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Velocity correlation derived from the Transactional Interpretation of Quantum Mechanics.

Peter Tanguay

A velocity correlation is investigated and developed from the Transactional Interpretation of Quantum Mechanics. This assigns frame invariant and relative velocities to wave and particles respectively as defined by TI with modifications for particles with mass. The theoretical support for this correlation is investigated using Minkowski space time and the quasiclassical state. The experimental support is investigated using the lifetime of the μ-Meson, the double right angle prism beam splitter experiment by Y. Mizobuchi and Y. Ohtake, and several others. A time dilation experiment is proposed which has not been performed and would give different results from current theory. The proposed theory is analyzed and presented in a Minkowski-like geometry.

Key Words: special relativity; quantum mechanics, Lorentz transformations; Transactional Interpretation; action at a distance; time dilation; frame invariant velocity; non-locality.

Une Corrélation de vélocité est développée de l'Interprétation de Transaction de Mécanique Quantique.

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Une corrélation de vélocité est examinée et est développée de L'intrprétation de Transactional de Mécanique Quantique. Ceci assigne le cadre vélocités invariants et relatifs pour onduler de le et les particules respectivement comme défini par TI avec les modifications pour les particules avec la masse. Le soutien théorique pour cette corrélation est examiné l'espace temps de Minkowski utilisant, et L'état de quasiclassical. Le soutien expérimental est examiné l'utilisation de la vie du μ - Meson, l'expérience de splitter de rayon de prisme d'angle droit double par Y. Mizobuchi, et Y. Ohtake, et plusieurs autres. Une expérience de dilation de temps est proposée qui n'a pas été exécuté et donnerait des résultats différents de la théorie actuelle. La théorie proposée est analysée et est présentée dans un Minkowski comme la géométrie.

1.0 Introduction

There have been many attempts at an interpretation of Quantum Mechanics that include a real physical wave. Those who have contributed to the debate include deBroglie, Schrodinger, Bohm, Bell, and Einstein among others. There are several motivations for seeking such and interpretation. First, there is the logical argument that quantum mechanics cannot simultaneously have the properties of locality and contrafactual definiteness [1], but rather, must lack one or the other, or both. This is the center of much of the debate brought about by the Einstein Podolsky Rosen paradox. [2] Secondly, there is something unsettling about describing a real physical system with a model whose central variable (the state vector) does not represent a physical system; just knowledge or even consciousness. To some, this is perfectly acceptable, while to many others this appears as an unnecessary dive into the metaphysical, or simply ad-hoc. Thirdly, a motivation to delve into this seemingly philosophical morass, is to lead to insights into new and unexplored qualities of nature. This is the goal of this paper.

One interpretation that contains a real physical wave is The Transactional Interpretation (TI) by John G. Cramer [3]. It makes a compelling case. In addition to satisfying its own criteria of economy, compatibility, plausibility, and insightfulness, it resolves the debate between contrafactual definiteness and locality. It eliminates the need for a conscious observer to have a special role, as demonstrated in TI's version of the Wheeler delayed choice experiment. But even more alluring, is the simple way in which the Born probability law falls out as a natural consequence. There is nothing ad-hoc about the interpretation, when the mathematical formalism is a direct result. Even the Copenhagen Interpretation (CI) does not do this. In CI, Borns' law is simply stated as a fact of the interpretation.

I am concentrating on TI to see if the insights gained from this original Wheeler-Feynman wave interpretation could lead to potential advantages. These advantages would come from connecting different branches of physics; producing experimental results that differ from current theory; and/or bringing together stand alone concepts.

1.1 Transactional Interpretation of Quantum Mechanics

I do not wish to recite the entire work of TI, but rather give an overview of the main points, so that the relativistic modification can be described with clearer contrast. A quick review of the Transactional Interpretation TI is warranted to fully describe the modification and its' results.

The Wheeler-Feynman[4] description of radiative processes can be applied to the microscopic exchange of a single quantum of energy, momentum, etc., between a present emitter, and a single future absorber through the medium of a transaction. A transaction occurs when the quantum value boundary conditions are met for a Wheeler-Feynman exchange of advanced waves:

$$\Psi^{*} = e^{-i\,(kx-wt)} \tag{1}$$

and retarded waves:

$$\Psi = e^{i\,(kx-wt)} \tag{2}$$

The retarded wave has eigenvalues characteristic of $+\hbar\omega$ and momentum $+\hbar k$ with the advanced wave having negative eigenvalues of energy and momentum.

