GENTLE QUANTUM EVENTS AS THE SOURCE OF EXPLICATE ORDER

by Geoffrey F. Chew

Abstract. It is proposed that multiple emission and absorption of soft photons in a discrete quantum world (implicate order) generates the continuous Cartesian-Newtonian-Einsteinian space-time world of localizable objects and conscious observers with measuring rods and clocks (explicate order).

David Bohm (1981) has introduced a notion of "implicate order" to complement the classical Newtonian-Cartesian real-world view of separable objects moving through a space-time continuum. In the present note this classical view will be characterized as "explicate order." Quantum-mechanical and relativistic considerations preclude a satisfactory overall world picture based on explicate order; at the same time explicate order is for many purposes accurate and useful—being the underpinning of hard science. What is the source of such accuracy? We propose in this note that explicate order together with space-time is an approximation emerging from complex but coherent collections of "gentle" quantum events—the emission and absorption of soft photons.

It is well known that order can emerge from complexity; the laws of thermodynamics and hydrodynamics constitute examples. We suggest that space-time and the attendant explicate order emerge from soft-photon complexity in a sense analogous to the emergence of temperature, pressure, heat content, and so on, from the complexity of atomic collisions. The complexity responsible for objective reality within an apparently-continuous space-time we propose to associate with multitudes of coherent low-energy electromagnetic quanta. Immensely

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large numbers, stemming from the combinatorics of soft-photon event patterns, are conjectured to be responsible for the notion of separately-moving objects. We shall identify special properties that endow the photon with unique capacity to generate explicate order.

Underlying our thinking is the Heisenberg matrix representation of quantum mechanics—which associates a complex number S_{ab} with a discrete event $b \rightarrow a$ (Iagolnitzer 1978). The event might be a particle decay such as that of figure 1 or it might be a collision between particles, such as that of figure 2.

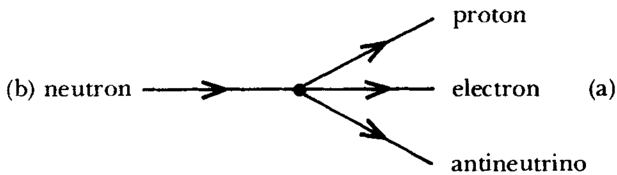

FIG. 1

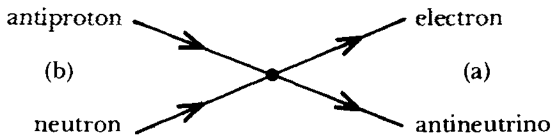

FIG. 2

The probability that the event shall occur is given by the absolute-value squared of the complex number S_{ab}:

$$P_{ab} = |S_{ab}|^2. \quad (1)$$

One does not speak, in the matrix picture, of space or time but only of a sudden event. There is a "before" and an "after" but no continuous evolution therebetween. We start with the premise that our "world" is built from such discrete quantum events. We conjecture that our sense of continuous space-time is to be understood through collections of certain special "gentle" events in which an initial electrically charged particle emits or absorbs a photon and a final charged particle appears with attributes almost the same as those of the initial particle. Figure 3 gives an example. The events of figures 1 and 2 are, by contrast, "violent." The situation after the event is totally different from that before.

Violent events provide no basis for the approximate continuity essential to explicate order. What endows the photon with its unique capability for gentle (almost continuous) events? The zero photon rest mass is one essential. A photon may carry an arbitrarily small amount of energy and momentum and thereby, in its absorption or emission, disturb the charged particle to an arbitrarily slight extent. Particles with nonzero rest mass lack this capability; a minimum "kick" accompanies their emission or absorption. A second essential photon characteristic is its failure to carry any nonzero conserved quantum numbers: Photon emission or absorption by a charged particle leaves the type of charged particle unchanged (e.g., electrons are not changed into protons). A third necessary characteristic involves spin; the photon is able to avoid disturbing the spin of the charged particle with which it interacts. A "gentle event"—synonymous with "soft-photon" emission or absorption—leaves a charged particle unaffected except for an arbitrarily tiny momentum impulse.

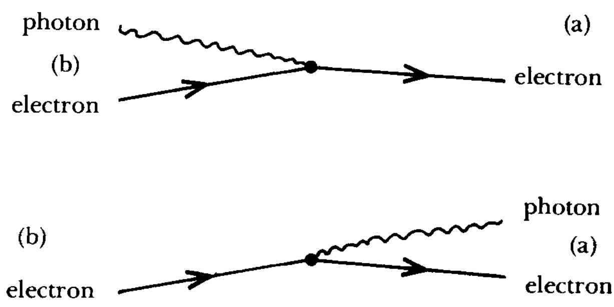

FIG. 3

The classical notion of electric field corresponds to a coherent superposition of large numbers of soft photons. The language of explicate order describes a charged particle moving through an electric field as subject to a *force* which continuously changes the particle's momentum. From the quantum point of view, however, momentum impulses are discrete—associated with individual photons. The illusion of continuity stems from the very large number of gentle quantum events. What I am proposing in this note is that *another* consequence of a multitude of gentle events is the classical notion that the charged particle follows a *trajectory in space-time*.

