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IS THE HYPOTHESIS OF TIME MULTI-DIMENSIONALITY AT VARIANCE WITH THE FACTS?

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1. INTRODUCTION

In the middle of the last century C. F. Gauss in Göttingen and N. I. Lobachevsky in Kasan attempted to ascertain experimentally if the surrounding space is curved or not. Presently one may put an analogous question on a dimensionality of our time. Is it one-dimensional as we have got used to think or there are some hidden for us directions of time flow? Using the known Niels Bohr's classification, one can say that the question is believed, undoubtedly, to be "mad" one, however, theoretical constructions being a natural development of special relativity suggest that it is quite possible.

The Einsteinean theory of relativity was the first to reveal a symmetry in properties of space and time, the subsequent generalizations introducing a proper time for each particle and for each space point equalized space and time in right still more. Though this advance by himself did not discover any new physical effects, it improved essentially the theory and allowed to formulate a condition of compatibility for motion equations forbidding an exchange of faster-than-light signals and to develop a simple renormalizatiom procedure. It is interesting now to take a next step on this way and to consider a more consistent from relativistic viewpoint theory with the equal number of space and time co-ordinates.

The performed investigations [1] convince us that such an approach is logically consistent. True, several authors concluded that in any multi-temporal theory difficulties must appear due to negative particle masses and energies (2,10,11), however, taking into account the principle of time irrevesibility, one can avoid this shortcoming (12,13) [2].

[1]See papers (1–6) and reviews (7,8) where one can find a more detailed bibliography.

[2]By the way, the difficulties with negative masses and kinetic energies take place already in the usual one-time theory where one gets rid of them only by means of an special prohibition to use the negative values of mass and energy though a presence of such quantities is permissible in the modern theory from a logical point of view (9). In multi-time theory the energy is directed along the time vector, therefore its negative

The goal of our paper is to compare the multi-time theory with the known experimental data at level of large macroscopic scales. The availability of contradictions would be a proof of time one-dimensionality, their lack, on the contrary, attracts, we hope, physicists attention to the multi-time generalizations. A peculiar attention will be focused on an Mercury perihelion advance for which a value strong contradicting the observed one is calculated in the paper [14].

2. IRREVERSIBLE TIME VECTOR

Let us consider space and time co-ordinates as utterly equal in right quite independent components of a six-dimensional vector [3].

$$(\hat{\mathbf{x}})_\mu = (-\mathbf{x}, c\hat{t})^\mu = (\mathbf{x}, c\hat{t})^{T\mu}.$$

Positions of any body on its trajectories in x- and t-subspaces are determined by a scalar "proper time" t:

$$\mathbf{x} = \mathbf{x}(t) \quad , \quad \hat{t} = \hat{t}(t),$$

where t is a length along the t-trajectory. This trajectory itself can be determined in this case by a unit vector $\hat{\tau} = d\hat{t}/dt$.

An important feature of our approach is a requirement of time irreversibility, i. e. of impossibility to reproduce any event in all its details backward in time what is a direct consequence of an inexhaustibility of inner and outer interconnection of every material object. Namely, this property of Nature, but not a specific time non-invariant process is a reason of the invariant "time arrow". A punctual repetition of all alterations

sign corresponds to an opposite time flow what is forbidden by the principle of time irreversibility. This principle is dicussed in the next section.

[3]Here and in what follows the superscript "T" denotes the transpose, three-dimensional vectors in x- and t-subspaces will be denoted, respectively, by bold symbols and by a hat. We shall denote six-dimensional vectors by bold symbols with a hat. The latin and greek indices take values $k = 1, ..., 3, \mu = 1, ..., 6$).

of any system is possible only in approximate theories taking into account a finite number of parameters. Only such theories are T-invariant what, however, comes never true in the real world where one can find for every process a preceding cause and its more late in time effect. These events can not be displaced. On philosophical level it is formulated as the principle of causation [4]. We are always able to distinguish them in every process and that reveals quite uniquely the time arrow which is given for our world during a'priory, i. e. at the first moments of its creation.

Basing on the mentioned material reason of time irreversibility, one has to admit that this property must be true for any time direction. It means that a preferred ("relic" from the cosmological point of view) time reference frame must exist in multi-dimensional universe. Projections of all time trajectories on the axes t_i must be always positive: $\hat{\tau} = d\hat{t}/dt \geq 0$. Particularly, in the two-dimensional case the t-trajectory of every body must pass on from the third angular quadrant to the first one.

The use of other co-ordinate systems turned with respect to the relic one makes sense of a formal renumbering of time co-ordinates just as an inverse time reading which we use some time in our everyday practice.

