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Synchronization of Sources of Radiation with the Help of Tunneling

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Author's contribution

This whole work was carried out by the author YNZ.

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ABSTRACT

This article is devoted to investigation of the mechanism of synchronization of the sources of electromagnetic radiation due to tunneling between two vacuums of the Maxwell-Einstein equations. The implementation of this mechanism permits to avoid the hypothesis of the inflation stage of the Universe expansion which is adopted for the explanation of relict radiation isotropy.

Keywords: Tunneling; instanton; synchronization; relict radiation.

1. INTRODUCTION

A problem of synchronization of sources of radiation, for example, electromagnetic, has key significance in a number of actual physical phenomena. It`s answer defines the selection of one physical models amongst others which lays in the basement of physical description of such a phenomenon. Probably, the most known of that phenomenon is the cosmic microwave background (CMB) radiation. The traditional explanation of the high degree of isotropy of its temperature involves the proposition of the special stage of spreading of the Universe, which is known as "inflation". According to the inflationary cosmology the sources of the radiation were causally connected in the inflationary era. Inflation makes reasons for the sources to have a common Past which origin in time is shifted so far that those sources could send a signal and receive an answer in order to synchronize. It is supposed that the

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signals have electromagnetic nature and are propagating with light speed. At present time that picture is adopted by the science community worldwide.

Meanwhile, there are some other ways of synchronization. Imagine, for example, that electromagnetic sources are located at the vicinities of different space-time vacuums which are connected through tunneling only[1]. In that case they could synchronize through so-called "instantons" and there is no need to have common Past for them because such a synchronization happens instantly. This feature is a common one for tunneling processes in general. It is often "explained" as an infinite speed of a tunneling signal[2], what is not the case because for the tunneling particles the sense of "speed" is absent.

If the sources of radiation were to synchronize with the help of wave signals, i.e. radiation itself then for sources at a distance l a time of synchronization will be of value l/c where c – is a speed of light. For order of distances l compared with the size of the Universe the time of synchronization will be of the order of the lifetime of the Universe. This is in contradiction with the high level of isotropy of CMB coming from the points which are separated far enough because they had not enough time for the synchronization.

In order to overcome this contradiction it was made a proposition about very fast (exponential) stage of Universe spreading, named "inflation" which puts a moment of BIG BANG so far last in time that it gives an opportunity for the sources to have a common past [4].

But one can give another explanation of CMB isotropy which is not connected with the inflation hypothesis. As was shown in the author's works [5,6,7] there are some special solutions of the Maxwell-Einstein equations which are describing light propagation in space-time which is curved by light waves themselves which looks like instantons. Those solutions connect two degenerate vacuums of a problem which is corresponding to states at which there are convergent and divergent spherical electromagnetic wave at space infinity. These vacuums do not connect by any classical evolution. That connection is possible due to tunneling only which can be described as a process in Minkowski space-time with co-ordinates x^0, x^1, x^2, x^3 or as some state in pseudo-Euclidean space with "co-ordinates" $y^0 = ix^0, x^1, x^2, x^3$[3].

In the present article some aspects and conclusions of that scenario of synchronization are discussed. One of the conclusions is the elimination of one of the reasons to introduce in theory the phenomenon of inflation stage of spreading of the Universe[4].

2. SCHRÖDINGER EQUATION: SIMPLE EXAMPLE OF SYNCHRONIZATION

Let us discuss a particle obeying Schrödinger equation in two-well one-dimensional symmetrical potential U(x) = U (-x) (Fig. 1):

[1] *Now it is usual to say about instantons which are describing the transition between two vacuums in the pseudo-Euclidean space which is received from the Minkowski's space-time by the substitution real time to imaginary one. An analogously "tunneling states" in solid state tunneling were introduced in author's work [1]*

[2] *Firstly in the articles of E.O. Kane [2,3]*

[3] *Gravitational instantons was firstly discussed in [8]. General Information about instanton theory could be found in [9]. The influence of gravitation on light propagation was discussed in many works: see for example [10] and a lot of works on http://arxiv.org. Geometrical aspects of gravitation was discussed in [11].*

