Эпистемология и философия науки
2016. Т. 49. № 3. С. 105–123
УДК 115

Epistemology & Philosophy of Science
2016, vol. 49, no. 3, pp. 105–123
DOI: 10.5840/eps201649354

WHAT IS TIME IN MODERN PHYSICS?*

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The problem of time is not an entirely physical problem. Physics itself does not contain a "time theory". That is particularly true in the sense that physics has not made any direct attempts to find the natural-science definition of the notion of time. Nevertheless, the concept of time emerges in science one way or another and still requires an explanation. Time fulfills an important role in the physics of XX and XXI centuries, though often a hidden one. Such a statement could be applied to both theories of macrocosm and microcosm. In the theory of relativity, time has been established as a secondary feature, a derivative of velocity and mass. However, it exists (although, as an illusion) and yet evokes the need of its philosophical interpretation. In quantum field theory time also (though implicitly) occurs according to the interpretation of the experiment results – for example, "where the particle was before its observation". Such "before"-cases indicate the very presence of time (more precisely, the observer`s perception of its presence). Further theories, which have been the attempts to solve the problem of incompatibility of general relativity theory and quantum mechanics, such as the theory of loop quantum gravity, superstring theory, Shape Dynamics and others, also mention the concept of time. Time fulfills there a definite role and again evokes the question of its explanation in the frameworks of these theories. Most importantly, to find an exact meaning of this "time" term used here. This article deals with the problem of time in the context of several theories of modern physics. In particular, it attempts to give a definition of the term of time in relation to the philosophy of physics (physics itself does not characterize it). Such a task formulation has its relevance and novelty due to the facts that the discourse on the nature of time is still stipulated by Zeno`s paradoxes, and the philosophy of science uses the obsolete vocabulary while describing the term. However, evidence suggests that modern physics has developed the new rules, or to be more precise, has stated the new principles, which the philosophy of science can not take into consideration without changing its vocabulary (the last also involves the modernization of intellectual intuition).

Keywords: time, philosophy of science, modern physics, concept of space and time

ЧТО ТАКОЕ ВРЕМЯ ДЛЯ СОВРЕМЕННОЙ ФИЗИКИ?

Проблема времени не является исключительно физической проблемой. Физика сама по себе не содержит «теории времени». Не будет преувеличением, если скажем, что физики не предпринимали прямых попыток найти естественнонаучное определение времени. А потому понятие времени, так или иначе бытующее в науке, до сих пор нуждается в объяснении. Время занимает важное значение в физических теориях XX и XXI вв., хотя зачастую лишь подразумевается. Данное утверждение сохраняет значимость как в отношении микрокосмических, так и в отношении макрокосмических теорий. В теории относительности

* This work is an output of a research project implemented as part of the Basic Research Program at the National Research University Higher School of Economics (HSE).

время представляется вторичным свойством, производным от скорости и массы. Тем не менее, оно сохраняется (хоть и в виде некоторой иллюзии) и требует философских разъяснений. В теории квантовых полей время также (хотя и имплицитно) появляется в результате интерпретации результатов эксперимента – например, «где частица находилась до наблюдения». Подобные «предшествующие» случаи отражают само присутствие времени (или, точнее, восприятие наблюдателем его присутствия). Дальнейшие теории, представлявшие собой попытки решить проблему несоотносимости теории относительности и квантовой механики, как например, теория петлевой квантовой гравитации, теория суперструн и другие, также учитывают понятие времени. Понятие времени занимает в них определенное место и требует разъяснения в рамках этих теорий. В статье рассматривается проблема времени в контексте нескольких современных физических теорий. В частности, предпринимается попытка объяснения понятия времени с отсылкой к философии физики. Подобная задача сохраняет свою актуальность и новизну постольку, поскольку понятие времени в философии науки описывается в устаревших терминах. Тем не менее, обнаруживаются свидетельства тому, что современная физика создала новые правила, или, точнее, установила новые принципы, которые не могут быть приняты к рассмотрению философией науки, если та не изменит свой собственный понятийный аппарат.