As an inflation swelling of the universe violated a space-time co-ordination of its remote regions (during the superluminal inflation there is no point in a notion of the co-ordinate system), these regions, gener-

[4]Several elucidation of the time irreversibility must be added in the case of elementary particle interactions which possesses a high symmetry with respect to a change of time direction. Some authors (see, for example, the books [15,16] conclude on these grounds that the time irreversibility is the purely macroscopic property arising in a process of a statistical averaging of completely T-invariant microscopic events. One must not forget, however, that our description of elementary processes demands taking into account macroscopic surroundings. This circumstance is reflected already in a notion of ψ-function itself. Describing elementary processes, we attract ourself away from a consideration of accompanying time irreversible alterations of the macroscopic, large scale surroundings. It means a some idealization, an approximate excising of some important for us phenomena from an extremely complicated background of unessential details. One can say that T-invariance is peculiar to physical laws but not to reality itself [17].

ally speaking, possess the own relic reference frames and exist in a times which can be different from our one. However, due to a great space between such parts of the world, a chance to meet any macroscopic body with "not our" time trajectory is as small as a chance to discover a relic magnetic pole (if only such bodies are not created anywhere inside our part of the universe; see sec. 6).

3. SUPERLUMINAL VELOCITIES

Let us define now a six-dimensional velocity vector

$$\hat{\mathrm{v}} = \frac{d\hat{\mathrm{x}}}{d\hat{\tau}} = -(\hat{\tau}\hat{\nabla})\hat{\mathrm{x}} = \tau_i \frac{\partial \hat{\mathrm{x}}}{\partial t_i} = \frac{d\hat{\mathrm{x}}}{dt} = (\mathrm{v}, c\hat{\tau})^T, \qquad (1)$$

where $\hat{\nabla} = (-\partial/\partial t_1, -\partial/\partial t_2, -\partial/\partial t_3)$ is the time analog of the three-dimensional space operator ∇ taken with the opposite sign.

If we notice that a differential of the squared length in the six-dimensional space-time

$$ds^2 = c^2(d\hat{t})^2 - (d\mathrm{x})^2 = c^2(dt)^2\,[1 - c^{-2}(d\mathrm{x}/dt)^2] = dt^2/\gamma^2, \qquad (2)$$

where $\gamma = [1 - (v/c)^2]^{1/2}$, then the velocity vector can be written in the covariant form

$$\hat{\mathrm{u}} = d\hat{\mathrm{x}}/ds = \gamma d\hat{\mathrm{x}}/dt = \gamma\hat{\mathrm{v}}. \qquad (3)$$

As in the one-time case the scalar product

$$\hat{\mathrm{u}}^2 = \gamma^2\hat{\mathrm{v}}^2 = \gamma^2(c^2\hat{\tau}^2 - \mathrm{v}^2) \qquad (4)$$

and a light wave front has always the spherical form:

$$\sum_i(\Delta x_i^2 - c^2\Delta t_i^2) = \Delta t^2 \sum_i (v_i^2 - c^2\tau_i^2) = \Delta t^2(v^2 - c^2) = 0, \qquad (5)$$

i. e. in any direction of the x-subspace the body speed does not exceed the light velocity.

It is very important to emphasize that the body speed $\mathbf{v}$ is defined with respect to an increment Δt along the body time trajectory $\hat{t}$. If it is unknown and an observer uses his proper time $\Delta t_p = \Delta t \cos\theta$ where θ is the angle between the body and observer's time trajectories, then the quantity $\mathbf{v_p} \equiv \Delta \mathrm{x}/\Delta t_p = \mathrm{v}/\cos\theta$ defined in this way may turn out to be larger than the light velocity. In this case the considered body behaves, from the observer's viewpoint, like a tachyon. For example, if $\theta \simeq \pi/2$, it passes any finite distance practically instantaneously and "grows old" straight away. Nevertheless, as it was shown in the papers [2-4], Lorentz transformations depend on $\mathbf{v}$ but not on $\mathbf{v_p}$, therefore, in the multi-temporal world no acausal effects can be observed by transformations to moving reference frames in contrary to true tachyons which transfer an information in the new frame, as it is judged by the observer, backwards in time [17,18].

A discovery of any superluminal motions in experiment would be a serious indications on multi-dimensionality of world time. As it is known, faster-than-light objects are indeed observed by astronomers. Though up to now they succeeded in interpreting suchphenomena as optical illusions within the limits of one-time notions as optical illusions(see, for example, papers [19,20] where there are more detailed references), one can not exclude that among the observed superluminal objects there are bodies moving along the distinct time directions.We need more experimental information to identify such bodies.

