

Synchronization of sources of radiation with the help of tunnelling

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 relict photon radiation. Traditional explanation of high degree of isotropy of its temperature goes from proposition of the special stage of spreading of the Universe, which is known as "inflation". 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 signals have electromagnetic nature and are propagating with light speed. At present time that picture is adopted by 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 only¹. 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 signal², what is not the case because for the tunneling particles the sense of "speed" is absent.

At present article some aspects and conclusions of that scenario of synchronization are discussed. One of the conclusions is the absence of a reason to introduce in theory the phenomenon of inflation stage of spreading of the Universe. In paragraph 2 a simple example of synchronization of states in two-well one-dimensional potential which is described with the help of Schrödinger equation is presented.

¹ Now it is usually to say about instantons which are describing the transition between two vacuums in the pseudo-Euclid space which is received from the Minkowsky'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]

the cosmic background microwave radiation (CMB) is early in the inflationary era.

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There are many other reasons for introducing inflation.

can

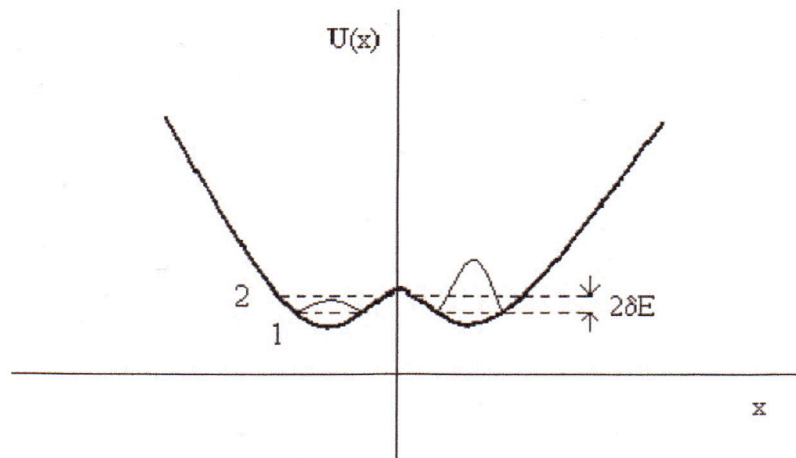
36 In paragraph 3 it is supposed that these ideas could be implemented to the synchronization
37 of the sources of electromagnetic radiation in the Universe³.
38 In paragraph 4 a mechanism of synchronization by entangled states of photons is discussed.
39 In paragraph 5 some ideas of possible structure of phase space of problem are considered.

41 2. SCHRÖDINGER EQUATION: SIMPLE EXAMPLE OF SYNCHRONIZATION

42
43 Let us discuss ~~one-dimensional~~^a particle obeying Schrödinger equation in ~~two-well~~^a
44 symmetrical potential $U(x) = U(-x)$ (Fig. 1):
45

$$46 \quad i\hbar \frac{\partial \Psi}{\partial t} = H\Psi, H = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + U(x) \quad (1)$$

47
48
49 H – is a Hamiltonian, Ψ – wave function of a particle, m – its mass, x – co-ordinate, t – time.
50 It is known that Eq. (1) has symmetric ($\Psi(-x) = \Psi(x)$) and anti-symmetric ($\Psi(-x) = -\Psi(x)$)
51 solutions [5].
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56 **Fig. 1. Synchronization of the states, localized in two-well potential $U(x)$, x – co-**
57 **ordinate.** Bold line – potential, thin lines – wave functions of the lowest (symmetrical) state
58 (schematically) [5]. Dashed lines – energy levels, which are splitted due to tunneling of
59 particle through central barrier (arbitrary scale);
60 1,2 – energy levels corresponding to symmetrical(anti-symmetrical) states; $2\delta E$ – splitting of
61 the level of ground state due tunneling.

