m}$, *i.e.* to summarize the above argument we have

$$\begin{aligned}&\frac{\mathrm{d}X_{nm}(t)}{\mathrm{d}t}\xrightarrow[{[P,X]=\frac{\hbar}{i}I}]{}\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{P}{m}\\&\text{iff }[P,X]=\frac{\hbar}{i}I\end{aligned}\tag{6}$$

A similar set of arguments, allows us if, we use for a potential we write as a Polynomial we can get

$$\begin{aligned}&V(X)=a_0+a_1X+a_2X^2\\&\&\ H=\frac{P^2}{2m}+V(X)\\&\&\ [P,V(X)]=\frac{\hbar}{i}V'(X)\\&\frac{\mathrm{d}P}{\mathrm{d}t}=\frac{i}{h}[H,P]\xrightarrow[{[P,X]=\frac{\hbar}{i}I}]{}\frac{\mathrm{d}P}{\mathrm{d}t}=-V'(X)\end{aligned}\tag{7}$$

What we have obtained, especially in the bottom of Equation (7) is what we will refer to in the Schrodinger equation picture as Ehrenfest's Theorem, which will be showed to be correct, so in doing so, what we will show is that in the Schrodinger Equation picture, that we will have, then

$$\begin{aligned}&(\text{Heisenberg})\frac{\mathrm{d}P}{\mathrm{d}t}=\frac{i}{h}[H,P]\xrightarrow[{[P,X]=\frac{\hbar}{i}I}]{}\frac{\mathrm{d}P}{\mathrm{d}t}=-V'(X)\\&\Leftrightarrow(\text{Schrodinger Ehrenfest Theorem})\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t}=-\langle V'(X)\rangle\\&\&\ (\text{Schrodinger})\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t}=-\langle V'(X)\rangle\text{ for classical }\frac{\mathrm{d}P}{\mathrm{d}t}=-V'(X)\\&\Leftrightarrow(\text{Heisenberg})\frac{\mathrm{d}P}{\mathrm{d}t}=\frac{i}{h}[H,P]\xrightarrow[{[P,X]=\frac{\hbar}{i}I}]{}\frac{\mathrm{d}P}{\mathrm{d}t}=-V'(X)\end{aligned}\tag{8}$$

So, now then we will give a proof of 3rd equation of (8) above in the Schrodinger Equation representation. Note that the above equations are a fairly succinct presentation in QM of the Correspondence principle.

So as to give reality to the last part of Equation (8) above, we will next go to III. And prove Ehrenfest's Theorem.

3. Proving Ehrenfest Theorem, via Schrodinger Mechanics

We will use this section to show the proof of the following Equation.

$$\begin{aligned}&\left(\text{Schrodinger Ehrenfest Theorem}\right)\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t}=-\langle V'(X)\rangle\\&\text{for classical }\frac{\mathrm{d}P}{\mathrm{d}t}=-V'(X)\end{aligned}\tag{9}$$

Now, following [1] [2] [3] [36] and [37] we can write the Schrodinger Equation as having the following representation, namely if Ψ is a wave function, and H a Hamiltonian, then by [36] we write the following

$$|\dot{\Psi}\rangle=-\frac{i}{\hbar}H|\Psi\rangle \;\&\; \langle\dot{\Psi}|=\frac{i}{\hbar}\langle\Psi|H \tag{10}$$

If so then, for any generalized Schrodinger equation, for an operator Ω we find then that the following holds [1] [2] [3] [36] and [37]

$$\frac{\mathrm{d}\langle\Omega\rangle}{\mathrm{d}t}=-\frac{i}{\hbar}\langle\Psi|[\Omega,H]|\Psi\rangle \tag{11}$$

Then, largely from [4] [36] we can write if we use the Schrodinger based operator equation

$$\vec{p}=-i\hbar\vec{\nabla} \tag{12}$$

Will then lead to the following:

$$\begin{aligned}&\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t}=-\frac{i}{\hbar}\langle\Psi|[P,H]|\Psi\rangle=\frac{1}{i\hbar}\langle\Psi|[P,V]|\Psi\rangle\\&\xrightarrow[3\text{ dim}\to1\text{ dim}]{}-\int\Psi^*\cdot\frac{\mathrm{d}V(x)}{\mathrm{d}x}\cdot\Psi\mathrm{d}x\\&\xrightarrow[1\text{ dim}\to\text{Any dim}]{}\left\langle-\frac{\mathrm{d}V(x)}{\mathrm{d}x}\right\rangle\sim\langle-\vec{\nabla}V\rangle\equiv F(\text{force})\\&\text{when }\vec{p}=-i\hbar\vec{\nabla}\Leftrightarrow\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t}=\langle-\vec{\nabla}V\rangle\equiv F(\text{force})\end{aligned}\tag{13}$$

We assert that then, via these techniques, the Correspondence principle is upheld and by Equation (8) then that the Schrodinger and Heisenberg formulations of Quantum mechanics are giving equivalent information.

4. Summing up the Similarities of Both II and III, in Terms of the Correspondence Principle

I.e. in both situations, for both the Heisenberg and the Schrodinger equations, the commentator relationships as given by

$$[P,X]=\frac{\hbar}{i}I \tag{14}$$

Will lead to at a mean representation of force = mass times acceleration, thereby leading to in the mean a representation of local system quantum phenomenology being averaged out in a mean, to the astounding results that we then, through judicious application of Equation (14) obtain in the mean, the following equations

$$
\begin{aligned}
&\text{if } H(\text{Quantum Hamiltonian}) \\
&\text{if } \Im(\text{Classical Hamiltonian}) \\
&\text{if } x_0 = X(\text{classial average position} = \text{QM } X) \\
&\text{if } p_0 = P(\text{classical average momentum} = \text{QM } P) \\
&\dot{x}_0 = \langle \dot{X} \rangle = \left\langle \frac{\partial H(X,P)}{\partial P} \right\rangle \simeq \left. \frac{\partial H(X,P)}{\partial P} \right|_{X=x_0,P=p_0} = \frac{\partial \Im(x_0,p_0)}{\partial p_0} = \frac{p_0}{m} \\
&\& \ \dot{p}_0 = \langle \dot{P} \rangle = -\left\langle \frac{\partial H(X,P)}{\partial X} \right\rangle \simeq -\left. \frac{\partial H(X,P)}{\partial x} \right|_{X=x_0,P=p_0} = -\frac{\partial \Im(x_0,p_0)}{\partial x_0} = \text{Force}
\end{aligned}
\tag{15}
$$

Having said this, and given the behavior of both the Schrodinger and Heisenberg pictures as far as their relationships to the correspondence principle, as given by Equation (15) after application of Equation (14), in both cases, we will then in section V show by example how the conceptually simple arrangement as summarized by Equation (15) for both the Schrodinger and Heisenberg ideas, we will then next start discussion of the Pilot model, initially of De Broglie, which was taken up later by Bohm, and describes its variance from both Equation (14) and Equation (15).

Note that Einstein was in many ways an adherent to at least part of the Pilot model, and that partly due to the issue of Hidden variables, *i.e.* after a description of the basics of the Pilot Model, leading to its later formulation by Bohm, and the idea of a trajectory for a "particle" as in substitution of probability, quantum mechanics style, we will after we present the Pilot model go to the main part of our document which is in the Bohr-Einstein debates over the Uncertainty principle.

5. The Pilot Model, and Its Variation from the Simplicity of Equation (15) and Its Rejection of Equation (14)

The Pilot model was initially brought up by De Broglie, and this was in response to a desire to bring in an alternative to complementarity as stated by [1]. *I.e.* see page 62. We will start with the version of the Pilot wave equation set by De Broglie, in Solvay [3], which was abandoned by De Broglie, on account of having problems with inelastic scattering. *I.e.* a challenge by Pauli, of this theory lead to its abandonment.

However, Bohr, revived it on the basis of a multi particle wave function [37] and [38]. We will get back to that later on after dealing with the single particle case of the Pilot model first. *I.e.* both the single particle Pilot Wave equation and Schrodinger Equation use much the same differential Equation, as given by [1] [2] [3]. And this is for the single particle case.

$$-i\hbar\frac{\partial\Psi_{\text{Pilot}}}{\partial t}=\left[-\frac{\hbar^2\nabla^2}{2m}+V\right]\Psi_{\text{Pilot}} \tag{16}$$

However, instead of the usual 1 particle Schrodinger equation wave function we would have, instead. Even if

$$\Psi_{\text{Pilot}}=\sqrt{\rho_{\text{Probability denity}}}\exp\left(\frac{iS}{\hbar}\right)\equiv\sqrt{\tilde{\rho}_{\text{Pilot}}}\exp\left(\frac{iS}{\hbar}\right) \tag{17}$$

The term, S is a solution to a modified Hamilton-Jacobi equation, as given by Equation (19) on the next page.

In addition, there is in the single particle wave function case, the problem of how to interpret the quantum Potential as given in Q, in Equation (18) below

Notice, in the formulation of Equation (19) below there is the oddball treatment of the time derivative which has among other things the hydrodynamic style

$$\frac{\mathrm{d}}{\mathrm{d}t}=\frac{\partial}{\partial t}+v_{\text{Pilot}}\cdot\nabla \tag{18}$$

$$\begin{aligned}
&\rho_{\text{Probability denity}}=\tilde{\rho}_{\text{Pilot}},\\
&S=S_{\text{Pilot}}\\
&-\frac{\partial S_{\text{Pilot}}}{\partial t}=\frac{\nabla S_{\text{Pilot}}}{2m}+V+Q\\
&Q=Q(\text{Pilot quantum potential})=-\frac{\hbar^2\nabla^2\sqrt{\tilde{\rho}_{\text{Pilot}}}}{2m\sqrt{\tilde{\rho}_{\text{Pilot}}}}\\
&v_{\text{Pilot}}=\frac{\nabla S_{\text{Pilot}}}{2m}\\
&\frac{\partial\tilde{\rho}_{\text{Pilot}}}{\partial t}+\nabla\cdot\left(\tilde{\rho}_{\text{Pilot}}v_{\text{Pilot}}\right)=0\\
&\Psi_{\text{Pilot}}=\sqrt{\rho_{\text{Probability denity}}}\exp\left(\frac{iS}{\hbar}\right)\equiv\sqrt{\tilde{\rho}_{\text{Pilot}}}\exp\left(\frac{iS}{\hbar}\right)
\end{aligned} \tag{19}$$

The main result of this set of Equation (19) is a direct replacement of the concept of wave-Particle duality, and the reality of the results of the Schrodinger equation via the Born postulate, with the idea of a guidance equation, and of a particle trajectory.

Key to the simplicity of Equation (15) above, especially in the idea of Probability due to Wave Particle duality and the Born rule [39].

By way of contrast as opposed to the Born rule [39] and probability interpretation of the wave function, the Pilot theory has this so called Guidance equation (single Particle trajectory!!!). *I.e.* this is the allegedly main law of Pilot theory! See the below. For point particles!!!!

$$v_{\text{Pilot}}=\frac{\nabla S_{\text{Pilot}}}{2m} \tag{20}$$

So what is the problem? If all the machinery of Equation (19) is employed, one has the frankly absurd replacement for the force equation, *i.e.* no connection with classical physics, in certain cases, *i.e.*

$$\frac{\mathrm{d}}{\mathrm{d}t} = \frac{\partial}{\partial t} + v_{\text{Pilot}} \cdot \nabla$$
$$m\frac{\mathrm{d}v_{\text{Pilot}}}{\mathrm{d}t} = -\nabla \cdot (V + Q) \tag{21}$$

The problem is with the quantum potential, Q as given in the bunch of equations, Equation (19).

The only way to recover, continuity with Equation (15) in the correspondence of small Quantum effects being averaged to Classical effects, *i.e.* is to have that in the mean, the quantum potential Q, as given in Equation (19) would effectively dissipate. One needs a decoherence mechanism to get rid of it. Interaction with the environment can provide this mechanism [40] [41] [42] [43].

So with further ado, we will briefly list what could be called a cheat sheet as far as de coherence.

6. Decoherence and the Chance to Remove Quantum Potential *Q* as a Factor

Here is the problem in a nut shell, *i.e.* De coherence requires that particles have no quantum interference with each other. Is this true? *I.e.* the Phenomenon of Quantum entanglement really exists, *i.e.* see [44]. *I.e.* in order to kill the term Q, in Equation (19) in particular with respect to having no chance of Q being a factor in a limiting case, we would like there to be no chance of Entanglement of particles, or terms.

