Trans-Coordinate qRules

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The qRules that govern the collapse of quantum mechanical wave functions are given in a previous paper. They are at odds with the form of trans-coordinate physics that is outlined in another paper. It is the purpose of this paper to restructure the qRules to accommodate the trans-coordinate formulation. The difference is that each component is now specified relative to a specific event, and that the probability current flowing into ready components is now spread out over the events in the component. This difference is illustrated in the case of a charged particle being captured by a detector.

Introduction

A previous paper gives three *qRules* that describe the collapse of the quantum mechanical wave function [1]. These rules refers to *orthogonal discontinuities* that exist between two square modular components of a wave function. A square modular component is also *trans-representational* in Ref. 1 because it is formed by integrating out all of the variables (except time) of the system. In another paper, quantum mechanics is formulated in a way that avoids the use of space-time coordinate systems, resulting in a *trans-coordinate* physics [2]. The usual meaning of orthogonality between components is not defined in this physics, and quantum mechanical wave functions are specified at individual events in space and time; so some accommodation must be made between the two papers. It is the purpose of this paper to rewrite the qRules to conform to the nomenclature and requirements of trans-coordinate physics.

Partition lines flow through every event inside the wave packet of a non-zero mass particle, and specify its local time direction at that event. Groups of these lines intercept spatial volumes (in 3 + 1 space) to form two dimensional enclosures that separate the particle into its fractional parts. The object's square modulus in any volume enclosed by partition lines remains constant in time. Partition lines do not cross one another and can be characterized as streamlines of the object's square modular flow through space and time. They are used at each event to define the *local grid* consisting of four unit vectors $\hat{x}$, $\hat{y}$, $\hat{z}$, and $\hat{t}$ that specify the directions of derivatives of the wave function at that event.

Partition lines are generated by the wave function and will flow smoothly and continuously through space and time to the extent that the object's wave function flows 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. For instance, 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. During the time it takes for the interaction to be carried out, the object will therefore support two different partition patterns that have different grids and wave functions defined at each affected event. We recognize these differences as being different *components* of the wave function that are in superposition for a time. The mathematical form of the discontinuity generated by the dynamic principle (in a quantum jump) is that of orthogonality. However, in the trans-coordinate case it is the above *discontinuity of the partition lines* that is caused by (and simultaneously cause) a discontinuous change in the wave function. In this paper the term 'component' is reserved to mean a square modular component rather than the wave function component, for when considering the qRules we are more concerned with the square modulus than we are with the wave function. We take the further liberty of calling two such (discontinuous square modular) components *orthogonal components*.

We may represent the square modular component at event **a** as $u(\mathbf{a})$. A *qRule equation* is a solution of the dynamic principle in the form of a superposition of orthogonal components

$$U(\mathbf{a}) = u_0(\mathbf{a}) + u_1(\mathbf{a}) + u_2(\mathbf{a}) + \ldots \qquad (1)$$

where $U(\mathbf{a})$ is the square modular state function at event **a**.

There is an important distinction in Ref. 1 between realized and ready components, where the latter is designated by an underline. A *realized component* $u(\mathbf{a})$ at an event **a** is understood to have 'physical significance' whereas a *ready component* $\underline{u}(\mathbf{a})$ is understood to have *no* physical significance; or at least, it has no physical significance until it is stochastically chosen. These two kinds of components are physically different although they have the same mathematical status so far as the dynamic principle is concerned. The initial state of any real physical system is given by a realized component, whereas ready (unreal) components are generated by subsequent interactions leading to quantum jumps as prescribed below in qRule (1).

Trans-Coordinate qRules

The first qRule describes how ready components are introduced into qRule equations.

qRule (1): *An orthogonal component that is generated by a non-periodic interaction is a 'ready' component. All components following ready components in a qRule equation are also ready components.*

[**note**: If the first component $u_0(\mathbf{a})$ in Eq. 1 is realized (i.e., physically real), and if the interaction that generates the second component $u_1(\mathbf{a})$ is periodic (e.g., a Rabi oscillation), then the second component will also be realized. In that case the first two components in Eq. 1 will oscillate as indicated by a double arrow in an equation like $u_0(\mathbf{a}) \Leftrightarrow u_1(\mathbf{a})$. However, if the interaction is non-periodic, the second component will be ready and the equation will take the form $U(\mathbf{a}) = u_0(\mathbf{a}) + \underline{u}_1(\mathbf{a})$. In that case a third component will also be ready, giving

$$U(\mathbf{a}) = u_0(\mathbf{a}) + \underline{u}_1(\mathbf{a}) + \underline{u}_2(\mathbf{a}) + \ldots$$

independent of the kind of interaction that carries $\underline{u}_1(\mathbf{a})$ into $\underline{u}_2(\mathbf{a})$.]

