Numerical order of physical events has no duration

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Abstract

With clocks we measure numerical order $t_0, t_1, t_2 .... t_n$ of a physical event. A sequence t_{n-1} is "before" a sequence t_n equivalently to natural number $n-1$ is before natural number n. Numerical order $t_0, t_1, t_2 .... t_n$ of a physical event has no duration. It runs in a timeless space where physical time is run of clocks. Duration of an event is a result of experiencing its measurement with a clock through the frame of psychological time "past-present-future" but events happen exclusively in space.

Key words: time, space, space-time, run of clocks, numerical order, duration, psychological time

Introduction

In space "before" and "after" exist only as a numerical order $t_0, t_1, t_2 .... t_n$ of a physical event: t_{n-1} is "before" t_n equivalently to natural number $n-1$ is "before" natural number n. We measure numerical order of physical events with "ticking" of a clock. The numerical order t_0 represents the beginning of the measurement, the numerical order t_n represents the end of the measurement.

Fundamental unit of numerical order of physical events is Planck time $t_p = 5{,}39124 * 10^{-44} s$ that is derived from light speed: $t_p = \frac{c}{l_p}$ where l_p is Planck distance. Planck time t_p exists in the universe as a fundamental physical unit that governs numerical order of all physical events.

At the photon scale information and energy transfers in space happen with the light speed and are described by a numerical order $t_n > 0$. At the scale bigger than the photon one, information and energy transfers in space have a speed lower than light speed and are described by a numerical order $t_n > 0$. There are then certain physical events for which clock/time is zero, since no measurable time elapses for them to happen. These events can be appropriately defined as “immediate physical events”. They are described by a numerical order $t_n = 0$ (1).

For example in the article *Attosecond Ionization and Tunneling Delay Time Measurements in Helium* by Eckle et al., a conclusion is drawn that "an electron can tunnel through the potential barrier of a He atom in practically no time" (2).

In analogous way, in Einstein-Podolski-Rosen (EPR) experiment the elapsed time for quantum entanglement is zero. Here space in which particles exist can be considered as a direct information medium between the entangled quanta.

According to a recently suggested interpretation, in an EPR-type experiment, physical space assumes the special “state” represented by the symmetrized quantum potential, and this allows a non-local, instantaneous communication between the particles into consideration. In the case of a system of N particles the symmetrized quantum potential assumes the form

$$Q = \sum_{i=1}^{N} -\frac{\hbar^2}{2m_i}\left(\frac{\nabla_i^2 R_1}{R_1} - \frac{\nabla_i^2 R_2}{R_2} \right) \quad \text{(Eq. 1)}$$

where R_1 is the amplitude function of the wave-function $\psi = R_1 e^{iS_1/\hbar}$ describing the forward-time process and R_2 is the amplitude function of the wave-function $\phi = R_2 e^{iS_2/\hbar}$ describing the time-reverse process. On the basis of Eq. 1, we can explain non local correlations in many-body systems – and thus EPR experiments - in the correct way (namely also filming back the process of these correlations). The symmetrized quantum potential (Eq. 1) can be considered the most appropriate candidate to provide a primary physical reality to space as a direct information medium (3). While the standard Schrödinger equation and the original bohmian theory imply that filming back a physical event it is not possible to see what effectively happens, with the introduction of the symmetrized quantum potential we can interpret in the correct way both the forward-time process and the time-reverse process and thus the numerical order of a quantum process and the idea of space as a direct information medium can receive a primary physical significance. By means of the special state represented by the symmetrized quantum potential, we can say that in the subatomic world at a fundamental level physical space can be physically interpreted as an immediate information medium, as an entity that puts the particles in an immediate contact. In EPR experiment it is just the symmetrized quantum potential that makes physical space an “immediate information medium” which keeps two elementary particles in an immediate contact. We can call this peculiar interpretation of quantum non-locality as the “immediate symmetric interpretation”.