Ключевые слова: время, философия науки, современная физика, концепт пространства и времени

Problem statement

The author of ones of the fundamental works on the notion of time, Gerald James Whitrow, has pointed out [Whitrow, 1976; Whitrow, 1980; Whitrow, 2003], that basically, time geometrization is typical for physics. Albert Einstein has noted the same [Einstein, 1954, p. 141]. If we have got used to conceive space with the coordinate system, regarding dimensions and distances, then there are no specific temporal concepts, which would characterize time itself. To some extent, this explains the difficulty in interpretation of various physics theories usage of time concept – it is hard to interpret something that has no endemic characteristics. Because of such absence of its essential attributes, time has become the subject for geometrization.

The traditional time discourse creates purely spatial questions: if time is discrete or continuous, whether it is identical to succession (sequence of events) and duration, whether it is objective or subjective, relative or absolute, fundamental or not, etc. These issues result from the classical intellectual intuition, revealed back at works of Zeno, then Aristotle, the Stoics and later Augustine. Galileo Galilei`s and Isaac Newton`s works have also noteworthy preserved that intuition almost unaltered.

In fact, the key problem lies in the following: whether the classical methods for the discussions on time issues are suitable in the modern philosophical and scientific context. New physical theories set the new requirements for what should be considered as time. According to further research, the classic time is widely construed in common terms of the space characteristics. In this regard, the main question here is if the time (in the traditional sense) exists in modern physics. Otherwise, the new physical concepts involve modification of the philosophical intuition so that the time study should be further elaborated in the way of assigning the time concept with specific features different from the properties of space.

Brief historical background of the problem

Zeno of Elea in his famous paradoxes has, apparently, first described the problem of time concerning its discreteness and continuity. The *Achilles*, *Dichotomy, Arrow* and *Stadium* paradoxes are aimed against the motion. The first two of them deny the motion if space and time are continuous, the latter two when both space and time are discrete. Alexander Koyre in *Notes on the Zeno's paradoxes* [Koyre, 1985, p. 27–51] has made an important observation that these paradoxes, in fact, are not related to motion and only concern it insofar as the motion takes place in both time and space. Then an important question arises: is movement (or any succession) possible regardless of time? We shall return to this matter in the following analysis.

Further, Koyre reveals that all the four arguments allow a double interpretation, which means that the *Achilles* and *Dichotomy* paradoxes stay valid if we consider space and time discrete. Similarly, if we suppose space and time continuous in the *Arrow* and *Stadium*, the paradoxes remain unsolvable as before.

The next step suggests to abstract from the concepts of space and time and stick to the mathematical continuum instead of them, while the paradoxes will keep their original meanings. After applying such transformations, Koyre has concluded that the problem is much more complicated than the experts and critics of Zeno had imagined. After paradoxes translation into the language of mathematics, he has discovered that these paradoxes are occultly rooted in any geometric theorem, algebraic formula, arithmetic assertion. I. e., the problem is inherent to mathematics and geometry, but within this mathematical approach, it ceases to be a problem since continuity is not paradoxical in mathematics. It may lead us to a conclusion that our traditional intuitive ideas about motion, time and space require serious consideration – only then the paradoxes will become solvable. Other, but quite the same, way, these misconceptions about movement, space and time have generated the paradoxes in the first place.

The possibility of actual "flow" of time is another issue, which refers to Zeno's paradoxes. Bertrand Russell [Russell, 1959, p. 813] has not seen any contradiction in the arrow seemingly leaping from one place to another. Such supposal allows understanding the motion in time as a change of positions, following the example of the trotting second hand. A quick repositioning is perceived as smooth motion. From this point of view, the motion lacks its intuitive internal substance. At any given moment the arrow resides in a new place. However, we can consider this to be motion.

In *Timaeus* Plato describes time as a rotating similarity of eternity [Plato, 2007, 37a–38c], apparently, in accordance with the cyclic tradition. Real time is a frozen eternity. The time of rotating sky, a move from number to number, is its similarity.

Aristotle in *Physics* might have formulated the first attempt to analyze the concept of time scientifically. He has been naturally dissatisfied by Plato's approach, primarily because he could not accept Plato's ideas as prototypes of the observed reality. According to Aristotle, time and motion are related, but not identical. In his words, "time is the number of motion" [Aristotle, 1981, p. IV, 11] and it is continuous. Time measures motion and motion determines time. However, space is a necessary condition of motion, which means that time does not exist without space. Perfect motion is circular (here again, we witness the tradition of cyclical time concept: the movement of celestial bodies, the circle of life, the change of seasons, etc.).

