Space-Time and Matter as Emergent Phenomena

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Annotation

An axiomatic deterministic theory of physics based on a single unified field was proposed.

In the theory model at the fundamental level there is no time and dynamics. It is shown how space-time with matter and fields emerge in this model. It is shown that the anthropic principle emerges as a consequence of the theory. The causality principle is derived as a consequence of the main principles of the theory. All three Newton's equations are obtained as consequences of the theory and in the nonrelativistic approximation. Mass, energy and other concepts of mechanics were obtained. The Schrödinger equation is derived. An explanation of the nature of particle spin is proposed. It is shown that the maximum speed of interactions must be finite and be the same in all inertial frames of reference. It is shown that the light speed and the maximum speed of interactions are exactly equal. A special theory of relativity with all its equations is obtained. The Klein-Gordon-Fock equations and, with some assumptions, the Dirac equations are obtained. Particles interaction is considered. There were given explanations of what virtual particles and quanta of field interactions are, and how renormalization works in quantum field theory. Seemingly fundamental interactions, such as strong, weak and electromagnetic are shown. Maxwell's equations are obtained, with some assumptions. It is shown that the standard model does not contradict the proposed theory. The nature of gravitation is considered. A strong equivalence principle is proved, all assumptions on which the general theory of relativity is based are proved. Based on this, it can be argued that the equations of the general relativity theory satisfy the theory of emergent space-time-matter. It is shown that gravity can not have quanta. Thus, this theory asserts that no theory of quantum gravity can exist. An explanation of the origin of the universe is proposed. An explanation is offered for the nature of dark energy and dark matter. Physical foundations of mathematics are considered.

Introductory

In this article I develop the theory of emergent space-time-matter [1-11]. An insight into previous publications on this topic is not required, in this article I give a complete description of the current state of this theory.

At present, known physics laws allow for the existence of singularities, for example, inside black holes. Many view these singularities as a sign that a new physics begins next to singularities. We are looking for new laws of physics that describe the state of space, time and matter near these singularities. A common feature of all these searches is that the authors imply that space, time and matter still exist in such conditions, albeit in some unusual form.

However, there is another option, which, to the best of my knowledge, is the first fully considered only within the framework of the proposed theory. This second option is that in some neighborhood of the singularity, space, time and matter do not transfer into something unusual, but cease to exist. In this case, since something inside this neighborhood of singularity affects its environment in space-time, this something can not be nothing. The question is, what can be this something?

If this something does not contain space-time and matter, then it must be something more fundamental. But then, since it does not contain space-time-matter and fields, space itself, time and matter must be derived from this something. From this perspective, space-time-matter and fields must emerge from properties of this something. Moreover, they can not be defined everywhere, but only where there are suitable conditions for this.

Time is a phenomenon, the manifestations of which we constantly observe. Physics still does not know the nature of time, the existing description of time and its properties is phenomenological. Special and general relativity theories have established a relationship between time, space and gravity. This shows that time is not an independent phenomenon, and has a connection with space and matter that causes gravity. Physics has established the properties of time. However, there is no knowledge of why there is time, why it is unidirectional, whether there are quanta of time, why time has one dimension, whether it is possible to travel to the past.

There are phenomena called emergent. For example, the second law of thermodynamics. The properties of thermodynamics are based on the properties of individual atoms and molecules, described by quantum mechanics. However, the equations of thermodynamics can be applied practically independently of the equations describing individual atoms and molecules.

Do space, time, matter and fields exist independently or are they a manifestation of something more fundamental?

This article presents the theory of emergent space-time-matter (hereinafter referred to as ESTM-theory). In this theory, space, time, matter and fields are viewed as emergent properties of a more fundamental entity.

Let us start our consideration of the theory from the theory model.

Theory Model

The theory is based on the assumption that at the fundamental level there is only Euclidean space with a certain still unknown amount of dimensions and a field defined on this space. The field at each point has a value belonging to the set of real numbers. There is nothing else at the fundamental level except the listed, including the time, space and matter observed by us. All dimensions are the same; there are no any specific dimensions. I assume smoothness of the fundamental field . A field is described by some unknown differential equation. It can be written as follows:

$$f(x) = g\big(x, S, f(S)\big) \tag{1}$$

where x is a point in the fundamental space, $f(x)$ is the value of the fundamental field at the point x, S is the closed surface surrounding the point x, $f(S)$ is the field value on the surface S, g is some function.

The fundamental space with a field defined on it I will call Metauniverse.

The absence of time and dynamics in the model of the theory at the fundamental level leads to the question - can there be intelligent life in the described timeless system?

Postulate of theory

If intelligent life cannot exist in the described timeless system, then the described system cannot describe our world. This means that the consideration of this theory makes sense only if there is the possibility of the existence of intelligent life.

Thus, it is necessary to introduce a postulate.

Postulate:

A system in which there is no time and dynamics at the fundamental level can contain intelligent life.

It does not follow from the postulate that any possible system without time and dynamics contains intelligent life. All known models of intelligent life require space and time. Thus, in order for such a system to have intelligent life, the possibility of constructing space-time as emergent phenomena is necessary. Suppose we have somehow constructed the emergent space-time with matter and fields, but there is no intelligent life in such a space. Can this spacetime be considered objectively existing? Here a problem arises with definitions and with what is considered objectively existing, with respect to a system without time. If we consider only the fundamental level to be objectively existing, then the emergent space-time cannot be objectively existing. Thus, the generated space-times can only be subjectively existing. The subjects can only be intelligent life. Thus, it turns out that consciousness is more fundamental than space-time. However, consciousness is not primary, it is only an epiphenomenon of a more fundamental timeless structure.

If some generated space-time does not contain intelligent life, then such space-time remains a mathematical abstraction.

Anthropic Principle

From the postulate and model of the theory it follows that the observer is necessary for the existence of the universe. Thus, from the theory follows the anthropic principle.

The anthropic principle was proposed [12] [13] in order to explain from a scientific point of view, why in the observable universe there are a number of nontrivial correlations between the fundamental physical parameters necessary for the existence of an intelligent life. There are different formulations; usually weak and strong anthropic principles are singled out.

A variant of the strong anthropic principle is the anthropic participation principle, formulated by John Wheeler [14]:

> « *Observers are necessary to bring the Universe into being*

In the ESTM-theory is a direct consequence of the basic principles of the theory.

Causality Principle

All models of intelligent life known to me require fulfillment of the casuality principle. Observers are necessary for the existence of the Universe. Only a rational being can be an observer. It means that intelligent life is necessary for the existence of the Universe. For this reason, the emergent space-time-matter-field must be constructed in such a way that the causality principle is fulfilled. Thus, the causality principle is a consequence of the anthropic participation principle.

Symmetry to Translations of Emergent Time and Space

To fulfill the causality principle, it is necessary to understand which properties must physical laws have with respect to translations of the emergent time and space. In case if there is no symmetry for the translations of the emergent time and space, there is no way to fulfill the causality principle. For this reason, it can be concluded that such a symmetry, which still can be called homogeneity, must exist. This means that any solution with emergent space-time must contain such symmetries.

The order of statement of the theory in the article

At the fundamental level of the theory there are no such basic theoretical concepts as time, observable space, matter, fields. For each of these concepts, it is necessary to find a correspondence in the proposed theory. It is also necessary to find a correspondence for related concepts, such as mass, energy, velocity, elementary particles etc. Each of these concepts is linked with each other. One may identify in one place what these concepts correspond to in this theory, but it might be difficult for perception and understanding. Therefore, the theory will be presented in several iterations.

First, we will consider the plane Euclidean emergent space-time with long-range action. This part shows how this space-time emerges. It shows how and why inertia emerges. The mass and energy are found.

Newton's laws and Galileo transformations are obtained. An elementary particle was given a definition in terms of the theory. The Schrödinger equation is derived. An explanation is proposed for the spin of particles.

In the next part, we again consider the emergent space-time, but more precisely. It considers a flat pseudo-Euclidean emergent space-time. Lorentz transformations and equations of the special relativity theory are derived. The Klein-Gordon-Fock and the Dirac equations are obtained.

Next we will consider interactions of elementary particles. An explanation is proposed for what is an electric charge. The Maxwell equations are obtained. An explanation of what virtual particels are is given. It is shown that the light speed must be exactly equal to the maximum interaction speed. It is shown that the proposed theory is compatible with the standard model of elementary particle physics.

