Why We Can Not Walk To and Fro in Time as Do it in Space? (Why the Arrow of Time is Exists?)

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Existence of arrow of time in our world may be easy explained if time has multifractal nature. The interpretation of nature of time arrow is made on the base of multifractal theory of time and space presented at works [5]-[19]. In this paper shown possibility to walk to and fro in space and necessity of huge amount of energy for stopping time and changing direction of it in microscopic volumes.

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I. INTRODUCTION

As is well known the time flows in our world only in future (arrow of time of Eddington [1] and Prigogin [2]) and now nobody knows is it possible to change direction of the time flow or is it impossible and why if it is possible or impossible. The problems of arrow of time are very intriguing and many of physicians presented interesting models of it phenomenon (see for example [3], or new interesting experiments [4]). For analyzing this problem it is necessary to investigate the models of time in which the time is not simple time axes, but has complicated structure. The purpose of this paper is to investigate problem of time arrow in the multifractal model of time presented in fractal model of space and time at [5]-[19]. In this model the time and the space are real fields with fractional dimensions and multifractal structure (multifractal sets) defined on sets of their carriers of measure. In every time (or space) points the dimensions of time (or space) determine densities of Lagrangians energy for all known physical fields (or Lagrangian of new physical fields for space dimensions) in these points. This model allows understand reason of existence of the arrow of time: this reason has pure energetically nature and consists in necessity to use huge amount of energy for changing of direction of time.

II. UNIVERSE AS TIME AND SPACE WITH FRACTIONAL DIMENSIONS

In this paragraph we summary the main results of the fractal theory of time and space [5]-[19]. In this theory, when Universe was born (the moment of "big bang") from vacuum (in this theory Universe was born from the set of carrier of measure which plays role of physical vacuum) only material fields were born (or appear on surface of carrier of measure-vacuum): the time and the space fields with fractional dimensions. So our Universe are real fields of time and space and not conclude something yet. Fractional dimensions of time and space are appearing in our world as physical fields (all physical fields, known and new fields that will be find, are characteristics of time with fractional dimensions). When temperature of Universe (i.e. the temperature of fields of time and space) was changing, fractional dimensions was changing too and new physical fields were appearing in accordance with known theory of "big bang" and broken symmetry (depending at Universe temperature). The equations for physical fields appear as consequences of principle of fractal dimensions functional (FDF) minimum. These equations are Euler equations with generalized fractional Riemann-Liouville derivatives (the generalization consists in propagating the Riemann-Liouville derivatives on domain of multifractal sets where fractional dimensions are functions of time and coordinates). For case of integer dimensions these derivatives and equations coincide with ordinary derivatives and the theory in whole coincides with known physical theories. So
only difference of the theory [3] - [19] from known theories consists in using the algorithm for propagating modern theories on the domain of the Universe with fractional dimensions of time and space and geometrization of all physical fields in frame of fractal geometry of world. In cited works many equations of modern physics were researched in fractal space and time. It was shown that in multifractal model all physical fields are geometrized. It differs this theory positively from general relativity theory (the latter is a special case of multifractal theory of time and space in special selection of measure carrier and integer dimensions (see [3] ) where only one field (gravitation field) is geometrizationed. In the world of fractional dimensions there are many new special physical characteristics and peculiarities. The main of them are:

a) in the world with fractal dimensions there are no constant physical values because fractional derivative with respect to constant value is not zero. So all physical values are changing in time and in space ( for example, electric charge of electron has changed from the time of big bang as \( e \delta t = e \varepsilon / t \) where \( t = t_0 + \delta t \) and \( \delta t \) is current time, \( t_0 \) -is the time of existence of Universe). Consequences of it are absence in this world any rigorous laws of preservation (they are fulfilled only as very good approach, but not as rigorously laws);

b) there are no inertial systems in Universe because there are no constant velocities and special Einstein theory must be replaced by theory of almost inertial systems (it coincide with special relativity theory on the surface of Earth till velocities \( v = c - \delta v \), \( \delta v \sim 100 \text{msec}^{-1} \); On the surface of Earth the fractional dimensions of time differs from unity on value \( \sim 10^{-9} \).