The following invented false-time summary represents the transactional process. The emitter produces a retarded offer wave (OW) which travels to the absorber, causing the absorber to produce a confirmation wave (CW). The CW follows the track of the OW to the emitter. There the CW amplitude is proportional to OW X OW^*, or CW~ $|\,OW\,|^2$. CW is evaluated at the emitter locus and OW is evaluated at the absorber locus. The exchange then cyclically repeats, until the net exchange of energy and other conserved quantities, satisfies the quantum boundary conditions of the system, at which point the transaction is complete. An observer would perceive only the completed transaction, which he would interpret as the passage of a single photon traveling at the speed of light from emitter to absorber.

This process is described in TI as that of a four-vector standing wave, namely the CW, which has been established between emitter and absorber. As a standard 3 space standing wave is a superposition of waves traveling in space, this four-vector standing wave is the superposition of advanced and retarded components. This standing wave accounts for non locality as it applies to action at a distance. The photon and the collapsed state vector are identical with the completed transaction. The state vector is a real physical wave and is the offer wave of this transaction. Because this standing wave is four-vector with superimposed forward and reverse time Wheeler-Feynman waves, this transaction is atemporal.

The Born probability law is a natural consequence of this with:

$$\langle x \rangle = \int_{vol} \Psi_2^{\,*}\,\mathbf{X}\;\Psi_1 \tag{3}$$

Ψ_1 is the offer wave, and $\Psi_2^{\,*}$ is the Wheeler-Feynman advanced wave. TI views this as an average over space of the possible values of x, which the operator X *projects* from the components of the offer wave, which appear in the completed transaction.

For relativistic quantum mechanics TI employs the Schrodinger equation:

$$-(\hbar^2/2m)\nabla^2\;\Psi = i\,\hbar d\Psi/dt \tag{4}$$

for retarded waves. The complex conjugate:

$$-(\hbar^2/2m)\nabla^2\;\Psi = -i\,\hbar d\Psi/dt \tag{5}$$

for advanced waves. These are derived from the non relativistic limit of the Klein-Gordan equation.[5]

1.2) Theoretical support for TI.

The Wheeler delayed choice experiment [6] is a shining example of how TI explains quantum phenomena with neither paradoxes, nor conscious observer, and the fewest postulates. The key of this double-slit experiment is that the operator decides whether an absorbing emulsion blocks a photon, after it has passed through a slit or not. Each detector sees only one slit through a telescope. The retarded wave from the emitter passes through both slits, where it finds the emulsion and is absorbed. If it finds the emulsion down, and proceeds to a telescope aimed at the first slit, where it is absorbed, or it finds the emulsion down, and proceeds to the second telescope aimed at the other slit. The collimation of the telescope prevents the confirmation wave from passing through more than one of the slits, as it is aimed at only one slit. Since this transaction is atemporal, the issue of "when" the observer decides to place the emulsion, is not a factor. The offer wave passes through two slits but the resultant confirmation wave passes through only 1 slit.

2.0 Development of velocity correlation with TI for photons.

TI states that "The particle and the collapsed state vector are identical with the completed transaction." This is restated here for photons only, in proposition 1.

Proposition 1
"The transfer of light energy, using real Wheeler-Feynman waves between emitter and absorber, is simultaneous with the event of state vector (SV) collapse. This simultaneous event is experimentally observed, as the detection of the photon as a quantum at the absorber."

The photon is the event which marks the end of this atemporal transaction. The atemporal nature of the wave requires an event to start measuring time at all. For it is events, and the measured relationship, that define time. Under this proposition, photons do not travel independently.

2.1 Observed Correlation

There is now an observation of a correlation, which has not been explored before, as this is only a correlation under this interpretation, as described by proposition 1. The correlation is as follows: When light energy is transferred to a detector and it is absorbed, it goes from a frame invariant velocity c to a relative velocity. It is the same energy, but it is now traveling relativistically with the particles that absorbed it. This correlates with the only direct experimental proof of the photon.

The need for a model of the photon is apparent. Anti-Correlation experiments only imply a photon path using a Copenhagen Interpretation (CI). In addition, the CI description of complimentarity has recently been called into question[7]. This is demonstrated when one considers the double right angle prism beam splitter experiment by Yutaka Mizobuchi and Yoshiyuki Ohtake[8].

I am aware that correlation does not mean causation. However, when I began to think that the only direct experimental proof of the photon is at absorption, and with TI giving credence to a real physical wave, Its' consequences are worthy of an investigation.

