

GLOBAL CAUSALITY IN SPACE-TIME UNIVERSE

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Abstract. The problems connected with a causality of space-time universe and with the paradox of Einstein, Podolsky, and Rosen are considered. A main philosophical problem and its possible solutions are briefly discussed. A concept of unified local field theory is considered. It is shown that in the framework of such theory there are nonlocal correlations between space separate events. These correlations are predicted by quantum mechanics and they are confirmed by Aspect type experiments for testing of Bell inequality. The presence of these nonlocal correlations in the framework of a local field theory is connected with the fact that its solution is nonlocal in character. Prospects for possible applications of an unified local field theory are considered.

1. Philosophical Introduction

In general the problem of causality is closely connected with basic philosophical problems.

The main philosophical problem concerns a relation between matter and spirit. There are two extreme points of view on this problem:

1. matter is primary and spirit is secondary;
2. spirit is primary and matter is secondary.

In connection with this topic we should remember the discussion between Einstein and Tagore [1]. In this discussion Einstein upheld a materialistic view (1.) and Tagore upheld an idealistic one (2.).

I think that in some sense these extremes can meet or some medium point of view is possible. But at first I determine some characteristic features of these extreme views as I understand them:

1. a materialistic view
 - (a) there is a common or physical or objective time and space (space-time),
 - (b) there is an unified (physical) law,
 - (c) there are a theoretical predictability for space-time events and a world order,
 - (d) a person (human) is a part of material world, he has no a free will;
2. an idealistic view
 - (a) an individual spirit is free from time and space,
 - (b) any spaces and laws can be formed by consciousness (or consensus),
 - (c) an individual spirit is unpredictable,
 - (d) a person (human) is an incarnation of an individual spirit which has a free will.

A materialistic view (1.) is confirmed by advances of natural science. An idealistic view (2.) can be confirmed by demonstrations of parapsychology phenomena.

My opinion is that there are space-time with an unified law and the world order. Being “normal” an individual acts in the framework of the world order but may be he (his spirit) can also escape (in a certain sense, sometimes or often) from the material world and space-time. Thus I think that intermediate states also are possible.

In any case a knowledge of an unified law gives significant advantages for the civilization, in creation of new technical devices.

Thus the object of my present investigation is an unified law of matter. The quantum mechanics description can not pretend to this role because it gives probabilistic predictions in principle. (In the known expression by Einstein “God does not play dice” just an unified law is considered as God.)

In this connection I consider an unified local field theory.

2. Concept of Unified Local Field Theory of Matter

The whole history of pre-quantum physics naturally led to the idea of unified field theory for description of matter. All particles of matter and its apparent mutual influence must be represented by some solution of an appropriate field model which must be nonlinear. Also this model must be

local, i.e. it is represented by some purely differential system of equations. This is an essence of the ideas which was inspiring for many scientists in their working. Let us mention just a few: A. Einstein, L. de Broglie, H. Weil, A. Eddington, G. Mie, E. Schrödinger, M. Born, L. Infeld, J. Plebansky, etc.

But on the other hand the impressive success of quantum mechanics has eclipsed the idea of unified field theory which was in the air. The quantum mechanics is essentially a linear theory which is much more simple for investigation than nonlinear one. But the quantum mechanics gives the probabilistic predictions only.

Einstein, Podolsky, and Rosen in their famous article [2] had advanced the arguments for the standpoint that quantum mechanical description of reality is incomplete. Bohm and Aharonov [3] had proposed an example (see also my article [4]) for demonstration the EPR paradox in which two spin particles scatter in opposite directions. According to the quantum mechanical description for this experiment, a spin states of the individual particles are indeterminate until a measurement event. But as soon as we have measured a spin state for one particle then a spin state for another particle becomes determinate immediately. This resulting situation is connected with the conservation law of full angular momentum for the system of two particles.

This situation looks as though there was an instantaneous interaction between space separate particles. It contradicts with the thesis for locality of interactions. Thus quantum mechanics predicts nonlocal correlations between the events. Well known Aspect experiment [5] for testing of also well known Bell inequalities [6] determines that there are the nonlocal correlations.