No such luck. *I.e.* Quantum Entanglement is here to stay [45], So here in a nutshell is what we are up against, in order to insure that Quantum potential Q,. is not a factor.

The decohered elements of the system no longer exhibit quantum interference between each other, as in a double-slit experiment. Any elements that decohere from each other via environmental interactions are said to be quantum entangled with the environment. The converse is not true: not all entangled states are decohered from each other.

7. Now What Can We Say about Multi Particle Pilot Theory Models?

The Guidance equation becomes, for each jth particle

$$(v_{\text{Pilot}})_j = \frac{\nabla_j S_{\text{Pilot}}}{2m_j} \tag{22}$$

As was mentioned earlier, these single particle trajectories, would be "non local" and would depend upon other particles. It gets worse, as mentioned earlier, [8] [9] indicate that the Guidance equation for point particles, due to the fact the particle trajectories are "non local" get so complicated, by default, even though the [39] Born rule is not used, the trajectories need quantum style probabilities, this in the complex system dynamics which are treated macroscopically by Equation (15).

The Schrodinger Equation would then become similar to having

$$-i\hbar\frac{\partial\Psi_{\text{Pilot}}}{\partial t}=\left[-\sum_{j=1}^{n}\frac{\hbar^{2}\nabla_{j}^{2}}{2m_{j}}+V\left(r_{1},\cdots,r_{n}\right)\right]\Psi_{\text{Pilot}} \tag{23}$$

Due to the snarled up mathematics, the multiple Pilot theory still is hard to link to Special relativity, as noted in [8] [9] And people are still working on that special relativistic extension, but it is extremely mathematically difficult.

Q, would become a bigger mess, *i.e.* hard to calculate, although not impossible, but the biggest problem would be that one would have to contend with the existence of empty waves, represented by wave functions propagating in space and time but not carrying energy or momentum. *I.e.* Einstein called them ghosts waves, and their existence or lack of, is one of the main impediments toward full acceptance of this theory, even more than the problems associated with *Q*, which are more severe in the multi particle case, than in the single particle case, See [46] [47] [48] and [49].

We will end this by saying that there appears to be certain experimental configurations which may favor the Pilot Model, but it depends also upon the notion of hidden variables, [49] Einstein definitely favored hidden variables [3] [15], and so did Bohm [50].

In closing, this is a mathematically complicated theory and it is not necessarily wrong. Also, Bell thought enough of this idea of hidden variables to include it in [51], in his Quantum unspeakables book.

Note though that complexity does not mean the theory is useless. *I.e.* note that it is being pursued even today, with applications [52].

8. The Heisenberg Uncertainty Principle, and the Bohr-Einstein Debates on Such. Starting with 1927 5th Solvay

A review of the Solvay 1927 Bohr Einstein debate as given in **Appendix A**, will be investigated here, with a lead into the very unexpected development of Quantum Entanglement.

There were several phases as far as Einstein's attitudes toward Quantum mechanics. *I.e.* the most revealing show up In appendix A, We also refer the reader to [53], *i.e.* Einstein should be viewed directly in the context of what was brought up in [3] where we will directly reference the text: One of the big takeaways is that in 1927 that Einstein essentially stated the main points of the EPR thought experiment, 8 years ahead of the [19] reference in concise form, which I do not believe was entirely understood by Bohr at the time [3].

Go to page 194 and 195 of [3]. In it, we will go to the following:

Quote: (Page 194 of [3])

Einstein compares and contrasts the view of the wave function Ψ for the case of a single electron. According to view I, Ψ represents an ensemble (cloud) of electrons. According to view II, Ψ is a complete description of an individual electron.

Einstein argued that View II is incompatible with locality. We will as a side bar put in the following definition of locality.

In physics, the principle of locality states that an object is only directly influenced by its immediate surroundings. A theory which includes the principle of locality is said to be a "local theory".

Now back to Einstein.

And that to avoid this, in addition to Ψ there should be a localized particle (along the lines of De Broglie's theory).

This was the main point of the page 194 of [3].

Next:

On page 195 of [3] Einstein is quoted as saying.

If $|\Psi|^2$ were simply regarded as the probability that at a certain point that a given particle is found at a given time, it could happen that the same elementary process produces an action at two or several places on a screen. But the interpretation according to which $|\Psi|^2$ expresses the probability that the particle is found at a given point, assume an entirely peculiar mechanism of action at a distance which prevents the wave continuously distributed in space, from producing an action in two places on the screen.

End of Einstein quote

This is, in essence the EPR hypothesis, in [19] given 8 years earlier than is usually ascribed. **Appendix A**, from Wiki, as cited below makes it a matter of the idea of "indeterminacy", but in reality, the idea brought up by Einstein was about action at a distance.

It goes further than that. On page 195, of [3] the authors conclude.

Quote:

Einstein's wording conveys a distinction between probability for a single particle (leading to multiple detections) and probability for "this" particle (leading to single detection only).

End of quote

Furthermore, we have that on page 196 of [3].

Quote:

Einstein's argument is that quantum theory is either nonlocal or incomplete.

End of quote

Next, from page 196 of [3].

Quote

For the rest of his life, Einstein believed that locality was a fundamental principle of physics so he adhered to the view that quantum physics must be incomplete.

End of quote

This in 196 of [3] is succinct and to the point.

However, it is worth noting that on page 196 of [3].

Quote:

However, further reasoning by Bell (1964) showed that any completion of quantum theory would will require nonlocality.

End of quote

To see this, references [54] [55].

In addition, in a point that will be elaborated upon in the conclusions, as future works in progress, there is evidence that a modified three body problem (classical!) can with certain caveats give some the same phenomenology of the double slit experiment, *i.e.* see [18]. The fact is, that there are mixed quantum and classical systems giving much the same implied results as commented upon in Solvay [3] is in my mind of decisive phenomenological import. We will revisit this later, but in passing it is useful to go to the reaction of Bohr, in 2927 to a challenge of the Solvay 1927 argument as to the double slit experiment and HUP.

We can see that the reaction of Bohr, as to this issue in 1927, *i.e.* the Einstein challenge to the double slit interference hypothesis, *i.e.* as an addendum to Appendix A, Bohr, according to [20].

Quote from [20], as a reaction to Appendix A.

Bohr's response was to illustrate Einstein's idea more clearly using the diagram in Figure A. (Figure A shows a fixed screen S_1 that is bolted down. Then try to imagine one that can slide up or down along a rod instead of a fixed bolt.) Bohr observes that extremely precise knowledge of any (potential) vertical motion of the screen is an essential presupposition in Einstein's argument. In fact, if its velocity in the direction *X before* the passage of the particle is not known with a precision substantially greater than that induced by the recoil (that is, if it were already moving vertically with an unknown and greater velocity than that which it derives as a consequence of the contact with the particle), then the determination of its motion after the passage of the particle would not give the information we seek. However, Bohr continues, an extremely precise determination of the velocity of the screen, when one applies the principle of indeterminacy, implies an inevitable imprecision of its position in the direction *X*. Before the process even begins, the screen would therefore occupy an indeterminate position at least to a certain extent (defined by the formalism). Now consider, for example, the point *d* in figure B, where the interference is destructive. It is obvious that any displacement of the first screen would make the lengths of the two paths, *a-b-d* and *a-c-d*, different from those indicated in the figure. If the difference between the two paths varies by half a wavelength, at point *d* there will be constructive rather than destructive interference. The ideal experiment must average over all the possible positions of the screen S_1, and, for every position, there corresponds, for a certain fixed point *F*, a different type of interference, from the perfectly destructive to the perfectly constructive. The effect of this averaging is that the pattern of interference on the screen *F* will be uniformly grey. Once more, our attempt to evidence the corpuscular aspects in S_2 has destroyed the possibility of interference in *F*, which depends crucially on the wave aspects.

End of quote from [20]

This response although extremely clever, does not really answer the particulars of what Einstein was asking, in his questioning which is given in [3] and rendered above this quoted text.

Interested readers who wish for a summary of the 2nd argument as to the use of the Energy and time uncertainty principle in the 1930 Solvay conference are enjoined to read the summary as given in [53] and also [54] and [55].

We will next, go to the EPR thought experiment, which has been already given in its essential talking point, and then the emergence of quantum entanglement.

The point we wish to state here, is that the ideas of refutation of the EPR thought experiment, as done by the physics community lead to the astounding Quantum entanglement phenomena, an active area of research which is engaging physics researchers, now [56].

The point which we will focus upon next is what information does Entanglement actually involve exchanging. So with that, we will be going to our next section.

9. EPR Paper, Entanglement and then the Question of How Information Transfer in Quantum Entanglement Process Occurs

In [57] the discussion about the Quantum theory and EPR are cited in the following quote from [57] namely;

Quote

Initially Einstein was enthusiastic about the quantum theory. By 1935, however, his enthusiasm for the theory had given way to a sense of disappointment. His reservations were twofold. Firstly, he felt the theory had abdicated the historical task of natural science to provide knowledge of significant aspects of nature that are independent of observers or their observations. Instead the fundamental understanding of the wave function (alternatively, the "state function", "state vector", or "psi-function") in quantum theory was that it only treated the outcomes of measurements (via probabilities given by the Born Rule). The theory was simply silent about what, if anything, was likely to be true in the absence of observation. That there could be laws, even probabilistic laws, for finding things if one looks, but no laws of any sort for how things are independently of whether one looks, marked quantum theory as irrealist. Secondly, the quantum theory was essentially statistical. The probabilities built into the state function were fundamental and, unlike the situation in classical statistical mechanics, they were not understood as arising from ignorance of fine details. In this sense the theory was indeterministic. Thus Einstein began to probe how strongly the quantum theory was tied to irrealism and indeterminism.

He wondered whether it was possible, at least in principle, to ascribe certain properties to a quantum system in the absence of measurement. Can we suppose, for instance, that the decay of an atom occurs at a definite moment in time even though such a definite decay time is not implied by the quantum state function? That is, Einstein began to ask whether the quantum mechanical description of reality was complete. Since Bohr's complementarity provided strong support both for irrealism and indeterminism and since it played such a dominant role in shaping the prevailing attitude toward quantum theory, complementarity became Einstein's first target. In particular, Einstein had reservations *about the uncontrollable physical effects invoked by Bohr in the context of measurement interactions, and about their role in fixing the interpretation of the wave function. EPR was intended to support those reservations in a particularly dramatic way.*

End of quote, from [57]

First of all, this entry in [57] is partially incorrect, As shown in section VIII, as far back as 1927, Einstein was laying out his action at a distance dispute with the Quantum interpretation as in Copenhagen, and the problem was that Bohr, as we stated earlier, in 1927, really did not understand the gist of what was on Einstein's mind in 1927. *I.e.* seeing the quoted sections from pages 194 to 196 of [3], as far as the indeterminacy of the relative positions of minimum's on a screen past a two slit experiment, and the idea of a cited "action at a distance" phenomena, as crucial, so with that, we will initiate a discussion as to what the EPR thought experiment was about.

Above all, in 1927, Einstein was upset by the idea of a nonpoint particle interpretation, and was an early adherent to the De Broglie Pilot theory, namely its Guidance equation, as a point particle, represented by Equation (20) in our text.

While, as mentioned, the interaction of Pauli and De Broglie, in Solvay, 1927, lead to the abandonment of the single particle Pilot theory, as mentioned in [3], at the time of the EPR thought experiment, Einstein still, in fidelity with Bohm, [50] was in favor of a multi particle version of the Guidance Equation of the Pilot model, as seen in Equation (22) of our text.

To begin this discussion, we urge the readers to first access [19] and to read it, if possible. Next we will outline the argument, pages 179-182 of [1], in terms of two spin ½ particles whose net spin is zero. Which according to [1] leads to the following set up, *i.e.* this is quoting the set up given on page 179 of Omnes in reference [1].

Quote:

Consider 2 spin 1/2 particles, P and P'. Set it so a measuring device, M, measures the spin component of P along a direction, n, and another measuring device, M' measures the spin component of system P' along a direction, n'.

The basic idea is that the two instruments, M and M' can be arbitrarily distant from each other. Also, we have that we can form a state vector with a total spin zero, which is written as

$$\frac{1}{\sqrt{2}}\cdot\left\{\left|S.n=1/2\right\rangle\otimes\left|S'.n=-1/2\right\rangle-\left|S.n=-1/2\right\rangle\otimes\left|S'.n=1/2\right\rangle\right\} \tag{24}$$

This above, is the State vector for total spin zero.