The next part deals with gravity and the curved emergent space-time. Equivalence of acceleration and gravitation is derived. It is shown that the Einstein equations of the general relativity theory correspond to the proposed theory. It is shown that the proposed theory implies the absence of a carrier particle of gravitational interaction, i.e. the absence of a graviton is predicted.

Next we will consider cosmology. In this part, an explanation is offered for the origin of the Universe. It is explained why the Universe has three spatial and one time dimension. An explanation is proposed for dark matter and dark energy. The possibility of existence of parallel universes is considered. It is shown that the Meta-Universe probably has more than four dimensions.

Next we considered the physical foundations of mathematics

In each of these parts, the correspondence of the theoretical concepts and theory model is consistently introduced and equations of the theory are refined. The final form of equations of the theory is obtained after the cosmology section.

Flat Space-Time With Long-Range Action

Let us first consider the case of a flat emergent space-time. In order to find it, we consider a family of hyperplanes satisfying the properties described below.

- Hyperplanes belonging to the same family must not overlap and be parallel.
- There is a continuous transformation that transforms one hyperplane of the family into another.

Besides the described properties, hyperplanes must satisfy a number of properties associated with expansion of a fundamental field on hyperplanes. First, we need to give a definition to expansion of a field on a hyperplane.

I will use the smooth functions defined for the Euclidean space with the number of dimensions equal to the number of hyperplane dimensions. Each function has some set of parameters that allow one to definitely indicate its location on the hyperplane. One of these parameters is some point. For symmetric functions you can use a symmetry point, and it can be a single parameter. For nonsymmetric functions one may also need a vector indicating the function orientation.

Suppose there is some family of functions with the indicated properties.

I will call the expansion of the fundamental field by the basis of functions the case when the field values at any point on the hyperplane can be represented with sufficient accuracy as the sum of the functions that belong to this family, with certain coefficients and with a series of conditions considered later.

The same function can enter the expansion repeatedly. The definition to "sufficient accuracy" will be given later. In this case, we can say that the family of functions form an almost complete functional basis for the expansion and form a certain set of functions $\{w\}$.

Suppose $L(\vec{r}_f) = 0$ where $\vec{r}_f$ is a vector in the fundamental space, this is an equation describing a certain hyperplane of the family under consideration. Suppose $X = (x_1, .., x_n)$ is a point on the hyperplane under consideration

Suppose $f(X)$ is the value of the fundamental field at the point X. Then the expansion function of the field will be as follows:

$$f(X) = f_0 + f_{ext}(X) + \sum_i \sum_k u_{ik} w_i\big(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}\big) \tag{2}$$

where f_0 is a some constant, $f_{ext}(X)$ is a function characterizing the accuracy of the expansion. In the case when $\{w\}$ form a complete functional basis, f_{ext} equals zero, otherwise it must be much less than the rest of the expansion. More detailed requirements to f_{ext} will be found later. Y_{ik} is a point on the hyperplane characterizing the position of the function w_i used for the i-th time. u_{ik} are the coefficients of the amplitude of the function. $\{Q_{ik}\}$ is a set of all other parameters that allow you to definitely identify the location and possible other characteristics of the function. It can be seen yet that this set should include a vector for specifying the direction of asymmetric functions. Further there will be shown other possible parameters. In order to calculate the field value at the point X, it is enough to sum it. The field value at any point of the hyperplane, if f_{ext} and f_0 are neglected, can be calculated using only the expansion functions.

Now, after defining field expansion along the hyperplance, one can again return to hyperplanes and add the necessary requirements to both the family of hyperplanes and to the functions of basis of expansion.

We want to get an effective space based on hyperplanes, and effective time based on the distance between them. For this it is necessary that the causality principle is fulfilled. The causality principle will be fulfilled if the functions of expansion basis are the same on all the metrics of the emergent hypersurface space of one family, and if all $u_{ik}, Y_{ik}, \{Q_{ik}\}$ on a single hyperplane of the family are known, then with sufficient accuracy we can calculate the values of the expansion on any other hyperplane of this family. This is another requirement for the family of hypersurfaces and for the expansion functions.

If the effective time corresponds to the distance between the hyperplanes, then we can talk about the time vector. The quesion is, where this vector is directed to?

To answer this question, we can recall that there is no preferential direction in the fundamental space. Thus, this vector must be directed in the most symmetrical manner towards the hyperplane. The greatest symmetry is obtained if the time vector at each point of the hyperplane is directed perpendicular to the hyperplane.

I will call the family of hyperplanes as emergent space-time with the indicated properties. Furthermore the space of hyperplane belonging to the family will be the emergent space, the distance between hyperplanes will be emergent time.

The notion of a world line for the point in the emergent space can be introduced. it is a curve in the fundamental space, at each point of which the time vector is parallel to this curve, and which passes through the indicated point. One can say that the point x from one hypersurface is mapped to the point x' on another hypersurface if the world line of the point x passes through the indicated hypersurface to the point x'. For the case of flat space-time, the world line is straight.

Suppose there are two distinct points x_1 and x_2 lying on the hyperplanes of the family under consideration, and not necessarily on one hyperplane. Using the notion of the world line, their relative position can be described as $(\vec{r}, t)$ where $\vec{r}$ is a vector in the emergent space, t is the difference in the emergent time. The vector $\vec{r}$ can be found by finding the intersection of the world line from the point x_1 with a hyperplane containing x_2, or vice versa. t is directly proportional to the distance between the hyperplanes, with some constant coefficient.

Let me get back to the expansion of the field. The expansion of a field on a hyperplane, according to equation 2, can be written as a vector of the state Ψ consisting of the values u_{ik}, Y_{ik} and $\{Q_{ik}\}$ for all functions w_i. From the requirement for the causality preservation, it follows that these values for each subsequent hyperplane must be calculated on the basis of the previous values:

$$\Psi(\mathrm{t}+\mathrm{dt}) = \mathrm{U}\Psi(\mathrm{t}) \tag{3}$$

here U is some operator that transfer the state vector into another state vector at a subsequent time point.

In order for the laws of physics to be always the same, symmetry is necessary for a time shift. This means that the operator U preserves the product, i.e., it is unitary. If in equation 3 dt = 0, then $U = I$ where I is the unit operator. Further, I assume that the function Ψ is differentiable, which means continuity of space-time. Therefore, it can be written as follows:

$$\Psi(\mathrm{t}+\mathrm{dt}) = \Psi(\mathrm{t}) + \mathrm{d}\Psi(\mathrm{t}) \tag{4}$$

From the other side,

$$\Psi(\mathrm{t}) = I\Psi(\mathrm{t}) \tag{5}$$

Then

$$\Psi(\mathrm{t}+\mathrm{dt}) = (\mathrm{I}+\mathrm{dU})\Psi(\mathrm{t}) \tag{6}$$

The equation can be shortened:

$$\mathrm{d}\Psi(\mathrm{t}) = \mathrm{dU}\,\Psi(\mathrm{t}) \tag{7}$$

dividing by dt:

$$\frac{d\Psi}{dt} = \frac{dU}{dt}\Psi(\mathrm{t}) \tag{8}$$

The derivative of the operator $\frac{dU}{dt}$ is also an operator, although not necessarily unitary. Marking it as A, we get the final differential equation of the unitary system evolution:

$$\frac{d\Psi}{dt} = A\Psi(\mathrm{t}) \tag{9}$$

Elementary Particles

It is known that our Universe contains elementary particles. It is necessary to find out what elementary particles correspond to in the model of this theory. On the basis of the observed properties of elementary particles, I introduce the following definition of an elementary particle within the framework of the proposed theory:

An elementary particle is a part of the expansion of the field of the Meta-universe on the emergent space, which is stable at least some emergent time, interacts in the emergent space-time with other elementary particles as one.

Inertia, Newton's Laws and Mass

Let us corollary of the equations 2 and 3 for the case when the expansion consists of only one function w. At the timepoint t_0 the field on the metric of the emergent space has the form:

$$f(\vec{r}, t_0) = u(t_0) w(\vec{r}, \{Q\}, t_0) \qquad (10)$$

where u is the expansion coefficient, the $\{Q\}$ set is the set of all parameters that uniquely characterize the position of the function and other properties of the function. For a symmetric function, this set must contain a symmetry point, for non-symmetric functions there are some additional parameters characterizing the position of the function in space. For the case when the function is asymmetric, this set must contain a vector characterizing the direction of the function in space.