Plotinus disagrees with Aristotle. Following Plato, he states time to be derivative from eternity. However, he perceives time as neither motion nor its measure (nor the number of motion) [Plotinus, 2004, III, 7].

Briefly, his objections towards time as motion or a number of motions are as follows: motion presupposes time, but time does not require motion and can fully coincide with quiescence. Which means that "if we assume the possibility of motion regardless of time, then equating time to motion will become even more incomprehensible, because consequently, time would be one thing and motion quite another" [Losev, 2000, p. 442]. So, time is one thing, and motion is another. Also, Plotinus shows that since motions can be different, i.e. different distances can be covered in the same period, then times must be different too, which is impossible (it is interesting that idea of time relativity has already appeared here, derived from motion, but though denied). Consequently, distance can not be conceived as time. Such a statement can be interpreted as a protest against the spatial nature of time.

Later Plotinus claims that time is not a number, as soon as numbers can measure anything, but not just time. So time is time, and a number is a number. As for a definition, then according to Plotinus, the time is the length of an eternal life of a soul (the length again as a spatial characteristic).

Famous reflections of Augustine have occupied a special place in the time studies. He claims that time is not motion because there is no real past and no real future, but there is present. However, this present lacks durability; it is momentary, so, in fact, it does not exist. However, all the three periods – the past, the present, and the future – exist in the human soul. We wish to interpret this as the statement of time illusiveness, its subjectivity, but we do not find this exact words in Augustine`s works. Time still exists, and the author embeds it in his famous formula: "time only exists because it tends to disappear" [Augustine, 199, 111.XIV.17]. He is most likely revealing the psychology of time perception – an image of the present, which has occurred in one's soul, allows conceiving of the past and the future through the model of existing present (a kind of induction). Augustine has also introduced a novelty, which can be directly attributed to physics. Discussing a popular issue of that time – "what God had been doing before he created the world" –he has boldly declared: nothing. For the simple reason that time has been created together with the world, how can we speak of before and after, if there was no time? Without time, these concepts simply do not make sense. Thus, Augustine states the following idea: there is no external fundamental eternal time as an arena for physical laws. Time occurs together with the Universe.

In his commentary to Plato's *Timaeus,* a Neo-Platonist Proclus [Proclus, 2011] has developed kind of time and eternity dialectics (apparently, following the Iamblichus's ideas). For him time is duration, fluidity, continuity. With Plato`s spirit, time is a motile image of eternity and eternity is a fixed image of time. Time is associated with motion, and the time`s flow requires something to force every event into motion, as each event needs something to cause its movement. The initial cause of motion is eternity.

Damascius has developed these ideas working on the problem of the essence of time [Losev, 2000, p. 436–439]. However, he has introduced the quantum of time. If time consists of non-durable moments of the present, it would be impossible to pile them up into a proper duration. The same situation is with adding even an infinite number of non-dimensional pieces – amounts to nothing. Thus, the time should consist of indivisible segments of the present, which all have durations. In other words, time leaps. Damascius explains with an example of human thinking: a thought seems to be continuous; however, it cannot contemplate all at once: at first, it is aimed at one thing, then at another, and so on. This attitude can be interpreted as an attempt to prove the discreteness of time. Moreover, the velocity of the time leaping motions results in the fact that different motions have different time (which was denied by Plotinus). In fact, this proves that time is relative, and motion velocity determines its relativity (though, compared to the later relativists, Damascius has obviously been guided by entirely other grounds for his intuition).