4. GHOSTLY BODIES

Besides the superluminal illusions, multi-time theory predicts another amusing phenomenon which can be observed in experiment. In our world luminous bodies remain visible all the time while they emit light, however, in the multi-temporal case their luminescence is seen, as a rule, only in some restricted time interval. For example, if a motionless in x-

subspace luminous body intersects the observer's t-trajectory at an angle θ, one can show (12) that this observer sees its luminescence only in the interval

$$T = \frac{R}{c}\frac{\sin(\varphi+\theta)}{\sin\theta}[1+\cot(\varphi+\theta)] \tag{6}$$
$$\simeq R/c\theta \qquad \text{for} \quad \varphi, \theta \ll 1,$$

Where R is the constant distance between the body and the light detector, φ is the inclination of the observers t-trajectory with respect to the axis of the mentioned above preferred ("relic") reference frame (Fig.1).

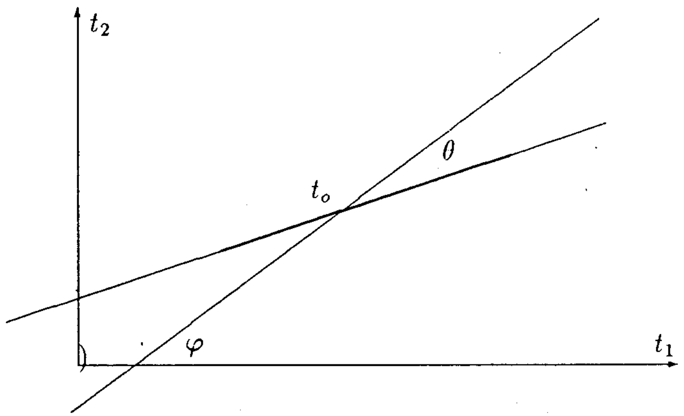

Fig.1. The luminescence is seen only in a restricted interval of the observer's proper time around the intersection point t_o. In order not to complicate the picture, we confine oneself by a case when the luminous body and observer's trajectories are disposed on the same plane and the axis t_3 can not be mentioned.

One should notice that the expression (6) differs from the that derived by Cole and Starr [21,22] who did not take the time irreversibility into account. Nevertheless, in both cases the conclusion about the limitedness of luminescence time is valid. Particularly, because the duration of an interaction of two bodies is proportional to their mutual distance, the interaction time of nearly placed bodies is equal practically to zero, i.

e. they "see" each other only an instant, when their trajectories are intersect.A subsequent communication of these bodies is possible only with the help of subluminal signals. For angles $\theta \leq 1^{\circ}$ and distances of the order of thousand km and less the interaction duration is equal to part of second i. e. the close light sources turn practically at once into invisible "ghostly bodies". Only very remote cosmic objects can shine uninterruptedly for a long time.

One may wait also for any unusual explosive phenomena at the moment when the time trajectories of located an the same place bodies intersect each other.

As we do not encounter, however, an appearance of material objects "from anywhere" or their disappearance "in nowhere", and do not observe inexplicable explosions, one may be sure that the time trajectories of all surrounding us bodies are extremely close to each other: $\theta = 0$.

5. MERCURY ORBITAL PRECESSION

As it is noticed above, the discussion of this phenomenon is of special interest because the calculated in paper [14] advance of Mercury perihelion is 2.3 times larger than observed one.

We start from a lagrangian

$$L = \frac{1}{2mc^2}\hat{\mathbf{u}}^2 - \frac{m}{c}\hat{\mathbf{u}}\hat{\mathbf{A}}, \tag{7}$$

where the potential $\hat{\mathbf{A}} = (0, \hat{\varphi}(\mathbf{x}))$ and

$$\hat{\varphi}(\mathbf{x})\hat{\tau}_s = -\kappa M/r \tag{8}$$

is a solution of the Poisson equation

$$\nabla^2\hat{\varphi} = 4\pi\kappa M\hat{\tau}_s\delta(r). \tag{9}$$

Here M and $\hat{\tau}_s$ are the Sun mass and the Sun time vector, m and $\hat{\mathbf{u}}$ are the planet mass and its covariant velocity.