End of quote of middle of page 179 by [1], Now for the suppositions at the end of Page 179 of [1].

Quote, end of page 179 of page [1].

Assume that the measurement made by M precedes the one by *M'* ($t'<t$) *and gives the result* $S.n=s\left(\pm 1/2\right)$, *and the second one gives the result* $S'.n'=s'$

Then this reference, [1] makes the following claim pp 179-180.

Then (*allegedly*) *there exist two complimentary properties of the spin of P'* (*which*) *can be induced. They refer to a time* t'' *when P' is not measured while P is* ($t < t'' < t'$). *One property asserts that the spin of P' to be defined by the initial state* (*here, refer to Equation* (*24*)), *that is* $S'.n = -s$. *On the contrary, the other property anticipates the measure by M' to be* $S'.n' = s'$. *One can then introduce the negations of the various properties to obtain two complete complementary families of histories. Then are easily shown to be consistent and the implications*

$$\begin{aligned}&\left(S_P.n(t)=s\right)\Rightarrow\left(S_{P'}.n(t'')=-s\right)\\ \&\ &\left(S_{P'}.n'(t')=s'\right)\Rightarrow\left(S_{P'}.n'(t'')=s'\right)\end{aligned} \tag{25}$$

Hold consecutively. In the two frameworks. Both intermediate assertions are therefore logically consistent although they are, of course, complimentary.

Next, go to page 181 of [1] for the conclusion as to how this is viewed, as an EPR thought experiment.

Einstein, Podolsky and Rosen (*EPR*) *were mainly concerned with the question of reality. They went as far as proposing a definition for it, or rather for an* "*element of reality*" *whose knowledge would be direct information about what really* "*is*": "*If without in any way disturbing a system, we can predict with certainty* (*i.e. with probability equal to* '*unity*') *the value of a physical reality quantity.*"

So then go to the next paragraph in page 181 of [1] which is their next claim:

One may stop a moment at this point, for noticing how bold this step is: They are giving a definition of reality! This is not a definition of the category of reality of our consciousness but rather of reality itself!

Next, still in page 181 of [1].

After their definition, EPR proceed to show (*in our example that the property* $S_{P'}.n = -s$ *is an example of reality. It indeed gives the value of a physical quantity,* $S.n$ *for the particle P', although only the distant particle P is disturbed by the measurement* (*of its only Spin component along n*). *Looking at the station vector* (*here it is Equation* (*24*)) *and using Born's formula with wave function reduction, one finds that the probability* $S_{P'}.n = -s$ *is 1. There is no doubt that this is an element of reality according to the EPR's definition.*

The linkage to the issue of the alleged incompleteness of the quantum theory is next given by the next paragraph: in page 181 of [1].

EPR contended that their result implies an incompleteness of quantum theory. They said that: "*The following requirement for a complete theory seems to be a necessary one: Every element of the physical reality must have a counterpart in the physical theory*".

More to the point we can refer to page 76 of [58] by Bell, and also note that Bell is quoting [59] as an alleged quote of Einstein

The statistical character of the present theory would then have to be a necessary consequence of the incompleteness of the description of the systems in quantum mechanics, and there would no longer exist any ground for the supposition that a future…physics most be based upon statistics.

This is in tandem with the last part of the EPR article jointly brought up by Bell [58] and also in [19] whereas,

Quote: from page 82 of [58]

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 that such a theory is possible.

End of quote from page 82 of [58]

We shall, now that we have outlined the issue of alleged incompleteness of the Quantum mechanical wave function next go to a description of how this presumed absurd model, outlined by the EPR paper as allegedly impossible, experimentally became the now thriving field of Quantum entanglement. The outlines of Entanglement via the EPR thought experiment are given in [59] whereas we provide the details of this amazing thought experiment, and its resolution next.

10. Now for a Quantum Mechanical Answer to the Charge of Incompleteness, as Raised by Einstein, in the [19] Reference and Subsequently Amplified by Bell in [58]

A good working definition of what is called entanglement is given by Wiki [60] as Quote from [60].

Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently of the others, even when the particles are separated by a large distance—instead, a quantum state must be described for the system as a whole.

Now, why did Einstein reject such a configuration, as impossible? This is, from Wiki again what he assumed to be impossible:

Quote, from [60]

It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances.

End of quote

This is exactly the outcome outlined in section IX, above, and to add insult to injury as far as electrons, as was the example given in section IX, that [61], definitely do show that the predictions of the EPR, are given experimentally.

Furthermore, there is on line a simple explanation as to the violation of the Bells Inequality rules, as given in [62] by Fellows, *i.e.* with the main point given below.

Quote, from [62] top of page 14

Quantum theory sidesteps that problem by simply asserting that entangled particles don't have a particular spin or polarization until the spin/polarization of one of the entangled particles is actually measured. According to quantum theory the act of measuring fixes the spin/polarization for both entangled par-

ticles at the same instant in time. Einstein believed, however, that this explanation still necessarily means that action taken at one point in space must have an instantaneous effect on a particle in a distant location, and that such an effect is prohibited by the Special Theory of Relativity.

End of quote

I.e. the question, ultimately of the Entangled states, is what information is actually exchanged, and at what propagation speed? *I.e.* this will be the point of deliberation of the next section.

This is what is brought up again, in the 2nd part of page 14, by [62] whereas we have the given quote.

Put another way, Bell simply assumed that the experimental apparatus used to measure the entangled particles plays a completely passive role, having no significant effect on the resulting statistics. This tacit Passive Apparatus Assumption, in turn, leads directly to the additional implicit assumption that, in order for an entangled photon to "know" whether its axis of polarization should be at one angle or another when it reaches its polarizing filter, it must "know" for each of the different optional polarizer angle settings how it must respond when it arrives at any one of those optional settings. In other words, if the correlation experiment allows for three optional polarizer settings, the minimum required bits of hidden information must total no less than three. As will be shown below, there is no logical basis for the first of these two critical assumptions, and the second the Minimum Information Assumption is demonstrably false. These erroneous assumptions are, in fact, the source of the mystery surrounding quantum entanglement! The failure to recognize the falsity of those two assumptions is precisely what has misled the entire community of physicists and researchers exploring this extraordinarily important area of science into believing that the statistical results of correlation experiments are necessarily inconsistent with Einstein's Special Theory of Relativity and the Locality Principle.

So, then at what speed does information as to the two conjoined states, connected by entanglement travel, and at what speed? What is precisely communicated between two entangled conjoined states?

This will be the next section of our article.

11. What Information Is Exchanged between Entangled States, and at What Speeds of Propagation? *i.e.* Doing Away with the Presumed "Necessity" of Hidden Variables. The Quantum Entangled States May Not Be a Separable Physical Phenomenon

What we are doing here, is to look at what information is exchanged between entangled states, and what this pertains as to the question of presumed hidden variable theories.

Renato Renner∗ and Stefan Wolf in [63] characterize the issue of locality (preferred by Einstein as a guiding principle) or the issue of nonlocal quantum states, which is elucidated in words in [64].

THE PROBLEM IS, that LOCALITY, as demanded by Einstein "demands" Faster than light transferal of "information" which violates special and general relativity.

Now, [62] has a novel introduction as to how to avoid this presumed problem, namely first starting off with what was presumed to be impossible:

Quote, from page 4 of [62]

The EPR paper constituted a full frontal attack on the very foundations of quantum theory. In response to that attack, Niels Bohr one of the greatest proponents of, and contributors to, quantum theory pointed out that the so-called "EPR paradox" was entirely predicated on the aforementioned fundamental principle of relativity theory which states that action taken at one location cannot have an instantaneous effect at some other location, a principle often referred to as the Locality Principle. Bohr struck back at the EPR paper by arguing that the Locality Principle simply must not be valid. In other words, according to Bohr, measuring the location of one of a pair of entangled photons does have an instantaneous effect on the other entangled photon, even though it may be located a great distance away. Bohr dismissed the EPR paradox by saying that the Locality Principle simply must not be part of our reality, despite Einstein's belief that it should be.

End of quote:

So what is a reasonable replacement for "locality"?

First here is a description of the famous Bell's inequality which has been repeatedly shown to be problematic.

Quote, from page 5 of [62]

Bell's Inequality is written as some version of the following equation:

$$n[X,-Y]+n[Y,-Z]\geq n[X,-Z] \tag{26}$$

That equation, however written, expresses a relationship between three related quantities (X, Y and Z). Stated most simply, Bell's Inequality says that, for any three categories or groups of any kind of items or objects of any sort one wishes to consider, the number which will fall into the first category, but not into the second category, plus the number which fall into the second, but not the third category, will always be equal to or greater than the number which fall into the first, but not the third category.

End of quote. From page 5 of [62]

You can look up how [63] re-stated the Bell's inequality, but the gist of it, is that the terms which are described as in different categories, are thereby linked in what is a "non-local" state.

So what is a "nonlocal" state, and what does this happen to say about propagation between point A, and Point B, of different positions in a "generalized" "nonlocal" state?

Here is a working definition to consider:

In theoretical physics, quantum nonlocality most commonly refers to the phenomenon by which measurements made at a microscopic level contradict a *collection of notions known as local realism that are regarded as intuitively true in classical mechanics*.

So, how does one create a state consistent with all of this?

In short, *entanglement of a two-party state is necessary but not sufficient for that state to be nonlocal. It is important to recognise that entanglement is more commonly viewed as an algebraic concept*, *noted for being a precedent to nonlocality as well as quantum teleportation and superdense coding*, *whereas nonlocality is interpreted according to experimental statistics and is much more involved with the foundations and interpretations of quantum mechanics*.

So what is entanglement? And why is this not necessarily the same as nonlocality? What we are interested in entangment is the process of exchange of "information".

Quantum teleportation is a process by which quantum information (*e.g. the exact state of an atom or photon*) *can be transmitted* (*exactly*, *in principle*) *from one location to another*, *with the help of classical communication and previously shared quantum entanglement between the sending and receiving location. Because it depends on classical communication*, *which can proceed no faster than the speed of light*, *it cannot currently be used for faster-than-light transport or communication of classical bits. While it has proven possible to teleport one or more qubits of information between two* (*entangled*) *atoms. That is for now technically all which is allowed*.

Any application of Entanglement in terms of information exchange by necessity involves application of Quantum Teleportation.

Note that the fact is, that we are using classical equipment, means the process is bound by the speed of light.

However, the entangled positions, may, by "quantum" logic sharing information at "superluminal speed" which we cannot measure.

We can only measure the teleportation phenomena, through classical devices, which restrict the information to the speed of light.

I.e. the encoding of teleported information is done through classical devices, but the precursor of interconnectivity between the "entangled" states may be "instantaneously set" at superluminal speeds (*i.e*. effective instantaneously).

Sounds confusing? It is, but the precursor of quantum teleportation of information is quantum entanglement.

1) Quantum teleportation in the present time, due to classicality in the emission/receiver ends of allegedly separated states, is bound by the speed of light.

2) Entanglement, as a precursor for states being "aligned" as a necessary condition for Quantum teleportation may, indeed have NO "speed of light" restrictions!

Reference [65] introduces this idea of entanglement and it is confirmed by [66].

How do we know this? This is the current state of the art, and is in its own way richly confirmed via these two references: [61] and [66].

I.e. the mix up in the language of entanglement and, of quantum teleportation, is then solved though a careful reading of the two references, above, plus a review of two others, *i.e*. [67] and [68].

Note that a careful reading of reference [69] and its remarks, as we will quote: below.

Quote [69] in the abstract.

Quantum mechanics, information theory, and relativity theory are the basic foundations of theoretical physics. The acquisition of information from a quantum system is the interface of classical and quantum physics. Essential tools for its description are Kraus matrices and positive operator valued measures (POVMs). Special relativity imposes severe restrictions on the transfer of information between distant systems. Quantum entropy is not a Lorentz covariant concept. Lorentz transformations of reduced density matrices for entangled systems may not be completely positive maps. Quantum field theory, which is necessary for a consistent description of interactions, implies a fundamental trade-off between detector reliability and localizability. General relativity produces new, counterintuitive effects, in particular when black holes (or more generally, event horizons) are involved. Most of the current concepts in quantum information theory may then require a reassessment.

End of quote

Upon a careful re reading of their article, and perusal of the language, the difficulty and the alleged clash with special relativity can be removed simply by stating:

1) Quantum entanglement, as a precursor to Quantum Teleportation does not have a speed of light limitation.

