Trans-Coordinate States

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Abstract

In a previous paper introducing ‘trans-coordinate physics’, the state of a system cannot be defined along a space-like plane. A non-planar definition of state is therefore proposed that completely discards the notion of simultaneity. The new state is illustrated in the case of a spin measurement of two spin-correlated particles, where a superluminal collapse of the state is assumed to be of the Hellwig-Kraus variety. The causal loops that are commonly associated with this kind of collapse are completely avoided in this treatment. This state definition and collapse mechanism leads to an absolute ‘causal’ priority among collapse events, and results in a unique Minkowski architecture. The Hamiltonian of a trans-coordinate system is also proposed. It is shown that the total square modulus of this new kind of state is conserved during an interaction.

The rules that govern the collapse of quantum mechanical wave functions are given in another previous paper. They are at odds with the form of trans-coordinate physics, so they are restructured in the Appendix.

Keywords: invariance, state reduction, wave collapse.

Introduction

In a previous paper it was shown that a particle’s quantum mechanics wave function and its derivatives can be defined independent of space-time coordinate systems [1]. Differentials are obtained from a trans-coordinate limiting process that allows a dynamic principle to be applied everywhere within a particle’s wave packet. This provides for the quantum mechanical evolution of the packet over the invariant metric background. The variables of this wave function are not coordinates because they do not carry numerical values that uniquely label events or stipulate distant zero-points of those values.

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Trans-coordinate quantum mechanics is locally defined, but the collapse of a wave function has a wider consequence. In order to preserve invariance, this influence is transmitted through invariant metric space over the surface of the backward time cone of the initiating event (such as a measurement event) in the manner described by Hellwig and Kraus [2]. The original H-K collapse leads to troublesome causal loops [3], but this objection is not valid if a modified Hellwig-Kraus collapse is adopted that makes use of the trans-coordinate state. When that is done the influence of a collapse is still transmitted over the surface of the backward time cone; but in this case absolute causal priorities overcome the a-causal objections to a H-K collapse.

A Hamiltonian is defined for trans-coordinate states, and the rule is given for the conservation of expectation value of an operator $P$. A discontinuous interaction is evaluated in the interaction picture and it is shown that the square modulus of the state is conserved.

**Definition of State**

In this physics, events are identified with non-systematic letters in the manner of Euclid. The state of three particles are therefore given by an equation of the form

$$\Psi(a, b, c) = \Phi_1(a)\Phi_1(b)\Phi_3(c)$$

(1)

where $a$, $b$, and $c$ are three events that are confined to their respective wave functions and are required to have a space-like relationship to each other. There is no common time implicit in Eq. 1, for this state is not defined over a single space-like surface to which a common time can be assigned. Each particle in Eq. 1 has its own space-time differentials defined by a trans-coordinate limiting process. Integrated space-time variables are not introduced.

Consider a *coordinate based* equation of the form

$$\Phi(t_f \geq t \geq t_0) = a(t)b(t) + c(t)$$

This equation might represent a free particle $a(t)$ that interacts with a detector $b(t)$, where $c(t)$ is the same detector after capture. Probability current flows from the first component to the second for a period of time $t$ between the initial state at time $t_0$ and the final time $t_f$. A capture is realized when the second component is stochastically chosen at time $t_f$.

The same *trans-coordinate state* is given by

$$\Phi(a, b, c) = a(a)b(b) + c(c)$$
where \(a\) is any event inside the free particle wave packet that lies between the initial interaction and the final moment of capture, \(b\) is any event in the pre-capture detector that lies between the initial interaction and the final moment of capture, and \(c\) is any event in the post-capture detector that lies between the initial interaction and the final moment of capture. All three events have a space-like relationship to each other.