There is no *a priori* continuous space-time in the matrix representation of quantum mechanics, but Richard Feynman discovered that the *superposition* aspect of quantum mechanics allows the complex number S_{ab}, associated with a discrete event, to be evaluated through an infinite summation over terms, each of which associates with a graph (see Bjorken and Drell 1965):

$$S_{ab} = \sum_{G} S^{G}_{ab}. \tag{2}$$

In this Feynman series, the symbol G stands for "graph." Each graph corresponds to a pattern of "intermediate events" that might intervene between a (after) and b (before). The violent event of figure 2, for example, admits the intermediate event patterns of figure 4, where the wiggly lines denote soft photons. Indefinitely-large numbers of intermediate soft-photons can be emitted and reabsorbed by the charged-particle lines of a Feynman graph. Feynman's rules for the complex number $S_{ab}{}^{G}$ belonging to a graph G are such that large collections of *violent* intermediate events associate with such small complex numbers $S_{ab}{}^{G}$ as to be relatively unimportant; a multitude of *gentle* intermediate events dominates the Feynman graphical-series (Iagolnitzer 1978). The problem of summing the gentle-event series has taxed the ingenuity of two generations of particle theorists.

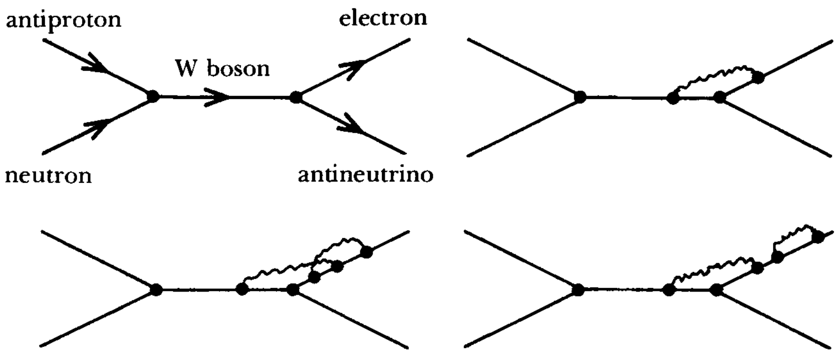

FIG. 4

Although Feynman-Heisenberg rules make no reference to space-time, they do attribute energy and momentum to particles. Through Fourier transformation, energy-momentum variables can be replaced by *formal* space-time variables, but there is no *a priori* physical significance for these latter. It was recently discovered by H. P. Stapp (1983), however, that summing the intermediate gentle-event Feynman series leads to a result interpretable through a notion of *approximate space-time localization*. Stapp shows that the coherent superposition of a multitude of soft intermediate photons can approximately place charged particles on trajectories and also approximately localize their violent events.[1] Fourier transformation becomes physically relevant.

I propose that the space-time of explicate order arises from Stapp's mechanism. One should not accept a physical space-time continuum as an *a priori* notion but rather as an approximation emerging from large numbers of coherent but discrete gentle quantum events. My expectation is that such an understanding of space-time will allow the Copenhagen interpretation of quantum mechanics to be replaced by a quantum theory of measurement. The approximate isolation of observer from "observed entity" will be related to the gentleness of intervening soft-photon connections. Electric "screening" will be important—related to the photon's coupling to a conserved charge and to the tendency of complex particle systems to be electrically neutral. One will not describe measurement as occurring "within space-time" but rather as generating an approximate meaning for space-time.

I close this note with some remarks about "implicate order" and "hidden variables"—terms which Bohm has invoked (1981). The foregoing speculations about explicate order have arisen in connection with an attempt to understand particle properties through the consistency of their graphically-expressed relationships (Chew 1983b, 976; 1983a, 217). Analysis of consistency depends on classifying Feynman graphs according to complexity. Photons and electrons do not occur at the lowest level of complexity, even though these particles dominate development of explicate order. At the lowest level of graphical complexity there occur "hidden variables"[2] which have disappeared at the photon-electron level but which are responsible for the existence and properties of *elementary nuclear particles*[3] which precede photons and electrons in the hierarchy of complexity (Chew 1983b, 976; 1983a, 217). An example of a "hidden" variable is a feature of graphical order called "color." The property of color is not exhibited by any particles accessible to the hard-scientific measurements based on explicate order, but a full picture of graphical order demands recognition of color and other hidden variables. At the level where such variables function there has not yet developed the degree of complexity prerequisite to the space-time on which explicate order relies. Theorists who use graphical complexity to understand particles do not employ the term "implicate order," but where color and other hidden variables occur such a term may be appropriate.

It should be apparent from the foregoing that the author envisages areas of contact between graphical particle theory and the ideas of Bohm (1981). The advantage of graphs is their providing an unambiguous and unprejudiced language—free from the semantic traps of ordinary language that stem from explicate-order roots. I anticipate graph language gradually to yield detailed understanding of how the continuity of explicate order, with the attendant space-time, relates to the discrete world of quantum events. It is furthermore not ruled out, in the author's opinion, that graphs with gentle links will illuminate the meaning of life and consciousness and also cosmology—including gravitation. Supplemented by Feynman superposition and by distinction between violent and gentle vertices, graph language has immense untapped capacity.

NOTES

1. Stapp also makes a precise distinction between soft photons and "hard" photons—that can change spin and deliver substantial increments of momentum in violent events.
2. In the literature of graphical particle theory the adjective *inaccessible* rather than *hidden* has been used.
3. Graphical-particle theory makes a distinction between "elementary particles" and particles accessible to hard-scientific observations interpreted through explicate order, but explanation of this distinction will not be attempted here. Suffice it to say that there is a connection with "hidden" variables. Two recent reviews of topological partical theory have been written by Capra (1984) and Chew (1983a).

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