I assume that other parameters from $\{Q\}$ do not depend on the coordinate $\vec{r_s}$. In this case, we can consider the expansion, using two numbers, the amplitude u and the point $\vec{r_s}$ in the emergent space. The rest of the parameters from $\{Q\}$ can vary, in accordance with equation 1, but their evolution can be considered independently from the evolution $u$and $\vec{r_s}$.

Equation 3 for this case is rewritten as:

$$\begin{pmatrix} u(t+dt) \\ \vec{r_s}(t+dt) \end{pmatrix} = U \begin{pmatrix} u(t) \\ \vec{r_s}(t) \end{pmatrix} \qquad (11)$$

If the expansion coefficient u changes, this will mean that the amplitude of the function will change with time in one direction, grow or decrease. It does not look as a proper solution, therefore I assume that the amplitude is constant.

$$u(t+dt) = u(t) \qquad (12)$$

Then the equation above can be rewritten as:

$$\vec{r_s}(t+dt) = U\vec{r_s}(t) \qquad (13)$$

Considering that the emergent laws must be the same at all times, it follows that the change $\vec{r_s}$ must be linear. Consequently, the motion must be uniform and rectilinear. The change per time unit is the speed:

$$\vec{v} = \frac{\vec{r_s}(t+dt) - \vec{r_s}(t)}{dt} \qquad (14)$$

Applying similar arguments for the case when the expansion consists of a set of functions and represents one elementary particle, we obtain a similar result, the motion must be uniform and rectilinear.

Thus, within the framework of the theory of emergent space-time-matter, Newton's first law was derived.

Next, I would like to consider the motion with an external action on a moving particle. The concept of external influence within the framework of this theory has not yet been determined, it is not entirely correct to use it. However, for the time being I will use this concept in its firmly established meaning, since no other related concepts have been defined so far. Later the question of inertia will be considered in the article again, when will be considered interaction of elementary particles with each other.

How does the inertia of such a system change under external influence, from what parameters can this change depend on?

The parameters that can be seen are speed, acceleration, coefficients of the expansion of functions.

I will name the change of inertia during acceleration by force. The proportionality coefficient between acceleration $\vec{a}$ and force $\vec{F}$ will be called mass m. The mass, according to what was written above, can depend only on the speed, acceleration and expansion parameters:

$$\vec{F} = m(\vec{v}, \vec{a}, \Psi)\vec{a} \tag{15}$$

Let us consider the system consisting of two different elementary particles. We consider that the evolution of this system is described by equation 9.

Then this system also saves inertia.

Assume particle 1 interacts with the particle 2, and this interaction leads to a change in the speeds of these particles. Since the inertia of the system of these particles is preserved, then:

$$m_1(\vec{v}_1, \vec{a}_1, \Psi_1)\vec{a}_1 + m_2(\vec{v}_2, \vec{a}_2, \Psi_2)\vec{a}_2 = 0 \tag{16}$$

Hence it follows that:

$$m_1(\vec{v}_1, \vec{a}_1, \Psi_1) = -m_2(\vec{v}_2, \vec{a}_2, \Psi_2)\vec{a}_2/\vec{a}_1 \tag{17}$$

As can be seen, the mass of the first particle is also a function of the speed, acceleration and the coefficients of expansion of the second particle. It condradicts with what was found earlier. This contradiction is solved if the mass is a constant.

Then it follows that:

$$\vec{F} = m\vec{a} \tag{18}$$

$$m_1\vec{a}_1 + m_2\vec{a}_2 = 0 \tag{19}$$

Thus, Newton's second and third laws are obtained.

It should be noted that these laws are obtained taking into account the earlier reservations. Later they will be reviewed in the article again, after considering the necessary questions.

Energy and Energy Conservation Law

According to Noether's theorem, the consequence of the homogeneity of time is the preservation of some scalar quantity for an isolated physical system. The differential equation system describing the dynamics of the physical system has the first integral of motion associated with symmetry of equations with respect to the time shift. I will call this scalar quantity an energy. Since it must be preserved for an isolated physical system, we can talk about the the energy conservation law. Using the concept of energy, we can introduce the concept of the potential energy of a field, in its usual sense. What are fields other than the fundamental field has not yet been clarified, but it will be shown later in the article.

Wave Function and Expansion Functions of the Field

As it is known, the concept of wave function is one of the central concepts of quantum mechanics. Is it possible to find out what the wave function corresponds to within the framework of the proposed theory?

Considering the properties and behavior of the wave function, it can be seen that it roughly corresponds to the expansion functions. The difference lies in the requirement of normalization and complex-valuedness. The square of the modulus of the wave function corresponds to the probability density of observing the particle. In order to calculate the probabilities of observing particles directly on the basis of the equation of the fundamental field, it is necessary to have this equation and be able to use it to calculate the probabilities. So far, neither that nor that is not present, and the way how to combine decomposition functions and wave function is searched in the assumption, that the further development of the theory will allow to make such calculations. If we assume that the expansion functions are quasiperiodic and the probability of observing the particle at any point depends on the square of the amplitude of the function and does not depend on the phase of the function, we obtain an analog of the wave function. Under the above assumptions, in order to find the probability of observation at any point, the phase of the expansion function must be eliminated. How can I do that?

Lets consider the function $f(x) = a(x) * \cos(kx)$. This function may be rewritten as $f(x) = Re\ (a(x) * e^{ikx})$. The square of the amplitude $a(x)$ is obtained by the following formula $(a(x))^2 = \left(a(x) * e^{ikx}\right) * \left(a(x) * e^{ikx}\right)^*$, here $\left(a(x) * e^{ikx}\right)^*$ is conjugate function.

From this perspective I conclude that real part of the wave function $Re(\Psi)$ corresponds to the expansion functions up to a certain normalization factor a, which can be different for different particles:

$$Re(\Psi) = \sum a_k u_{ik} w_i\left(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}\right) \tag{20}$$

Here Ψ is the wave function, the summation is over the particles where - is the number of the particle and by the particle expansion functions, where i is the function number for the k-th particle. $a_k$is the normalization factor for the k-th particle.

The imaginary part of the wave function corresponds to the phase of the quasiperiodic part of the expansion.

Schrödinger Equation

Equation 9 shows the behavior of the time expansion functions. Can this equation be detailed?

Taking into account the inertia derived above and Newton's laws, the equation must have mass as a characteristic of inertia. From energy conservation it follows that a more detailed equation must also contain energy conservation. A more detailed equation must pass into Newton's laws at some limit.

Schrödinger equation satisfies equation 9, contains mass and supports the energy conservation law. Thus, one can say that it is a more detailed equation for equation 9, considering the normalization factors described above. Although it can not be said that the Schrödinger equation is derived, but one can say that it satisfies all the requirements of the proposed theory. Уравнение Шредингера:

$$ih\frac{\partial\Psi}{\partial t} = \hat{H}\Psi \tag{21}$$

It should be noted that the Schrödinger equation contains the Planck's constant. Before that, all the arguments were far from concrete numbers and dimensions. Planck's constant acts here as a manifestation of the properties of the fundamental field. As we further consider the theory, there will be found other manifestations of properties.

Particles with Spin

As it was already written, functions from equation 2 may not be symmetric in the emergent space and contain a spatial orientation.

Suppose there are two types of elementary particles that have similar expansion functions in the expansion. Let assume that:

$$w_k{}' = Uw_k \tag{22}$$

where w_k is the k-th expansion function for a particle of the first type, $w_k{}'$ is the k-th expansion function for a particle of the second type, U is a unitary operator that performs the rotation of the function w_k in the emergent space.

Since all directions are equal both in the fundamental space and in the emergent space, the types of particles described above differ only in the direction of the expansion functions, these types of particles will have completely identical properties except for the spatial orientation.

These types of particles must have, among other things, an identical mass. These are particles can be considered the same type that have a certain additional parameter. I will call this parameter a spin.

Suppose there is a system of a particle which has a spin and a particle has two sets of expansion functions which differ in spin. State of the particle for the first spin Ψ_1, for the second Ψ_2. Then, taking into account what was written above, the wave function of a particle is two-component:

$$\psi(r,t) = \begin{pmatrix} \psi_1(r,t) \\ \psi_2(r,t) \end{pmatrix} \quad (23)$$

For the case when the number of function sets is more than two, the number of components is correspondingly increased.

In accordance with what was written, I change equation 2 in order to take into account the spin:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{ikps} w_{ips}(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}) \quad (24)$$

Here u_{ikps} are expansion coefficients, w_{ips} are the functions over which the expansion takes place. s is the summation over different sets of expansion functions, goes from 1 to function $N(k)$, where k is the summation over different types of elementary particles. $N(k)$ is equal to 1 for particles with spin 0, for spin 1/2 the value will be 2 etc.