If in the subatomic world the symmetrized quantum potential makes physical space the real direct medium of information transfers between elementary particles, in a complete physical theory the possibility is opened that a fundamental arena in which space functions as a direct information medium is the primary element from which every field and object of physics derives and which is able to reproduce the fundamental interactions and physical fields in a unified way. If non-locality is considered as the essential characteristic of the physical world and the idea of the symmetrized quantum potential seems the most general and consistent way to introduce non-locality, in a fundamental physical theory the symmetrized quantum potential should assume a crucial role and all the objects of physics might emerge from it as special states. In particular, the possibility is opened that there is an important link between this fundamental arena and the Planck scale, in particular with the granular structure of space predicted by loop quantum gravity. According to loop quantum gravity, space is made out of quanta of space (4). On the basis of the immediate symmetric interpretation, the perspective is opened that direct quantum information transfers run over quanta of space which have the size of Planck length. According to this interpretation, at the Planck scale space acts as an immediate information medium. At this scale information transfers are immediate: elapsed time for them to happen is zero.

The idea of space as a direct information medium introduces interesting perspectives also as regards the interpretation of the gravitational interaction in the general relativity theory context. One can say that at a fundamental level curvature of space can be considered as a direct medium that generates gravitational motion of material objects into direction of higher curvature of space. There is no direct attraction force between material objects. Material object causes curvature of space and curvature of space causes gravitational motion. Gravitational interaction $mass \leftrightarrow space \leftrightarrow mass$ is immediate: presence of mass increases curvature of space that causes gravitational motion. Mass acts on other mass indirectly via curvature of space: $mass \leftrightarrow curvature \leftrightarrow mass$. Curvature of space is defined by Einstein curvature tensor:

$$G\mu\nu = \frac{8\pi G}{c^4} \cdot T\mu\nu \text{ (Eq. 2).}$$

In this view gravity is interpreted as immediate physical phenomenon. On the basis of the interpretation of space as a direct information medium, for example the gravitational interaction between the earth and the sun is immediate in the sense that the curvature of space caused by the presence of the sun (given by Eq. 2) acts instantaneously on the earth determining its motion in its own trajectory. The sun acts instantly on the earth via the curvature of space (determined by the sun) which functions a direct, immediate information medium between the earth and the sun.

In original papers of 1916 Einstein do not mention gravitational waves. This idea arises few months later. Einstein introduces gravitational waves as space-time perturbations (5). With the introduction of gravitational waves that propagate with light speed gravity is interpreted a non-immediate phenomenon as propagation of gravitational waves requires some “tick” of clock.

Discussion

Some researchers are challenged with the view that space-time is the fundamental arena of the universe. They point out that the mathematical model of space-time does not correspond to physical reality, and propose a “state space” or a “timeless space” as the fundamental arena.

For example, in *A New Geometric Framework for the Foundations of Quantum Theory and the Role Played by Gravity*, Palmer underlines that, since quantum theory is inherently blind to the existence of state-space geometries, attempts to formulate unified theories of physics within a conventional quantum-theoretic framework are misguided, and that a successful quantum theory of gravity should unify the causal non-Euclidean geometry of space-time with the a-temporal fractal geometry of state space (6). In this paper, Palmer introduces a new geometric law of physics about the nature of physical reality based on an Invariant Set Postulate. The Invariant Set Postulate conjectures that states of physical reality are defined by a fractal geometry *I* , embedded in state space and invariant under the action of some subordinate causal dynamics D_I . The postulate is motivated by two concepts that would not have been known to the founding fathers of quantum theory: the generic existence of invariant fractal subsets of state space for certain nonlinear dynamical systems, and the notion that the irreversible laws of thermodynamics are fundamental rather than phenomenological in describing the physics of extreme gravitational systems. The Invariant Set Postulate posits the existence of a fractionally-dimensioned subset *I* of the state space of the physical world (namely the universe as a whole). *I* is an invariant set for some presumed-causal (namely relativistic) deterministic dynamical system D_I; points on *I*, called also "world states", remain on *I* under the action of D_I. World states of physical reality are those, and only those, lying precisely on *I*. It is important to underline that in Palmer's theory, the subset *I* of the state space is more primitive than the deterministic dynamical system D_I. Given *I*, $D_I(t)$ maps some point $p \in I$, a parameter distance *t* along a trajectory of *I*. Crucially, D_I is undefined at points $\notin I$: if states of physical reality necessarily lie on *I*, then points $p \notin I$ in state space are to be considered literally "unreal". For practically-relevant theories (such as quantum theory) the intricate structure of *I* is unknown and these points of unreality cannot be ignored. As regards the key question of how to represent quantum-theoretic states in a mathematically-consistent way for such points of unreality, the Invariant Set Postulate provides support to the search for an timeless description of physics: by treating the geometry of the invariant set as primitive introduces a fundamentally a-temporal perspective into the formulation of basic physics.