In modern times, Newton has insisted on the objective status of time. However, he avoids metaphysics; he has not defined the time notion. Also, he claims it to be absolute. "Absolute, true and mathematical time flows equably by itself and from its own nature regardless of everything external and is also called duration" [Newton, 1989, p. 30]. Time exists, and it is duration. Trying to prove the existence of absolute space, Newton has conducted an experiment with a rotating bucket (which, however, proves nothing, as noted by Ernst Mach [Mach, 1909, p. 198–199]), but for proving the existence of absolute time he has had no reasoned arguments. On the contrary, Gottfried Leibniz, the opponent of Newton, has postulated the relativity of time, deriving it from the principles of sufficient reason and the identity of indiscernible. One can say that he has deepened Augustine's argumentation on the matter of what God had been doing before he created the world [Leibniz correspondence with S. Clarke, 1960, p. 56]: without events and objects (of the world) there is no time. However, this does not mean that Leibniz has denied time; it does exist and, moreover, it is universal (obviously, here there is nothing in common between Leibniz's and Einstein's concepts of time).

Kant has put the objectivity of time under the question once again. It is interesting how Losev makes a rather sharp remark about Kant's idea of apriority of time, arguing that it Kant had entirely borrowed it from Plotinus [Losev, 2000, p. 447]. According to Kant, time is an a priori form of sensuality, which enables us to organize the experience of interaction with the world in our perception [Kant, 1994, p. 56–58]. It is nonobjective; there is no time itself. Therefore, discussions on the nature of time, its essence or properties are meaningless – we must limit it to our perception, to the activity of consciousness.

Developing the relativity concept, Einstein has formulated the last fundamentally new idea about time, which corresponds to the classical intuition (intuition about macrocosm only – to quantum mechanics, for instance, this intuition can not be applied). The fundamental novelty of his step lies in the assertion of the relativity of simultaneity, where the same events seem to be variously separated in time for different observers, depending on the movement velocity (including direction) of the last.

The current state of the problem

In modern physics, the notion of time discreteness is rather popular. The fact of mathematical time continuity is not anyhow contradicted here: a mathematical theory that would virtually explain time does not exist. Therefore, following the ideas of Russell and Zeno, one can assume that a time quantum, "chronon", is a Planckian quantity. However, two issues arise upon this assumption. The first and the most obvious issue is the debatable representation of a time unit as a quantum, i.e. something that has fixed dimensions. In this case, time appears to be just a particular spatial dimension, where the specific movement takes place. Thereat one can say that there is a certain number of time quanta between point (event) A and point (event) B. In theory, there is no paradox here – movement in time can be represented as a saltatory (quantized) motion in a quiescent state at the maximum permissible velocity. In other words, when something is stationary in a point of three-dimensional space, it can be interpreted within the STR in such a way that it moves at the velocity of light in time and, therefore, moves in the space, because the space changes over time run.

Here another problem raises. If time is quantized, what do the changes of space in time mean? Does the time exist in the “gaps” between time quanta? If it does, we would have to admit the existence of space out of the time intervals, which seems absurd, because it would make us admit another kind of time and so on, and so forth – leads us to a vicious circle. Instead, if time does not exist in the “gaps”, at every moment the world is created all over again, which also contradicts our intellectual intuition.

Durability, as a characteristic of time, is in close relation to the notion of locality. In classical physics, starting with the works of Galileo, Newton and up to Einstein, time is described as local. Basically, this idea corresponds to our intuition. In general, the concept of locality concerns space, of course. Its main idea is that to get from point A to point B, it is necessary to cover a certain distance. However, since the maximum possible velocity is finite (the velocity of light), locality implies the need to spend the certain time to cover any distance. It is interesting that Newton’s universe is not entirely local, contrary to common belief – in his theory, the gravity extends instantaneously. In the relativity theory, gravity has a fixed velocity – the velocity of light.

