The Universal Arrow of Time III: Nonquantum gravitation theory.

Kupervasser Oleg

Abstract

The paper is dealing with the analysis of general relativity theory (theory of gravitation) from the point of view of thermodynamic time arrow. Within this framework «informational paradox» for black holes and «paradox with the grandfather» for time travel "wormholes" are resolved.

1. Introduction.

In paper we consider thermodynamic time arrow [1-2] (defined by a direction of the entropy increase) within the limits of not quantum relativistic gravitation theory. In the classical Hamilton mechanics any initial and final states are possible. Besides, between them there is a one-to-one correspondence. In relativistic theory of gravitation a situation is other. There are topological singularities of space which make possible a situation when for *finite* time different initial states give an identical final state. It is a collapse of black holes. On the other hand, having considered inverse process in time - white holes, we receive a situation when a single initial state can give a set of different final states for *finite* time. There are also situations of other sort - when not arbitrary initial states are possible. It is a case of "wormholes" through which it is possible to travel in the past. Thus there is necessary of self-consistency between the past and the future, making impossible some initial states. Black Holes lead to informational paradox, and "wormholes" - to «to paradox with the grandfather». Analysis of these situations with a point of view of thermodynamical time arrow and resolution of the defined above paradoxes are a topic of this paper.

2. Black Hole

In the modern cosmological models there are additional appearances, except the appearances already featured in the classical mechanics. In Einstein's relativity theory as well as in classical mechanics the motion is reversible. But there is also an important difference from the classical mechanics. It is *ambiguity* of a solution of an initial value problem: deriving a final state of a system from the complete set of initial and boundary conditions can give not single solution or no solution. In general relativity theory, unlike the classical mechanics, two various states for *finite* time can give infinitesimally close states. It happens at formation of a black hole as a result of a collapse. Hence, formation of the black hole goes with its entropy increase.

Let's consider an inverse process featuring a white hole. In this process infinitesimally close initial states for *finite* time can give different terminating states. Time reversion leads to appearing white hole and results in entropy decrease. The white hole can not exist in a reality because of the same reasons that processes with entropy decrease are impossible in the classical mechanics.

However its instability is much stronger than instability in the classical mechanics. It has finite value already with respect to *infinitesimally small* perturbations. As consequence there are alignment of thermodynamic time arrows between the white hole and the observer/environment. The white hole transforms to a black hole for the observer. It means that the observer/environment even *infinitesimally weakly* interacting with the white hole can affect considerably its evolution for finite time. Thus the gravitational interaction of the observer/environment with the white hole is always distinct from zero.

Here there is a well-known informational paradox **[**3**]**: the collapse leads to losses of the information in the Black Hole. It, in turn, results in incompleteness of our knowledge of a state of system and, hence, to unpredictability of dynamics of system, including Black Hole. The information, which in the classical mechanics always conserves, in a black hole disappears for ever. Is it really so? Or, probably, it is stored in some form inside of a black hole? Usually only two answers to this problem are considered: Or the information really vanishes completely; or the information is stored inside and can be extracted by some way. But, most likely, the third answer is true. Because of inevitable influence of the observer/environment it is impossible to distinguish these two situations experimentally in principle! And if it is impossible to verify something experimentally, it can not be a topic for the science.

Actually, suppose that the information is stored in a black hole. Whether is it possible to resolve informational paradox and to extract this information from it? Perhaps, we can reverse a collapsed black hole, to convert it into a white hole and to extract the disappeared information? It would seem impossibly. But recently there appeared an interesting paper, which though and not directly, but allows to make it [4]. There is proved, that a black hole is completely equivalent to an entry to the channel, pairing two Universes. The entry of this channel is similar to the black hole, and an exit is similar to the white hole. This white hole can be considered, in some sense, as the reversed black hole. But to verify that the information does not disappear, we should come into the second Universe. To do it we suppose, that there is some "wormhole" which connects these two Universes. Let the observer can pass it and observe the white hole. But even if it happens, we know that the white hole is extremely unstable with respect to any observation. Attempt to observe it will result in its transformation into a black hole. It will close any possibility to verify, that the information is stored. Hence, both solutions of informational paradox are really equivalent and observationally are not distinguishable.

This property of nonreversible information losses results in fact that the entropy increase law turns to be an exact law of the nature within framework of the gravitational theory. Really, there is such new fundamental value, as entropy of a black hole. It distinguishes gravitational theory from classical mechanics where the law entropy increase law has only approximate character (FAPP, for all practical purposes).

The accelerated expansion of the Universe results in the same effect of nonreversible information losses: there are unobservable fields, whence we are not reached even by light. Hence, these fields are unobservable, and the information stored in them is lost. It again results in unpredictability of relativistic dynamics.