**Correlated Particles**

The zero spin state of two spin correlated particles \(p_1\) and \(p_2\) at time \(t\) is normally given by

\[
\Phi(t) = \frac{1}{\sqrt{2}} \{ p_1(t, \uparrow)p_2(t, \downarrow) - p_1(t, \downarrow)p_2(t, \uparrow) \}
\]

In the trans-coordinate case this is written

\[
\Phi(ab) = \frac{1}{\sqrt{2}} \{ p_1(a, \uparrow)p_2(b, \downarrow) - p_1(a, \downarrow)p_2(b, \uparrow) \}
\]

This particle state is taken together with two spin detectors \(d_1\) and \(d_2\) to make up the initial state of the system given by

\[
\Psi = \Phi(ab)d_1(m)d_2(n) \quad (2)
\]

This equation is pictured in Fig. 1a. The world lines of the detectors are labeled \(d_1\) and \(d_2\), where \(m\) and \(n\) are the identifying events on those lines. The locations of \(m\) and \(n\) need only occur prior to the interaction with the particles on the diagram (i.e., when the particle world line overlaps the detector world line), where \(m\) and \(n\) are space-like separated. The world lines of the particles are

![Figure 1: Correlated particle measurement](image-url)
the slanted shaded lines labeled $p_1$ and $p_1$ that are identified by events $a$ and $b$. Their location along these world lines need only occur prior to their interaction with the detectors, where all four events are space-like separated. The double arrows in Fig. 1a indicate that each particle is in a superposition of spin-up and spin-down. The diagrams in Fig. 1 lack trans-coordinate significance because they are specific to the displayed Lorentz frame. However, Eq. 2 and all the other equations given below are completely trans-coordinate.

There are six possible outcomes of an interaction between one or both of these particles with their detectors. These appear in the form of six components shown in the right-hand column of Eq. 3 that are generated by the dynamic principle acting on the initial state (i.e., the first component in Eq. 3).

$$\Psi + \Psi' = \Phi(ab)d_1(m)d_2(n) + d_1(a' \uparrow m')p_2(b' \downarrow)d_2(n')$$

The initial state is a realized component, which means that it is empirically real as explained in Ref. 1. The six possible outcome components on the right are called ready components that are identified by the underline of their first state. They are not empirically real, or at least they are not yet empirically real. This means that during the interaction in Eq. 3 the particles and detectors remain physically real in their initial state, and neither one of the six possible outcomes of the interaction is as yet realized. Only one of these six will become realized when it is stochastically chosen. When that happens all the other components collapse to zero. The probability that one of the ready components is stochastically chosen at any instant is governed by the magnitude of the probability current flowing into the component at that instant from the initial state component.

The state $d_1(a' \uparrow m')$ in the first ready component of Eq. 3 represents the interaction of the $1^{st}$ particle with its detector with its spin up. This leaves the non-interacting $2^{nd}$ particle with its spin down $p_2(b' \downarrow)$. The second ready component begins with the $1^{st}$ particle interacting with its spin down $d_1(a' \downarrow m')$ and the non-interacting $2^{nd}$ particle with its spin up $p_2(b' \uparrow)$. The third and fourth ready components describe an interaction of the $2^{nd}$ particle with similar spin down and spin up possibilities. The fifth and sixth ready components in
Eq. 3 represent a dual interaction that results when both particles are stochastically chosen “together”. This is a second order effect with negligible probability.

There are three possible scenarios. The first is that probability current from the realized component will flow into both the first and second ready components, but not into the other four. This will happen when the 1st particle interacts with its detector but the 2nd particle does not. The second scenario is that probability current will flow from the realized component into the third and fourth ready components, but not into the other four. This will happen when the 2nd particle interacts with its detector but the 1st particle does not. The third scenario is that probability current flows ‘at once’ into all six ready components. This happens when the 1st and 2nd particles interact ‘together’ with their separate detectors.

Figure 1b is a diagram of the first ready component in Eq. 3. We cannot include all of Eq. 3 on a single diagram, so we represent just one possible outcome. It shows the 1st particle interacting with the first detector with spin up, although this is still not a physically realized capture. It is only a ‘potential’ capture in this ready state. The 2nd particle is still not interacting with the second detector in that diagram.

If the first ready component in Eq. 3 is statistically chosen it will become a realized component as has been said, and all the other components in that equation will go to zero. The measured state of the system is then given by

$$\Psi'' = d_1(\uparrow A)p_2(b'' \downarrow)d_2(n'')$$

defining event $A$ in Fig. 1c. This is the vertex of a modified Hellwig Kraus collapse. Above the backward time cone of event $A$ the state is identical with that shown in Fig. 1b. The important thing about event $b''$ in Fig. 1c is that it occurs ‘causally after’ event $y$ (on the surface of the backward cone) and ‘causally before’ interacting with its detector. The darkened world line above event $A$ refers to the first detector that now includes an additional particle.