c) all systems of reference are absolute systems (time and space are non homogeneous and non isotropic). So Michelson experiments had proved independence of speed of light at moving of origin of light are only very good approach ( on the surface of Earth the changing of direction \( v \) on \( -v \) in the fractal world gives change of speed of light on value \( \sim 0.1 \text{cm/sec}^{-1} \));

d) in the fractal world velocities of moving bodies may be equal speed of light in vacuum (there are no singularity at \( v = c \) or exceed it and it is possible to propagate information with any wished velocities;

e) there are no singularities in the theory because for \( V(r) \sim \infty \) (\( V \) is a potential of any fields) all fractional differential operators of the theory turns into fractional integrals;

f) all physical (i.e. Newton ,Shrödinger, Maxwell, Dirac, Einstein and so on ) equations of modern physics are irreversible;

g) the laws of thermodynamics are consequences of multifractal structure of Universe for its domain with state near thermodynamics equilibrium;

h) the theory predicts existence of new fields originated by fractional dimensions of space ;

i) the theory predicts existence of new physics in the domain of superluminal velocities in vacuum for ordinary (not taxions) particles with new effects that may be experimentally discovered;

j) in the fractal world the time has inertial characteristics described by \( m_t \) in analogy with well known Newton mass \( m_t \) and equations for \( t(r) \) are exist (analogies of Newton, Dirac and so on equations);

k) the theory have two masses: masses \( m_t \) as measure of inertia for moving in the time(Newton masses) and masses \( m_r \) as measure of inertia for moving in space (masses concerned with inhomogeneous time in the space);

l) the presented theory is a natural generalization of all modern physical theories for domains of time and space with fractional dimensions and coincide with any of them in the case when fractional parts of dimensions are zero. This theory is not the variant of theories of quantum time and quantum space, because the multifractal "intervals" of space and time had used in the theory (the time and the space are consist of them) are very composed multifractal sets and researching its structure lay in future.

The question about irreversibility of time (the arrow of time) in the theory of fractal time and space ( (3) - (4) ) was not researched. This paper has purpose to investigate why the time has only one direction in our world on the base of the multifractal theory of time and space (3) - (19).

III. WHY TIME HAS DIRECTION ONLY TO FUTURE AND WHY IMPOSSIBLE TO WALK IN TIME TO AND FRO?

In the theory of fractal time and space the problem of existing in Universe the arrow of time may be considered (we show it below) as the problem of decreasing of the energy for the states when the time arrow has direction to future. We will show that in the domain of multifractal Universe with time dimensions less than unit and when the fractional parts of time dimensions are small additions (with negative signs) to unit , the arrow of time with direction to future gives decreasing of energy for any body in this domain of Universe. So the arrow of time gives spontaneous decreasing (diminishing) of Universe energy in these domains (and in Universe on the whole).

For demonstrating it let us write the quantum equations for model particle with a rest mass \( m \) and momentum \( p = 0 \) for two cases: in the time space with integer dimensions and in the time space with fractional dimensions

\[
i \hbar \frac{\partial}{\partial t} \psi(r, t) - mc^2 \psi(r, t) = 0 \quad (1)
\]

\[
i \hbar D_{0,t}^{d_1} \psi(r, t) - m^2 \psi(r, t) = 0 \quad (2)
\]

In (3) we used generalized fractional derivative \( D_{0,t}^{d_1} \) defined as (see [3] - [19] ). Following these works we consider
both time and space as the initial real material fields existing in the world and generating all other physical fields by means of their fractal dimensions. Assume that every of them consists of a continuous, but not differentiable bounded set of small intervals (these intervals further treated as "points"). Consider the set of small time intervals $S_t$ (their sizes may be evaluated in rude approach as Planck sizes). Let time be defined on multifractal subsets of such intervals, defined on certain measure carrier $\mathcal{R}^N$. Each interval of these subsets (or "points") is characterized by the fractional (fractal) dimension (FD) $d_i(r(t),t)$ and for different intervals FD are different. In this case the classical mathematical calculus or fractional (say, Riemann - Liouville) calculus \[22\] can not be applied to describe a small changes of a continuous function of physical values $f(t)$, defined on time subsets $S_t$, because the fractional exponent depends on the coordinates and time. Therefore, we have to introduce integral functionals (both left-sided and right-sided) which are suitable to describe the dynamics of functions defined on multifractal sets (see \[3\], \[4\]). Actually, these functionals are simple and natural generalization of the Riemann-Liouville fractional derivatives and integrals:

$$D_{\tau,t}^d f(t) = \left(\frac{d^d}{dt^d}\right) \int_{\tau}^{t} \frac{f(t')dt'}{\Gamma(n-d(t'))(t-t')^{d(t')-n+1}}$$

$$D_{\tau,t}^{-d,t} f(t) = (-1)^n \left(\frac{d^n}{dt^n}\right) \int_{\tau}^{t} \frac{f(t')dt'}{\Gamma(n-d(t'))(t-t')^{d(t')-n+1}}$$