Palmer's theory can be considered a significant mathematical proof that at a fundamental level space is timeless, that the duration of physical events has not a primary existence. The view of physical time as a run of clocks in a timeless space, and thus the view according to which with clocks we measure the numerical order of material motions can be considered the most direct and natural development of Palmer's approach: it is an a-temporal description of motion in physics. Motion does not run in time. Time/clock is a measuring device for motion that runs in a timeless space.

Girelli, Liberati and Sindoni have recently developed a toy model in which they have showed how the Lorentzian signature and a dynamical space-time can emerge from a non-dynamical Euclidean space, with no diffeomorphisms invariance built in. In this sense this toy-model provides an example where time (from the geometric perspective) is not fundamental, but simply an emerging feature (7). In more detail, this model suggests that at the basis of the arena of the universe there is some type of “condensation", so that the condensate is described by a manifold R^4 equipped with the Euclidean metric $\delta^{\mu\nu}$. Both the condensate and the fundamental theory are timeless. The condensate is characterized by a set of scalar fields $\Psi_i(x_\mu)$, i=1,2,3. Their emerging Lagrangian L is invariant under the Euclidean Poincarè group ISO(4) and has thus the general shape

L = F(X1;X2;X3) = f(X1) + f(X2) + f(X3); $X_i = \delta^{\mu\nu}\partial_\mu\Psi_i\partial_\nu\Psi_i$ (Eq. 5).

The equations of motion for the fields $\Psi_i(x_\mu)$ are simply given by

$$\partial_\mu\left(\frac{\partial F}{\partial X_i}\partial^\mu\Psi_i\right) = 0 = \sum_j\left(\frac{\partial^2 F}{\partial X_i \partial X_j}\left(\partial^\mu X_j\right) + \frac{\partial F}{\partial X_i}\partial_\mu\partial^\mu\Psi_i\right) \quad \text{(Eq. 6)}$$

The fields $\Psi_i(x_\mu)$ can be expressed as $\Psi_i = \psi_i + \varphi_i$ where φ_i are the perturbations around the solutions ψ_i of the above equation. The lagrangian for ψ_i is given by

$$F\left(\bar{X}_1, \bar{X}_2, \bar{X}_3\right) + \sum_j \frac{\partial F}{\partial X_j}\left(\bar{X}\right)\delta X_j + \frac{1}{2}\sum_{jk}\frac{\partial^2 F}{\partial X_j \partial X_k}\left(\bar{X}\right)\delta X_j \delta X_k + \frac{1}{6}\sum_{jkl}\frac{\partial^3 F}{\partial X_j \partial X_k \partial X_l}\left(\bar{X}\right)\delta X_j \delta X_k \delta X_l$$

(Eq. 7)

where $\bar{X}_i = \delta^{\mu\nu}\partial_\mu\psi_i\partial_\nu\psi_i$ and $\delta X_i = 2\delta_\mu\psi_i\partial^\mu\psi_i\partial_\mu\varphi_i\partial^\mu\varphi_i$.