2) The experimentally vetted, so far limitations of propagation speed for quantum teleportation, mainly due to the classical equipment in receiver/transmitter set ups is bound by special relativity.

The adaptation of A. above, removes the onus of locality. *I.e.* the author views Bohr as essentially correct in is statement that there is no reason to invoke locality.

3) Until we have evidence, saying otherwise, the separate from entanglement phenomena of Quantum teleportation at this time appears bound by Special relativity.

There may be in the future equipment designed which removes the onus of classicality, in the measurement phenomena, but right now, we are not there yet.

In the meantime, here is, in [70] a brilliant commercially useful way to utilize all of this, and to remain in fidelity with the 1927 Solvay conference, and the commercial uses of Quantum entanglement aided quantum teleportation.

Finally, here is another view of quantum information, which is popular which I do not quite agree with but which may be acted upon technologically, *i.e.* see [71].

Having said all this we next will investigate the role of Time, as viewed in Solvay, This is important, because it heavily impinges upon the idea of quantum statistics. We have delineated a solution to the presumed conflict between GR and Quantum entanglement, via the device of saying that at this present time, there appears to be a speed of light limitation on Quantum teleportation, but this is separate from Quantum entanglement. And that quantum entanglement is a precursor to speed of light bound Quantum teleportation (at least in terms of known technological demonstrations at this time).

So, is time a classical, quantum, or an embedding of quantum mechanics within the frame work of an overarching deterministic phenomenon? We then will proceed to section XII, where some of these issues are ascertained.

12. Actual Information Exchange, Commented on with Respect to Entanglement and How This Differs from Quantum Teleportation

In the idea of quantum entanglement, Quantum entanglement is a quantum mechanical phenomenon in which the quantum states of two or more objects have to be described with reference to each other, even though the individual objects may be spatially separated. This leads to correlations between observable physical properties of the systems.

Note this point, *i.e.* in entanglement we are talking about correlation of observable physical properties.

How do we correlate properties in two separate physical objects, in entanglement? First take a look at [72] and see the following quote, on page 10 of [72].

Quote

Another common attitude is that the violations of the Bell inequalities (confirmed experimentally) have exposed an essential nonlocality built into the quantum description of Nature. One who espouses this view has implicitly rejected the complementarity principle. If we do insist on talking about outcomes of mutually exclusive experiments then we are forced to conclude that Alice's choice of measurement actually exerted a subtle influence on the outcome of Bob's measurement. This is what is meant by the "nonlocality" of quantum theory. By ruling out local hidden variables, Bell demolished Einstein's dream that the indeterminacy of quantum theory could be eradicated by adopting a more complete, yet still local, description of Nature. If we accept locality as an inviolable principle, then we are forced to accept randomness as an unavoidable and intrinsic feature of quantum measurement, rather than a consequence of incomplete knowledge.

End of quote

As stated by the author, the idea of avoiding having hidden variables as a way to explain a linkage between presumed widely separated in space events. We assert here that in effect, what we are seeing can also be viewed as a quantum extension in space, via entanglement of a quasi single matter/energy wave. *I.e.*, a nonlocalized state.

Such a supposition can only be held if in effect, the EPR outlined a space-(instantaneous) bridging of nonlocal states to each other, and that in effect, this morphing, occurred "instantaneously", *i.e.* a super wave function of space-time, by default.

I.e. The correlation so referenced in quantum entanglement is stranger than what is supposed. Although the name is inspired by the teleportation commonly used in fiction, there is no relationship outside the name, because quantum teleportation concerns only the transfer of information. Quantum teleportation is not a form of transport, but of communication; it provides a way of transporting a qubit from one location to another, without having to move a physical particle along with it.

This means a qubit of information exchanged for site A to site B, at least 100,000 times faster than C, for correlation of information.

So the information of correlated states is transferred at 10^5 times the speed of light, whereas in doing so no mass.

In so many words, Entanglement is not of particle or energy transfer, but of communication; it provides a way of transporting a qubit of information for property correlation of states from one spatial location to another, without having to move a physical particle along with it.

While information, *i.e.* information of properties which may be correlated between each other are exchanged at up to 10^5 times the speed of light, any properties, say of matter-energy transfer, are moved at "only" the speed of light.

Hence, this shows what sort of information may be exchanged almost "instantaneously" whereas the projection of matter/energy, either as a particle-wave duality or something similar may only do it at the speed of light.

It is a truism that correlation "information" exchange between two spatially separated states would not move the time "clock" but anything involving matter and energy transfer would move the time clock. Hence it is time to discuss what can be said, as an extension of Solvay's time in physics deliberations as brought up in Solvay, 1927.

Hence we go to the next part of our deliberation. That is given as in XIII, below.

13. Examining the Idea of Time, as Ascertained in the Solvay Conference, with Open Issues Brought Up

The problem with time, as given in the Solvay meeting is that it is still in many times stuck in debate by advocates whom are in one way or another in between the probabilistic interpretation of space time, locality of particles. Or in favor of dynamics as given in a governing equation of the sort given by Equation (22), *i.e.* our "point source" evolution equation of the Pilot model, as given by De Broglie, (subsequently later updated by Bohm), as is discussed in [3]. The modern preference is generally with the Heisenberg-Bohr picture of probabilities of the location of the sub atomic pictures.

This revulsion against the probability approach toward the location of a "point particle" was reflected in the 1927 clash between Bohr-Einstein over the double slit experiment, as given in **Appendix A**, but what is not appreciated, as is noted in pages 143 to 149 of [3] that Schrodinger himself struggled with the idea of a probability interpretation of electrons in atoms, and tried to find a middle ground between the very classical de Broglie "governing equation" as given in Equation (22) and a probability interpretation of electrons in atomic orbits. One can see the flavor of his deliberations in page 131 of [3], which was a result of a profound unease with the purely probability approach given by Bohr and Heisenberg.

Today, the debate is more nuanced, but in certain ways far more dramatic.

Zeh, in [73] writes that: on pages 3 and 4, that

Our world is known to obey quantum theory, which is characterized by an indeterminism occurring in measurements and other "quantum events". There is absolutely no consensus among physicists about the interpretation and even the precise dynamical role of this "irreversible coming into being" of the observed facts, such as the click of a counter. Has it to be regarded as a specific part of the dynamical laws (as assumed in the form of von Neumann's "first intervention" or more explicitly in collapse theories), as representing events that (according to Pauli) occur outside the laws of nature, as a "normal" increase of information (as claimed in the Copenhagen interpretation), as determined by hidden variables that are not 4 counted in conventional ensemble entropy (as in Bohm's theory), or as the consequence of inderministically splitting observers (as in Everett's interpretation)? Some quantum cosmologists refer to initial uncertainty relations or "quantum fluctuations" in order to justify the stochastic evolution of their quantum universe, although a global quantum state is never required to be "uncertain" (only classical variables would be).

In other words, no consensus on the origins of time, so it is difficult to initiate professional discussion on the defacto origins of time, as far as the creation of the universe, other than the supposition as commented upon in many parts of the literature of a linkage between entropy and time.

However, we should in fact, view this as progress, as compared to when Schrodinger, as well as even Bell, in 1987 who in [74] write "Are there Quantum Jumps" as to recounting the struggles Schrodinger had in [75] with particle tracks in track chambers, since he had replaced point particles with wave packets. But in reality, both Bell and Schrodinger objected to an allegedly smoothly evolving QM dynamics starting initially with Stationary states as a start, then violently interrupted by abrupt probability jumps.

As given by [74], Bell wrote that Schrodinger objected to what he regarded as hangovers from the Old Bohr theory, *i.e.* the idea of radical quantum jumps, and that he, Schrodinger, as given in [75] wished to have the dynamics of a wave packet as totally dominated by the wave function itself.

I.e. if we have such violent jumps, is this due to a fault in mathematical formalism, or was it due to our understanding of time itself?

In 1927, the Solvay conference had no idea of the existence of solitons, which do exhibit solitary initial states, and the following marriage of the idea of a Schrodinger equation, with a non linear potential with Solitons [76], *i.e.* the Schrodinger equation Schrodinger was aware of had LINEAR potentials.

So he could only think of faulty mathematics, or of a faulty interpretation of time itself.

So with this introduction, let us go to the idea of time evolution and the nature of time, as viewed in [3] and the participants of the Solvay conference, 1927, and contrast some of the issues arising then, and compare that with the modern issues, especially those brought up by Zeh in [73]. In order to start the inquiry we want on this most contentions topic, a reference to a PhD dissertation by Thomas Pashby [77] on the role of time in Quantum theory will be briefly alluded to, as well as a discussion of the problem, in [77] as to the passage of time, and what makes a "good" quantum clock.

Quote, from [77], page 121

6.1 NO IDEAL QUANTUM CLOCKS

Let us examine exactly what Pauli's Theorem manages to tell us about quantum clocks. Classically, a clock is a time function that covaries along the dynamical curves either locally or (in addition) globally. In Section 2.3, this was distinguished from an event time, which covaries with the initial data (and in the opposite direction). In Hamiltonian (analytical) classical mechanics, the existence of a clock function was sufficient to allow one to infer the value of the time parameter (up to periodicity) from the instantaneous state (in conjunction with the initial data). There is a sense in which quantum mechanics replicates this idea quite nicely, and a sense in which it makes it much more problematic. First, the good news. Given a non-periodic quantum system whose Hamiltonian is exactly known, precise knowledge of the state at two times suffices to determine the time interval between those states. If one knows the Hamiltonian and the state ψ *at* $t = 0$ *then, since the Schrodinger equation is first order in time, one knows the state at all other times* $\psi t = Ut\psi$. *This family of states parameterized by* t *associates with each instant of time* t *a unique state* ψt, *knowledge of which can be used to infer the elapsed time. This is analogous to the use of a classical time function to infer the elapsed time in terms of a parameterized curve in phase space. Where quantum mechanics complicates matters is in seemingly providing in principle limitations on the extent to which the state can be precisely known at a moment of time.*

End of quote,

I.e. we will use this as a start to discussion of some of the positions presented at Solvay, 1927, with the positions of each of the participants outlined.

A good place to examine the interplay between classical and quantum systems, as visualized, is to go to [5], page 175, the section on " The Introduction of Action-angle variables" and in particular to go to pages 181-183 which derives in part the reasoning Dirac used to obtain equations of motion in the case of the Hydrogen atom, as well as linkage to their classical equation formalistic counter parts. In doing so, the issue of how well a quantum state can be known is partially addressed, and then we will review what was said by other Solvay participants in 1927 as far as what is accessed in the passage of time, and quantum systems.

14. Action Angles, Both Classical and Quantum and the Problems of Time in Quantum Systems

In page 181-2, of [5], Dirac obtained a result for $1/r$, with this result used later for the angular dependence of an angle change in time of the orbit.