3. Time wormhole

Let's consider from the point of view of the entropy such paradoxical object of general relativity theory, as time "wormhole" **[5]**. We will consider at the beginning the most popular variant, offered by Morris and Thorne **[6].** Let we have space wormhole with the extremities laying nearby. By very simple procedure (we will ship one of the extremities on a spaceship, we will move it with a velocity close to light, and then we will return this extremity on the former place) space wormhole can be conversed into time wormhole (wormhole traversing space into one traversing time). It can be used as a time machine. Such wormhole demands the special exotic matter necessary for conserving its equilibrium. However there were models of a time machine which allow to be bypassed absolutely without exotic substance [7, 9]. Or, using an electromagnetic field, allow to be bypassed by its small amount [8]. Use of such time machine can lead to well-known «paradox of the grandfather» when the grandson, being returned in the past, kills his grandfather. How this paradox can be resolved?

From the physical point of view, the paradox of the grandfather means, what not all initial states which exist before time machine formation are realizable. Introducing the additional feedback between the future and the past a time wormhole makes their impossible. Hence, we or should explain nonrealizability such initial states. Or suppose, that time "wormhole" is unstable, like a white hole, and easily changes.

Curiously enough, but both explanations are true. However for macroscopic whomeholes the first explanation has priority. Really, it would be desirable very much to have a macroscopic topology of the space to be stable. Constrains on initial states appears from entropy increase law and the correspondent alignment of thermodynamic time arrows, related to instability of states with opposite directions of these time arrows [1-2]. But macroscopic laws of thermodynamics are probability. For very small number of cases they are not correct (large-scale fluctuations). Both for these situations, and for microscopic wormholes where the concept of a thermodynamic time arrows and thermodynamics laws are not applicable, priority has the second explanation. It is related to extremal instability of the topology, which is defined by the time machine [9]. We discussed above such type of extremal instability for white holes. For macroscopic wormholes the solution can be discovered by means of the entropy increase law .It is ensured by instability of processes with the entropy decrease with respect to the Universe. This instability results in alignment of thermodynamic time arrows.

Really, space wormhole does not lead to paradox. The objects immersed by its one extremity, go out other extremity during later time. Thus, the objects from more ordered and low entropy past hit in less ordered and high entropy future. During a motion through the wormhole the entropy of the travelling objects also increases: they transfer from more ordered state in less ordered one. Thus, time arrow of the object, travelling inside of the wormhole, and time arrow of the world around the wormhole have the same directions. It is also true for travelling through the time wormhole from the past to the future.

However for travelling from the future to the past of the time arrow directions of the traveler into the wormhole and world around the wormhole will be already opposite [10, 11-13]. Really, the object travels from less ordered future to the more ordered past, but his entropy increases, instead of decreases! Hence, thermodynamic time arrows of the Universe and the traveler have opposite directions. Such process, at which entropies of the traveler decreases concerning the Universe, are unstable [1-2]. Hence, «memory about the past» of the traveler will be destroyed (and, may be, he will be destroyed completely), that will not allow him «to kill the grandfather».

Which mechanism at travelling in the wormhole ensures alignment of thermodynamic time arrows of the traveler and the Universe? Both extremities of "wormhole" it is the large bodies having finite temperature. Both extremities under the second thermodynamics laws inevitably should radiate light which partially hits to the wormhole. Already at the moment of "time machine" formation (transformation of the space wormhole into the time one) between its extremities there is a closed light ray. Every time when the ray features a circle, it is more and more biased to a violet part of the spectrum. Transiting a circle behind circle, rays are lost by the focal point, therefore energy does not amplify and it does not become infinite. Violet bias means, that the history of a particle of light is finite and defined by its coordinate time, despite the infinite number of circles [14]. This and other rays of light in wormhole fluctuate. They also have a direction of its thermodynamic time arrow coinciding with a thermodynamic time arrow of the Universe. Thanks to inevitable interaction with this radiation very unstable state of the traveler destroys. The state of the traveler is unstable because his thermodynamic time arrow is opposite to the Universe thermodynamic time arrows. The resulting destruction is enough to prevent the paradox of the grandfather.

"Free will" allows us to initiate freely only irreversible processes with the entropy increase, but not with its decrease. Thus, we cannot send a object from the future to the past. Process of alignment of thermodynamic time arrows and the correspondent entropy increase law forbids *the initial conditions* necessary for travelling of the macroscopic object to the past and resulting in "paradox of the grandfather".

In paper **[**10**]** it is strictly mathematically proved, that the thermodynamic time arrow cannot have identical orientation with the coordinate time arrow during all travel over closed timelike curve. Process of alignment of thermodynamic time arrows (related to instability of processes with entropy decrease) is such *physical mechanism* which actually ensures performance of the entropy increase law.