[4] *These results were shortly discussed in the Internet report at the SFM'13 [12].*

$$i\hbar\frac{\partial\Psi}{\partial t}=H\Psi, H=-\frac{\hbar^2}{2m}\frac{\partial}{\partial x^2}+U(x) \quad (1)$$

H – is a Hamiltonian, Ψ – wave function of a particle, m – its mass, x – co-ordinate, t – time. It is known that Eq. (1) has symmetric (Ψ(-x) = Ψ(x)) and anti-symmetric (Ψ(-x) = -Ψ(x)) solutions [13].

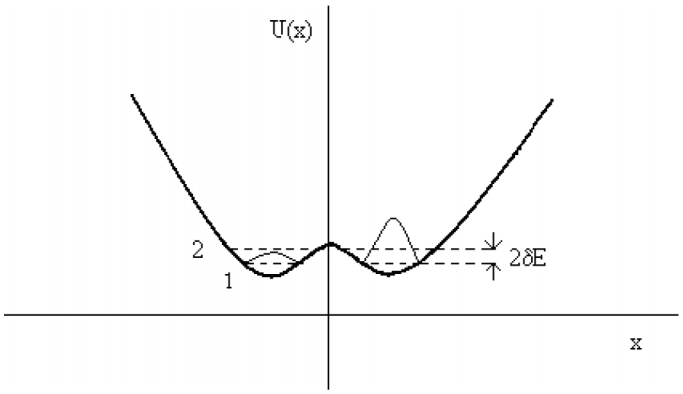

Fig. 1. Synchronization of the states, localized in two-well potential U(x), x – co-ordinate

Bold line – potential, thin lines – wave functions of the lowest (symmetrical) state (schematically) [13]. Dashed lines – energy levels, which are splitted due to tunneling of particle through central barrier (arbitrary scale);
1, 2 – energy levels corresponding to symmetrical (anti-symmetrical) states; 2δE – splitting of the level of ground state due tunneling

It is known also that the level of the ground state E_0 in wells splits into two levels $E_{1,2}= E_0 \pm \delta E$, which are corresponding to symmetrical (1) and anti-symmetrical (2) states. If one denotes by $\Psi_{L,R}$ the wave functions of a particle in the left (right) well so the wave functions of the lowest (symmetrical) and highest (anti-symmetrical) states are $\Psi_{1,2} = (\Psi_L \pm \Psi_R)$. A solution of the Schrödinger equation (1) looks as follows [3]

$$\Psi=\exp\left(-\frac{iE_0t}{\hbar}\right)\left[\left(\Psi_L+\Psi_R\right)\exp\left(\frac{i\delta Et}{\hbar}\right)+\left(\Psi_L-\Psi_R\right)\exp\left(-\frac{i\delta Et}{\hbar}\right)\right]= \\ =2\exp\left(-\frac{iE_0t}{\hbar}\right)\left(Cos\frac{\delta Et}{\hbar}\Psi_L+iSin\frac{\delta Et}{\hbar}\Psi_R\right) \quad (2)$$

The phase of the solution (2) corresponds to finding a particle in left well at time t = 0. After a time $\tau \sim \hbar/\delta E$ has been spent a particle will transfer into the right well. This process cooperates with particle motion in the left well with the period $T \sim \hbar/E_0$, where $T << \tau$ because $\delta E << E_0$ due to the small probability of tunneling $w \sim exp(-Im\, S/\hbar)$, where S is the imaginary action addition which is arising when the particle moves under the central barrier. After the period of time τ the right and left wells will exchange their roles and that process will repeat periodically. The period 2τ is characterizing the energy rate exchange between the wells. Due to the condition $T << \tau$ this process looks very slow [3]. On the other hand the

phase of wave packet transfers from one well to another instantly [2][5]. During the whole lifetime of a particle a constant phase shift exists between the wave packets in left and right wells. Thus if we are interested in the process of information transfer between the wells only, it seems that tunneling is an ideal mechanism for this purpose. Let us remind that the amplitude of a packet doesn't play any role in this process. So, synchronization of packets in wells needs no time expenditure which takes place in the process of synchronization with signals of a wave nature.