In the equation there is also a restriction on the summation, the summation goes over a finite set of functions, from iMin to iMax. More detailed it will be considered and justified later, after considering gravity.

Inertial Reference Systems

I will define inertial reference system as reference systems moving linearly and uniformly relative to each other.

As described above, the time vector at each point is perpendicular to hyperplane. If the body is motionless relative to the hyperplane, then it evolves along the time vector. If the body has some velocity relative to the hyperplane, then it evolves along a vector consisting of the sum of the time and velocity vector. The vectors of time and velocity are perpendicular to each other, since the velocity vector lies in the hyperplane.

I want to find out how to go into the reference system, corresponding to a moving body. Since the resting body evolves along the time vector, the transition to the reference frame corresponding to the moving body will be a transition to such a hyperplane where the velocity is zero and the body evolves along the time vector. For such a transition, it is necessary to rotate the hyperplane in such a way that the time vector of the new hyperplane is parallel to the vector of time and velocity of the body on the previous hyperplane.

From consideration of transitions from one reference system to another, we obtain a number of corollaries.

The first consequence, relativity of simultaneity. The events occurring on the hyperplane are occurring simultaneously. After the rotation of the hyperplane in the transition to the reference system, corresponding to the body moving at a certain speed relative to the previous one, earlier simultaneous events may cease to be simultaneous.

Another consequence is the observed difference in the course of hours in different reference frames. Since there is no distinguished direction in the fundamental space, the length corresponding to the unit of time must be constant and not depend on rotations. Before turning, the evolution of a body moving at a certain velocity is described by a vector consisting of a time vector with a length equal to a time unit and a velocity vector with a length that depends on the velocity. After the rotation and transitions into the system, where the body is motionless, the evolution of the body proceeds along the time vector with a length corresponding to a time unit. As can be seen, the lengths of these vectors are different, which means the difference in the hour course in different reference systems.

Another consequence is that the expansion functions must be constructed in such a way that when the hyperplane rotates, it transforms into other functions of the same basis of expansion.

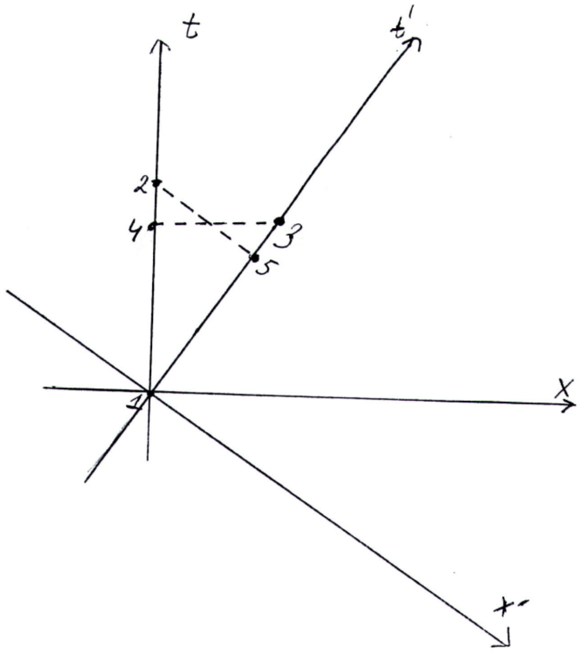
Consequence of equality of nature laws. Since there is no preferential direction at the fundamental space level, this means that in the emergent space-time physical laws are the same in all inertial reference frames.

For a more detailed analysis of the arising consequences, it is necessary to consider how the limiting velocity of interactions arises.

Special Relativity Theory and Lorentz transformations

Let's find ratio of the duration of time in two inertial frames of references, moving relatively to each other. I will name v_t distance in fundamental space, equal to unit of time. As described above, this value is the same in all inertial reference systems.

Let there be two inertial frames of reference moving relative to each other with speed v along axis x,



and their origin points coincide.

The figure above shows the axes x and t for first frame of reference and axes x' and t' for second frame of reference. The second frame of reference, moving with relative velocity v, is tilted at an angle α relative to the first. I would like to emphasize that the axis t is usual space axis in Euclidean space. Length l along this axis is related to the observed time by the following relation:

$$t = l/v_t$$

Simultaneous events are those events that occur on a same plane, perpendicular to the axis$t$.

There are several points in the figure. Point 1 is the beginning of the coordinate system. I consider case when the beginning of the coordinate system is same for both systems.

Because v_t in all inertial frame of references is same, so $v = v_t \sin(\alpha)$

Let t be the time elapsed in the first reference frame from point 1, and t' - time elapsed in the moving reference frame during time t. Time duration t in first frame corresponds to the distance $v_t t$, this is distance between points 1 and 4. Same time span t in second frame of reference corresponds to same distance, it is distance between points 1 and 5. Point 2 is the intersection of a line perpendicular to the axis t', and passing through the point 5. Similarly, point 3 is the intersection of a line perpendicular to the axis t, and passing through the point 4. In order to determine which time interval in the first frame of reference corresponds to the time t' in second, it is necessary to find the length of the hypotenuse of a triangle of points 1, 5 and 2. From the figure it can be seen:

$$t = \frac{t'}{\cos(\alpha)}$$

Then, from the known value of the sine, we get:

$$\cos(\alpha) = \sqrt{1 - sin^2(\alpha)} = \sqrt{1 - \left(\frac{v}{v_t}\right)^2}$$

$$t = \frac{t'}{\sqrt{1 - \left(\frac{v}{v_t}\right)^2}}$$

From the same figure it can be seen:

$$t' = \frac{t}{\cos(\alpha)} = \frac{t}{\sqrt{1 - \left(\frac{v}{v_t}\right)^2}}$$

Now consider the coordinate transformations and see how point (x, y, z, t) will be transformed. Let velocity v be directed along x axis. Then, when you rotate the coordinate system to switch to moving frame of reference, y and z will remain unchanged:

$$y = y'$$

$$z = z'$$

In the first frame of reference $x(t) = x_0 + vt$

In the second reference system, after turning, $x' = x_0 \cos(\alpha)$

Then

$$x' = (x - vt)\cos(\alpha) = \frac{x - vt}{\sqrt{1 - \left(\frac{v}{v_t}\right)^2}}$$

$$t' = \frac{t - (v/{v_t}^2)x}{\sqrt{1 - \left(\frac{v}{v_t}\right)^2}}$$

These equations become familiar if

$$v_t = \mathrm{c}$$

Here c – light velocity. This means that the distance corresponding to the unit of length of time is equal to the distance traveled by the light for the same time duration.

Thus, I can say that the special theory of relativity with its Lorentz transformations is derived from the proposed model.

Let’s consider question of how to calculate sum of velocities and what it is. From the equations above one can derive the equation of the relativistic velocity addition. This equation is different from the velocity addition equation, which can be obtained if we consider the sum of the velocities through the addition of angles. Is this difference a problem for the proposed hypothesis?

To answer this question, it is necessary to remember that all physics in this hypothesis is built around an observer. The observer will see the addition of velocities in accordance with the relativistic formula for the addition of velocities. If there is another observer in the second frame of reference, he will see his picture of events, and nothing says that this picture should be derivable from the picture of the first observer. Based on the above, I can conclude that the transition to another frame of reference is not isomorphic. The violation of isomorphism during the transition to another frame of reference means that for accelerating observer his past changing.

Let's consider a thought experiment. Two observers decided to observe some phenomena in some spatial area. Both observers meet, each takes a clean notebook where they will record the results of the observations. Then the first observer remains in same area, the second at some vehicle accelerates to near-light velocity. Each of them regularly records observable phenomena in the assigned region of space. Then the second observer returns, meets with the first observer, and they compare the results recorded in notebooks. Can there be different results in notebooks? To answer this question, it is necessary to remember that the space-time in this hypothesis is built around the selected observer, and is built with the requirement to satisfy to principle of causality. Therefore, for each of the observers, what he sees in the notebook should satisfy the principle of causality. This means that while observers may record different events, the causality principle must be followed for them. This means that for any observer the events during the transitions to another inertial frame of reference look isomorphic. However, if in any way the observer could see events at the same time in different reference frame, he would see that events in different reference frames are not isomorphic with respect to each other.

Thus, I can say that the special relativity theory with all its equations is derived from the theory model of emergent space-time-matter.