We assume that the 2nd particle will subsequently interact with its detector, so Eq. 4 generates the ready state $\Psi'''$ in Eq. 5 that is not diagramed in Fig. 1.

$$\Psi'' + \Psi''' = d_1(\uparrow A)p_2(b'' \downarrow)d_2(n'') + d_1(\uparrow m''')d_2(b'' \downarrow n''')$$

When the ready component in this equation is stochastically chosen it collapses to

$$\Psi''' = d_1(\uparrow m''')d_2(\downarrow B)$$

defining event $B$ in Fig. 1d. And finally

$$\Psi'''' = d_1(\uparrow m''')d_2(\downarrow n''')$$

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that is not diagramed in Fig. 1.

The collapse in Eq. 4 or 6 is assumed to be instantaneous. It follows from the rules of collapse given in a previous paper [4] that are updated in the Appendix of this paper to accommodate a trans-coordinate format.

**The Causal Order**

Event \( A \) occurs ‘absolutely’ before event \( B \) because the first ready eigenstate is chosen in Eq. 3 – excluding other choices. Once that is done, there is no going back to the other choices. Event \( B \) cannot influence event \( A \) because \( A \) has already happened in Eq. 4, which is a realized state before the 2\textsuperscript{nd} particle interacts with its detector. This is shown in Fig. 1d where the backward light path emanating to the left of event \( B \) does not penetrate the backward time cone of event \( A \). On the other hand, event \( A \) can influence event \( B \) as is apparent in Eqs. 4-6. This asymmetry is implicit in the stochastic choice of one of the six possibilities in Eq. 3, and has nothing to do with the Lorentz frame that is used to picture the events. The temporal order pictured in Fig. 1d imagines that \( A \) and \( B \) occur at the same time, but that is not the causal order determined by Eq. 4. The relativistic ordering of events as seen by different Lorentz observers has nothing to do with the absolute causal ordering that puts event \( A \) before event \( B \).

The influence of a Hellwig-Kraus collapse may seem to extend infinitely far into space and time but that is not true. The limited influence of event \( B \) in Fig. 1d is characteristic of what generally happens. Every state reduction follows many other state reductions that will limit its influence. This is shown in Fig. 2 where several state reductions are arranged according to their causal priority. They appear as a mountainous landscape where the mountain peak in the foreground is causally prior to a peak in the background. This means that the ones in the back are causally limited in their influence by the ones in the

![Figure 2: Mountainous architecture of Minkowski space](image)
front. In a 2 + 1 space, the landscape will appear as a two dimensional super-
position of mountaintops on a landscape of prior mountaintops. In the second
order probability that both events $A$ and $B$ are chosen in a single component,
neither one would influence the interior of the backward time cone of the other,
so we would have a double-peaked mountain.

Every event in the universe is located in one or another of these mountainous
peaks – like event $a$ in the background peak on the left in Fig. 2, or $b$ in the
middle-right peak. A modified Hellwig-Kraus collapse not only provides a non-
local causal influence, it also organizes events into an absolute causal framework
without regard to relativistic simultaneity. Figure 2 is the view from one Lorentz
frame in which the foreground mountain peak is higher than the background
peak immediately to its right. In another Lorentz frame the background frame
might be higher than the foreground peak. However, the causal order will be
the same in both. Every mountain peak has a space-like relationship to every
other mountain peak.

The Hamiltonian

Let the wave function of a system of two non-interacting objects be given by

$$\Phi(a, b) = a(a)b(b)$$

Define the operator $d/dt_{12}$ through the trans-coordinate limiting process (Eq. 2
of Ref. 1) acting on $\Phi(a, b)$ to be

$$\frac{d}{dt_{12}}\Phi(a, b) \equiv \frac{d}{dt_1}\Phi(a, b) + \frac{d}{dt_2}\Phi(a, b) = \frac{da(a)}{dt_1}b(b) + a(a)\frac{db(b)}{dt_2}$$

Dropping references to $a$ and $b$, the dynamic principle for these independent
particles is therefore

$$i\frac{d}{dt_{12}}\Phi = H\Phi \quad \text{where } H = H_1 + H_2$$

$$i\frac{d}{dt_{12}}\Phi = i\frac{d}{dt_1}\Phi + i\frac{d}{dt_2}\Phi = H_1\Phi + H_2\Phi$$

giving

$$i\frac{d}{dt_1}\Phi = H_1\Phi \quad i\frac{d}{dt_2}\Phi = H_2\Phi$$

$$i\frac{d}{dt_1}a = H_1a \quad i\frac{d}{dt_2}b = H_2b \quad (8)$$
The expectation value of an operator \( P(a) \) at an event \( a \) in \( a(a) \) evolves in the usual way, except we leave it as per unit volume.