Macroscopic laws of thermodynamics are probabilistic. For very small number of cases they do not work (large-scale fluctuations). Both for these situations and for microscopic systems where thermodynamics laws are not applicable, the other explanation of the grandfather paradox have priority. In this case the time wormhole, like a white hole, appears unstable even with respect to infinitesimally weak perturbations from gravitation of travelling object. It can result in its fracture and prevention of the paradoxes, as is proved strictly in **[**9**]**. What are outcomes of reorganization of the space-time topology after fracture of the time wormhole? The author of [9] writes:

«As we argue … non-uniqueness does not let the time travel paradoxes into general relativity — whatever happens in a causal region, a space-time always can evolve so that to avoid any paradoxes (at the sacrifice of the time machine at a pinch). The resulting space-times sometimes … curiously remind one of the many-world pictures».

Let's formulate a final conclusion: *for macroscopic processes* instability of processes with the entropy decrease and correspondent alignment of thermodynamic time arrows makes almost impossible existence of initial conditions that allow travel to the past. Thereby it prevents both wormholes fracture and traveling of macroscopic bodies in the past leading to "paradox of the grandfather".

For very improbable situations of macroscopic wormholes and for microscopic wormholes the wormhole fracture must occur. This fracture is result of remarkable property of general relativity theory - extremal instability: infinitesimal external action (for example, gravitation from traveler) can produce wormhole fracture for finite time!

4. Conclusions.

Let's summarize above. Observation process should be taken into account inevitably during considering any physical process. We must transform from ideal dynamics over coordinate time arrow to observable dynamics with respect to thermodynamical time arrow of observer. It allows us to exclude all unobservable in the reality phenomena, leading to paradoxes. Thus it is necessary to consider following things. The observer inevitably is a nonequilibrium macroscopic chaotic body with the thermodynamic time arrow defined by his entropy increase direction. He yields all measurements with respect to this thermodynamic time arrow. Dynamics of bodies with respect to this thermodynamic time arrow is named as observable dynamics. It differs from ideal dynamics, with respect to the coordinate time arrow. All bodies are featured in observable dynamics in macroparameters, unlike the ideal dynamics using microparameters. The coordinate does not exist at thermodynamic equilibrium. It can change the direction and is not coincide with the coordinate time arrow of the ideal dynamics. Always there is a small interaction between the observer and observable system. It leads to alignment of thermodynamic time arrows of the observer and the observable systems.

We can see misterious situation. The same reasons which have allowed us to resolve paradoxes of wave packet reduction in quantum mechanics, paradoxes Loshmidt and Poincare in the classical mechanics allow to resolve informational paradox of black holes and the paradox of the grandfather for time wormholes. Remarkable universality!

Acknowledgment

We thank Hrvoje Nikolic and Vinko Zlatic for discussions and debates which help very much during writing this paper.

Bibliography

1. Oleg Kupervasser, Hrvoje Nikolic, Vinko Zlatic "The Universal Arrow of Time I: Classical mechanics", Foundations of Physics 42, 1165-1185 (2012) http://www.springerlink.com/content/v4h2535hh14uh084/, arXiv:1011.4173
2. Oleg Kupervasser "The Universal Arrow of Time II: Quantum mechanics case" arXiv::1106.6160
3. Preskill, John (1992), *Do black holes destroy information?*, arXiv:hep-th/9209058
4. Nikodem J. Popławski «Radial motion into an Einstein–Rosen bridge» Physics Letters B 687 (2010) 110–113
5. Joaquin P. Noyola, Relativity and Wormholes, Department of Physics, University of Texas at Arlington, Arlington, TX 76019, (2006)
http://www.uta.edu/physics/main/resources/ug_seminars/papers/RelativityandWormholes.doc
6. M. Morris, and K. Thorne, Am. J. Phys. 56 (4), (1988).
7. Amos Ori, A new time-machine model with compact vacuum core, Phys Rev Lett, 95, 021101 (2005)
8. I.D. Novikov, N.S. Kardashev, A.A. Shatskii Physics-Uspekhi, V. 177, N 9, P.1017, (2007)
9. S. V. Krasnikov, The time travel paradox, Phys.Rev. D65 (2002) ,
http://arxiv.org/abs/gr-qc/0109029
10. Hrvoje Nikolic, CAUSAL PARADOXES: A CONFLICT BETWEEN RELATIVITY AND THE ARROW OF TIME,Foundations of Physics Letters, Volume 19, Number 3, June 2006, p. 259-267(9)
11. H.D. Zeh, *The Physical Basis of the Direction of Time* (Springer, Heidelberg, 2007).
12. H. D. Zeh Remarks on the Compatibility of Opposite Arrows of Time *Entropy* 2005, *7*(4), 199-207
13. H. D. Zeh Remarks on the Compatibility of Opposite Arrows of Time II *Entropy* 2006, *8[2]*, 44-49
14. Hawking S.W., Thorne K.S., Novikov I.,Ferris T., Lightman A., Price R. "The future of Spacetime", California, Institute of Technology (2002)