Later in the article, when obtaining Maxwell's equations, I will return to the question of equality of these two velocities and prove their equality. In the meantime, I assume that the maximum interaction velocity and the light speed are equal.

This also means that in the equation of the field expansion one must introduce changes in order to take into account the light speed. I will rewrite equation 24 as:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{ikps} w_{ips}(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}, c) \qquad (25)$$

here I have also added the dependence on the light speed c. The evolution equations obtained on the basis of this equation must be relativistically invariant.

Klein-Gordon-Fock Equation

The Schrödinger equations obtained above are not relativistically invariant. I want to find a relativistically invariant analog of the Schrödinger equations.

The Schrödinger equation for a free particle is written as follows (units used, where $h = c = 1$):

$$\frac{\hat{p}^2}{2m}\psi = i\partial_t\psi \qquad (26)$$

where $\hat{p} = -i\nabla$ is the momentum operator, and the operator $\hat{E} = i\partial_t$ will simply be called an energy operator, as distinguished from the Hamiltonian

The Schrödinger equation is not relativistically covariant, i.e., it does not agree with the special relativity theory.

We will use the relativistic dispersion (binding energy and momentum) ratio (from SRT):

$$p^2 + m^2 = E^2 \qquad (27)$$

Then simply substituting the quantum mechanical momentum operator and the energy operator, we obtain:

$$((-i\nabla)^2 + m^2)\psi = i^2{\partial_t}^2\psi \qquad (28)$$

It can also be written as:

$$\partial_x^2\psi + \partial_y^2\psi + \partial_z^2\psi - \frac{1}{c^2}\partial_t^2\psi - \frac{m^2c^2}{h^2}\psi = 0 \qquad (29)$$

In such a manner the Klein-Gordon-Fock equation was obtained within the framework of the ESTM theory.

Going back to inertia again. This equation, like its nonrelativistic analogue, contains inertia. Therefore, it can be said that that inertia in the ESTM theory exists in the relativistic case.

The Dirac equation

After describing the nature of the spin in the framework of the proposed theory, the problem of deriving the Dirac equation has been reduced to the well-known one. To derive the Dirac equation in the framework of the ESTM theory, it is enough to repeat exactly the same assumption as did Dirac, about the derivatives with respect to the spatial coordinates of only the first order. Accordingly, it is possible to use the known methods of obtaining this equation, described in many textbooks. And as it is known, the Dirac equation satisfies the Klein-Gordon equation.

Particle velocity change

The first question to be considered is particle velocity change. Assume there is a particle moving with a velocity less than the maximum velocity of interactions. At some point in time, the particle changed its velocity. I want to understand what will happen in this case, although I do not consider gravity field effect, as I consider space-time to be flat. I will point out that, in accordance with the inertia derived above, a particle without external action moves in a straight line, and to fully consider the change in velocity, it is necessary to take into account other interacting particles. To make it simple, I will only consider the change in velocity, without taking into account the interaction with other particles.

Taking into account the fact that I consider only one particle, then before changing the particle velocity and neglecting $f_{ext}(\vec{r})$, on the basis of equation 25, the field can be represented as:

$$f(\vec{r}) = \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{is} w_{is}(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}, c) \qquad [30]$$

Here $u_{is}$are the expansion coefficients in three-dimensional functionsw_{is}, which constitute the particle.

After changing the particle velocity, the field can be represented as:

$$f(\vec{r}) = \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{is}' w_{is}(L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}, c) \qquad [31]$$

Here u_{is}' are the expansion coefficients for all the same functions. Since the particle velocity has changed, this means that the expansion coefficients must also change.

According to the special relativity theory derived above, the maximum velocity of interactions for our Universe should be equal to the light speed, and is the same for all particles. Thus, changes in the expansion coefficients should propagate at a speed not exceeding the light speed.

There must exist the possibility to propagate the changes at a rate exactly equal to the maximum interaction velocity. Otherwise, it will be impossible to provide this maximum velocity. Let us consider this case, the propagation of changes with the maximum interaction velocity.

How the transition from one to another set of coefficients will occur on the boundary of expansion change? If the transition from one set of coefficients to another will occur instantaneously, then it is obvious that in the Meta-Universe field there will be instantaneous changes in values. This contradicts the assumption that the function of fundamental field is smooth.

Therefore, in order not have an instantaneous change in the field it is necessary to somehow prevent it. It is possible to enter a new particle that would move with a speed exactly equal to the maximum speed of interactions. In this case on the boundary between the new and the previous velocity of the particle the expansion by sets of functions $\{w_c\}$ corresponding to this particle will be added to the expansion. These functions should be such that the transition goes smoothly, without instantly changing the value of Meta-Universe field.

Thus it is obtained that the existence of particles moving with a velocity exactly equal to the maximum velocity of interactions is necessary, and they are emitted when the velocity of some particles changes. What particles emit them will be discussed later in the article.

Now about the possible propagation of changes in the expansion functions with a velocity less than the maximum rate of interactions. I apply the same logic as above, we find that particle-carriers of interaction moving with a speed less than the maximum speed of interactions are necessary.

Nature of Charge

One of the properties that most fermions possess is charge. We want to understand what is the charge, what is its nature. In order to find a possible explanation of the nature of charge, we can recall that the charge is of two kinds. What is there in the theory of emergent space-time-matter, which can also be of two kinds?

Equation 1 shows how the field of Meta-Universe depends on the boundary conditions:

$$f(x) = g\big(x, S, f(S)\big) \qquad [32]$$

How will this equation behave if we change the sign of the field on the boundary? It can be assumed that the values at each point inside the closed surface will Salso change the sign and the function will $g$not be changed:

$$g\big(x, S, -f(S)\big) = -g\big(x, S, f(S)\big) \qquad [33]$$

Consider a slightly different situation but similar. Imagine $f(S)$as:

$$f(S) = f_0 + f_1(S) \qquad [34]$$

Where $f_0$is the average value of the field on a closed surface$S$, $f_1(S)$is the deviation of the value of the field from the surface Sfromf_0. The question arises, what are the functions $g(x, S, f_0 + f_1(S))$ and $g(x, S, f_0 - f_1(S))$? It can be assumed that with adequate accuracy:

$$f(x) = g\big(x, S, f(S)\big) = g(x, S, f_0 + f_1(S)) \approx g(x, S, f_0) + g(x, S, f_1(S)) \qquad [35]$$

As well:

$$g(x, S, f_0) + g(x, S, f_1(S)) \approx g(x, S, f_0) - g(x, S, -f_1(S)) \qquad [36]$$

What is with adequate accuracy? The accuracy of this approximation should be sufficient to ensure that the resulting emergent space-time could contain an intelligent life.

How true this assumption is, it will be possible to understand only in the course of further work on the theory model.

So, presumably the function of Meta-universe field is symmetric to the sign change, including the current average value. It follows that for each set of functions {w} there is a set of functions with a different sign:

$$w'_{is} = -w_{is} \qquad [37]$$

Thus, each particle has an antiparticle, which is distinguished by the sign in the expansion functions. In some cases, the properties of particle and antiparticle can coincide, and then it will be a simple neutral particle. What will happen with acceleration / deceleration of such a particle? In this case, in order to recieve the expansion at the front of function change of such particle, some particle moving with light velocity should be emitted or absorbed, but not a photon.

Based on the above, a possible explanation of the nature of charge is the average value of functions that make up the particle relative to the mean value of the fundamental field. If the average value of functions making up the particle is greater than the mean value of fundamental field, then one sign of charge, otherwise the opposite.

Completeness of Functions of Elementary Particles

Each elementary particle is represented as a set of one or more expansion functions. The question arises: if we take all the expansion functions for all elementary particles, does this function form a complete basis for the expansion? In other words, is it possible to expand the arbitrary field over this basis?

Before we start looking for the answer to this question, it is interesting to understand the answer to another question: is it necessary to expand the arbitrary field in the basis of functions of elementary particles? The field of Meta-Universe is described by some equation, although still unknown, and thus the possibility for expansion of arbitrary field is not required. Then the initial question can be reformulated differently: if we take all the expansion functions for all elementary particles, do these functions form a complete basis for the expansion of Meta-Universe field?

There are grounds to confirm that these functions do not form a complete basis. The reasons will be shown later, when considering gravity.

However, on a small scale and not Planck energies, we can assume that the basis of expansion is complete.