Different choices of the solutions ψ_i lead to different metrics

$$g_k^{\mu\nu} = \frac{df}{dX_k}\left(\bar{X}_k\right)\delta^{\mu\nu} + \frac{1}{2}\frac{d^2 f}{\left(dX_k\right)^2}\left(X_k\right)\partial^\mu\psi_k\partial^\nu\psi_k \quad \text{(Eq. 8).}$$

If one considers the specific class of equations of motion for which $\psi_i = \alpha^\mu x_\mu + \beta$, the SO(4) symmetry leads to $\bar{\psi} = \alpha x_0 + \beta$ which shows that the choice of the coordinate is completely arbitrary. Hence the Lorentzian signature can be obtained for the condition $\frac{df}{dX}(\bar{X}) + \frac{\alpha^2}{2}\frac{d^2 f}{(dX)^2}(\bar{X}) < 0$, $\frac{df}{dX}(\bar{X}) > 0$ and in this case the lagrangian becomes $L_{eff} = \sum_i \eta^{\mu\nu}\partial_\mu\varphi_i\partial_\nu\varphi_i$ where $\eta^{\mu\nu}$ is the Minkowski metric. Moreover, Girelli, Liberati and Sindoni have showed that by means of the change of variables

$$\begin{pmatrix}\varphi_1 \\ \varphi_2 \\ \varphi_3\end{pmatrix} = \Phi\begin{pmatrix}\phi_1 \\ \phi_2 \\ \phi_3\end{pmatrix} \quad \text{(Eq. 9)}$$

with $\Phi^2 = \sum_i \phi_i^{\,2} = l^2$ where l is related to Planck scale, a dynamical space-time emerges from L_{eff}, which is characterized by the Einstein-Fokker equations

$$R = 2\pi G_N T \text{ (Eq. 10)},$$

$$C_{\alpha\beta\gamma\delta} = 0 \text{ (Eq. 11)}$$

where

$$R = \frac{6}{l^2} T \text{ (Eq. 12)},$$

$$T(\phi_i) = g^{\mu\nu} T_{\mu\nu}(\phi_i) = -\Phi^2 \sum_i \eta^{\mu\nu} \partial_\mu \phi_i \partial_\nu \phi_i \text{ (Eq. 13)},$$

$$g_{\mu\nu} = \Phi^2(x) \eta_{\mu\nu} \text{ (Eq. 14)}$$

(which shows that the gravitational degree of freedom is encoded in the scalar field Φ) and where G_N is proportional to l^{-2}.

The toy model developed by Girelli, Liberati and Sindoni shows in a clear way that at a fundamental level space is a timeless condensate and that different solutions of the equations of motion of the fields characterizing this condensate determine different metrics of the space-time background. This means that on the basis of this model time as humans perceive it cannot be considered a fundamental physical reality, the duration of material change has no existence of its own, time exists only as run of a clock in a timeless space, with clocks we measure only the numerical order of physical events.

Recent neurological research shows by measuring a physical event with a clock we experience numerical order $t_0, t_1, t_2 ....t_n$ of event through psychological time "past-present-future". However numerical order of physical event runs in timeless space and has no duration. In the article *What makes us thick?, Functional and neural mechanisms of interval timing* Buhusi and Meck underline: "Traditionally, the way in which time is perceived, represented and estimated has been explained using a pacemaker–accumulator model that is not only straightforward, but also surprisingly powerful in explaining behavioural and biological data. However, recent advances have challenged this traditional view. It is now proposed that the brain represents time in a distributed manner and tells the time by detecting the coincidental activation of different neural populations" (8).

Conclusions

Planck time t_p exists in the universe as a fundamental physical unit that governs numerical order $t_0, t_1, t_2 .... t_n$ of material change i.e. motion. Numerical order of physical events is measured with clocks. By immediate physical events $t_n = 0$. By non-immediate physical events $t_n > 0$. Numerical order of events runs in timeless space and has no duration.

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