3.0 Correlation inconsistencies with TI and the Special Theory of Relativity (STR) for particles with mass.

If this is a true correlation, then there also develops an inconsistency with TI and other current theories. This is:

Under TI, particles with mass travel at a relative velocity from emission to absorption. If this were a direct correlation, when particles with mass were localized, they would have a relative motion, and when they act non-locally they would have a frame invariant velocity. This leads to proposition 2 which extends proposition 1 to all particles.

Proposition 2

"When an atemporal state vector has a localized projection into a Lorentz reference frame then it has a relative velocity. When an atemporal state vector (OW) has no projection, then it has a frame invariant velocity."

Here, a frame invariant velocity is a velocity that is the same for all reference observers, as measured with the same state vector or offer wave clock. Once again, the offer wave (OW) of the transaction is identical with the state vector. This proposition would appear to be impossible, as it not only separates itself from just being an interpretation, to also being ignominiously at odds with relativity. The following is a development of how this is possible.

Eugene V. Stefanovich [9] in his paper "Is Minkowski space time compatible with Quantum mechanics?" presents an idea, which I had arrived at independently, and resolves the inconsistency with relativity. He states this idea so perfectly, and it is so central to the velocity correlation investigation that I must restate it here. In his review of the special theory of relativity, he separates the propositions of relativity which have been well-tested and those which have not.

"It is common to say that special relativity is derived as a consequence of the principle of relativity (1), and of the following 3 propositions which have been well tested experimentally.

1)In all inertial laboratories the laws of nature are the same, they do not depend on the position and orientation of the laboratory in space, and there is no experiment which can tell whether the laboratory is moving or at rest.

2)The speed of light is the same for all inertial observers, and does not depend on the velocity of the source.

The heart of special relativity is in Lorentz transformations for time and position of events. Generally, events are defined as physical processes localized in space and time. In special relativity, one starts with more specific class of photonic events which are related to light pulses or photons. An example of a photonic event is when a light pulse is reflected from a mirror or is registered by a detector. As described in virtually all textbooks on special relativity, when Propositions 1 and 2 are applied to thought experiments with such events one obtains:

3) If observer **O** registers a photonic event localized at position (x_e, y_e, z_e) and time t_e, then space time coordinates of this event measured by the observer **O**' are:

$$t_e' = t_e \cosh\theta - x_e \sinh\theta$$
$$x_e' = x_e \cosh\theta - t_e \sinh\theta$$
$$y_e' = y_e$$
$$z_e' = z_e$$

In special relativity, eqs. (above) are derived for photonic events only, and say nothing about events involving other (e.g. massive) particles, either free or interacting with each other and/or with an external potential; nevertheless this theory introduces a hypothesis!

4)Lorentz transformations are exact and universal. They are valid for all kinds of events (not only photonic); they do not depend on the composition of the system, on the state of the system, and on the form of interaction acting in the system.

This hypothesis is often omitted in derivations of special relativity, however, its' importance in STR cannot be overestimated, Virtually all significant results are based on (4) which does not have theoretical or experimental support."

It is clear from this set of logical statements that non photonic events *may* have different phenomena associated with them.

3.1) TI Modification for particles with mass.

Under TI, the only requirement for particles is that the wave equations must have both advanced and retarded solutions. There is only one problem with this. Under TI an atemporal non-local wave completely describes the dynamics through both nonrelativistic solutions to the Klien-Gordan equations, yet a particle does have a localized position, until it is scattered; diffracted; collided with another particle, or encountered with a boundary. This is directly witnessed as trajectory paths in a bubble chamber. Ballistic and electromagnetic laws are generally used on particles with mass to describe dynamics until these events. It then has a non-localized position until it is absorbed. It is at these events that the Schrodinger wave equations become necessary for calculations of cross section, boundary value problems, etc..

This sounds like the Schrodinger semi-classical interpretation [10],but it is not, as the discrepancies between experiment for Schrodingers' semi-classical interpretation are not problems here. With insights gained from TI, the two problems associated with the semi-classical interpretation are addressed, with this modified TI for particles with mass.

The two discrepancies between Schrodingers' semi-classical interpretation and experiment are:

1) a particle's localization as described by a wave packet does not match experiment.
2) the semi-classical wave that is temporal cannot be non-local.

Discrepancy 1 is resolved differently here than in standard TI. It is resolved using another principle from TI. The particle localization cannot be a wave packet as that is not consistent with experiment. Under TI, this is resolved as a particle has no separate identity from emission to absorption. This is from TI principle element TI4. However, in order to develop a velocity-type correlation, another principle element of TI can be used to describe a particle until scattering, etc.. If one uses principle element TI1 the localized particle with mass can be described as a continuous position projection of the state vector.