At first glance the existence of this nonlocal correlations rejects a possibility for description of matter by an unified local field theory. However, actually, this is not the fact. In the following I show that nonlocal correlations between events must exist in the framework of an unified local field theory of matter.

3. Concept of Material World and its Nonlocality

Actually the concept of unified local field theory for the material world is similar to the concept of ether, if we understand it in the broad sense but not a narrow mechanical one. This concept supposes only two basic properties: continuity and locality. Mathematically these properties are expressed in the fact that we consider some purely differential field model or some system of equations with partial derivatives. To describe naturally the interactions between material objects, this system of equations must

be nonlinear. We believe also that there is a model solution which is determinate in space-time. Thus, according to this concept, we can consider some Cauchy problem or the problem with initial condition for obtaining the world evolution.

Within the framework of such theory a single elementary particle is represented by some space-localized solution. Moreover, because, as we know, elementary particles have wave properties, this solution must have an appropriate wave part. The wave part is considered here in the sense of time Fourier expansion for the solution in own coordinate system of the particle, where this part has the form of a standing wave.

There is a simplest example for such standing wave even for the customary linear wave equation. These well known solutions of the wave equation in a spherical coordinate system include spherical harmonics. For the spherically symmetric case we have the standing wave

$$\frac{\sin(\underline{\omega} r)}{\underline{\omega} r} \sin(\underline{\omega} x^0) \quad (1)$$

which is formed by the sum of divergent and convergent spherical waves. With the help of Lorentz transformation we can obtain the appropriate solution in the form of moving nondeliquescent wave packet. Then own frequency $\underline{\omega}$ transforms to wave vector k_μ such that

$$|k_\mu k^\mu| = \underline{\omega}^2 \quad . \quad (2)$$

Using the linear relation between the wave vector and a vector of momentum $p_\mu = \hbar k_\mu$ we obtain

$$|p_\mu p^\mu| = m^2 \quad . \quad (3)$$

A single elementary particle solution of a nonlinear field model may be called also as *solitron*. This term has a similar sense that “solitary wave” or “soliton”. But usually the term “soliton” is used in mathematical context for some special solutions.

It is significant, the concept of unified field theory supposes that all variety and evolution of the material world are represented by some space-time field configuration which is an exact solution of the nonlinear field model. It is evident that this solution is very very complicated but it is determinate on space-time by the field model with initial and boundary conditions. In the vicinity of a separate elementary particle this world solution is close to the appropriate single elementary particle solution, but each elementary particle behaves as the part of the world solution. Thus the behavior of each elementary particle is connected with the whole space-time field configuration of the world solution.

For certain conditions it is possible to consider the world solution part connecting with a separate elementary particle as the appropriate solitron solution with slowly variable velocity. (For the case of nonlinear electrodynamics see, for example, my article [7].) This level for investigation of the world solution relates to the classical (not quantum) physics.

It is evident that although the model is local, the world solution is nonlocal in character because it is determined on a whole space-time applicable domain. This means, in particular, that there are undoubtedly nonlocal correlations between space separate parts of the common world solution. This sentence may be explained with the help of the following simplest example.

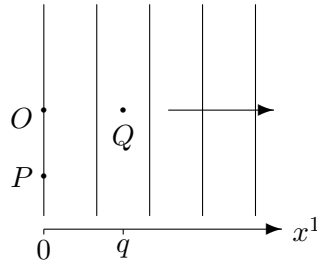


Figure 1. Customary plane wave.

Let us consider a customary plane wave travelling on axis x^1 with a fixed wave-length λ (see Fig. 1) such that

$$f = \sin[(2\pi/\lambda)(x^0 - x^1)] \quad . \quad (4)$$

This wave is the solution of the customary linear wave equation. At the points O , P , and Q the field evolution has the forms

$$\begin{aligned} O : f &= \sin[(2\pi/\lambda) x^0] \quad , \\ P : f &= \sin[(2\pi/\lambda) x^0] \quad , \\ Q : f &= \sin[(2\pi/\lambda) (x^0 - q)] \quad . \end{aligned}$$

Thus here there are the nonlocal correlations between the field evolution at the points O , Q , and P . Totality of such nonlocal correlations is, in fact, the solution in space-time for the local field model. The possible world solution (which is extremely more complicated than a plane wave) is also the continuous set of nonlocal correlations for the field evolution at the points of three-dimensional space.