The change in time of the angle of an orbit of the Hydrogen atom showing up in page 183 of [5] as, if $\dot{w}$ the time derivative of the "uniformizing angle *w*, and θ a polar angle of an orbit about the Hydrogen atom, and this is the quantum mechanical case, which is written as

$$\frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{k}{m_e r^2} = \dot{w} + \cdots. \tag{27}$$

The term, $1/r$, squared, as in the Equation (28) was given on page 182 in reference [5] as having the following very long derivation, as given in Equation (30) below, next page, where we assume, also, that $k = xp_y - yp_x = m_e r^2 \dot{\theta}$ is in the quantum mechanical case, a constant of motion, and that the equation given below closely corresponds to the classical equation of motion as given by $1/r$ for an ellipse with the lattice rectum l, eccentricity ε, and with χ (classical) as being the angle between the major axis of the ellipse, and the angle given as $\theta = 0$. Then the classical $1/r$ equation has the form given, if we can say

$$\begin{aligned} (1/r)_{QM} &= a_0 + a_1 \exp\{i\theta\} + a_2 \exp\{-i\theta\} \\ (1/r)_{CM} &= l^{-1} + l^{-1}\varepsilon\cos(\theta - \chi) \\ a_0(QM) &\leftrightarrow l^{-1}(CM) \\ \chi(QM) &\leftrightarrow \chi(CM) \end{aligned} \tag{28}$$

And we have the following on the next page for details of the quantum version which gives justification for the filling in, of the similarities of $1/r$ in both the classical and quantum cases, as alluded to in Equation (28) above.

$$\begin{aligned} (1/r)_{QM} &= a_0 + a_1 \exp\{i\theta\} + a_2 \exp\{-i\theta\} \\ a_0 &= \frac{m_e e^2}{k_1 k_2}, \\ a_1 &= \frac{a_0 k_2}{2k}\sqrt{1 - \frac{k_1^2}{P^2}}\exp\{-i\chi\}, \\ a_2 &= \frac{a_0 k_1}{2k}\sqrt{1 - \frac{k_2^2}{P^2}}\exp\{i\chi\} \\ \chi &= \text{inverse latus} = \text{rectum}(\text{of Hydrogen atom orbit}) \end{aligned}$$

$$\begin{aligned} k &= xp_y - yp_x = m_e r^2 \dot{\theta} \\ k_2 &= k + \frac{h}{2\pi}, \\ k_1 &= k - \frac{h}{2\pi} \\ H &= \frac{1}{2m_e}\left(p_r^2 + \frac{k_1 k_2}{r^2}\right) - \frac{e^2}{r} \\ \frac{\mathrm{d}r}{\mathrm{d}t} &= [r, H] = \frac{p_r}{m_e}, \\ \frac{\mathrm{d}p_r}{\mathrm{d}t} &= [p_r, H] = \frac{k_1 k_2}{m_e r^3} - \frac{e^2}{r^2}, \end{aligned}$$

$$\frac{\mathrm{d}\theta}{\mathrm{d}t} = [\theta, H] = \frac{k}{m_e r^2},$$
$$\frac{\mathrm{d}k}{\mathrm{d}t} = 0 \tag{29}$$
$$2m_e H = -\left(\frac{m_e e^2}{P}\right)^2$$

The main point here, being also that we can represent the momentum variable as a constant of motion, in the quantum case, *i.e.* note that if we have a mandate to explain for the hydrogen atom

$$\begin{aligned} \nu_{n,m} &= \text{frequency change from } |n\rangle \text{ to } |m\rangle \text{ atomic states} \\ &= (E_n - E_m)/h = \text{Alternation for Hydrogen like atoms} \end{aligned} \tag{30}$$

We thereby have obtained an angular dependency behavior, in the onset of jumps between energy levels n and m, of the hydrogen atom, and at least qualitative connections to the classical and quantum "pictures of reality" with some correspondence to the classical to quantum regimes implied by Equation (15) of our document.

In terms of what was brought up 2 pages before about the problem of quantum indeterminacy, in terms of what constitutes a quantum jump, the similarities between the classical and quantum regimes for 1/r argue that if there is a stationary state, or nearly stationary, as would be implied by the ground state of the hydrogen atom, may be in a sense possible, and that there would have to be a case by case analysis of what would correspond to a classical $1/r$ and quantum $1/r$ picture of hydrogen like atoms as to make full sense out of the results from Equation (28) to Equation (30).

Furthermore, to understand the indeterminacy of states, possibly implied by Equation (27) in this document, one would have to go to a case by case analysis of all the terms on the right hand side of Equation (27) in order to come up with a careful iteration look at as an example, something like

$$\frac{\Delta\theta - \Delta w}{H.O.T.} \sim \Delta t \tag{31}$$

Actually it is worse than that, *i.e.* this will now have to explore the inter relationship between quantum statistics, as envisioned by both Bohr, Bohm, Einstein and Schrodinger, and the issues of what role time played in their formulation, as argued from 1923 to 1927, in the Solvay (1927) conference, as to microstates and macrostates of presumed quantum systems, and the role of time in their formulation and analysis.

15. How the Solvay Participants, in 1927 Analyzed Quantum Statistics, In Terms of Presumed Roles of Time, for Physical Systems Modeled, as a View as to the Presumed Role of Time in Physics

We begin this with a side view first, as to what is a way to embed the quantum paradigm in 5 dimensional physics, as given by Paul Wesson, where he presented a deterministic embedding in 5 dimensions, as of the 4 Dimensional treatment of the Heisenberg Uncertainty principle [78].

This among other things is a fulfillment of the dream by Kaluza Klein [79], of sorts as far as how to unify Gravity and Electromagnetism in cosmology, but it has a much bigger cache than this, mainly as to understand the role of time, itself in quantum statistical ensembles, *i.e.* the idea of a deterministic large scale state, which would encompass quantum microstates in an ensemble within which the quantum microstates would be a way to analyze basic quantum thinking in terms of time dependence. In doing this, it also links itself to the question of why Schrodinger was so aghast at the idea of quantum jumping.

Let us now, briefly allude to the [78] and [79] reference, namely:

Start with the idea of an embedding of four dimensional space-time in a 5 dimensional time interval. [78] [79] and realize its inter connections with [80] [81] [82] [83], where L = length of canonical metric in 5 Dimensional theory

$$\begin{aligned} &\mathrm{d}S^2_{5\text{-dim}} = \frac{L^2}{l^2}\mathrm{d}s^2_{4\text{-dim}} - \left(\frac{L^2}{l^2}\right)^2 \mathrm{d}l^2 \\ &x_4 = l = h/mc \\ &\Lambda = 3/L^2 \\ &L = \text{scale of scale of (universe) Potential well} \end{aligned} \tag{32}$$

And then we present, the five momenta as given by

$$\begin{aligned} P_\alpha &= \frac{2L^2}{l^2} g^{\alpha\beta} \frac{\mathrm{d}x^\beta}{\mathrm{d}x} \\ P_l &= -\frac{2L^4}{l^4}\frac{\mathrm{d}l}{\mathrm{d}s} \end{aligned} \tag{33}$$

Then, if

$$\begin{aligned} &P_\alpha = \frac{2L^2}{l^2} g^{\alpha\beta} \frac{\mathrm{d}x^\beta}{\mathrm{d}x} \\ &P_l = -\frac{2L^4}{l^4}\frac{\mathrm{d}l}{\mathrm{d}s} \\ &\int P_A \mathrm{d}x^A = \int P_\alpha \mathrm{d}x^\alpha + P_l \mathrm{d}l = 0 \ \text{ iff } \mathrm{d}S^2_{5\text{-dim}} = 0 \\ &\Leftrightarrow l = l_0 \mathrm{e}^{\pm s/L} \ \&\left(\mathrm{d}l/\mathrm{d}s\right) = \pm l/L \end{aligned} \tag{34}$$

One eventually, as given by [78] obtains the Heisenberg type of relations that

$$\left|\mathrm{d}p_\alpha \mathrm{d}x^\alpha\right| = h \cdot \left\{\frac{n}{c}\cdot\left(\frac{\mathrm{d}l}{l}\right)^2\right\} \tag{35}$$

Depending upon how we evaluate $\left\{\frac{n}{c}\cdot\left(\frac{\mathrm{d}l}{l}\right)^2\right\}$, we can then say that if $n = L/l$, and if we have L as the length of the additional dimension, that we have from deterministic reasoning in 5 dimensions achieved Equation (35) which in four dimensions, depending upon how $\left\{\frac{n}{c}\cdot\left(\frac{\mathrm{d}l}{l}\right)^2\right\}$ is evaluated is in common with $\Delta x \Delta p \geq \hbar$ [84].

To proceed with this further in [85] we have that $\Delta E \Delta t \geq \hbar$, and that the following holds, in cosmological physics, in a general sense, *i.e.* in cosmology we can depend upon the following assumptions, namely, as derived by the author in [86].

We use the approximation as presented in [86] which we reproduce below as also in [87] [88]

$$\begin{aligned}(\Delta l)_{ij} &= \frac{\delta g_{ij}}{g_{ij}} \cdot \frac{l}{2} \\ (\Delta p)_{ij} &= \Delta T_{ij} \cdot \delta t \cdot \Delta A\end{aligned} \tag{36}$$

If we use the following, from the Roberson-Walker metric [86]

$$\begin{aligned}g_{tt} &= 1 \\ g_{rr} &= \frac{-a^2(t)}{1 - k \cdot r^2} \\ g_{\theta\theta} &= -a^2(t) \cdot r^2 \\ g_{\phi\phi} &= -a^2(t) \cdot \sin^2\theta \cdot d\phi^2\end{aligned} \tag{37}$$

Following Unruh [67] [68], write then, an uncertainty of metric tensor as, with the following inputs

$$a^2(t) \sim 10^{-110}, r \equiv l_P \sim 10^{-35} \text{ meters} \tag{38}$$

Then, if $\Delta T_{tt} \sim \Delta \rho$ [86] [87] [88]

$$\begin{aligned}&V^{(4)} = \delta t \cdot \Delta A \cdot r \\ &\delta g_{tt} \cdot \Delta T_{tt} \cdot \delta t \cdot \Delta A \cdot \frac{r}{2} \geq \frac{\hbar}{2} \\ &\Leftrightarrow \delta g_{tt} \cdot \Delta T_{tt} \geq \frac{\hbar}{V^{(4)}}\end{aligned} \tag{39}$$

This Eq. is such that we can extract, up to a point the HUP principle for uncertainty in time and energy, with one very large caveat added, namely if we use the fluid approximation of space-time [86]

$$T_{ii} = diag(\rho, -p, -p, -p) \tag{40}$$

Then by [86]

$$\Delta T_{tt} \sim \Delta \rho \sim \frac{\Delta E}{V^{(3)}} \tag{41}$$

Then, by [86]

$$\begin{aligned}&\delta t \Delta E \geq \frac{\hbar}{\delta g_{tt}} \neq \frac{\hbar}{2} \\ &\text{Unless } \delta g_{tt} \sim O(1)\end{aligned} \tag{42}$$

In this case, looking at a re write of the Equation (35) to read, approximately as

$$\left|\mathrm{d}p_{\alpha}\mathrm{d}x^{\alpha}\right| \sim h\cdot\left\{\frac{n}{c}\cdot\left(\frac{\mathrm{d}l}{l}\right)^{2}\right\}_{\alpha} \tag{43}$$

With the

$$\alpha = 0 \Rightarrow \left|\mathrm{d}p_{0}\mathrm{d}x^{0}\right| \sim h\cdot\left\{\frac{n}{c}\cdot\left(\frac{\mathrm{d}l}{l}\right)^{2}\right\}_{\alpha=0} \Rightarrow \delta t\Delta E \geq \frac{\hbar}{\delta g_{tt}} \neq \frac{\hbar}{2} \tag{44}$$

$$\text{Unless } \delta g_{tt} \sim O(1)$$

I.e., what we have done is to say that Equation (44) establishes that the HUP as derived in [86] is embedded within a deterministic structure in 5 dimensional Kaluza-Klein theory.

We argue that Equation (44) which is embedding the HUP, and in effect, time within a deterministic 5 dimensional structure, as given by [78] is in the end no different from the radical supposition given by Schrodinger as to quantum statistics, which was argued over in Solvay, as seen in [3] and [5] that the modeling of black body style quantum statistics, for a macro system was in a state which did not have an explicitly time dependent dynamic, *i.e.* as given in [36] by Shankar,

$$\frac{\mathrm{d}E}{Q[\text{Thermal cavity volume}]} = \rho(\omega)\mathrm{d}\omega = \frac{\hbar\omega^{3}}{\pi^{2}c^{3}}\cdot\frac{\mathrm{d}\omega}{\exp[\hbar\omega/k_{B}T]-1} \tag{45}$$

Notice that this is a standing wave, frozen in space-time result, for a quantum Macrosystem. There was in this accounting, only time independent quantum dynamics, with the blackbody statistics fixed, if you will by macroscopic values of both T, temperature, and frequency, ω. This was held by Schrodinger, as the inevitable results of a quantum macro system, with the microscopic time fluctuation dynamics, for time independent Schrodinger equations, due to the microscopic behavior of sub systems, in Quantum Mechanics, as stated within what could pass,, as could Equation (45) as a macroscopic deterministic system (*i.e.* if frequency, ω, and temperature T. fixed, by the relation given as Equation (45).

We will discuss more of this next section, with more examples of microscopic and macroscopic physics examples, which were argued over in Solvay, 1927.

16. The View as Far as [3], *i.e.* the Request by Lorenz. And the Astonishing Later Push Back against This Idea by Sir Author Eddington

Quote, from page 209 of [3] by Lorenz

"A conclusion, of theoretical considerations, and not assign an a priori axiom, though may well admit that this indeterminacy corresponds to experimental possibilities would always be able to keep my deterministic faith for the fundamental phenomena…Lorentz seems to demand that the fundamental phenomena be deterministic, and that indeterminism should be merely emergent or effective. Probabilities should not be axiomatic, and some theoretical explanation is needed for the experimental limitations encountered in practice."

From the rest of this quote from the Paragraph in question, which explains

Lorentz's remarks.