Normalization at an event **a** was established in Ref. 2 by requiring that $U(\mathbf{a})d\Omega = df$, where $d\Omega$ is the differentially small volume around **a** and df is the differential fraction of the object contained in that volume (i.e., enclosed by partition lines). Because of the definition of df, this equation has the effect of normalizing the entire function to 1.0 when one integrates over the spatial volume perpendicular to the partition lines (see example in Ref. 1). When there is more than one component, each one is equal to $u_k(\mathbf{a})d\Omega = c_k(\mathbf{a})df_k$, where $c(\mathbf{a})_k$ is a coefficient between 0 and 1 and df_k is the fraction of u_k contained in the volume $d\Omega$. Each df_k therefore integrates to 1.0 over the perpendicular spatial volume. The dynamic principle determines the value of $u_k(\mathbf{a})$ as well as $df_k/d\Omega$ at each event, so $c_k(\mathbf{a})$ is completely determined by the dynamics and is constant over the perpendicular spatial volume. Normalization at an event **a** is then

$$U(\mathbf{a})d\Omega = c_0(\mathbf{a})df_1 + \underline{c}_1(\mathbf{a})df_2 + \underline{c}_2(\mathbf{a})df_3 + \ldots \qquad (2)$$

or
$$U(\mathbf{a}) = c_0(\mathbf{a})df_0/d\Omega + \underline{c}_1(\mathbf{a})df_1/d\Omega + \underline{c}_2(\mathbf{a})df_2/d\Omega + \ldots$$

so
$$U(\mathbf{a}) = u_0(\mathbf{a}) + \underline{u}_1(\mathbf{a}) + \underline{u}_2(\mathbf{a}) + \ldots$$

The probability current per unit volume flowing into any event **a** of a component *k* is given by $J_k(\mathbf{a})$. When a coordinate based square modular component $u_2(x, y, z)$ receives probability current it is possible to imagine that every 'point' receives its share, so each point can be said to receive an 'infinitesimal' amount of current. In a similar way, event **a** in every component $u_k(\mathbf{a})$ can be thought of as receiving an infinitesimal amount of current as a result of the dynamic principle operating at that event. The infinitesimal terminology is heuristic only, and is not used below in any definitive way. Because $U(\mathbf{a})$ is given in per unit volume, its magnitude in Eq. 2 is finite as is the initial value of $u_0(\mathbf{a})$. A similar qRule equation holds for the square modular state $U(\mathbf{b})$ at any other event **b**.

The second qRule establishes the existence of a systemic 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 k^{th} ready component at **a** is equal to $J_k(\mathbf{a}) = \dot{u}_k(\mathbf{a})$.

qRule (2): *The stochastic trigger can only strike a 'ready' component k 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* $J_k(\mathbf{a})$ *that flows into k from a 'realized' component.*

[note: Notice that 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.

[note: In Ref. 1 the value of *J* refers to the probability current that flows into an entire (integrated) ready component from an entire realized component. It is not specific to a single event as is the present formulation.]

[note: Also in Ref. 1, the value of *J* is divided by the square modulus of *U* because total normalization is not necessarily assumed to equal 1.0. However, the fundamental use of partition lines based on fractional separations implies the usual overall normalization of 1.0, so the division the square modulus of *U* is not necessary in the trans-coordinate case.]

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

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 will go immediately to zero in that same region.*

[note: The collapse is instantaneous because a stochastically chosen component cannot linger between being empirically real and empirically non-real. There is no “in-between” existence and non-existence.]

These rules can be applied to all the examples of collapse given in Refs. 1 and 3. The difference is that the qRule components are now specific to a given event and the probability current into each event is infinitesimally small. A detailed application of these rules is illustrated below for the capture of a charged particle by a detector.

Particle capture

This process during the interaction is described in Eq. 1 of Ref. 1 by a qRule equation of the form

$$U = pd_0 + \underline{d}_1$$

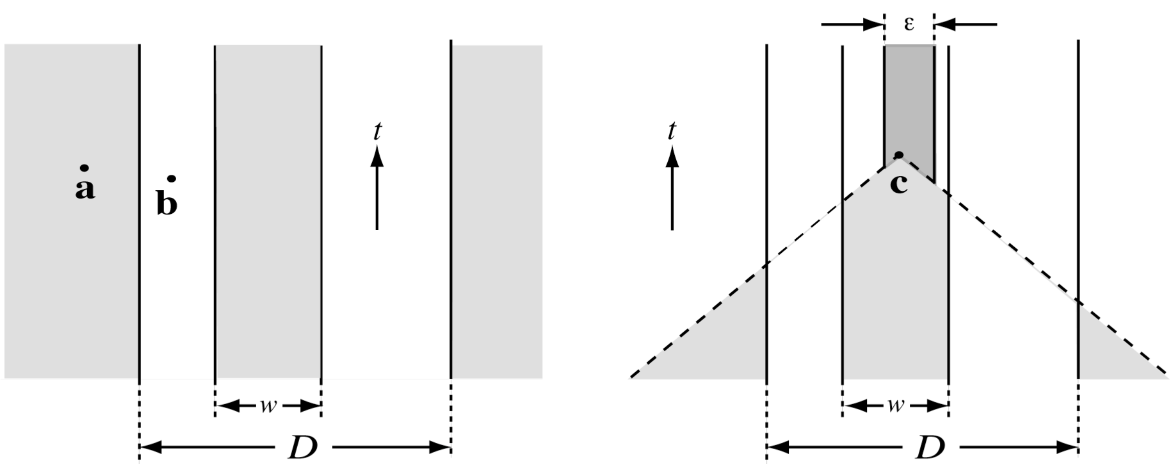
where the u's are replaced by letters describing the system. In this case, p is the free particle prior to capture, d_0 is the detector prior to capture, and d_1 is the detector after it has captured the particle. We now write this