\[
\frac{d}{dt} a^* P a = (\frac{d}{dt} a^*) P a + a^* P (\frac{d}{dt} a) + a^* \frac{\partial P}{\partial t} a
\]

\[
\frac{d}{dt} a^* P a = ia^* [HP - PH]a + a^* \frac{\partial P}{\partial t} a
\]

When \( P \) commutes with \( H \) and is explicitly time independent, its expectation values will be unchanged in time per unit volume. Because the direction of the differential variable \( dt \) through event \( a \) follows the square modular flow, the same may be said of the operator’s expectation value per unit volume at event \( a \).

**Discontinuous Interaction**

Some interactions, like a scattering interaction, give rise to a continuous change in the wave function that occurs entirely within a single component of the wave function. Other interactions produce a discontinuous quantum jump that requires the creation of a new component that cannot arise continuously from the given component.

If there is a discontinuous interaction between two objects \( a(a) \) and \( b(b) \) giving rise to a new ready component \( c(c) \), then the state function \( \Phi(a, b, c) = a(a)b(b) + c(c) \) will be dependent on three differential times \( dt_1, dt_2, \) and \( dt_3 \) such that

\[
\frac{d}{dt_{123}} \Phi(a, b, c) = \frac{d}{dt_1} \Phi(a, b, c) + \frac{d}{dt_2} \Phi(a, b, c) + \frac{d}{dt_3} \Phi(a, b, c)
\]

\[
\frac{d}{dt_1} \Phi(a, b, c) = \frac{da(a)}{dt_1} b(b) + a(a) \frac{db(b)}{dt_2} + \frac{dc(c)}{dt_3}
\]

Again dropping references to \( a \) and \( b \), the dynamic principle is now given by

\[
i \frac{d}{dt_{123}} \Phi = H \Phi \quad \text{where: } H = H_1 + H_2 + H
\]

where \( H \) is the interaction Hamiltonian. This equation does not break down into two independent parts as does Eq. 8 because the emerging function \( c \) is dependent on the given functions \( a \) and \( b \), and the interaction Hamiltonian \( H \) borrows from \( H_1 \) and \( H_2 \). The best way to proceed is in the interaction picture.
Interaction Picture

The interaction Hamiltonian introduces a new state variable

\[ \Psi \equiv \exp i(H_1 t_1 + H_2 t_2) \Phi \]

The time derivative of this is

\[
\frac{d}{dt_{123}} \Psi = i \frac{d}{dt_1} \Psi + i \frac{d}{dt_2} \Psi + i \frac{d}{dt_2} \Psi = -H_1 \Psi - H_2 \Psi + i \exp i(H_1 t_1 + H_2 t_2) \frac{d}{dt_{123}} \Phi
\]

\[
= -H_1 \Psi - H_2 \Psi + i(H_1 t_1 + H_2 t_2)(H_1 + H_2 + \mathbb{H}) \Phi \quad \text{from Eq. 9}
\]

\[
= -H_1 \Psi - H_2 \Psi + (H + \mathbb{H}_{\text{int}}) \Psi
\]

giving

\[
\frac{d}{dt_{123}} \Psi = \mathbb{H}_{\text{int}} \Psi
\]  

(10)

where \( \mathbb{H}_{\text{int}} = \exp i(H_1 t_1 + H_2 t_2) \mathbb{H} \exp [-i(H_1 t_1 + H_2 t_2)] \)

The new solution is propagated through time by the interaction Hamiltonian in this picture. It explicitly uses time coordinates \( t_1, t_2 \) in the definition of \( \mathbb{H}_{\text{int}} \). Nature does not introduce integrated times like these, but we use them because it is analytically useful to do so. It does no harm to introduce these variables inasmuch as they do not appear in the dynamic process that drives the system, and they do not appear in the final result below.