where $\Gamma(x)$ is Euler’s gamma function, and $a$ and $b$ are some constants from $[0, \infty)$. In these definitions, as usually, $n = \{d\} + 1$, where $\{d\}$ is the integer part of $d$ if $d \geq 0$ (i.e. $n-1 \leq d < n$) and $n = 0$ for $d < 0$. If $d = const$, the generalized fractional derivatives (GFD) \[3\]-\[4\] coincide with the Riemann - Liouville fractional derivatives ($d \geq 0$) or fractional integrals ($d < 0$). When $d = n + \varepsilon(t)$, $\varepsilon(t) \to 0$, GFD can be represented by means of fractional derivatives and integrals. For $n = 1$, that is, $d = 1 + \varepsilon$, $|\varepsilon| << 1$ it is possible to obtain:

$$D_{\tau,t}^{1+\varepsilon} f(r(t),t) \approx \frac{\partial}{\partial t} f(r(t),t) + a \frac{\partial}{\partial t} \varepsilon(r(t),t) f(r(t),t) + \frac{\varepsilon(r(t),t) f(r(t),t)}{t}$$

where $a$ is a constant and determined by choice of the rules of regularization of integrals ( \[3\]-\[4\], \[11\]) (for more detailed see \[1\]) and the last addendum in the right hand side of (5) is very small. The selection of the rule of regularization that gives a real additives for usual derivative in (3) yield $a = 0.5$ for $d < 1$. The functions under integral sign in (3) we consider as the generalized functions defined on the set of the finite functions \[22\]. The notions of GFD, similar to \[3\]-\[4\], can also be defined and for the space variables $\vec{r}$. The definitions of GFD \[3\]-\[4\] needs in connections between fractal dimensions of time $d_i(r(t),t)$ and characteristics of physical fields (say, potentials $\Phi_i(r(t),t)$, $i = 1, 2, \ldots$) or densities of Lagrangians $L_i$) and it was defined in cited works. Following \[3\]- \[19\], we define this connection by the relation

$$d_i(r(t),t) = 1 + \sum_i \beta_i L_i(\Phi_i(r(t),t))$$

where $L_i$ are densities of energy of physical fields, $\beta_i$ are dimensional constants with physical dimension of $[L_i]^{-1}$ (it is worth to choose $\beta_i$ in the form $\beta_i = a^{-1} \beta_i$ for the sake of independence from regularization constant). The definition of time as the system of subsets and definition of the FD for $d^i$ (see \[3\]) connects the value of fractional (fractal) dimension $d_i(r(t),t)$ with each time instant $t$. The latter depends both on time $t$ and coordinates $\vec{r}$. If $d_i = 1$ (an absence of physical fields) the set of time has topological dimension equal to unity. The multifractal model of time allows ( as was shown \[22\]) to consider the divergence of energy of masses moving with speed of light in the SR theory as the result of the requirement of rigorous validity of the laws pointed out in the beginning of this paper in the presence of physical fields (in the multifractal theory there are only approximate fulfillment of these laws). We bound consideration only the case when relation $d_i = 1 - \varepsilon(r(t),t)$, $|\varepsilon| \ll 1$ are fulfilled. In that case the GFD may be represented (as a good approach) by ordinary derivatives and relation \[3\] are valid. So the equation \[3\] reeds

$$\frac{i \hbar}{\partial t} \psi(\vec{r},t) - mc^2 \psi(\vec{r},t) + \frac{\hbar}{\partial t} \varepsilon(\vec{r},t) \psi(\vec{r},t) + i \hbar \frac{\partial}{\partial t} \left[ \varepsilon \psi(\vec{r},t) \right] + \frac{i \hbar}{\partial t} \frac{\partial \psi}{\partial \varepsilon} = 0$$

This equation describes behavior of the particle with point sizes in time and space (we remind that it is only the approach that we use and in reality minimal size of time intervals and minimal sizes of space intervals in the theory are bound, for example, by Planck sizes, thou the last are multifractal sets too) For free (more rightly almost free) particle choose solution for $\psi$ as a plane wave with energy depending of time ($\psi = \psi_0 \exp(-i \hbar E(t)/\hbar)$) and for domain of time-space where by members with $\partial \varepsilon/\partial t$ may neglect (i.e. fractional additives almost constant) receive

$$\psi(t) = \psi_0 \exp\left(-\frac{i \hbar}{\hbar} E(t) t\right)$$

$$E(t) = mc^2 + \frac{\hbar}{\varepsilon} \frac{\varepsilon - i \hbar \ln t}{\varepsilon}$$

or

$$\psi(t) = \frac{\psi_0}{\frac{\varepsilon}{\varepsilon}} \exp\left(-\frac{i \hbar}{\hbar} E(t)t\right)$$

where
that approach point particle presents because the fractional dimensions evaluation of the lose energy in the point of space where evaluates in next paragraph). Rigorously say we made sizes of particles ( partly the energy of damping will be alistic model it is necessary to take into account a really "interval" of space, described above). For more realistic model it is necessary to take into account a really sizes of particles ( partly the energy of damping will be evaluates in next paragraph). Rigorously say we made evaluation of the lose energy in the point of space where point particle presents because the fractional dimensions that are sources of the real particle mass may be so large that approach \( \varepsilon \ll 1 \) is not work.