$$U(\mathbf{a}, \mathbf{b}, \mathbf{c}) = p(\mathbf{a})d_0(\mathbf{b}) + \underline{d}_1(\mathbf{c}) \quad (4)$$

where $p(\mathbf{a})d_0(\mathbf{b})$ is the initial component considered at an event **a** in the particle and at an event **b** in the detector, and where the ready component $\underline{d}_1(\mathbf{c})$ indicates a ‘possible’ site **c** of the capture event inside the detector. Events **a**, **b**, and **c** have a space-like relationship to one another.

Figure 1a shows the detector during the interaction but prior to capture in a 1 + 1 space. The width of the detector is D and the width of the window into the capture chamber is w. The shaded area represents the free particle that envelops the outside of the detector, and that penetrates the capture chamber without yet producing a stochastic event. A possible capture site is not indicated on the diagram that shows only realized components.

Figure 1b shows the system after capture. Following event **c** (i.e., following the backward time cone of **c**) the particle is confined to a small configuration of width ε inside the capture chamber. This corresponds to the 'volume' of the discharge that initiates the cascade. That volume will surely expand in time to include the entire discharge chamber, but that is not shown on the diagram. It is possible that ε is too small to contain the particle with the available energy; and in that case, the system will take on a Heisenberg uncertainty ΔE for a brief time ΔT, where ΔT is measured on the local grid of the particle.



(a) (b)

Figure 1: (a) $p(\mathbf{a})d_0(\mathbf{b})$ before capture, (b) $d_1(\mathbf{c})$ after capture

The qRule equation in Eq. 4 can be given in further detail as

$$U(\mathbf{a}, \mathbf{b}, \mathbf{c}) = p(\mathbf{a})d_0(\mathbf{b}) + \underline{d}_1(\mathbf{c}) + \underline{d}_2(\mathbf{c}) + \underline{d}_3(\mathbf{c}) + \ldots + \underline{d}_n(\mathbf{c}) \tag{5}$$

where event **c** is subject to a stochastic choice for each possible 'discharge configuration' d_k. The symbol $\underline{d}_1$ now represents the detector with one discharge configuration (i.e., one value of ε occurring in one part of the capture chamber) and $\underline{d}_2$ represents the detector with another discharge configuration occurring in (possibly) another part of the capture chamber, and so forth. There may be an infinite number of possible discharge configurations at each event involved in the interaction, and this means that the probability current per unit volume flowing into each of the ready components in Eq. 5 is infinitesimal.

An external time variable does not appear in a qRule equation because it applies to only one event. The qRules were said to be trans-representational in Ref. 1 because all of the variables were integrated out of each component except time. In the present case the components in a qRule equation at any event are just numbers plus their derivatives in the specified directions; so they are now 'completely' trans-representational – including time. Of course, one can always include an internal coordinate description at each event as well as an external coordinate description; but this is something we do, not nature.

We view external time dependence by looking at a 'big picture' coordinate representation like that of Fig. 1, where the square moduli of the components on the right side of Eq. 5 rise and fall in time with the flow of probability current – that is, they rise and fall as one runs the eye over different events along a single partition line. That current begins to flow as soon as the wave function, driven by the dynamic principle, reaches the chamber. The dynamic principle will also determine how fast the interaction occurs as determined by the time derivative of each component relative to its own grid. Nonetheless, it is shown in the appendix in Ref. 2 that the total time rate of change of the right side of Eq. 5 is equal to zero, which means that the total current flow is 'conserved' across all of the components on the right side of any qRule equation at any event.

The shaded regions of Fig. 1a include all the events that are *potential* subjects of stochastic choice, so the temporal advance of the wave function is not indicated on that diagram. The shaded area inside the backward time cone of event **a** is retained in Fig. 1b because of its causal relationship to **a**. If this use of a space-time diagram is unusual it should be remembered that these diagrams are only intended to provide us with a "big picture'. They have no ultimate physical significance because they are only 'coordinate' constructions. It is the qRule equations that have physical significance because they describe the solutions of the dynamic principle at each event. One should look to them to resolve any ambiguity that may appear when constructing the diagrams.

References

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