In quantum mechanics, the nonlocality appears (surprisingly, Einstein has established it himself [Einstein, Podolsky, Rosen, 1935, p. 777–780] and believed that he would demonstrate the insufficiency of the quantum theory through it). Nonlocality means that photons do not have to cover any distance to get from point A to point B, they immediately reappear at point B. Therefore, it takes no time. An extensive understanding of the nonlocality [Markopoulou, Smolin, 2007; Chanda, Smolin, 2009] presumes that there are nonlocal connections between elementary particles in the Universe, and moreover, the more connections are there, the more notable the other dimensions are marked. In other words, if one or more dimensions were discovered in addition to the existing three in order to relocate macro objects, it would mean the presence of nonlocality. It is a curious crossover between quantum mechanics and the relativity theory. As previously noted, within the relativity theory there is no time itself, but there is space-time. Thus, every motion is a motion in space-time. If we assume the existence of extra dimensions (which, incidentally, Einstein has already tried on the basis of the Kaluza-Klein theory [Kaluza, 1921, p. 966–972; Klein, 1926, p. 895–906]) and add the quantum-mechanical nonlocality, it turns out that nonlocality means movement in other dimensions. Experiments to prove nonlocality (quantum teleportation) have already been carried out repeatedly with the last one quite recently [Bussières, Clausen, Tiranov, Korzh, Verma, Sae Woo Nam, Marsili, Ferrier, Goldner, Herrmann, Silberhorn, Sohler, Afzelius, Gisin, 2014, p. 775–778]. However, interpretation of their results is a big challenge. On their basis, it is possible to conclude that the concepts of distance (as a characteristic of space) and continuity (as a characteristic of time) are invalid, as they are only a matter of our perception. Therefore, there is only one place where everything happens (if only we can talk about an exact place here). However, quantum teleportation involves the creation of a duplicate of the original object *somewhere else*. The presence of this other place immediately undermines the idea of illusory distance. Otherwise, we should assume that this is not a different place, but the same one; and the photon is exactly the same; there is just one of them, not two. However, then the question arises: has the teleportation actually happened? What kind of manipulations have the experimenters performed if nothing has changed compared to the primary state? The idea that the object stays one and the same is quite consistent with the Leibniz's principle of identity of indiscernible.

The problem becomes irrelevant within Newton's absolute space (and Einstein's space). Considering nonlocality as staying in one and the same place is not necessary. It is all about photons, which share information instantly across any distance. Yes, the photons are indiscernible. However, Leibniz's principle remains inviolate – the availability of various positions in space is also a characteristic of photon (though in this case, the function of space is uncertain – it becomes even more artificial than the famous ether in the old physics, where it was at least required for the propagation of light waves with a finite velocity). However, time is eliminated completely. Thus, integration of the relative and quantum interpretations of nonlocality shows that time does not exist, and it is pointless to talk about any of its characteristics, features or properties. For more information on nonlocality and the measurement problem, see [Karpenko, 2015, p. 36–81; Karpenko, 2014, p. 16–28].

We shall enlarge upon the issue of the "flow" of time. The universe in the relativity theory is often called the "block" universe, which means a single space-time with no time indeed. The block can be "cut" at different angles (the velocity and direction of motion correspond to "cutting" process) – this defines the relativity of simultaneity. For various observers the different events will be perceived as happening in a different temporal order; what has happened earlier for some observers, is later for others. The order of events is permanent only within the boundaries of a single light cone. Events beyond the one cone may not be causally related. Here the key word is "to be perceived", as all events are set up within a block universe, they occur. Also, depending on certain conditions, our perception allows us to notice them in a certain order. This model excludes the flow of time; the sequence of events cannot be called time either. Therefore, it lacks continuity as well.

Such circumstances are not overall accepted as completely satisfactory. The reason for that is the existence of so-called "arrow of time". It is special because according to theory no matter where and how the observers move, they will observe arrow`s one and only direction – from the past to the future (in the sense that the past is different from the future). Although, the laws of physics are reversible in time; reality is irreversible. Order turns into chaos, and the opposite is very seldom (though, this must occur with the same frequency). Here is the famous second law of thermodynamics and its implications, first described by Rudolf Clausius [Clausius, 1854, p. 481–506], and studied by Ludwig Boltzmann [Boltzmann, 2003, p. 262–349]. Entropy always increases. Even if self-organization, the growth of the order, takes place, it presumes the use of energy. The expended sufficient energy leads to the release of insufficient energy (heat). Moreover, entropy (as a measure of disorder) is always greater than the increase in the order.

In this case, it is important that we might consider the second law of thermodynamics as an evidence of the time flow or, more boldly, as a description of time itself. In this context, time could be comprehended as a transition from less probable states to more probable – and the most probable state is the state of equilibrium. However, in this case, we would have to admit that time stops at the moment of equilibrium. Obviously, it is not true because fluctuations occur at any state of equilibrium, reducing the entropy in the area around them, and then a decrease in the order degree happens again. Thus, the second law is not the time, but it operates within the time (in the words of Aristotle, motion in time). It points at the arrow of time.