This could be justified by assuming a solution of Schrödinger equation (1) which is taking into account the two lowest energy levels in every well

$$\Psi = \Psi^0 + \Psi^1 = \exp\left(-\frac{iE_0 t}{\hbar}\right)\left[(\Psi_L^0 + \Psi_R^0)\exp\left(\frac{i\delta E_0 t}{\hbar}\right) + (\Psi_L^0 - \Psi_R^0)\exp\left(-\frac{i\delta E_0 t}{\hbar}\right)\right] + \exp\left(-\frac{iE_1 t}{\hbar}\right)\left[(\Psi_L^1 + \Psi_R^1)\exp\left(\frac{i\delta E_1 t}{\hbar}\right) + (\Psi_L^1 - \Psi_R^1)\exp\left(-\frac{i\delta E_1 t}{\hbar}\right)\right] \quad (3)$$

Here $\Psi_{L,R}^{0,1}$ -are wave functions of the first (0) and second (1) levels in the left and right wells with energies $E_{0,\ 1}$ correspondingly, $2\delta E_{0,1}$ – are their splittings. At the time $t = 0$ $\Psi(0) = 2(\Psi_L^0 + \Psi_L^1)$, which is corresponding to a particle, localized in one of the halves of the left wells. The place of localization depends on the sings of $\Psi_L^{0,1}$. This corresponds to storing one bit of information in the left well[6]. According to equation (3) after spending an arbitrarily small time t in the right well the wave function will be looking as follows

$$\Psi_R(t) \approx \frac{2it}{\hbar}\delta E_1\left[\frac{\delta E_0}{\delta E_1}\Psi_R^0 + \Psi_R^1\right], \frac{\delta E_0}{\delta E_1} << 1 \quad (4)$$

According to Eq. (4) the "weight center" of the wave packet always, i.e. for arbitrary values of $\delta E_0 / \delta E_1$ will be shifted in the same direction from the center of right well as it was in the left well. So, the state (4) has just the same information as the state $\Psi(0)$. Rigorously speaking there is no reason to speak about a transition of information with infinite speed from one well to another because sources of information in wells are absent.

3. SYNCHRONIZATION WITH THE HELP OF ENTANGLED STATES

There is another point of view on the problem. Tunneling between two vacuums presents a mechanism of creating entangled states which do not obey the principles of "local reality" [15]. For the components of those states the notion of "signal speed", or "speed of propagation of information" from one vacuum to another one does not exist, because any

[5] *This fact in last time was often discussed and received different explanations. See for example [14]*
[6] *Let us remind that wave function of the ground state has no nodes, and wave function of the first exited state has one node.*

attempts to introduce them lead to infinity values. Those states are “here” and “there” simultaneously [15].

From this point of view the notion of synchronization loses its sense. There is no information transfer between points of space where entangled particles (photons, for example) are located because the role of the source of information plays the source of entangled particles (photons). Let us imagine such a source which is located, say in point O of space. Suppose that it is sending pairs of entangled particles with arbitrary but oppositely directed and equal values of kinetic moments, spins, angular momentum, etc. If anybody will measure distributions of those values in strictly opposite points at arbitrary distance he will find pictures which will be exact copies of one another. This permits to speak that both distributions of the particles have the same temperature. So, in this picture the idea of inflation is unnecessary.