The expansion functions, in order to form a complete basis, must have the necessary properties for this. Condidering the spin phenomenon above, the spin is described by equation:

$$w_{ip(s+1)} = pw_{ips} \qquad [38]$$

and in addition, for spin ½

$$w_{ips} = ppw_{ips} \qquad [39]$$

The question arises - why are the properties of spin exactly like that? Why does the repeated application of spin operator again lead to function corresponding to one of the possible values of spin? And again, I do not have a full answer yet. But on the basis of requirement for the possibility of constructing a complete basis (with specified accuracy), it can be assumed that otherwise a complete basis can not be constructed.

I think that many similar questions connected with symmetries can be resolved by detailed consideration of what requirements arise to functions for constructing a complete basis.

The presence of symmetry to change the sign of Meta-universe field, as shown in the previous part of article, facilitates the expansion of field. But at the same time, it is necessary to exclude obviously not physical expansions from possible expansions. For example, if we take a particle and an antiparticle in the same place, then the sum of their functions should give zero. Thus, one can obtain in any place by expanding, an arbitrarily large number of particle-antiparticle pairs. This looks explicitly as not a physical solution, so by expanding, there should be no cases when the particle and the corresponding antiparticle are in the same place.

The completeness of expansion functions means that a set of functions of one particle is sufficient to describe all the functions of the particles. This set allows to uniquely find all the other expansion functions for other particles.

Is it possible to find all the functions of particle expansion if only one of these functions is known? I think that it is possible. The expansion function corresponds to some state of the particle in the emergent space-time. Changing this state will cause the new function corresponding to this state to be different from the previous one. In both states, the particle must correspond to the Klein-Gordon-Fock equation. In this equation, there is a particle mass that characterizes how the energy of particle should change withvelocity change. The question arises: does this equation during change of particle state transforms the initial expansion function into a new one-to-one or not? If the transition is ambiguous, then you need to look for additional parameters, for example spin, which will allow to do this.

We also need to understand what possible values should the coefficients have for the expansion functions.

Suppose there is a particle with some values of coefficients of the expansion functions. Let it somehow interact with another particle. I will consider two cases of such interactions, where all the initial conditions are identical, except for the value of coefficients of the expansion functions for the second particle. For the second particle, in the first case it has some coefficients of expansion, and in the second case of interaction all its coefficients are twice as little than in the first case. Can we expect that in both cases the result of interaction will be the same? It is quite obvious that the result may be different. Therefore, for particles there should be no freedom in the values of coefficients, there should be some function of which these coefficients shall satisfy. To understand what this function may depend on and how this affects the expansion of the field into particles, it is necessary to consider more detailed the interaction of the particles.

Interaction of Two Particles

Let there be two identical particles that act on each other. Their interaction leads to change in their trajectory, and as a result they diverge. Initially, when the particles were far away, Meta-universe field in the area of each particle can be described using only the functions of these particles. After they have moved far apart and their interaction has become negligible, the field can also be described using only the functions of these particles. And how to describe the field where the particles interacted?

Since the particles interact, the field changes. Therefore, in the interaction space it may occur insufficient the expansion in functions of the interacting particles and it will be necessary to expand over the complete basis of functions of the emergent space.

What does the expansion on a complete basis look like? Without the presence of coefficients dependence of the expansion function, it could be simply used the already available equation. However, taking into account the revealed dependence, this equation needs to be clarified.

For modification, I am guided by perturbation theory. Therefore, it would be desirable to construct approximately the same expansion for particles. In addition, this expansion must satisfy equation 25, with the accuracy described above.

As shown above, the coefficients of different particles have some dependence on each other. I will introduce particles of different orders. Particles of the first order are particles that exist constantly. Particles of the following orders appear only in interactions, they correspond to virtual particles. Particles of the first order interact with each other and with particles of the following orders. In this case, when interacting particles of different orders, we need some coefficient that changes the force of interaction. For particles of the same order, the described dependence must be fulfilled. As a result, the expansion of Meta-Unverse field turns into:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum \varphi_{1i}\left(L(\vec{r}_f), X, Y_{2i}, \{Q_{2i}\}, c\right) + \sum \varphi_{2i}\left(L(\vec{r}_f), X, Y_{2i}, \{Q_{2i}\}, c\right) + \cdots \qquad [40]$$

Here φ_{1i}presents the i-th particle of the first order:

$$\varphi_{1i} = \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{1is} w_{is}(L(\vec{r}_f), X, Y_{1i}, \{Q_{1i}\}, c) \quad [41]$$

In addition u_{1is}should satisfy some unknown function:

$$f(u_{1is}, 1) = 1 \quad [42]$$

Similarly, for particles of the second order and the subsequent n-th order, the following condition must be fulfilled:

$$f(u_{nis}, n) = 1 \quad [43]$$

where $n \geq 1$. I note that equation 40 is not identical to equation 25, and the degree to which they closely correspond depends on equation 43.

Equation 40 also shows that the particles of the following orders have the same properties as the particles of the first order. This is possible only if the simultaneous change in all amplitudes of a particle does not affect with the specified accuracy the behavior of such particles in time.

It also shows that particles of all orders interact with each other.

The uniqueness of field expansion over the basis

In the part of the article above, the expansion of particles over the basis of three-dimensional functions was discussed. In this regard, the answer to the question is interesting: are there any reasons that such expansion over the known basis will be unique?

To answer this question, it is necessary to return to why such expansion is necessary at all. And it is necessary to fulfill the causality on the emergent space-time. Accordingly, at the entry there are initial conditions in the form of expansion into particles at the previous time point. The expansion into each of the subsequent points of time must follow from the preceding.

If it is possible to construct more than one such expansions preserving causality, then the Klein-Gordon-Fock equation will be violated.

Thus, it is not required that the field expansion at any given moment be unique, but it must be the only one that preserves causality.

Completeness of basis and types of elementary particles

From the completeness of basis (with accuracy indicated above) one more conclusion follows. If set of expansion functions is known for one particle, then it is possible to obtain all the other expansion functions. It is not yet clear how this can be done, the mathematical model of the theory is in development.

Virtual particles

I will return to the consideration of two particles interaction.

As was shown above during interaction of two particles a cloud of particles with n> 1, equation 40 is forming around them. The question arises, can one of these particles exist further, after the interacting particles have diverged a great distance?

To answer this question, we need to remember that the time of ESTM theory has a symmetry to the translations, from which the law of conservation of energy follows. Therefore, in order for one of these particles to exist further, it is necessary that the total energy does not change. Consequently, such a particle can appear only if the energy of the initial two particles decreases.

Virtual particles can exist in empty space, where one particle is distributed. In this case, the density of such particles will be determined by how many perturbations of Meta-Universe field are described by virtual particles. Part of the field of Meta-Universe, which is described in Universe by virtual particles, and which belongs to the space far from ordinary particles, is called the background noise of the Universe. If this background noise of Universe is a constant or it changes in time, while it is not clear.

Renormalization in quantum field theory

From equation 40 follows an explanation how renormalization works in quantum field theory. This equation shows that during interactions around each particle a cloud of virtual particles is formed. The convergence of series is obvious, since the series itself is the expansion of the field over basis. The possibility of ultraviolet and infrared divergences is eliminated by imposing a limit on the maximum and minimum wavelengths in equation 1, where $i$it can only vary from $iMin$ up to $iMax$. A more detailed question about $iMin$ and $iMax$ will be considered after considering gravity.

Basic Particles and Carrier Particles of Interactions

In one of the previous parts of the article it was found that a change in velocity of a particle moving with a velocity less than light velocity can lead to emission or absorption of some other particle that moves at a speed exactly equal to the light velocity. This leads to introduction of a new particle to describe the interactions. Other interactions may also require the introduction of additional carrier particles of interactions. It makes sense to introduce a division into two basic types of elementary particles: fundamental particles and carrier particles of interactions between fundamental particles.

How to identify fundamental particles? In the theory of emergent space-time-matter, the observed Universe is a product of consciousness. Consciousness, in turn, is an epiphenomenon from the field of the Meta-Universe. Therefore, it is logical to take as fundamental particles those particles from which the observers consist. All such particles move at a speed less than the light velocity. Then the fundamental particles are particles moving at a speed less than the light velocity and are not carriers of interactions. These particles form the basis of matter.

The carrier particles of interactions are those particles that are introduced to form a complete basis of expansion and describe the carrier particles of interactions.

Maxwell's Equations

What is the nature of interaction of electric charges? It can be assumed that the interaction is of a vector nature, and then the entire derivation of Maxwell equations within the framework of the ESTM theory is reduced to copying the derivation of these equations from one of the textbooks.