Of course, if we make some excitation for field at the point O then a propagation of this excitation from this point will have a finite speed. But in the scope of the world solution we do not be able to make this excitation

or to modify arbitrarily this world solution. Any excitations of the field at the point O belong to the world solution which is a single whole. That is, in this case we must consider also all excitations coming to this point and we will have some standing wave near it. Thus the world solution is rather a very complicated system of standing waves than progressing ones. The initial condition is a common cause of all field excitations and after a long evolution the different correlations may exist, even the strange ones. It can only be said quite positively that the world solution can be represented by Fourier integral (or series) on orthogonal space-time harmonics which are essentially nonlocal. (Here we must remember how a dominant role is played by orthogonal functions in quantum approach.)

The key to understanding the appearance of momentary distant interaction in the experiment, which is considered in section 2, is contained in a concept of chance choice. Within the framework of the world solution a chance choice is absent, but both experimenter and experimental apparatus are a part of this world solution. That is the orientation of particle spin detectors in the experiment under consideration is predetermined by the world solution. We speak about a chance choice because we do not know the world solution.

As experimentalists, we think that we establish the initial conditions for the process under investigation but may be this is too conceitedly and the veritable initial condition was established earlier. But as theorists, we can already calculate many correlations between space-time events.

Thus we can suppose that the quantum mechanical description is the level for investigation of the world solution. This level take into consideration, in particular, the global or nonlocal aspects of this solution.

Nonlocality was founded in quantum mechanics from the outset. In Schrödinger's picture a free elementary particle (which have a determinate momentum) is related with a plane wave having a constant amplitude on the whole space. In this case the quantum mechanical description does not determine a position of the particle. That is we have the representation of a free elementary particle by a non space-localized wave that accentuates just nonlocal aspect of matter.

As we see, there is nonlocality also in the framework of unified local field theory. But such theory supposes a solitron model for free elementary particle that is intuitively more preferable. Furthermore according to this concept there is a deterministic description of matter.

Thus having an unified mathematical model for matter we must also take into consideration the whole of the material world evolution from a start point when the initial condition was determined. And we can say that there is the global causality in the space-time universe.

As we see the unified field theory approach can give a strong determinacy of events in material world. But my opinion is that we must also take into consideration some things which are outside from the space-time framework of the physical world. Suppose here by definition that these things include spirits. Because a spirit is outside from the material world or a world solution, he may have an influence on initial and boundary conditions. Suppose that a spirit can partially modify the world solution, which is possible with the help of some dynamical boundary conditions. But these modifications must be again nonlocal in general. Thus the world solution is determinate in general and a possible intervention of spirit must be unexpected and unusual in character. This spirit intervention also realizes a global space-time causality in a sense, but this causality is not explained by physical laws. I think that this is a reasonable way for introduction a concept of will to the picture of material world stated above. Thus I believe that in the material world we have a partial nonlocal determinacy which however agree with an unified local field theory of matter.

In connection with the fact that I touch on philosophical problems in this article, I would like also refer to Schrödinger's book [8] including considerations which I accept in general.

4. Possible Applications of the Unified Local Field Theory

At present we consider a single atom and even a single electron as objects of technology. There is a concept of a single electron transistor [9] and we can seriously consider prospects for building an Avogadro-scale computer acting on $\sim 10^{23}$ bits [10]. In such computer using the nuclear magnetic resonance one nuclear spin must store one bit of information.

Traditional computation can do many useful things and this ability can become very much stronger with the possible Avogadro-scale technology. But the traditional computation needs a determinate controlling. Such controlling is possible if we have an unified field theory of matter in the sense that was stated above.

This is one of the possible applications of the approach under review. But, of course, a realization for the paradigm of unified field theory will discover abilities which we do not know at the present time.

In connection with the approach of unified field theory I propose to consider the nonlinear electrodynamics model of Born-Infeld type with singularities [11, 12, 7, 13]. In particular, in the framework of this model the two fundamental long-range interactions (electromagnetism and gravitation) may be unified (see my articles).

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