The arrow of time presupposes asymmetry of the universe in time: if the past is fundamentally different from the future, there must have been some special initial conditions. The choice of initial conditions (in the inflation model, for example) is to a great extent random. The point is that at the current state of the universe, it is impossible to reconstruct its original state; it could have reached its present state by many different ways. The history also provides an important role to random events (somehow nondeterminate by others) – fluctuations. Therefore, the choice of initial conditions is large enough. Moreover, even if we ever discover what they have exactly been, remains the question of why they have been one or the other since they could have been the other. In fact, the sort of “it has happened accidentally” answer is always possible (which does not withdraw the question of why an accident is possible).

Another problem is that the assumption of the arrow of time implies the choice of initial conditions with a high degree of order. If the most probable state is equilibrium, then the initial state of the object of our current observation should have been non-equilibrium. Alternatively, it has been an equilibrium, but from time to time massive fluctuations occur in various parts of the Universe, increasing its organizational level (the idea of Boltzmann) [Lebowitz, 1993, p. 32–38]. This assumption requires eternal past since the probability of large fluctuations is extremely low, and they could have hardly occurred in 14 billion years. If we choose initial state after the Big Bang, it is necessary to explain, where the original order has arisen, setting the direction of the arrow of time. Though, gravity is the very factor of the order in the initial conditions. The initial state of equilibrium after the Big Bang cannot be the same equilibrium in the presence of gravitational interaction, which makes the elements pull up together to form complex structures. In this case, we have to assume that time is somehow connected with the gravity and, perhaps, is derived from it (in a certain way the GR confirms this). If so, we should clarify what exactly the gravity is. In the GR sense, as the space-time curvature time is excluded again. It is possible to consider gravity as a result of actions of real carrier particles (gravitons), as the superstring theory does, for example, while predicting their existence. In this case, we will have to connect time not only to the force of gravity but, apparently, to repulsive gravity, the cosmological constant, too.

Another modern concept, which eliminates time, views the Universe as a hologram. This approach has emerged from the black hole studies, begun by Jacob Bekenstein [Bekenstein, 1976, p. 2333–2346] and Stephen Hawking [Hawking, 1974, p. 30–31], was continued by Gerard `t Hooft [Stephens, ‘t Hooft, Whiting, 1994, p. 621] and Leonard Susskind [Susskind, 1995, p. 6377–6399] and was completed by Edward Witten [Witten, 1998, p. 253–291] and Juan Maldacena [Horowitz, Maldacena, Strominger, 1996, p. 151–159]. T`Hooft and Saaskind showed that all the information about any object can be recorded on its surface area, i.e. the information within the area is always smaller than the surface. This suggests that the arena of physical laws is just the border, and the observed three-dimensional reality is a holographic projection. Maldacena, a string theorist, following the principles of Witten, has revealed the possibility of a dual description of reality. His string theory (the strings in the beam) is identical to the quantum field theory. Such a position has become possible because the same mathematical vocabulary is used to describe what is happening inside the Maldacena’s world and on the border of this world (the actual quantum field theory). Thus, both theories are essentially the same, but they describe reality from different perspectives. The essence of the concept is that you can describe what is happening *inside* by what is happening outside, in the border area. For example, a black hole may be a holographic projection of gas on its surface; then black holes may appear as quite trivial objects. Ultimately, the universe can be described as a hologram, i. e., as a projection from a distant flat surface.

What is the role of time in such a model of describing reality? Should we consider that time is also a projection (and if we consider the time to be a derivative from the laws of physics and arising from them, rather than preceding them, a projection of what is then the time)? In the spirit of Plato and Platonists one can say that it is “the projection of eternity”, but from the viewpoint of physics, the answer, of course, is not concrete enough. Probably, it would be right to say that there is no time on the surface, time is just a property of three-dimensional projection. The projection is moving, and here, as Heraclitus put it, "everything flows, everything changes", but the boundary surface remains unchanged (because it is atemporal). This means that time is not fundamental, and it is derived from something else that is encoded on the remote surface. And currently, it is not quite clear what that something could be.