At the level of the Meta-Universe there is only one field, this is the field of Meta-Universe. The question arises whether it is possible to distinguish some effective quasi-fundamental fields within the emergent space-time, and what properties should these fields possess?

Quasi-fundamental fields here mean that the fields within the emergent space-time-matter must look fundamental and not reducible to other effective fields in the emergent space. They can be distinguished if, for some conditions, it is possible to consider the dynamics of a physical system without taking into account other similar fields.

Before proceeding further and considering the consequences of the assumption of vector nature of electromagnetic field, it is necessary to consider whether this assumption is justified and corresponds to the ESTM theory. The vector nature of the field, as far as I can see, does not directly follow from the model theory. At the same time, it does not contradict the theory model. In equations of fundamental field expansion, we can introduce functions that have a spatial orientation. So in the theory model we get a vector field. The propagation of electromagnetic field signal with a velocity exactly equal to maximum propagation velocity of interactions follows from the theory model. As shown above, when a particle's velocity changes, a particle moving with a velocity exactly equal to the maximum velocity of interactions shall be also emitted. Since it is known that when accelerated motion of charged particles emits photons, then the light velocity should be exactly equal to the maximum speed of interactions.

A complete derivation of electromagnetic field could be called obtaining of equations of electromagnetic field, with all its properties, directly from the equation of fundamental field. So far, the development of theory has not run to that, there is a stage of searching for what properties the field of Meta-Universe should possess, so that the laws of physics that we observe are fulfilled. Consequently, since the vector nature of electromagnetic field does not contradict ESTM theory, and since it is shown that the accelerated motion of electric charges in ESTM theory model can lead to emission of particles moving with light velocity, this assumption is appropriate and can be considered.

From the assumption of vector nature of the field and the velocity of the carrier particles, which is exactly equal to the maximum rate of interactions, Maxwell's equations are derived. Their conclusion, with these assumptions, could be found in many textbooks on electrodynamics. On the basis of this, I conclude that based on the assumptions described above and without taking into account the quantum nature of interactions, the Maxwell equations are obtained in ESTM theory.

Quantum equations of electrodynamics are one of the parts of standard model. How does the proposed theory fit with standard model and gauge theories?

The Standard Model

The standard model is a gauge theory. Gauge theories are based on symmetries. Are there symmetries in the proposed theory of emergent space-time-matter?

Above we show a whole series of symmetries, for example, symmetry to time translation, symmetry to change in the sign of charge, and a number of others. From the theory model, such equations of quantum mechanics as Klein-Gordon-Fock equations and the Dirac equation are derived. Maxwell equations are derived with some assumptions. Hence, one can speak about U (1) symmetry. This shows that ESTM theory is compatible with gauge theories and with the standard model. I would like to get the whole standard model from ESTM theory, but so far this issue has not been resolved. I think that it can be resolved in the process of further development of the theory.

Gravitation and General Relativity

Gravity in the framework of ESTM theory is considered a consequence of curvature of the emergent space-time.

Before that, the article suggested that we cut the space of Meta-Unverse into a hyperplane. But what if in order to preserve the causality and identity of physical laws, a curved surface is needed? In this case, we need to talk about hypersurfaces.

- The hypersurfaces belonging to the same family must not overlap.
- There is a continuous transformation that transfers one hypersurface of the family to another.

The conclusion about the maximum speed of interactions and the light velocity by introducing the curvature of the emergent space-time is not changed.

Repeating the arguments about the direction of the time vector, we find that the time vector must have the largest possible angle with respect to hypersurface. For hyperplane this corresponds to perpendicular angle.

The body, motionless relative to the considered hypersurface, evolves along the world line.

Since the hypersurface is not flat, this means that the world line is not straight. Hence, gravitation leads and reduces to the rotation of tangent hyperplane, which represents the frame of reference, where the body is at rest. Acceleration of the body, as described in the article above, reduces to the rotation of hyperplane, which represents the frame of reference, where the body is at rest. But then it means that it is impossible to distinguish which force acts on a fairly small body - the gravitational or acceleration.

Thereby, existence of curvature leads to emergence in the emergent space of the effective field equivalent to acceleration. Also, it may be noted that effective fields in the emergent space are divided into two types:

- Fields which are some projection of fundamental fields on a hypersurface
- Field formed as result of curvature of a hypersurface.

The field formed as result of a curvature at a hypersurface depends on all other effective fields. This dependence arises from the fact that this field forms in such way so that the principle of causality for other effective fields can be achieved. Thereby, we can say that this field is universal in the emergent space and interacts with all other effective fields. As this field depends on a configuration of other fields, the speed of its change has to precisely equal to the maximum speed of configuration change of the fields. This speed is equal to maximum speed of interactions.

The field with such properties is known. It is gravitation.

For gravitation the strong principle of equivalence holds. It was shown above that gravitation and acceleration are demonstration of the same process, the process of turn of the tangent hyperplane in fundamental space. Thereby, within the suggested model the strong principle of equivalence is derived. It is shown that its speed has to be equal with the maximum speed of interactions. This speed, as we know, is equal to the speed of light. It is shown that gravitation is a universal interaction. Also gravitation in such model depends only on other effective fields, but not on itself.

In the general theory of relativity gravitation complies with all the properties described above. For example, there is only an energy-momentum tensor of other fields in it, there is no energy-momentum tensor of gravitation. Gravitation has universal character, as is predicted by the suggested model.

It may be noted that the above difference in types of fields means that many approaches applicable and being efficient for fields of the first type, will not work in the second case. As it is observed in attempts to apply quantization to gravitation.

Also I will note that in the suggested model there are no singularities at the level of fundamental space. Gravitation can result in gravitational singularities in the observed space, but at the same time in fundamental space singularities do not arise.This means that all the principles on which the general theory of relativity is built are obtained. Proceeding from this, I conclude that the general theory of relativity satisfies ESTM theory.

There is also one more conclusion about the absence of quantum of gravity. Since quanta are introduced on the basis of the field expansion, and gravity is based on fundamentally different approach, then according to ESTM theory, gravity quanta can not exist. Proceeding from this, ESTM theory is incompatible with any theory of quantum gravity.

I note that the derivation of all the principles on which the general theory of relativity is based does not allow us to assert that the equations of the general theory of relativity are obtained. The reason is that the action in the general relativity is postulated, but not deduced. Therefore, although the problem is reduced to the known one, it is also necessary to postulate this action in order to obtain the equations of general relativity.

For this reason, it can not be stated that it is impossible to construct another set of gravitation equations, in addition to general relativity, which satisfy all the requirements of ESTM theory. However, any other equations must also satisfy the requirements of ESTM theory listed above. With the development of ESTM theory, the equations of gravity must be derived directly from the equation of field of the Meta-Universe.

Since space metric must be taken into account when introducing the curved emergent space-time, this must be taken into account in the expansion equation of fundamental field of the Meta-Universe:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{ikps} w_{ips}\left(g, L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}, c\right) \quad (44)$$

A dependence on metric of space-time g is added here .

Returning again to the question of basis completeness of the expansion functions. If the expansion functions are complete, then in our Universe there should not be places where the approach with expansion of fundamental field does not work. However, there are known objects where there unremovable singularity exists, black holes. The existence of such objects says that the basis of expansion functions is not complete.

Going back to the question about $iMax$ and $iMin$ in the equation field expansion. Expansion functions should not include such functions that correspond to black holes with their singularities. Therefore, there is a restriction for too short waves of functions. Considering possible limitations from above, functions with characteristic dimensions larger than the observed size of Universe do not seem to be necessary. Perhaps, it is possible to find even more restrictive conditions for the maximum size of functions.

I also note that the strong equivalence principle proved above allows not to put forward additional requirements to the expansion functions.

Cosmological Constant and Dark Energy

Experimental observations show that the Universe expands, and that the cosmological constant in the Einstein equation is nonzero and is a constant.

The cosmological constant is usually interpreted as demonstration of the dark energy responsible for accelerated expansion of Universe.

All modern cosmological models say that the Universe has a beginning, and that in the past all areas of Universe were small enough to interact with each other. The smallness of fluctuations of cosmic microwave background radiation, depending on the direction, is one of the evidences of this.

How does the cosmological constant affect the expansion of field on a hypersurface, is it necessary to modify the equations?

In order to try to answer this question, it is necessary to understand how it is possible to construct a universe expanding with the same value of cosmological constant.