62
63
64 It is known also that level of ground state E_0 in wells splits ~~on~~^{the} two $E_{1,2} = E_0 \pm \delta E$, which are
65 corresponding to symmetrical (1) and anti-symmetrical (2) states. If one denotes $\psi_{L,R}$ wave
66 functions of a particle in the left (right) well so ~~the~~^{the} wave functions of the lowest(symmetrical) and
67 highest (anti-symmetrical) states are $\Psi_{1,2} = (\psi_L \pm \psi_R)$. A solution of Schrödinger equation (1)
68 looks as follows [3]

³ These results of the article were shortly discussed in Internet report at the SFM'13 [4].

$$\begin{aligned} \Psi &= \exp\left(-\frac{iE_0 t}{\hbar}\right) \left[(\Psi_L + \Psi_R) \exp\left(\frac{i\delta E t}{\hbar}\right) + (\Psi_L - \Psi_R) \exp\left(-\frac{i\delta E t}{\hbar}\right) \right] = \\ &= 2 \exp\left(-\frac{iE_0 t}{\hbar}\right) \left(\cos \frac{\delta E t}{\hbar} \Psi_L + i \sin \frac{\delta E t}{\hbar} \Psi_R \right) \end{aligned} \quad (2)$$

Phase of the solution (2) corresponds to finding a particle in left well at time $t = 0$. After time $\tau \sim \hbar/\delta E$ has been spent a particle will transfer into the right well. This process cooperates with particle motion in left well with the period $T \sim \hbar/E_0$, where $T \ll \tau$ because $\delta E \ll E_0$ due to little probability of tunneling $w \sim \exp(-\text{Im } S/\hbar)$, where S is imaginary action addition which is arising when particle moves under central barrier. After period of time τ right and left wells will exchange their roles and that process will repeat periodically. Period 2τ is characterizing energy rate exchange between wells. Due to condition $T \ll \tau$ this process looks very slow [3]. On the other hand phase of wave packet transfers from one well to another instantly [2]. During whole lifetime of a particle constant phase shift exists between wave packets in left and right wells. Thus if we are interesting in the process of information transfer between wells only it seems that tunneling is an ideal mechanism for this purpose. Let us remind that amplitude of a packet doesn't play role in this process. So, synchronization of packets in wells needs no time expenditures which takes place in the process of synchronization with signals of wave nature. This could be justified by assuming a solution of Schrödinger equation (1) which is taking into account two lowest energy levels in every wells

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

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 $t = 0$ $\Psi(0) = 2(\Psi_L^0 + \Psi_L^1)$, what is corresponding to particle, localized in one of the halves of left wells, in what namely – depends on signs of $\Psi_L^{0,1}$. This corresponds to storing one bit of information in left well⁵. It leads from the equation (3) that after spending arbitrary small time t wave function in the right well will be looking as follows

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

It leads from an Eq. (4) that "weight center" of wave packet always, i.e. for the 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 be in the left well. So, the state (4) has just the same information as the state $\Psi(0)$.

⁴ This fact in last time was often discussed and received different explanations

⁵ Let us remind that wave function of the ground state has no nodes, and wave function of the first excited state has one node.

100 Rigorously speaking there is no reason to ^{say} about the transition of information with infinite
101 speed from one well to another because sources of information in wells are absent.

105 3. SYNCHRONIZATION OF SOURCES OF ELECTROMAGNETIC RADIATION

107 If the sources of radiation were to synchronize with the help of wave signals, i.e. radiation
108 itself then for the sources ~~distanced one from another~~ at a distance l a time of
109 synchronization will be of value l/c where c – is a speed of light. For order of distances l
110 compared with the size of the Universe time of synchronization will be of the order of lifetime
111 of the Universe. It is in contradiction with high level of isotropy of relict radiation coming from
112 the points which are distanced far enough one from another because they had no enough
113 time for the synchronization.

114 In order to ~~overwhelm~~ this contradiction it was made a proposition about very fast
115 (exponential) stage of Universe spreading, named as "inflation" which puts a moment of BIG
116 BANG so far in time that it gives an opportunity for the sources to have a common past [6].

117 But one can give another explanation of relict radiation isotropy which is not connected with
118 the inflation hypothesis. Really, as it was shown in the author's work [7, 8, 9] there are some
119 special solutions of the Maxwell-Einstein equation which are describing the light propagation
120 in space-time which is curved by light waves themselves which looks like instantons. ^{Those} That
121 solutions connect two degenerate vacuums of a problem which is corresponding to states at
122 which there are convergent and divergent spherical electromagnetic wave at space infinity.
123 These vacuums do not connect by any classical evolution. That connection is possible due
124 to tunneling only which can be described as a process in Minkowski space-time with co-
125 ordinates x^0, x^1, x^2, x^3 or as some state in pseudo-Euclid space with "co-ordinates" $y^0 = ix^0$,
126 x^1, x^2, x^3 .