**IV. IS IT POSSIBLE TO CHANGE THE DIRECTION OF TIME AND HOW MUCH ENERGY IT NEEDS ?**

In this paragraph we research the question: may the time be turned in back direction? The energies needs for is possible to evaluate if use rude approach . The example for behavior of the free model particle has demonstrated the damping of energy in Universe with fractional time dimensions ( the case of decreasing energy as consequences of existence of fractional dimensions of space is analogies). Thus the question why the time has only one direction towards future has natural answer: it is because only in that direction of time the energy of particles ( or any bodies consisting of particles) decrease. If somebody wants to change the direction of time it is necessary to spend energy for changing structure of real fields of time and space. On the first look this energy is very small ( see above paragraph), but its smallness is related with the case when multifractal "intervals" of time and space ( \( \Delta t \) and \( \Delta r \) ) were treated as "points" with fractional (global for sets consisting of the time field) dimensions and equation (14) describes the lose energy only of such points "intervals". What are values of time and space "intervals " in our Universe? The theory of fractal time and space in her present state can not answer on this question. So we use some hypotheses about their values. As the rude approach we may take for its values Planck sizes: \( \Delta t \sim 10^{-43} \text{sec} \) and \( \Delta x \sim 10^{-33} \text{cm} \). Then one second consists of \( 10^{44} \) of "intervals" of time and one centimeter consists of \( 10^{33} \) "intervals" of space ( we needs to remember that every of "intervals" is multi-

\[
\Delta E \sim \frac{\varepsilon \hbar}{t_0} 10^{44} 10^{-32} 10^{99} \sim 10^{45} \text{ev}
\]  

(12)

If such gigantic energy will be received by time field with space volume \( 10^{-42} \text{cm}^3 \text{sec} \) the flow of time during one second be stopped and if double this energy during one second the time flow change its direction ( i.e. \( t \rightarrow -t \) and time will flow one second in back direction). Thus the direction of time in our Universe may be changed but it needs in the gigantic amount of energy. Of course, the value of this energy depends at the evaluation of the "intervals" of time and space values and if last values more than Planck intervals ( for example at \( 10^{5} \sim 10^{10} \) the energy will be smaller but also huge. Result is: in principle the inversion of direction of time may be reached but it is impossible on the modern state of humankind technology even for microscopic volumes. If values of time and space intervals needs in corrections, the evaluation of energy needs for inversion of direction must be corrected too.

V. HOW MUCH ENERGY NEEDS FOR STOPPING THE TIME AND MOVING IT BACK IN THE VOLUME OF ONE CUBIC CENTIMETER DURING ONE SECOND?

In the multifractal fractal theory of time and space where time and space fields are real themselves and are real origin of all physical fields in principle ( it was shown in above paragraph) there are possibilities to inverse the time flow in back direction. Now we write the equation for changing with time of one Planck interval of space \( x_p \) and see how the energy of it (as a part of real space field it has energy of rest which damping with flow of time) changes in time (let this Planck volume is in rest, i.e. \( p = 0 \))

\[
i \hbar \frac{D^p_{x_p} x_p}{t} = E_0 x_p
\]  

(13)

or

\[
i \hbar \frac{\partial}{\partial t} x_p = E_0 x_p - \frac{\varepsilon}{\hbar} x_p
\]  

(14)

The solution of (14) may be represented as

\[x_p = x_0 \exp \left( \frac{-i}{\hbar} E(t) t \right)
\]  

(15)

where

\[E(t) = E_0 + \frac{\varepsilon \hbar}{t}
\]  

(16)
Now evaluate the volume $x_p$ using Planck interval and use earlier values of $\varepsilon, t_0, h$. If connection binding every element $r$ with element $t$ has the form $dr^2 - dt^2 = 0$ and for each element of space spending energy each element of time spend energy too, thus for the energy lose of space volume equal one $cm^3$ during one second write

$$\triangle E \sim \frac{\varepsilon}{t_0^2} \times 10^{99} \times 10^{44} \times 10^{12} ev \sim 10^{-68} \times 10^{155} ev \sim 10^{87} ev \quad (17)$$

So we got the order of values of energy needs for stopping the time in the $cm^3/sec$. For inversion of time flow in this volume needs double this value of energy. For stopping time in the volume of one elementary particle necessary multiply above value at $10^{-42}$ (if size of particle $\sim 10^{-14} cm$). It gives $\triangle E \sim 10^{45} ev$. Nobody knows is it possible in far future to receive such energies and concentrate them in small volumes.