This view would nowadays be usually associated with deterministic hidden variables theories, such as de Broglie's pilot-wave dynamics (*though it might also be associated with the many-worlds interpretation of Everett*). *De Broglie's basic equations* (*the guidance equation and Schrödinger*).

End of quote of page 209 [3]

In the deterministic time evolution camp were Lorentz, sometimes Schrodinger with respect to quantum Macrosystems, as has been explained above (he thought otherwise of Quantum microsystems), Einstein, De Broglie, and others.

In the probabilistic camp, of time, and its involvement with quantum physics, were Bohr, Dirac, Pauli, Heisenberg, and Schrodinger for quantum microsystems.

I.e. Schrodinger did not have this view as far as quantum macro systems, and as noted earlier, he had no tolerance as to quantum jumping which he stated contravened the smooth evolution of states he expected from the Schrodinger equation. See [74] as far as Bell's restatement of the Schrodinger position as to this matter.

At the opposite end, firmly of the non deterministic camp was no other than Sir Author Eddington whom in [89] in the 1920s, as cited by [78], page 134-135 made the astounding claim for his time that the cosmological constant were associated with a given 1/squared length, [90], Eddington used the following

$$\Lambda_{\text{Cos}} = 1/R_{\text{radius universe}} \tag{46}$$

This lead to [91] [92] [93], *i.e.* many of Eddington's positions were far ahead of his time, and in [91] his value for the cosmological constant was, 9.8 times 10^{-55} centimeters 10^{-2}.

Also as given by [78] Eddington tied this radius of the universe, to the HUP, with the result that

$$\Delta R_{\text{radius universe}} \Delta p(\text{allowed momentum}) \geq \hbar \tag{47}$$

I.e. he thought that the permitted variance of momentum of space time "particles" was very small, but this as a consequence of Equation (47).

This presages much modern thinking, and that Pauli, as stated in [3] called it "romantic nonsense" but among other things, Eddington, as given in [3] [5] thought that the number of allowed "particles" in the Universe, was about 10^{80} [90].

I.e. if one uses the Ng idea of infinite quantum statistics [94] with

$$S(\text{entropy}) \sim n(\text{particle count}) \tag{48}$$

Then if one used the idea of Bayronic particles being, *n*, (Eddington did not know of Dark matter!!), this is within 8 orders of magnitude of the 10^{88} lower bound to the Entropy of the Universe as written up by Giovannini, in [95]. *I.e.* see page 156 of [95], formula 6.119 for details.

It would be a stretch to connect this with [96], but at least Eddington was very much in sync with modern ideas. *I.e.* the idea of entropy, as connected to an arrow of time, and its generation is a fairly modern idea. However, the flavor of the ideas cited in [90] is not incommensurate as a precursor to [97], and [98] has a section, page 104 which refers to discrete versus continuous eignspectrum values in Quantum mechanics, which may be a precursor and extension of the Eddington hypothesis so discussed as to the extreme values of the cosmological constant, the and the uncertainty principle. For those whom wish to know more of Eddington's search for a "Theory of Everything" the readers are suggested to access [99] and to compare this with [100], *i.e.* Penrose's compendium as to the fate of the physics quest for a final theory.

What we will do next will be to fill in the consequences of [101] [102] [103] [104] [105] [106] and [107] and what may be in store for future expansions of physics next.

17. A Suggestion by Corda, and Others as to Torsion, and Baker's Idea as to a Varying Time Rate, as Compared to Time Ideas in the Solvay Conference, 1927 Contrasted with Ephemeris Time, by Barbour

In [101] Zerczykowski, re stated the Barbour Ephemeris time result [102] of

$$\delta t = \sqrt{\frac{\sum_{j=1}^{n} m_j \cdot \left(\delta x_j\right)^2}{2\left(E - V\right)}} \tag{49}$$

In this case, the term δx_j refers to the position of a jth "Astronomical' body", and we ascribe as in common with [103] by G. Clemence. If this is purely a classical result, then the difference in total energy of the system denoted by *E*, minus *V*, *i.e.* this being proportional to a dimensional recasting as in dimensional terms to look like

$$\left(E - V\right) \sim \sum_{j=1}^{v} p_j^2 / 2m_j \sim \sum_{j=1}^{v} m_j \dot{x}_j^2 / 2 \tag{50}$$

Then as far as classical reasoning, we would have, up to a point.

$$\delta t = \sqrt{\frac{\sum_{j=1}^{n} m_j \cdot \left(\delta x_j\right)^2}{2\left(E - V\right)}} \sim \sqrt{\frac{\sum_{j=1}^{n} m_j \cdot \left(\delta x_j\right)^2}{2\sum_{k=1}^{v} m_k \dot{x}_k^2 / 2}} \tag{51}$$

This means, that the operative thing to keep track of would be a rough tally of mass times position squared, divided by mass times the square of object velocity. This would be very much in a mean value, so as the relative magnitude of velocity increased, the value of Ephemeris time would drop.

Now, let us to **Appendix B**, as given by Dr. Baker. To the author, namely the alleged slow down of the time rate. The only support which this author can see in it would be in a variant of the reasoning presented from Equation (49) to Equation (51) in a classical demonstration of a shift in the magnitude of δt . *I.e.* the larger the velocity becomes, the lower δt . Note that in doing this we are deliberately avoiding the quantum mechanical step which tends to on average to a semi classical result given by

$$\frac{\mathrm{d}X(t)}{\mathrm{d}t}=\frac{i}{h}[H,X]=\frac{i}{2mh}\cdot\left(P\cdot[P,X]+[P,X]P\right)$$
$$\xrightarrow[{[P,X]=\frac{h}{i}I}]{}\frac{P}{m} \tag{52}$$

Full details of this analysis would need a meshing of a relativistic version of Equation (51), and the author may indeed get to doing it at a later date. However the issue Dr. Baker has raised is suggestive and should be thoughly analyzed. The author finds that aside from inevitable scaling arguments, that the muons are still a sub system, within a larger general system. *I.e.* the adage of Schrodinger who postulated that quantum sub systems, of a macrosystem definitely exhibit quantum mechanical time dependent behavior. Equation (51) is not quantum mechanical, but it is a sub system, and so the same rule by Schrodinger, as to sub systems exhibiting definite time dependence, may be applicable here. *I.e.* think in terms of time variance. Readers wishing to follow upon what Dr. Baker is thinking of can go to [23].

Next, we will refer to the results as of Torsion, and more given in the early universe by [26].

On page 12, of the [26] reference there is the following quote:

Recently, it has been shown that observations admit the violation of ordinary energy-momentum conservation law meaning that the energy-momentum sources are nondivergence-free tensors in curved spacetimes [69]. Although this result motivates some physicists to consider the cosmological consequences of this energy conservation violation in $f(R,T)$ *gravity* [70] [71], *the idea that the energy-momentum tensor is not conserved in curved spacetime is coming back to Rastall [10].*

End of quote

How startling this is, cannot be overstated. A lack of energy-conservation, in effect, is implying that would be applications of a Hamiltonian based analytical system will be harder to employ. *I.e.* when there is a time dependence, in energy, as applied, then there is a divergence from the H = E rule. *I.e.* the Hamiltonian does not equal the total energy.

In other words, [26] is saying that a Hamiltonian based quantum gravity model, as to early universe cosmology, a.k.a. the style of ADM theory, as given in Crowell, [105] will not work in this model of cosmology as given by [26], i.e. only if gravity is embedded with in a deterministic structure, as would be quantum mechanics, i.e. see [25] by t' Hooft.

In other words, this model of relativity if it has any relations to quantum gravity at all would be quantized, if a person wanted to do that, after finding a deterministic embedding structure for would be quantization, first. As given by [25], which would then go right back to the.quantum structure. So [26], although it involves commutation relationships, is not amendable to the sort of classical-quantum bridging as was done by Dirac in [107] only if the following occurred.

A, Find a deterministic super structure which would embed quantum me-

chanics in a general sense.

b. Afterwards, show that this same embedding structure would be commensurate with the respect to the description of how time is analyzed in [26].

c. Finally, show that there is a bridge between the time dynamics of [26] *which does not contravene the dynamics of time evolution as set within the Ricci tensor structure of GR, i.e. see* [106].

The Barbour analysis, as referred to in Equation (49) as introduced by what is called "shape dynamics" by Barbor, and amplified in [106] STATES specifically that (see page 163 of reference [107].

Quote

All textbooks and popular accounts of the subject (*time evolution*) *positively encourage us to do so. They all contain* "*Pictures*" *of space-time. Now the picture is indeed there, and very wonderful it is, too. But it arises in an immensely sophisticated manner hidden away within the mathematical structure of the Ricci tensor. The story of time as it is told by General Relativity unfolds within the Ricci Tensor.*

For the reason noted above this quote, it is unlikely that Hamiltonian based GR, based upon quantization via Hamiltonian mechanics, can work with the Ragstall theory. *I.e.* the Hamiltonian in ADM theory is, times a wave function of the Universe, equals zero. But the Hamiltonian structure, as quantized, even if amended by the arguments given in [96] for an arrow of time would require modification, and so then with this, we conclude this section and prepare to analyze [22] and [27] issues in terms of relationship to the issues brought up in [3].

18. Introduction to Kieffer' [22] Reviewing an Argument by Kieffer about His Page 265, with Its Modified Einstein Equation Put in, and What It Portends as for Semi Classical Approximations Linked to Quantum Systems in Cosmology

As was stated by Kieffer, there is a relationship between a Hamiltonian form, H (Hamiltonian), and a constraint equation, for momentum p_N, along the lines of

$$p_N \;\&\; \left\{p_N, H\left(\text{Hamiltonian}\right)\right\} \approx 0 \tag{54}$$

This is, according to Kieffer, the Poisson brackets, equivalent to the following What we are looking at is, if we set the Lapse function, *N*, as = 1

$$\begin{gathered}\dot{a}^2 = -1 + a^2 \cdot \left(\dot{\phi}^2 + \frac{\Lambda}{3} + m^2 \cdot \phi^2\right) \\ \Leftrightarrow \ddot{\phi}^2 + 3\frac{\dot{a}}{a} \cdot \dot{\phi} + m^2 \phi = 0\end{gathered} \tag{55}$$

Here, the ϕ is a scalar field (here, called a "homogeneous field"), *m* is amass term, and *a* the scale factor, and Λ the cosmological constant. If m is set equal to zero, this has a simple $m = 0$ olution with

$$p_\phi = a^3 \cdot \dot{\phi} = \kappa = \text{const} \;\&\; \phi = \pm\frac{1}{2} \cdot \text{arcosh}\frac{\kappa}{a^2} \tag{56}$$

It cannot be solved analytically, if *m* is not equal to zero. Now as to a general problem between the Solvay 1927 conference methods and the application to GR will be alluded to, next.

I.e. this is in part why the problem of quantum gravity is so difficult. We will see that there is both by argument given by Dirac, as to inter relationships between the Poisson brackets and quantum equations of motion which create serious difficulties. But more seriously than that, using a very general set of principles, we will also see that there is a problem where one could conceivably make a quantum-classical bridge to the Fluid equation, relating evolution of the energy density, expression of GR, and quantum averaging to mimic classical conditions. However, in order to have acceleration of the universe covered, which is needed, we have different results of the Friedman equation (classical form) and Friedman equation (general relativistic form), which means that Ehrenfest type methods for connecting general relativity and Quantum systems would probably be next to impossible. So with that, we go to the next section.

19. A Generalized Problem to Making Quantization of the Einstein Field Equations Elucidated by First Principles

Worse than that, we do not have a quantum mechanical equivalent, and this due to the difficulties in terms of finding a quantum mechanical equivalent to the Poisson brackets $\{p_N, H(\text{Hamiltonian})\} \approx 0$ which is readily transferrable to the Friedman equation, *i.e.* so far a quantum bridge between quantized versions of Equation (54) and Equation (55) does not exist, right now.

I.e. the lectures on quantization of a classical Hamiltonian given by Dirac, in [108], pages 25 - 43 is ironically made more fraught by the requirement of extending the Hamiltonian *i.e.* if we have say $\phi_{a'}$ as so called first class secondary constraints, page 25 of [108] we find that there is an inability to do the following, if we wish to transfer to quantum systems, we need to do the following, *i.e.* add to the initial classical Hamiltonian, H_T

$$\begin{aligned} &H_E = H_T + v_{a'} \cdot \phi_{a'} \\ &\dot{g} \approx \{g, H_E\} \end{aligned} \tag{57}$$

Equation (57), in a Poisson bracket formulation, was used by Dirac to transform to a set of quantization conditions, in pages 25 to 43 of. The problem is, that it is difficult to come up with constraint equations, as given in the top level of Equation (57).