In quantum physics one can take photons of divergent $|d\rangle$ and convergent $|c\rangle$ waves as basic vectors of one-photon states. As much as they belong to different vacuums and can transfer one to another only through tunneling, so their symmetric ($|d\rangle+|c\rangle$) and anti-symmetric ($|d\rangle-|c\rangle$) superposition have different energies E_+ and E_- and $E_+ < E_-$. One may encode these states as “zero” ($|0\rangle$) and “one” ($|1\rangle$)

$$|0\rangle=\frac{1}{\sqrt{2}}\left(|d\rangle+|c\rangle\right),$$
$$|1\rangle=\frac{1}{\sqrt{2}}\left(|d\rangle-|c\rangle\right) \tag{5}$$

which will be orthonormal if $|d\rangle$ and $|c\rangle$ are orthonormal, too. One can take entangled Bell’s states [16] as basic states for two-cubit ones

$$\frac{1}{\sqrt{2}}\left(|00\rangle+|11\rangle\right)=\sqrt{2}\left(|dd\rangle+|cc\rangle\right) \tag{6}$$

Eqs (6) means that entanglement conserves in any basis. If one will send first a photon of entangled pair to one observer (say, Alice) and the other to a second observer (say, Bob) he can assert that results of their measurements will be corresponding to one another despite arbitrary long distance between them.

One should say some words about the real nature of that hypothetical source of entangled particles. Taking into account achievements of contemporary cosmology the role of that source could play Big Bang. Most of the particles arising should be presumably in entangled states, because their number is exponentially larger than the number of non-entangled ones.

4. TOPOLOGY OF THE CONFIGURATION SPACE OF THE PROBLEM

Configuration space K of the problem is a space of co-ordinates which define position or state of the system under consideration[7]. Its dimensionality is equal to the number of degrees of freedom of the system. It is interesting to investigate the topology of K, in particular its connectivity. It is shown in works [5–7] that connectivity of K is at least more than one because K includes sub-space K_d which is formed by the waves radiated by the source and sub-space K_c which is formed by the waves received by the receiver.

Let us prove that connectivity of sub-spaces K_c and K_d themselves is equal one. Really, K_d contains spherical electromagnetic wave S_d which is radiated by the source and all other radiated waves which differ from the S_d by the shape of their front and which could be transferred to S_d by smooth transformation of co-ordinates[8]. One could say just the same about sub-space K_c taking into account a wave S_c which is converging to receiver and other convergent waves. This proves that connectivity of K_c and K_d is equal one. The fact that K_c and K_d are not connected one with another follows from that waves S_d and S_c could not be transformed one to another by any classical transformation in the sense mentioned above, as it leads from works [5–7][9].

Fig. 2 depicts schematically the possible topology of K-space for two-dimensional bounded Universe. It looks like a torus, but has more complex structure, which depends on description of a problem. In quantum description there are two independent frequencies, one is a frequency of oscillation near every separate vacuums (if vacuums are symmetrical) and second is a frequency of oscillation between two vacuums. In this case topology of K-space coincides with topology of two-dimensional torus. In classical physics two different vacuums are not connected and transition between them is impossible. It is related with that transformation of convergent wave S_c to divergent one S_d has quantum nature [6,7].

Here vacuums V_c and V_d for convergent (S_c) and divergent (S_d) spherical waves are shown, which are coinciding in the center, i.e. in the fictive focus of that waves. Fronts of that waves look like co-centric circles which centers are lying on the axis of symmetry of the figure. The wave S_d has been born in vacuum V_d then extends until the point of maximal distance from fictive focus, which is determined by radius of the Universe and begins to converge to fictive focus but in the vacuum V_c.

[7] *Perturbation of metrics are significant only near the source and receiver at the distances of the order of length of electromagnetic wave.*

[8] *From the physical point of view role of that transformation plays wave's evolution in time according the Maxwell equations.*

[9] *Rigorously speaking results of works [5 –7] concern the case when the source and receiver coincide in space-time. It is easy to generalize those results in common case if include in the set of co-ordinate transformation such a one which is representing the motion of the source (receiver) of radiation.*