127 4. SYNCHRONIZATION WITH THE HELP OF ENTANGLED STATES

129 There is another ^{point of view} ~~sight on~~ problem. Tunneling between two vacuums presents a
130 mechanism of creating entangled states which do not obey the principles of "local reality"
131 [10]. For the components of those states the notions of "signal speed", or "speed of
132 propagation of information" from one vacuum to another one do not exist, because any
133 attempts to introduce them lead to infinity values. Those states are "here" and "there"
134 simultaneously [10].

135 From this point of view the notion of synchronization loses its sense. There is no information
136 transfer between points of space where entangled particles (photons, for example) are
137 located because ^{the} role of the source of information plays the source of entangled particles
138 (photons). Let us imagine that source which is located, say in point O of space. Suppose that
139 it is sending pairs of entangled particles with arbitrary but oppositely directed and equal
140 ^{set} by value pulses, spins, angular momentum, etc. If anybody will measure distributions of
141 those values in strictly opposite points at arbitrary distance he will find pictures which will be
142 exact copies of one another. This fact permits to say about the same temperature of
143 particles. So, in this picture the idea of inflation is unnecessary. ^{rewrite!}

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

$$\begin{aligned} |0\rangle &= \frac{1}{\sqrt{2}}(|d\rangle + |c\rangle) \\ |1\rangle &= \frac{1}{\sqrt{2}}(|d\rangle - |c\rangle) \end{aligned} \quad (5)$$

which will be orthonormal if $|d\rangle$ and $|c\rangle$ are orthonormal, too. One can take entangled Bell's states [10] as basic states for two-qubit ones

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

An Eqs (6) means that entanglement conserves in any basis. If one will send first photon of entangled pair to one observer (say, Alice) and the other to second observer (say, Bob) he can assert that results of their measurements will be corresponding one another despite arbitrary long distance between them. One should say some words about 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. The most of particles arising should be presumably in entangled states, because their number is exponentially larger than the number of non-entangled ones.

5. TOPOLOGY OF PHASE SPACE OF A PROBLEM ? What does this mean?

Phase space K of a problem is a space of co-ordinates and pulses which roles play electromagnetic potentials and fields which is created by source and receiver of radiation⁶. It is interesting to investigate the topology of K , in particular its connectivity. It is shown in works [7 – 9] that connectivity of K is at least more than one because K includes sub-space K_d which is formed by waves radiated by source and sub-space K_c which is formed by waves received by 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 shape of their front and which could be transferred to S_d by smooth transformation of co-ordinates⁷. 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 connectivities of K_c and K_d are equal one. The fact that K_c and K_d are not connected one with another leads 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 [7 – 9]⁸.

Figure 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 [7, 8]

⁶ Perturbation of metrics are significant only near source and receiver at the distances of the order of length of electromagnetic wave.

⁷ From the physical point of view role of that transformation plays wave's evolution in time according Maxwell equations.

⁸ Rigorously speaking results of works [7 – 9] concern the case when source and receiver coincide in space-time. It is easy to generalize their 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

The contents of this section seems to be separated from the rest of the paper.

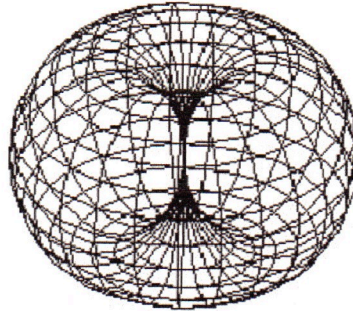


Fig. 2. Approximate topology of two-dimensional analog of K -space. Here vacuums V_c and V_d for convergent (S_c) and divergent (S_d) spherical waves are shown, which are coinciding in the center, i.e. in the fictive focus of that waves. Fronts of that waves looks like co-centric circles which centers lie on the axis of symmetry of figure. 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

6. CONCLUSIONS

Contemporary theoretical problems of field theory are solved with the help of topological methods which are based on using energy functional in Minkowsky space-time or functional of action in pseudo-Euclid space. The solution of interest are those which has finite pseudo-Euclid action [12]. These methods cannot be used to the full extent in the present case, because gravitational field rigorously speaking has no energy functional [13]. This fact, probably, restrained full solution the problem of propagation of electromagnetic waves in space-time which is curved by that waves themselves. It may be also, that solution of Maxwell-Einstein equations which was received by G.Y. Rainich [14] created the illusion of full solution of this problem.

Result presented in this article permits to formulate new approach in problems of cosmology, in particular to find new origin of isotropy of relict radiation. 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. Role of the source of entangled photons could play the Big Bang.

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