The quasiclassical state offers a challenging application of this principle, so I shall examine it here. The quasiclassical state $|\Psi>$ is described by the momentum-space wave function,

$$\Psi(q) = < q \,|\, \Psi> = N\, z_p(q)\, e^{-iqr} \tag{6}$$

where N is a normalization factor, $z_p(q) = e^{-\sigma(q-p)2}$, and r and p are the position and momentum expectation values, respectively. The uncertainty of the momentum of the particle is $|\Delta p| \approx \sigma^{-1}$, and the uncertainty in position is $|\Delta r| \approx \hbar\sigma$. Both position and momentum are localized functions in terms of σ.

The apparent localization here is defined differently for the quasiclassical state wave packet and the Schrodinger wave packet. The localization debate surrounding the Schrodinger wave packet is concerned with energy that is spread out over a region requiring spatial propagation greater than c in the event of SV collapse. This is different than localization discussed in the quasiclassical state. Localization in the quasiclassical state is exclusively concerned with maintaining a Guassian shape of the probabilistic position of an electron around a nucleus. [11]

The quasiclassical state is concerned with the shape of the expectation value of the particle position. Under TI, and this modification of TI, this is simply the shape of the state vector projection. This is consistent, and in fact describes, a localized particle with mass as a continuous position projection of the state vector.

Discrepancy 2 is resolved the same way as TI. TI's four vector atemporal wave addresses the non-locality concerns. The four vectors span spacelike, negative timelike or lightlike intervals, thus making it inherently atemporal and non-local. There is no "when" for the transaction.

3.2) Experimental Agreement with STR

One would at first glance think that proposition2 would have ample experimental evidence to refute it for particles with mass. Similarly, Eugene Stefonavich claims that there is no experimental evidence to support his proposition 4. In three experiments generally cited as direct experimental demonstrations of time dilation, none of them would disprove his proposition or this paper's proposition 2.

The lifetime of the μ- Meson at rest vs. the lifetime of the μ- Meson in motion experiment, measures a change in radioactive decay lifetime. [12] These μ- Mesons are in particle form, as an interference pattern is not observed. Time is measured with a light wave synchronized clock. There is no disagreement with experiment.

The Ives-Stillwell[13] experiment measures the optical waves which would travel at c. Time is measured with a light wave synchronized clock. There is no disagreement with experiment.

The experiments of Hay, Schiffer, Cranshaw, and Eglestaff [14] use the Mossbauer effect and a rotating cylinder to measure a shift in absorption frequency. This again uses waves of light which would travel at a frame invariant velocity c, and the motion of a particle, which would have relative motion. Again, three is no disagreement with experiment.

The Mossbauer effect is also used to measure absorption frequency shifts, if source and observer are at different temperatures. Results of these experiments would not have disagreements for the same reasons as the previous Mossbauer experiment.

All experiments to date, including routine neutron spectroscopy and electron interference, do not prove or disprove proposition 2 or Stefanovich's proposition 4.

4.0) Testable experimental evidence

In the previous sections, proposition 2 is shown not to be disproved by current theory or experiment. To prove proposition 2, it would have to give a different predicted result from STR for certain experiments. The following is a description of such an experiment.

The relative motion observed by electrons in countless experiments is different from the wave velocity measured in the experiment described below, as electron time dilation has not been directly measured in this wave state as defined by this QM interpretation.

An electron interferometer generates an interference pattern. Proposition2 would have the electrons as a non-local atemporal Wheeler-Feynman wave from the position split to the detectors. Using this as the wave to be measured, a time dilation experiment using two electron interferometers converted to electron wave clocks would give different results from STR as follows: Initially two electron wave clocks would be at rest in a laboratory on the ground. One would be placed aboard a plane at speed close to the electron particle velocity, as measured by a photon clock. A new frame invariant velocity would have to be related to the photon clock initially. The following velocities are entered into the equations below as measured by a photon clock. Presently STR has *all* clocks experiencing a time dilation:

$$\Delta t' = \Delta t /(1-\beta^2)^{1/2} \quad (7)$$

where:

$$\beta = v/c \quad (8)$$

However, if this proposition holds, then the electron wave clocks would have time dilation:

$$\Delta t' = \Delta t /(1-\beta'^2)^{1/2} \quad (9)$$

where:

$$\beta' = v/v_{ew} \quad (10)$$

where v_{ew} is the velocity of the electron wave clock on the ground or rather at rest, and v is the velocity of the electron wave clock on the plane.