Square Modular Conservation

From the equation \( \Phi(a, b, c) = a(a)b(b) + c(c) \) and the fact that the square modulus of \( \Phi \) is equal to that of \( \Psi = \exp i(H_1 t_1 + H_2 t_2) \Phi \) in the interaction picture, we have

\[ \Phi^* \Phi = (ab)^* (ab) + 2 \text{re}(abc^*) + c^* c \]  

(11)

This equation must be non-zero for some set of events \( a, b, \) and \( c \), although event designations have again been dropped. Take

\[
\frac{d}{dt_{123}} \Psi^* \Psi = \left( \frac{d}{dt_{123}} \Psi^* \Psi \right) \Psi + \Psi^* \left( \frac{d}{dt_{123}} \Psi \right)
\]

and from Eq. 10

\[
\frac{d}{dt_{123}} \Psi^* \Psi = i(\mathbb{H}_{\text{int}} \Psi)^* \Psi - i \Psi^* (\mathbb{H}_{\text{int}} \Psi) = 0
\]
inasmuch as \( H_{\text{int}} \) is Hermitean. From Eq. 11 we then have

\[
\frac{d}{dt} \Phi^* \Phi = \frac{d}{dt_{12}} (ab)^*(ab) + \frac{d}{dt_{123}} 2\text{re}(abc^*) + \frac{d}{dt_3} c^* c = 0 \quad (12)
\]

Therefore the square modulus of both \( \Phi \) and \( \Phi^* \) is conserved at any location \( a, b, \) and \( c \). As the square modulus of \( ab \) and \( 2\text{re}(abc^*) \) lose amplitude at their respective events, the component \( c \) gains square modulus at event \( c \).

This tells us that although the definition of state does not establish a common temporal relationship between the particles, the interaction Hamiltonian establishes a relationship between the derivatives \( \frac{d}{dt_1}, \frac{d}{dt_2}, \) and \( \frac{d}{dt_3} \). The result in Eq. 12 is independent of \( \Psi \) or \( H_{\text{int}} \) so it is independent of the integrated values of \( t_1 \) and \( t_2 \) that define them.

The question arises as to the physical significance of the cross term \( 2\text{re}(abc^*) \) in Eqs. 11 and 12. Whereas \( (ab)^*(ab) \) is understood to be the probability that the system is in its original state at events \( a \) and \( b \), and \( c^* c \) is the probability that the new state will be found at event \( c \), the cross term has no obvious interpretation. Normally one integrates Eq. 12 over all possible events, in which case the cross term goes to zero because the original function \( ab \) is orthogonal to the newly created function \( c \). But in trans-coordinate physics it is meaningless to discuss coordinate based functions and their possible orthogonality. We are therefore forced to consider the question of how to regard the cross term when we deal exclusively with individual events such as \( a, b, \) and \( c \).

Experimentally we normalize the state \( ab \) corresponding to the initial conditions at events \( a \) and \( b \), and then focus our attention on the probability of finding state \( c \) at event \( c \). That is, we do not normally pay attention to the sum \( (ab)^*(ab) + 2\text{re}(abc^*) \) after the experiment has begun. Also, we don’t normally pay attention to narrowly defined events within a piece laboratory apparatus (such as a detector) but record the behavior of the instrument as a whole. So both theory and experiment normally avoid the meaning of the cross term for individual events in Eqs. 11 and 12, and its implications for the Born interpretation of quantum mechanics.

There is no need to avoid this issue. This component presents no trans-coordinate paradox of meaning or significance for the following reasons.

There are special rules that are auxiliary to the dynamic principle when a quantum jump occurs. I call them qRules. They describe the conditions under which the wave function collapses, leaving the newly created component standing by itself. A complete description is given in Ref. 4. A trans-coordinate modification of these rules appears in the Appendix of this paper.

There is no reason to think that nature is concerned with the cross term
in Eqs. 11 and 12, for the square modulus $\Phi^*\Phi$ is only a consideration in our analysis. Nowhere in the dynamic principle or in the qRules (as given in the Appendix) is there a reference to a square modulus except in the definition of probability current in qRule #2, and that pertains only to the square modulus of the newly created (ready) component in a discontinuous interaction. Nature, we say, has no reason to refer to square modulus except in the narrow definition in the appendix qRule #2. This is consistent with the fact that we make no reference to the Born interpretation of quantum mechanics and in fact reject that interpretation. The ‘interpretation’ given here is entirely contained in the auxiliary qRule #2 and is not something we add on top of that. Probability is not a mere “rule of correspondence”. It is built operationally into the mechanics of quantum mechanics through qRule #2.