It is not difficult to proof that like the usual one-time theory the planet energy

$$\hat{E} = \partial L/\partial \hat{u} = mc\gamma\hat{\tau} - \kappa m M/cr$$

is conserved, therefore, if comparing values of a scalar product $\hat{E}\hat{\tau}_s$ at a point $\mathbf{x}$ and at some fixed point $\mathbf{x_o}$, one can determine the cosine of an angle between Mercury and Sun time trajectories:

$$\chi(\mathbf{x}) \equiv \hat{\tau}\hat{\tau}_s = \frac{1}{m\gamma c^2}\left(\frac{c}{m}\hat{E}\hat{\tau}_s + \frac{\kappa M}{r}\right) = \gamma^{-1}\left[\chi_o\gamma_o + Q(\mathbf{x})\right], \qquad (10)$$

where

$$Q(\mathbf{x}) = \kappa c^{-2} M(1/r - 1/r_o)$$

γ_o and χ_o are the values of the corresponding quantities at the point $\mathbf{x_o}$. In what follows we suppose that $\mathbf{x_o}$ is a perihelion point.

To calculate $\gamma(\mathbf{x})$, we use the equations of motion

$$d(\gamma\mathbf{v})/dt = -c^{-2}\xi\nabla\varphi \qquad (11a)$$

$$d(\gamma\hat{\tau})/dt = -\gamma c^{-2}\hat{\tau}_s\nabla\varphi. \qquad (11b)$$

obtained from (7) by means of the variation principle.

Let us multiply the first of these equations on the space vector $\mathbf{v}$ and the second equation on the time vector $\hat{\tau}_s$. Afterwards, multiplying cross-wise the left and parts of the resulting relations, we get a symmetrical expression

$$\mathbf{v}d(\gamma\mathbf{v}) = c^2 d(\gamma\chi). \qquad (12)$$

If we take into account now the relation $d\gamma = \gamma^3 v dv = \gamma^3 \mathbf{v}d\mathbf{v}$, one can rewrite (12) as

$$d\beta^2/(1-\beta^2) = d\chi^2/(1-\chi^2), \qquad (13)$$

where $\beta = v/c$.

An integral of this equation has the form

$$1 - \chi^2 = \alpha(1-\beta^2) \qquad (14)$$

or

$$\gamma^2 = \gamma_o^2(1-\chi_o^2)/(1-\chi^2) = \gamma^2 + Q(\mathbf{x})\left[2\chi_o\gamma_o + Q(\mathbf{x})\right], \qquad (15)$$

where the constant α is determined at the perihelion $\mathbf{x_o}$ and the expression (10) is taken into account.

While the planet velocity $\beta_o = \ell/mcr_o$ (r_o is the distance from the Sun, ℓ is the orbital angular momentum) and, besides, the quantities $Q(\mathbf{x}) \ll 1$ and $\gamma_o \simeq 1$ for all planets, one can rewrite the expressions (10) and (15) in the form

$$v^2 \simeq 2\kappa\chi_o M(1/r - 1/r_o) + (l/mcr_o)^2, \qquad (16)$$

$$\chi \simeq \chi_o + \kappa M c^{-2}(1/r - 1/r_o)(1-\chi_o^2). \qquad (17)$$

On the other hand, the velocity v can be expressed through a total planet kinetic and potential energy $\mathcal{E} = \hat{E}\hat{\tau} - mc^2 \simeq mv^2 + m\varphi\chi$:

$$v^2 \simeq 2\mathcal{E}/m + 2\kappa\chi M/r. \qquad (18)$$

Let us equate now the right parts of (16) and (18), we obtain then a quadratic equation with the solution

$$r = a(1-\varepsilon), \qquad (19)$$

where

$$a = \frac{km M\chi_o}{2\mathcal{E}}, \quad \varepsilon = \left[1 - \left(1 - \frac{2\mathcal{E}\ell^2}{\kappa^2 m^3 M^2 c^2}\right)^{1/2}\right], \qquad (20)$$

and ℓ is the Mercury orbital momentum.

If the planet velocity v is known as a function of r and r_o and we use the expressions (20) for the perihelion $r_o = a$, one can calculate [5] a perihelion precession angle per one planet turn stipulated by a deviation of the gravitation potential $\varphi\chi$ from the Newtonean one $\varphi = -\kappa M/r$:

$$\theta = \frac{2\pi}{1-\varepsilon^3} - \frac{\kappa M}{ac^2}\frac{1-\chi_o^2}{\chi_o - (1-\xi_o^2)\kappa M/r_o c^2} \simeq$$

[5] see, for example, analogous calculation in §15 of a book [23].

$$\frac{2\pi}{1-\varepsilon^2}\frac{\kappa M}{a\chi_o c^2}(1-\chi_o^2) \tag{21}$$

This value must be supplemented by a correction θ_{gr} stipulated by a space-time metric distortion due to the Sun gravitation. While, contrary to x-subspace where all three directions x_i around a motionless gravitating body are quite equivalent, in t-subspace a motion along some trajectory $\hat{t}(t)$ take place always, therefore only two time directions are independent and a squared space-time differential

$$ds^2 = e^{\nu}c^2(dt^2 + t^2 d\psi^2) - e^{\lambda}dr^2 - r^2(D\theta^2 + sin^2\theta d\varphi^2). \tag{22}$$

Here $d\psi^2 = d\chi^2/(1-\chi^2)$, the functions ν and λ depend on r, t, χ.