Now one needs to determine if v_{ew} is a new maximum velocity. To determine the maximum velocity one starts by relating c and v_{ew} with a scalar:

$$v_{ew} = c /\eta \quad (11)$$

where:

$$\eta > 1 \quad (12)$$

by substituting c /η for c, into Minkowski like space time geometry, a new frame invariant velocity is developed. It has the unitary hyperbolas:

$$x^2 - (ict)^2/\eta^2 = 1 \quad (13)$$

and

$$x^2 - (ict)^2/\eta^2 = -1 \quad (14)$$

This is shown in figure (1). Where:

$$\phi = \tan^{-1}(\beta') \quad (15)$$

and

$$\phi' = \pi/2 - \tan^{-1}(\beta') \quad (16)$$

The maximum limitation of velocity is found by performing several successive transformations in the x, ict plane, and if $\eta=1$, then v = c and:

$$\phi = \tan^{-1}(\beta') = \phi' \quad (17)$$

The passage from the first to the last system is now still a rotation through the angle ϕ where:

$$\phi = \Sigma\, \phi_n \quad (18)$$

the velocity of the final system with respect to the first is therefore:

$$V_n = -ic \tan(\Sigma\, \phi_n) \quad (19)$$

where z varies from zero to $+i\,\infty$, and the function:

$$\tan z = -i\,(e^{iz} - e^{-iz})/(e^{iz} + e^{-iz}) \quad (20)$$

increases from zero to i. In consequence, $\tan(\Sigma\, \phi_n) < i$, and therefore V < c. This maintains that c is still a maximum relative velocity.

Since $c > v_{ew}$ results could be obtained from a clock with a relative velocity greater than the frame invariant velocity. Interesting results could be obtained. Relating this to the proposed experiment, the second electron wave located on the plane would be made to move faster than the electron wave on the ground, as measured by a standard photon clock.

5.0) Dirac Aether

The Dirac Aether[15] and this theory of velocity correlation, seem to have a common element, namely a hyperbola for each velocity. I would have liked to have had additional theoretical support for this theory, however I cannot see a direct relation. The Dirac Aether deals with velocity through the probabilistic velocity hyperbola equation:

$$\upsilon_0^2 - \upsilon_1^2 - \upsilon_2^2 - \upsilon_3^2 = 1 \quad (21)$$

and the velocity correlation deals with any atemporal wave frame invariant velocity according to the hyperbolic equations (13) and (14).

6.0) Conclusion

The Transactional Interpretation of Quantum Mechanics is discussed with Born's probability law as a natural consequence of the interpretation. TI then allows for a velocity correlation. This velocity correlation is proposed, investigated, and analyzed against theoretical and experimental support. The investigation results in a theory of time dilation, and is presented in a Minkowski-like geometry. An experiment is proposed to test the theory against STR. The unitary hyperbolas are also contrasted with those of the Dirac Aether. Aside from the proposed experimental prediction, the main advantage of this modified TI is that it would give a real physical reason for position and momentum to be conjugate variables. Presently there is no physical system that causes position and momentum to be complimentary. It is just a statement of observed empirical data. Perhaps this would chip away at what many of the last century's great contributors, such as Feynman and Schrodinger, consider an abstraction without a coherent visualization.

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Caption List

Figure (1) Unitary hyperbolas for electron wave clock in Minkowski like geometry.

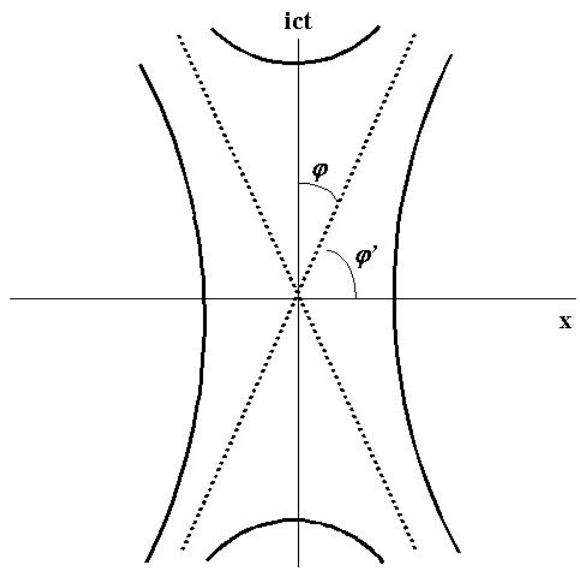

Fig. 1
Unitary Hyperbolas for electron wave clock in Minkowski like geometry

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