**Appendix**

The partition lines of a continuous wave function flow smoothly and continuously through space and time. But when there is as discontinuous change in the wave function, as in a quantum jump of some kind, there will be a discontinuous change in the pattern of partition line – i.e., there will be a discontinuous change in the fractional distribution of the object in space. If an electron falls from the second orbit of an atom to the first orbit its distribution in the space around the atom will discontinuously change, causing the pattern of partition lines to discontinuously change. Therefore during the time it takes for the interaction to be carried out, the atom will support two different partition patterns that have different grids and different wave functions. We recognize these differences as being different components of the wave function that are in superposition for a time. The mathematical form of this discontinuity generated by the dynamic principle is that of orthogonality. However, in the trans-coordinate case it is a discontinuity of the partition lines that identifies a discontinuous change in the wave function.

The rules of collapse are called qRules. They are found in their original form in Ref. 4 together with many examples of their application. In the following they are modified to conform to the requirements of trans-coordinate physics. The applications in Ref. 4 still apply.

The first of the modified qRules describes how ready components are introduced into qRule equations
qRule (1): If a non-periodic interaction acting on a component generates a partition discontinuity at any event $a$, then these discontinuous lines will establish a new component that will be a ‘ready’ component. Components are otherwise ‘realized’.

[Note: A single component of a wave function must have partition lines that are continuous over all of the objects in the state, or at least they must spread continuously from the initial interaction event to cover all the objects in the state.]

[Note: A single component of a wave function must be completely realized or completely ready. It cannot be in-between empirically real and unreal, just as a single component cannot support two different partition patterns.]

[Note: The initial component in a qRule equation is realized because it is assumed to be an empirically real initial condition. If the interaction that generates the second component is periodic (e.g., a Rabi oscillation), then the second component will also be realized. In that case the first two components will oscillate without collapse. If the interaction is non-periodic, then it will be ‘ready’ and will be subject to the second qRule.]

The second qRule establishes the existence of a stochastic ‘trigger’, and identifies the ready components of single events as the targets of stochastic choice. The probability current per unit volume flowing into the ready component $\phi(a)$ at event $a$ is equal to $J(a) = d\{\phi^*(a)\phi(a)\}/dt$.

qRule (2): The stochastic trigger can only strike a ‘ready’ component at a single event $a$. It does so with a probability per unit time per unit volume equal to the probability current per unit volume $J(a)$ that flows into it from a ‘realized’ component.

[Note: If the ‘effective physical volume’ of an event is thought of as infinitesimal $dΩ$, then the probability per unit time $J(a)dΩ$ of a stochastic hit on that event is also infinitesimal.]

[Note: A ready component can only be stochastically chosen when current flows into it from a realized component. Current coming from a ready component has no trigger attached.]

The collapse of a wave is given by qRule (3)

qRule (3): When a ready component is stochastically chosen at event $a$ it will immediately become a realized component everywhere forward of the backward time cone of event $a$, and all other components in that region will go immediately to zero.

[Note: A collapse is instantaneous. There is no reason to add another ‘non-
linear’ auxiliary dynamic process to the mix.]

[**note**: The form of this collapse is that given by Hellwig and Kraus in Ref. 2.]

[**note**: The collapse mechanism does not select a particle or a measuring device as do other theories. Instead it selects non-periodic discontinuous quantum jumps for state reduction.]

I regard the predictions of the qRules as being well substantiated. This is based on the exhaustive examples of their application in Ref. 4 that seem to me ‘correct’ beyond doubt. This is why I include them with the dynamic principle as part of the mechanics of quantum mechanics. It is nonetheless possible that they are not fundamental in the same way that the laws of spectroscopy are empirically true but not fundamental. It is possible that these rules might be integrated into the dynamic principle in the same way that Ghirardi and Pearle have included a stochastic term into the Hamiltonian, leading to a collapse of the wave function [5]. An integrated theory of that kind seems to me desirable, but to be correct it would have to predict the same experimental results as the qRules. The theory of Ghirardi and Pearle does not do that. I show in another paper that there is at least one experiment in which the qRules predict a collapse that contradicts the Ghirardi and Pearle theory of spontaneous decay [6].

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