The following is easy to do, if you ignore constraints

$$\begin{aligned} &\frac{\mathrm{d}\langle P\rangle}{\mathrm{d}t} = -\frac{i}{\hbar}\langle\Psi|[P,H]|\Psi\rangle = \frac{1}{i\hbar}\langle\Psi|[P,V]|\Psi\rangle \\ &\xrightarrow[3\text{ dim}\to 1\text{ dim}]{} -\int \Psi^* \cdot \frac{\mathrm{d}V(x)}{\mathrm{d}x} \cdot \Psi \mathrm{d}x \\ &\xrightarrow[1\text{ dim}\to \text{Any dim}]{} \left\langle -\frac{\mathrm{d}V(x)}{\mathrm{d}x} \right\rangle \sim \langle -\vec{\nabla} V \rangle \equiv F(\text{force}) \end{aligned} \tag{58}$$

Try doing this, to have equivalence with Equation (57) and match that with Equation (54) to Equation (55). *I.e.* what is so difficult is to put in a Hamiltonian system, for gravity, which is commensurate with Equation (57) which then leads to an extended Hamiltonian.

Dirac claims the bridge from Poisson brackets to the situation represented by Equation (58) always involves a carefully set extended Hamiltonian situation. *I.e.* see his discussion in 33 to page 35 of [108]. The challenge would be to make those extensions somehow commensurate with Equation (55) and Equation (56).

Having said, this, we will next go to the problem of Quantum Geometrodynamics. Before going to it, a notice as to the problems of bridging to general relativity using conventional Quantum mechanics, will be raised as a bridge to the use of $H_{ADM}\Psi = 0$ which makes a plausible bridge to the Fluid equation of general relativity, [109] but also a summary as to how and why the connection to the rest of general relativity is extremely difficult, *i.e.* the Friedman equation as seen in [109] has a classical analogue which cannot be linked to its general relativistic form, but the fluid equation of General relativity in [109] does have a Newtonian derivation yielding the exact same result in both Newtonian and GR physics. Hence, the quantum-classical bridge as exemplified by Equation (58) works for the fluid equation, but would not work for the GR Friedman equation, since the Friedman equation classical would be the only bridge to the quantum result, using the Equation (58) bridge. And of course, both the GR Friedman bridge plus the fluid cosmology bridge are both needed in the acceleration equation, *i.e.* from [109] the following cannot be linked to quantum mechanics, via Equation (58), namely the acceleration equation of GR has

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3c^2}\cdot(\varepsilon + 3P) \tag{59}$$

This requires two equations, namely,

$$\begin{aligned}
&\frac{\ddot{a}}{a} = -\frac{4\pi G}{3c^2}\cdot(\varepsilon + 3P) \\
&\text{Due to } \dot{\varepsilon} + 3\left(\frac{\dot{a}}{a}\right)\cdot(\varepsilon + 3P) = 0 \\
&\text{And } \dot{a}^2 = \frac{8\pi G}{3c^2}\cdot\varepsilon a^2 - \frac{\kappa c^2}{R_0^2}(\text{GR Friedman}) \\
&\text{as opposed to, if } U = \text{const.} \\
&\dot{a}^2 = \frac{8\pi G}{3c^2}\cdot\rho a^2 + \frac{2U}{r_s^2}(\text{Newtonian Friedman})
\end{aligned} \tag{60}$$

The derivation of the acceleration equation for GR, using the two equations cited is in [109], page 60.

In addition we will derive the Fluid equation also used, which is the same form used in Equation (58) making a linkage to relativity and quantum mechanics, possible, if one uses the following steps, as given on page 59 of [109] *i.e.* If exists a commoving radius r_S.

We then will get a clean derivation of the so called fluid equation, used in

Cosmology. This fluid equation, which has the same form used in both GR and Newtonian physics may be in principle linkable to the quantization program outlined in Equation (58). So with that, we go to the interactions given in Equation (61) below.

$$
\begin{aligned}
& V(t) = \text{Volume}(\text{universe}) = \frac{4\pi r_s^3 a^3}{3} \\
& \& \dot{V} = V \cdot \left(\frac{3\dot{a}}{a} \right) \\
& E = V(t) \cdot \varepsilon(t) \\
& \dot{E} = V \cdot \left(\dot{\varepsilon} + \frac{3\dot{a}}{a} \varepsilon \right) \\
& \quad \& \text{ First law thermo}(\text{universe}) \\
& \quad \dot{E} + P\dot{V} = 0 \\
& \quad \Rightarrow V \cdot \left(\dot{\varepsilon} + \frac{3\dot{a}}{a} \varepsilon + \frac{\dot{a}}{a} P \right) = 0 \\
& \quad \Rightarrow \dot{\varepsilon} + \frac{3\dot{a}}{a} \varepsilon + \frac{\dot{a}}{a} P = 0
\end{aligned}
\tag{61}
$$

The GR and classical physics forms of the fluid equation, so derived, in Equation (61) and the results at the bottom of Equation (60) would allow us to make connection, with a lot of work to the sort of reasoning used in Equation (58) above, but due to the difference in the Friedman equation, in classical and GR form, as noted in Equation (59), it would be using the Solvay methods, extremely difficult to make connection between an acceleration equation, using scale factors, as given in Equation (59) and Equation (60) with the Equation (58) connection between classical and quantum mechanics with respect to an acceleration of the universe acceptable in both GR and quantum form.

We can state though that a bridge to the Fluid equation, as given in Equation (61) and Equation (58) would at least in principle very doable. Having said that, let us now go to the ideas of Quantum Geometrodynamics, as far as their use and future prospects to the study of Solvay 1927 methods, and quantum gravity issues.

20. Quantum Geometrodynamics and Semi Classical Approximations, as Reference [22] and Evolutionary Equations, for Quantum States, and Its Relationships to Quantum Issues Arising in [3]

Due to how huge this literature is, we will be by necessity restricting ourselves to pages 172 to 177 of [22] as that encompasses Hamiltonian style formalism and also has some connections to the Hamilton Jacobi equation.

We will make this limitation so our methods are not too far removed from the Solvay conference, 1927, *i.e.* the Hamilton-Jacobi equation makes an appearance, as well as a full stationary Schrodinger equation.

In this discussion, the wave functions are often quantized, or nearly so, albeit usually added gravitational background is semi classical.

To begin our inquiry as to Geometrodynamics, which has some fidelity to the Solvay 1927 conference, we look at the following expansion of the Klein Gordon Equation, without an external potential, *i.e.*

$$\begin{aligned}
&\left(\frac{\hbar^2}{c^2}\cdot\frac{\partial^2}{\partial t^2}-\hbar^2\Delta+m^2c^2\right)\Psi_{KG}=0\\
&\&\ \Psi_{KG}=\exp\left(i\cdot S_{\text{example}}/\hbar\right)=c^2S_0+S_1+c^{-2}S_2\\
&\&\ S_0\sim\pm m\cdot t\Rightarrow\left(\Psi_{KG}\text{ at }c^2\right)\sim\exp\left(-imc^2t/\hbar\right)\\
&\&\left(\Psi_{KG}\text{ at }c^0\right)\sim\exp\left(iS_1/\hbar\right)\Rightarrow i\hbar\Psi_t=\frac{-\hbar^2}{2m}\Delta\Psi\\
&\&\left(\Psi_{KG}\text{ at }c^{-2}\right)\sim\exp\left(iS_2/\hbar\right)\Rightarrow i\hbar\Psi_t=\frac{-\hbar^2}{2m}\Delta\Psi-\frac{\hbar^4}{8m^3c^2}\Delta\Delta\Psi\\
&\&\ \frac{\hbar^4}{8m^3c^2}\Delta\Delta\Psi=\text{first relativistic correction term}
\end{aligned}\tag{62}$$

As a Klein Gordon result, this leads directly to the idea of quantum mechanics, as embedded within a larger theory.

I.e. this methodology as brought up by Kieffer, in page 177 of [22] in its own way is fully in sync with some of the investigations of the embedding of quantum mechanics within a larger structure, as has been mentioned in a far more abstract manner by t'Hooft, in [25], although to make further connections, it would be advisable to have a potential term put in, as well as to have more said about relativistic corrections.

As mentioned by [22], Lammerzahl, C. in [110] has extended this sort of reasoning to quantum optics in a gravitational field. The virtue of this, is that one is NOT using the functional Schrodinger equation, as seen in page 149 of the Wheeler De Witt equations, given in [22]. *I.e.* the above derivation, within the context of the orders of c, given above, has explicit time dependence put in its evolution equations, and avoids some of the issues of the Wheeler De Witt program. *I.e.* read page 149 and beyond in [22] as to some of the perils and promises as to this approach.

In addition the c^0 recovery of the Schrodinger equation, and the c^{-2} recovery of a Schrodinger equation within the context of the Klein Gordon equation is fully in sync with some of the Solvay 1927 deliberations. As given in [3]. And also directly linkable to [25]

We will say more about this in our conclusion of this paper.

Note that the entire ADM program, albeit fascinating is a bit outside the reference frame of Solvay, although we will fully comment upon it in our conclusion section of our document, as a jump off point from the Solvay 1927 conference.

The main take away from this review, is how, especially Equation (62) which is relevant to the issues of Solvay 1927, encapsulates decades later, the sheer dynamic interplay between classical and quantum worlds the Solvay Delegates were in 1927, and how the issues especially as given in [3] can give an excellent road map to debatable quantum gravity issues.

21. A Personal View of the Relevance of the Solvay 1927 Conference Methodologies and the Promise-Perils of Quantum Gravity-Conclusion

What this author has seen has been a succession of themes which have resonated through the years as to Solvay after 1927 which need to be considered.

1) First of all, the issue of if or not Quantum mechanics is embedded within a deterministic super structure, is very much with us, and that Solvay did not close this matter at all.

T' Hooft as of reference [25] continues to elucidate, using different guises, the specifics as to would be embedding structures. In addition, the datum as to Equation (62), as to if there is as an example a comparison of terms, in that case, powers of c, in an expansion of the Klein Gordon Equation, needs to be revamped. *I.e.* the action principle, as brought up is crude, and the connections to the Hamilton Jacobi equation work here, primarily because the overall equation, Klein Gordon, is written sans a potential field included.

One must keep in mind that any constituent classical field equation could do, and work in this situation provided that the action principle is sufficiently well chosen. *I.e.* this approach is in its infancy, and that exploring the same procedure with even an equation which is classical and has a potential in it should be investigated.

2) I predict that the Wheeler De Witt procedure as outlined by [22] is going to be very difficult to justify, later on, once the big news hits, as I expect, as of a repeating universe structure. *I.e.* WdW theory, which has no explicit energy term put in. It is a Hamiltonian system times the WdW wave function, as equal to zero. And if there is a repeating multiverse structure, which feeds into a recycled beginning for each new universe, which has been hypothesized by this author [111], that instead of the WdW, one will have to reconsider a different genesis of fed in initial conditions than what was envisioned by WdW. *I.e.* as given in [112] a quantized version of electromagnetic field generation, tied into the cosmological constant, as given in [112] may be necessary.

3) Replacing it, to a degree will be working as done by [26] as far as items like the Ragstall theory, and also the work by Corda and his Iranian counter parts which does away with neat conservation of energy theorems for the start of the expansion of our universe.

If Energy is not conserved, explicitly, at the start of the expansion of the universe, then the Hamiltonian structure no longer equals the total energy, and hence items like Torsion which play a role as far as initial conditions we may be able to ascertain if items like Torsion affect generation of relic Gravitational waves. This should be looked at carefully.

4) We have mentioned, in Equation (59), Equation (60) and Equation (61) a break point between the general relativistic Friedman equation and its Newtonian version of the Friedman equation as a reason why the initial acceleration of

the Universe, will, at least be hard to justify in terms of purely quantum processes. *I.e.* different paradigms will have to be constructed than just the Friedman and also the fluid equation used to link acceleration of the universe. The author is aware that dark energy is used as a start to reacceleration of the universe and has seen this in many journal articles [114]. Usually the cosmological constant, as given in [114] is the enabler of reacceleration of the universe, and the way to hit this problem will be in either confirming, or denying the basis of the cosmological constant, and to do it in a way which does not contravene experimental evidence as collated in [114].