Another option, which is in better compliance with the string theory, is that time (and space) is a predetermined pattern, a stage for events. Proposed in the superstring theory, one version of a cyclic universe (or multiverse) considers time precisely this way. In the model of Paul Steinhardt and his colleagues [Khoury, Ovrut, Steinhardt, Turok, 2001] our universe has become as a three-dimensional brane, located in the space of a higher dimension. From time to time, a collision with other brane-universes may occur, which means the end of these universes and the appearance of the new ones.

R. Penrose [Penrose, 2011] has proposed another cyclic theory within more classical beliefs. His concept suggests that a new Universe is the result of fluctuation (in fact, another Big Bang), which is inevitable after *an infinite* time later reaching the thermal equilibrium. The later universe becomes indistinguishable from the earlier one when the thermal equilibrium is accomplished. Thus, the end becomes a new beginning. Interestingly, despite the obviously strange need in the expiration of infinite time, this theory can be verified. The detection of gravitational waves and concentric circles from the collision of several black hole pairs may speak in its favor. There is evidence that such data have been obtained [Wehus, Eriksen, 2010].

But no matter what any cyclic model is based on, it requires the presence of predetermined time outside of the universe, which is not going to appear and die along with the universe. Indeed, the cyclic scenario makes no sense when time appears with the emergence of the universe. How can one claim the previous existence of universes, if their time had disappeared together with them? If there are timeless intervals between universes (which is absurd), we cannot use terms "before", "was", etc.

Such scenarios only complicate the problem of time. Time here appears to be a certain fundamental value, which is wittingly impossible to perceive, as placed outside the world. The same applies to the different concepts of the multiverse (see [Karpenko, 2015, p. 150–166]). If we exclude the external time and leave only the proper time of each world, the question arises: how do the worlds relate to each other in time? The theory of eternal inflation [Guth, 1997] raises another question: is there time in the inflaton field or does Plato`s eternity reign over it and time appears only together with the worlds, in "bubble" universes? In this case, timeless zones would separate worlds, which cannot be comparable over time and we can neither say that the worlds have different time, nor that they have the same one. This issue also does not lose its relevance in the case of Everett's many-worlds interpretation, string landscape, and some other multiverse theories.

The interpretation of time in quantum field theory is also quite special. The Schrödinger equation describes the wave function of the particle before its measurement, and at the very moment of measurement the wave function collapses and the macrocosm now dictates its rules for the situation. Thus, time plays a key role in the act of measurement. Measurement changes the future. Before the measurement the past of a particle is blurry (it may be anywhere with a number of the most likely positions and, more precisely, it may be anywhere at the same time if hidden variables are not allowed). At the moment of measurement, the particle is detected somewhere, and the rules of a microcosm no longer work for it. If the measurement had not been carried out, the particle would have been further described by a wave function. In this situation, the moment of measurement has special authority, determining the future – this is the very moment of the present, which separates the future from the past. On its only basis we cannot reconstruct the past and can only statistically predict the future. The past and the future are always blurred, only the present exists.

From the viewpoint of the hidden variable theories [Bohm, 1983] the act of measurement itself is nothing special. It just allows detecting the previously unknown location of a particle. The concept of Hugh Everett [Everett, 1957, p. 454–462] suggests that measurement also does not have any special status and appears to be one of the possible realizations in parallel universes. Most of the other interpretations of quantum mechanics also avoid the problem of measurement, see [Bell, 1987].

As an alternative to the general relativity theory, some physicists [Gomes, Gryb, Koslowski, 2011; Barbour, Koslowski, Mercati, 2014] have suggested the Shape Dynamics. The fundamental difference of the Shape Dynamics theory is that time here is considered to be universal, while space is relative. This means that there is a distinguished observer and, accordingly, allotted time. The relativity of space means that in different parts of the Universe the size of similar objects may be different or, more precisely, the concept of size over long distances has no independent meaning, just as the concept of simultaneity of events in the theory of relativity. Global time and simultaneous observation are possible, because, for example, a universal frame of reference had been chosen – the microwave background radiation. The observers will register its one and the same temperature in all directions of the universe, so there are separated observers (which fact, however, brings asymmetry into GRT). It is important that the Shape Dynamics is a dual description of GRT; the relativity of space replaces the relativity of time, two theories are equivalent to each other.