One may see from (17) that at large r and r_o (i. e. for $Q \ll 1$) the value of χ is practically constant and $d\chi \simeq 0$. In this case the known Schwarzschild's expression

$$e^{\nu} = e^{-\lambda} = 1 + \alpha/r \tag{23}$$

can be used for the functions ν and λ. The constant $\alpha = \kappa M\chi_o$ is determined in comparison with the solution of non-relativistic equation (9): $\alpha = \kappa M\chi_o$.

So, the desired angular correction differs from the one-time one θ^o_{gr} only by a factor χ^2:

$$\theta_{gr} = \theta^o_{gr}\chi^2 = \frac{6\pi\kappa M}{ac^2}\frac{\chi_o^2}{1-\chi^2}. \tag{24}$$

A predicted summary correction to advance of the perihelion calculated by means of the one-time theory

$$\Delta\theta = \theta + \theta_{gr} - \theta^o_{gr} = \theta^o_{gr}(\chi_o^2 - 1)(1 - 1/3\chi_o). \tag{25}$$

It is well known that within the experimental error of the perihelion advance $\Delta\theta_{exp} \simeq \pm 0.9''$ per century the observed perihelion advance agrees precisely with the one-time correction θ^o_{gr}. If we suppose that Mercury turns around the Sun approximately during the same time as our

Earth, than it follows from the expression (6) that $\Delta\theta < 10^{-10}\Delta\theta_{exp}$ and, therefore, the multi-dimensional correction (25) is less than $10^{-10}\Delta\theta_{exp}$.

A principal different results is obtained in the paper [14], where an angle independent multi-time correction $\Delta\theta = 7\theta^o_{gr}/3$. This result would be considered as a demonstration of the one-dimensionality of our Universe. However, it is a consequence of the use instead of the vector quantity $\overset{o}{\varphi}(\mathbf{x})$ the scalar potential $\varphi(r)$, which is independent of the time vector $\hat{\tau}_s$. Such an approach means an equivalent treating of all three time coordinates t_i what triples the coefficient in the expression of Ricci tensor determining the value of $\Delta\theta$. (In the paper [14] the non-relativistic correction (21) is not taken into account either).

6. CONCLUSION

In the region of macroscopic phenomena the hypothesis of the time multi-dimensionality does not contradict any known now experimental fact. It is quite possible that our World is like that indeed. Nevertheless, the comparison of the theory with experiment proves the high degree of a time flow parallelism in the surrounding us part of the Universe.

Energy conservation and time irreversibility laws forbid any change of body time trajectories because in each such a case the bodies with compensating energy components $E_i < 0$, i. e. moving backward in time, have to present. (It will be recalled that time vectors $\hat{\tau} \sim \hat{E}$). Objects whose time trajectories are differ from our one can be found only in microscopic phenomena and in regions with strong gravitation fields where usual (classical) energy conservation law does not act.

There is one more possibility to find an object possessing a distinct t-trajectory — when the time trajectories of a decaying body and products of its decay are strongly declined with respect to the axes of the mentioned above preferred reference frame. In such cases all projections of time vectors $\hat{\tau}$ can be positive. As we do not observe any described above peculiarities associated with time multi-dimensionality, one may conclude that our own t-trajectory is close to the preferred reference frame t-axis.

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Барашенков В.С., Юрьев М.З. E2-96-246
Противоречит ли гипотеза многомерного времени экспериментальным фактам?

Обсуждается, в каких макроскопических экспериментах и астрофизических наблюдениях можно обнаружить многомерность времени, если она действительно существует в нашем мире. Показано, что в настоящее время нельзя указать ни одного факта, который противоречил бы этой гипотезе.

Работа выполнена в Лаборатории вычислительной техники и автоматизации ОИЯИ.

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Barashenkov V.S., Yur'iev M.Z. E2-96-246
Is the Hypothesis of Time Multi-Dimensionality at Variance with the Facts?

We discuss in which macroscopic experiments and astrophysical observations one can reveal a multi-dimensionality of time, if it indeed exists in our world. It is shown that there is no fact at present which would be in contradiction with such a hypothesis.

The investigation has been perfomed at the Laboratory of Computing Techniques and Automation, JINR.

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