VI. WHY WE CAN WALK TO AND FRO IN OUR SPACE

Why we can not walk to and fro in time had been explained in the frame of multifractal time in paragraph above on the language of energetically reasons. The possibility of walking to and fro in space is conditioned by vector characteristics of fractional addendum to space derivatives in multifractal Universe. For simplicity we consider non relativistic case when particle is described by Shrödinger equation in multifractal space (see [3], [4], [10]). Let multifractal addendum to integer space dimensions $\varepsilon_i$ be very small ($|\varepsilon_i|<<1$). Than for GFD we can right (we conserve only main addendum necessary for our purpose)

$$D^{1-\varepsilon_i} \sim \left( \frac{\partial}{\partial r} + \frac{\varepsilon_i h}{r} \right) \quad (18)$$

and for Shrödinger equation in fractal space for free particle receive

$$i\hbar D^{1-\varepsilon_i} \psi = -\frac{\hbar^2}{2m} D^{1-\varepsilon_i} D_{1-\varepsilon_i} \psi \quad (19)$$

Now replace fractional space derivatives by means of (13) then (19) reads (if neglect the members of order $\varepsilon^2$ and non essential scalar members in right hand part of equation)

$$i\hbar D^{1-\varepsilon_i} \psi = -\frac{\hbar^2}{2m} \Delta \psi + \nabla \left( \frac{\varepsilon_i h}{r} \right) \psi \quad (20)$$

If in the (20) we replace $r$ by $-r$ the sign of fractal addendum from fractional space dimensions do not change its sign, so there are no energetically reasons forbidding walking to and fro in the fractal Universe. Of course, in the equation (13) omitted the members describing the lose of energy by particle reasoned by the fractional structure of space. We do not evaluate the energy lose reasoned by multifractal structure of space because in this case the evaluation is very difficult ( the value of $\varepsilon_r$ is unknown). It value defined by new fields (not discovered yet) that borne by fractional space dimensions (see [3], [4], [6]).

VII. CONCLUSIONS

The arrow of time in considered model of multifractal time and space as was seen above is consequence of energetically reasons. Direction of time may be changed (thou only in principle in our epoch because of huge amount of energy that needs for it). There are three main results of this article: a) the explanation of nature of arrow of time by natural lose of energy of our Universe and by necessity for energy compensation of this lose for changing of direction of time in any domain (small or large) of space and time; b) it is point out at the huge amount of energy in every bodies and fields ( more detailed consideration will be in special paper ) caused by the real nature of fields of time and space; c) the principle possibility to change directions of time and space fields in the remote future epoch. We considered the energy needs for changing direction of time, thou it is necessary to return the space in earlier state too.

Some general remarks. Any fractal or multifractal sets (Universe is multifractal set) always not belong and not coincide with measure of carrier on that they are defined (it include the cases when measure of carrier is multifractal set itself and not space $R^N$ type ). If describe the measure carrier of our Universe in terms of "physical vacuum", then "vacuum" do not belongs to our Universe. Main part of it lays out of Universe (see also [8]). The Universe may be treated as a gigantic energetic fluctuation ("metastable" long living fluctuation) in the measure of carrier and as the fluctuation it has strong binding with its "mother". The existence of strong binding with the vacuum (measure of carrier) consist in continual transferring to vacuum the huge amount of energy that was got from vacuum in the moment of "big bang" (or in the moment of birth in any over scenario) as was demonstrated in this paper. What future wait our Universe in the model of multifractal space and time ? Universe will spend her supply of energy that was got from vacuum in the moment of big bang. When all energy supply be spent process of Universe dying will be finished till time when new Universe borne from measure of carrier (vacuum). In this model many of universes (may be infinity) may existent because measure of carrier can give birth any huge amount of Universes (with their own times and spaces that can different at our time and space by it dimensions and energetical characteristics) and die of one of them is not essential for carrier of measure in this model of multi Universes structure of "vacuum " not belonging to our Universe. How name this world of infinity of Universes where birth and die of infinity of Universes change one another ? May be "perpetual universes eternity model"
will useful enough? I do not know.

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