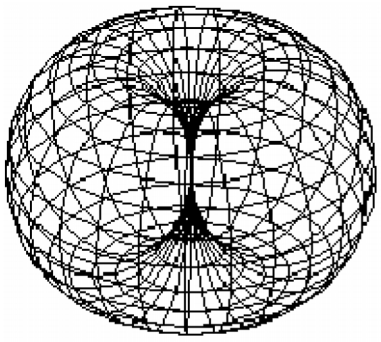

Fig. 2. Approximate topology of two-dimensional analog of *K*-space

5. CONCLUSION

Contemporary theoretical problems of field theory are solved with the help of topological methods which are based on using energy functional in Minkowski space-time or functional of action in pseudo-Euclidean space. The solution of interest are those which has finite pseudo-Euclidean action [17]. These methods cannot be used to the full extent in the present case, because gravitational field rigorously speaking has no energy functional [18]. This fact, probably, restrained the full solution the problem of propagation of electromagnetic waves in space-time which is curved by that waves themselves. It may be also, that the solution of the Maxwell-Einstein equations which was received by G.Y. Rainich [19] created the illusion of a full solution of this problem.

The result presented in this article permits to formulate new approach in problems of cosmology, in particular to find a new origin of isotropy of the CMB. It is supposed in this article that information exchange between sources of radiation occurs due to entangled photons, what does not require the acceptance of the inflation hypothesis. The source of entangled photons could play the Big Bang.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Zayko YN. States in forbidden zone of crystal, localized in the region of non-homogeneity of external field. Solid State Physics. 1976;18(4):951-55. Russian
2. Kane EO. Theory of Tunnelling. J Appl Phys. 1961;32(1):83-91.
3. Kane EO. Main Principles of Tunneling. In: Burstein E, Lundqvist S, editors. Tunneling Phenomena in Solids. New York: Plenum Press; 1969.
4. General Relativity. Ed. by Hawking SW, Israel W. Cambridge Univ. Press, Cambridge; 1979.
5. Zayko YN. Explicit Solutions of the Maxwell-Einstein Equations. Int Journ of Theor and Math Phys. 2011;1(1):12-6.
6. Zayko YN. Completeness' Problem of being Transmitted Information. Procof Saratov St Univ.ser Phys. 2013;13(2):13-9. Russian.

7. Zayko YN. Instanton for the Maxwell-Einstein Equations. Proc of Saratov St Univ.ser. Phys. 2014;14(1). (In press) Russian.
8. Hawking SW. Gravitational Instantons. Phys Lett. 1977;A60.
9. Rajaraman R. Solitons and Instantons. An Introduction to Solitons and Instantons in Quantum Field Theory. New York, Oxford, Amsterdam: North-Holland Publishing Company; 1982.
10. Weber J. Gravitation and Light. In: Chiu H-Y and Hoffman WF, editors. Gravitation and Relativity. NY – Amsterdam: WA. Benjamin, Inc; 1964.
11. Rees M, Ruffini R, Wheeler JA. Black Holes, Gravitational Waves and Cosmology: an Introduction to Current Research. New York, London, Paris: Gordon and Breach Science Pub; 1974.
12. Zayko YN. Synchronization of the sources of radiation through instantons. Internet report at the Saratov Fall Meeting symposia on optics and bio-photonics. Saratov. 2013;25-28. Available: http://sfm.eventry.org/report/660 Russian.
13. Bohm D. Quantum Theory. New York: Prentice Hall; 1989.
14. Barashenkov V, Rodrigues WA Jr. Launching of Non-Dispersive Sub and Superluminal Beam. Nuovo Cimento. 1998;B113:329-338.
15. Greenstein G, Zajonc AG. The Quantum Challenge. Modern Research on the Foundation of Quantum Mechanics. 2nd ed. Sudburg, Massachusetts. Jones and Bartlett Publishers, Inc; 2006.
16. Nielsen MA, Chuang IL. Quantum Computation and Quantum Information. Cambridge Univ. Press; 2000, 2001.
17. Shvartc AS. Quantum Theory and Topology. Moscow: Nauka; 1989. Russian.
18. Weinberg S. Gravitation and Cosmology. John Willey and Sons, Inc., New York; 1972.
19. Rainich GY. Electrodynamics in the General Relativity Theory. Trans Am Math Soc. 1925;27:106-36.

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