The postulation of absolute time, which is initial to physics laws, leads to curious consequences: laws can change over time. I. e. laws turn out to be variable, not so fundamentally basic for time determination, but they occur in time themselves. This is certainly an interesting approach that allows a fresh look at the evolution of the Universe. However, such an approach leaves the essence of time unexplained. On the contrary, the assumption of changing the laws of physics over time requires an explanation for the mechanism of this change, so there must be some principle of the laws evolution over time. There is also one more possibility: to accept that time is ultimate and it exists for no particular reason, but it would be a cognitive dead-end.

Another important feature of the Shape Dynamics, which makes it even possible to reconstruct events in the past, is that it is consistent with the theory of hidden variables in quantum mechanics, i.e. with the idea that all particles have a position and velocity at any point in time (such an assumption once again suggests the need for a distinguished observer). This is exactly what Einstein has demanded from the theory and what became possible under only the dual description of his theory.

Conclusion

Alongside with the growth of scientific knowledge, the intellectual intuition adapts to the formulation of new concepts and modernization of old ones (the opposite is also true here). The appearance of the new physical theories (experimental confirmation is optional) often requires an updating of traditional question formulation discourse. For example, the theory of relativity introduces the relativity of simultaneity concept – a fundamentally new step in science, which requires a rethinking of the category of time (that ends up in GRT with eliminating of time). Another example is the quantum field theory, where the time as the distinction between past and future occurs only during the transition from micro- to macro-level. The holographic principle, which has grown out of the possibility of a dual description of physical systems, again offers an entirely new way of time understanding: time as projection (or requires the acceptance of two-time origins). The multiverse (and the cyclic Universe) concepts raise a fundamental question on global time – whether the separated time periods exist in each universe or whether time is common to all of them.

Finally, the question of the time dimension is a really new issue in the problem. Time has traditionally been considered as either a circle (cyclical) or as an arrow. If time can have larger dimension, as the folded spaces in superstring theory, it is most likely confirming the validity of the concept of time geometrization and shows a lack of grounds for a search of essentially temporary categories. I. e., it is possible that time is a variety of space.

As it has become possible to find out, most of the time-related issues have not been significantly changed, comparing to earlier attempts of its philosophical interpretation.

Considering that, the key question, which has been stated at the beginning – if the time exists – has no positive solutions. In those theories, where the answer is positive, it is fundamental in the sense that it is initial. This option can not still define the time notion, but on the contrary, takes a step back in an attempt to define it. After declaring something as initial, we can continue considering it only in the spirit of negative theology, since nothing has caused it.

In the concepts, where the time notion appears, it is possible to consider its existence, but so far space is the only variant for its explanation. However, rather familiar understanding of time as a movement in space (the sequence of events in space or even a special kind of space) sort of eliminates the time itself from the concept of time. These approaches deny temporality of their own time specifics (which may become true).

It is likely that the part of the problem lies in that intellectual intuition is unable to exceed the bounds of the ordinary idea of time and in constant attempts of fitting time into the familiar pattern of the macrocosm. In this case, an effective way to overcome such difficulties would be a formulation of new concepts of time and space on the basis of the experimental results and mathematical description, denying the tradition that has produced problems, formulated by Zeno. In a sense, the essence of his paradoxes specifically points to a disparity between the intellectual intuition and physical reality, rather than to the impossibility of movement.

Thus, summing up, it is necessary to state the following. While using the classic interpretation of time – as it used to be presented in the philosophical tradition till nowadays – we should necessary ascertain its elimination. Time actually does not exist; it is either an illusion or a derivative of something more general (possibly, more fundamental). The only way to bring back the time is through getting it out of the traditional language and developing the new, specific vocabulary for it. Apparently, such path should be taken, in particular, within the framework of philosophical interpretation of quantum mechanics, because the destruction of the usual concepts of distance and duration happens exactly at the micro level. Even using the cyclic models, which postulate eternal time, it is necessary (because of their straight correspondence to the results of the general theory of relativity) to renounce time existence as fundamental quantity and to accept its derivation (so familiar from antiquity) from eternity. However, such a way does not seem a reasonable solution because in this case, of course, the question of eternity defining arises.

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