5) In [115] as given Sakar, on pages 471 to 473 speak of the breaking of super symmetry as a precursor for the creation of a cosmological constant.

Going to Equation (17.16) of page 473 of [115] a typical Lagrangian for a Quinessence field can be built up, usually involving a single field ϕ which may be, as the author expects, pseudo-Nambu-Goldstone bosons, [116]. Needless to say even with that being done, that the author would expect some connectivity, no matter what potential system is picked with the procedure given in Equation (59), Equation (60) and Equation (61) but with a different updated version of the Friedman equation which would avoid the problem outlined where the Friedman equation is replaced with a different parameterization, and done in such a way that there is some fidelity with Eq, (58). This also should be checked against [116].

We also will expect to use some commonality with the ideas given in [112] namely on page 14 via:

Quote: [112], page 14

$$\text{Energy} \sim \text{Volume} \cdot \frac{B^2}{8\pi} \tag{63}$$

However, we can only have a nonzero INITIAL volume, if the Weyl Tensor, as we define it is NOT equal to zero!

Hence, taking the square of the magnetic field, we will have

$$\text{Energy} \sim \text{Volume} \cdot \frac{1}{8\pi} \cdot \left(\frac{\sqrt{\varepsilon\mu_0}}{\sigma} \cdot \left(1 + \left(\frac{\sigma}{\varepsilon\mu_0} \right)^2 \right)^{1/4} \cdot \frac{\gamma}{2\pi G} \cdot \frac{\omega}{\Delta t} \cdot \left[1 - \frac{1}{\Delta t} \cdot \sqrt{\frac{\gamma \cdot (3\gamma - 1)}{8\pi G \cdot V_0}} \right] \right)^2 \tag{64}$$
$$\sim N(\text{gravtion number}) \cdot m_g(\text{gravtion mass})$$

End of quote

This idea uses the idea of a quantum bounce, and is in its own way of some similarity with Loop quantum gravity, as given in [117] or perhaps, more in common with [118] which has the following, *i.e.* an energy density, p 166 of [118]

$$\rho(\text{Friedman}) = \frac{1}{2} \cdot \left(\dot{\phi}_{\text{Friedman}}^2 + m^2 \phi_{\text{Friedman}}^2 \right) \tag{65}$$

Here the mass m, could be say tied into the assumed matter of the early universe, and scalar field as given in Equation (65) subjected to Quantum mechanical constraints, as would be in [112] [113] and [117].

All these suppositions should be checked with their equivalents in [3].

Acknowledgements

This work is supported in part by National Nature Science Foundation of China grant No. 1137527.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix A. As Copied from [20] (This Will Be Heavily Amended Later)

The first serious attack by Einstein on the "orthodox" conception took place during the *Fifth Solvay International Conference* on and Photons in 1927. Einstein pointed out how it was possible to take advantage of the (universally accepted) laws of conservation of energy and of impulse (momentum) in order to obtain information on the state of a particle in a process of interference which, according to the principle of indeterminacy or that of complementarity, should not be accessible.

In order to follow his argumentation and to evaluate Bohr's response, it is

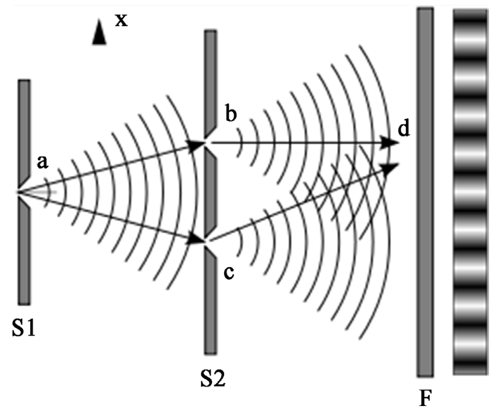

Figure A1. A monochromatic beam (one for which all the particles have the same impulse) encounters a first screen, diffracts, and the diffracted wave encounters a second screen with two slits, resulting in the formation of an interference figure on the background *F*. As always, it is assumed that only one particle at a time is able to pass the entire mechanism. From the measure of the recoil of the screen S_1, according to Einstein, one can deduce from which slit the particle has passed without destroying the wave aspects of the process.

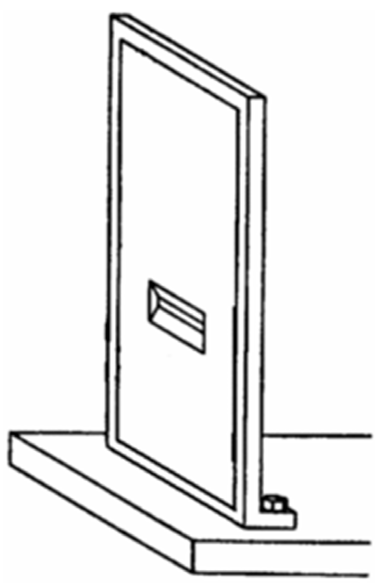

Figure A2. Einstein's slit.

convenient to refer to the experimental apparatus illustrated in figure A. A beam of light perpendicular to the X axis propagates in the direction $z$and encounters a screen S_1 with a narrow (relative to the wavelength of the ray) slit. After having passed through the slit, the wave function diffracts with an angular opening that causes it to encounter a second screen S_2 with two slits. The successive propagation of the wave results in the formation of the interference figure on the final screen F.

At the passage through the two slits of the second screen S_2, the wave aspects of the process become essential. In fact, it is precisely the interference between the two terms of the quantum superposition corresponding to states in which the particle is localized in one of the two slits which implies that the particle is "guided" preferably into the zones of constructive interference and cannot end up in a point in the zones of destructive interference (in which the wave function is nullified). It is also important to note that any experiment designed to evidence the "corpuscular" aspects of the process at the passage of the screen S_2 (which, in this case, reduces to the determination of which slit the particle has passed through) inevitably destroys the wave aspects, implies the disappearance of the interference figure and the emergence of two concentrated spots of diffraction which confirm our knowledge of the trajectory followed by the particle.

At this point Einstein brings into play the first screen as well and argues as follows: since the incident particles have velocities (practically) perpendicular to the screen S_1, and since it is only the interaction with this screen that can cause a deflection from the original direction of propagation, by the law of conservation of impulse which implies that the sum of the impulses of two systems which interact is conserved, if the incident particle is deviated toward the top, the screen will recoil toward the bottom and vice versa. In realistic conditions the mass of the screen is so large that it will remain stationary, but, in principle, it is possible to measure even an infinitesimal recoil. If we imagine taking the measurement of the impulse of the screen in the direction X after every single particle has passed, we can know, from the fact that the screen will be found recoiled toward the top (bottom), whether the particle in question has been deviated toward the bottom or top, and therefore through which slit in S_2 the particle has passed. But since the determination of the direction of the recoil of the screen after the particle has passed cannot influence the successive development of the process, we will still have an interference figure on the screen F. The interference takes place precisely because the state of the system is the *superposition* of two states whose wave functions are non-zero only near one of the two slits. On the other hand, if every particle passes through only the slit b or the slit c, then the set of systems is the statistical mixture of the two states, which means that interference is not possible. If Einstein is correct, then there is a violation of the principle of indeterminacy.

End of the Wiki quote.

Appendix B. E Mail from Dr. Robert Baker, August 24, 2017

Speed of Time Based on Muon Lifetime Decay Analyses By Robert M L Baker, Jr., August 24, 2017.

1. Introduction A muon is an elementary particle similar to the electron, with a negative electric charge, a spin of 1/2, but with a much greater mass than an electron. Muons decay over a well measured couple of microseconds and almost always produce at least three particles, which include an electron and two neutrinos. Because their lifetime or decay time has been very accurately measured over many years, they represent a possible means to establish the speed of time.

The ticking rate of the fast or slow clocks is here suggested to be related not only to time dilatation, caused by moving frames of reference, accelerated frames of reference as the strength of a gravitational field (Margalit, Y. *et al*. Science 349, 1205-1208), where clocks move slowly, but also the flow or speed of time may be related to the value of time itself, that is, it may change as the years pass after the early Universe or the Big Bang.

During a possible inflation of the early Universe (time is just getting started) clocks there might need to be very "fast" in order for the "material" of the early, rapidly inflating, Universe not to exceed the speed of light. Here we discuss measuring that speed of time as it might change over the years, decelerating from the early universe, utilizing the muon decay time as an indicator.

Consider an analogous situation:

Suppose you are a trainer of a runner who you just measured as doing a three-minute mile. Other trainers say that cannot be correct "Your stopwatch must be running slow since last year he only ran a four-minute mile." Well, you argue "No, you all had stopwatches that were running fast and miss-measured my runner's speed!" Therefore, in order to account for possible very fast clocks in the early universe it may well be that the "stop watches" in the early universe were moving faster than the watches of today. 2. Early Measurement of Muon Decay Time.

Historically, there appears to be some rather old and relatively inaccurate studies of the decay lifetimes of Muons (from Table 1, page 4 of Tarun Chitra "Multivariable Statistical Analysis of Muon Lifetime" a Cornel University publication): Measurement Year Microseconds Converse and Picsion 1946 2.33 ± 0.15 Ticho 1948 2.11 ± 0.10 Valley 1952 2.06 ± 0.08 Because of the inaccuracy, little can be concluded from these findings except the tendency of the Muon decay times to decrease with the increase in time (years), at least that decrease is not ruled out. 3. Recent Analyses of Muon Decay Time.

The following recent analysis are based upon D. M. Webber, *et al*. (2011), "Measurement of the Positive Muon Lifetime (decay) and Determination of the Fermi Constant to Part-per-Million Precision," Phys.Rev.Lett.106:041803, 2011; Phys.Rev.Lett.106:079901, 2011, the MuLan Collaboration.

Specifically, FIG. 2. shown below, is a Muon-Lifetime measurement summary. The MuLan R06 and R07 results are plotted separately and illustrate the consistency. The vertical shaded band is centered on the MuLan weighted average with a width equal to the combined uncertainty. FIG. 2 from D. M. Webber, *et al.* (2011), the MuLan Collaboration The newer combined results (circa 2009-2010 or 2009.5) due to MuLan give Muon-Lifetime = 2,196,980.3 (±2.2) ps, more than 15 times as precise as any previous experiment. On the other hand, the two previous determinations) by Chitwood (2007) of 2,197,015 (±20) ps and Barczyk (2008) of 2,197,085 (±30) ps in FIG. 2 give a decay time shortening with the MuLan value of −34.7 microseconds and −104.7 microseconds respectively. The slowdown for Chitwood over 2009.5 − 2007 = 2.5 years is −13.88 microseconds per year and for Barczyk over 2009.5 − 2008 = 1.5 years is −69.8 microseconds per year.

Consideration of FIG. 2 supports the view that, since 2000, except for Gioanetti (1984), the Muon lifetime is apparently decreasing.

The speed of time is, as originally suggested, slowing down and computed to be on the order of −35 (±25) ps per year (ps = 10 - 9 s). If linear, then over 13.7 billion years (1.37 × 1010 years) since the "Big Bang", clock speed would be reduced by about 500 seconds. It appears more likely that the speed of time decrease since the early universe would probably be exponential.

Perhaps, Cepheid-variable frequency would provide a possible determination of the speed of time variation. 4. Most Recent Measurement of Muon Decay Time and Conclusion Most recent, 2017, data are as follows:

M. Adams, Cosmic Ray Meeting, February, 2017.

(https/indico.cern.ch/event/5960021/contributions/2463437), found the muon decay time as: 2,047,270 (±43,021) ps IOP Science 2017, J. Phys Conference Services 866012011.

Physics OpenLab, August, 2017 "Cosmic Ray Muons and Muon Lifetime", found the muon decay time as: 2,078,000 (±11,000) ps at 2017.5. Since it has the lowest error and is the most recent, we will choose the Physics OpenLab result. Therefore, the difference in the Muon (decay) lifetime between MuLan of 2,196,980.3 (±2.2) ps at 2009.5 and 2,078,000 (±11,000) ps at 2017.5 is 2,078,000 −2,196,980.3 (±2.2) ps = −118,980.3 (±11,000) ps.

According to these numbers, over eight years since the MuLan measurements, the speed of time is slowing on the order of −14,900 (±11,000) ps per year. This result is quite different from the −35 (±25) ps per year formerly calculated. Because it has relatively less error associated with it, we will select the former, −35 (±25) ps per year, estimate. In any event, the trend, as confirmed by the 2017 analyses, is for the Muon (decay) lifetimes to decrease significantly with time and the speed of time to slow after the Big Bang.