If the entire expansion is caused by the external curvature of hypersurface of the emergent space, then the curvature must change, provided the speed of time and the function of emergent distance are unchanged. This contradicts the observation, therefore, either the speed of time and the function of emergent distance depend on the external curvature, so in total we getan invariable internal curvature caused by cosmological constant, or external curvature does not play an important role.

If the external curvature does not play an important role, then the question is how one can obtain an expanding emergent space on a hypersurface with zero average curvature. The equation contains the distance metric in the emergent space-time. If, with increasing age of Universe, this metric for points with the same distance in the Meta Universe will produce an increasing distance in the emergent space, then one can obtain an expanding emergent space on a hypersurface with zero average curvature. From this it seems logical that the amplitude of expansion function will also decrease with time. Thus, in equation 44 it is necessary to add a dependence on the age of Universe t:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} \sum_{s=1}^{s=N(k)} u_{ikps} w_{ips}(g, L(\vec{r}_f), X, Y_{ik}, \{Q_{ik}\}, c, t) \quad (45)$$

Cosmological constant is thus a function of the ratio of average emergent distance between points at the same distance in Meta Universe at subsequent times:

$$\Delta = \Delta\left(\frac{<l(t+dt)>}{<l(t)>}\right) \quad (46)$$

Black Matter

Equation 45 contains a part $f_{ext}(\vec{r}, t)$ that does not lead to the appearance of elementary particles. If this value somehow affects the metric of emergent space-time, then it can explain the observed effects from the dark matter.

Meta Universe and Emergent Universes

According to ESTM theory, the Meta Universe is an untimely space containing field. Elementary particles, time, space that we observe - all these are emergent phenomena.

Our Universe is part of the Meta-Universe.

The methods of finding space-time-matter, described above, can lead to finding of several different solutions. The define area of these solutions may intersect in the space of Meta-Universe, may not intersect, some solutions can be defined on the same space of the Meta-Universe. Probably there are no solutions defined for some areas of the Meta-Universe.

Each of these solutions, according to the postulate of this theory, corresponds to the existing universe, if intelligent life is possible in the corresponding emergent universes.

I'll write few definitions:

The Multiverse is the set of all universes defined in Meta-Universe.

Close universes are universes that have intersections in Meta-Universe space.

Close universes do not mean that a particular area of space-time of one universe intersects with the area of another universe. The intersection could have occurred billions of years ago or forward, or in megaparsecs from this area.

Locally parallel universes are all universes that have intersections in the area of Meta-Universe space with the allocated part of the space-time of some universe.

Locally parallel universes do not mean that interaction is possible between them. For the interaction between the universes, it is necessary, although perhaps not enough, to have at least some correlations between the equations of elementary particles belonging to different universes.

Interacting parallel universes are universes, actions in one of which can influence the state of another, and vice versa.

If the action to influence another universe will produce a reasonable being, in another universe the consequences of such actions will look like consequences of their own physical laws and will have cause-effect relationships independent of the first universe.

Not so long ago, a fantasy genre with parallel worlds became popular in the fantastic fiction. According to ESTM theory, the existence of parallel Earth is possible if the area of matter concentration in our

Universe corresponds to the concentration of matter of some other locally parallel universe. Perhaps extraterrestrial santient beings are very near, on a parallel Earth?

Space-Time Properties of our Universe

Does time in our Universe have a beginning and an end? There are several possible options, I'll list them all:

1. Time in the Universe has a beginning but has no end.
2. The Time in Universe has a beginning and there is the end of time.
3. Space-time in Universe is closed.
4. Time in Universe has no beginning and no end.
5. The Time in Universe has no beginning but has the end.

All variants with infinite time mean the infinite space of Meta-Universe.

Modern astronomical data show that time in our Universe has a beginning. This throws back all options except 1 and 2.

Accordingly, at the beginning, before the occurence of time, there was (and still exists in the Meta-Universe, although far from us) some state where the formation of the emergent space-time with the same as now laws was impossible. Then, in some area of the Meta-Universe, the phase of formation of our Universe began, at the end of which our space-time and matter appeared. It is impossible to say how long this process took, because the time itself was in this stage of formation in this phase. The further development of ESTM theory should allow us to study in detail the stage of formation of Universe and even see what was before the Big Bang, when there was neither time nor space.

Universe

In this part, I will describe how our Universe looks from the point of view of ESTM theory.

We are in an untimely Meta-Universe. The Meta-Universe has a field defined on the whole space of Universe, the space of Meta-Universe is Euclidean. The equation of field is the same everywhere. Our Universe exists in Meta-Universe, is formed on the basis of one of the variants of space-time formation and the methods for quantization described above.

The emergent laws of physics should not have a noticeable unpredictable component over the entire range of particle energies and the values of gravitational field that is accessible for study. As a result, this means the ability to describe the properties of particles and their interactions, based on states.

The emergent space-time can be curved. As result, it leads to gravity. Gravity ensures the same laws of physics and the fulfillment of causality, where they would be violated in the case of flat space-time.

Both quantum mechanics and the general theory of relativity, according to ESTM theory, are approximate and have limitations on their range of applicability.

Both quantum mechanics and gravity are emergent phenomena.

Is the initial singularity in the Big Bang required?

The impossibility of avoiding the singularity in cosmological models of the general theory of relativity was proved, among other singularity theorems, by R. Penrose and S. Hawking [15] in the late 1960s. These proofs are based on the visible homogeneity of Universe, which is impossible to achieve if all areas of Universe once in the past did not interact with each other.

In ESTM theory, the visible homogeneity of Universe can be reached without initial singularity. To do this, it is sufficient that in the phase of space-time formation, there are approximately the same conditions everywhere in the forming space-time. Before the formation of space-time, the emergent physical laws are inapplicable.

How many dimensions are in the Meta-Universe?

One of the questions that arises when trying to understand the structure of Universe, is why in Universe there are four dimensions, three spatial dimensions and one time dimension.

Ehrenfest showed [16] why the number of spatial dimensions equal to three is the most suitable. If there are more than 3 dimensions, atoms can not exist. In the case of dimensions less than three, the motion would always occur in a restricted area. Only with a number of dimensions equal to three, both stable finite and infinite motions are possible.

Proceeding from the described and using the anthropic principle of participation, it can be stated that the Universe has four dimensions because this is the amount that is necessary for existence of intelligent life. Perhaps it is impossible to build emergent universes with a large number of dimensions because of the impossibility of developing an intelligent life there.

The fact that the four dimensions are most appropriate for emergent universes is at the same time an argument in favor of the fact that the number of dimensions in Meta-Universe is greater than four. No matter how many dimensions are there in Meta-Universe, all the emergent universes will have only four dimensions. Therefore, the assumption that Universe contains only a part of Meta-Universe dimensions looks, in my opinion, plausible.

Physical Foundations of Mathematics

Why does mathematics describe our world so well? Usually this question is considered in philosophy, the philosophical foundations of mathematics are sought. Consider the physical foundations of mathematics from the point of view of the proposed theory of emergent space-time-matter.

In the framework of this theory, the value of fundamental field at each point of the fundamental space satisfies a certain differential equation.

The physics equation for the emergent space is a consequence of this equation. It turns out that in order for mathematics to describe our world well, it is enough that it describes the most fundamental structure of nature. Proceeding from this, it follows that mathematics is a consequence of the fundamental physical structure of nature. All mathematics is a consequence of equation describing the fundamental field.

Logic is also a consequence. Logic is a set of rules that allow you to draw conclusions based on certain facts. Any facts, including purely speculative constructions, in emergent space are based on fundamental field and its properties. Thus, we can conclude that logic is also a consequence of fundamental physical structure of nature.

Suppose the most fundamental level was described by something else, not by mathematics. In this case, according to the above statement, there would be no mathematics or logic in the emergent world.

Can the logic be applied when there is no logic? For such a case, plausible reasoning can be used. Plausible reasoning can be close to the truth, if as a result of application of this "no mathematics" appears something similar to logic. The closer it is to logic, the more accurate are the plausible arguments.

Using plausible reasoning, we can say that if the resulting space-time was obtained, then instead of mathematics in it would be something based on "not mathematics" describing fundamental level and something replacing the logic.

I note that all the arguments were in a certain framework:

1. A fundamental space exists. Both mathematics and "not mathematics" should contain space with a certain number of dimensions.
2. A fundamental field defined on the fundamental space exists.
3. The value of fundamental field is determined by some differential equation for the case of mathematics, and is defined "somehow" for the case of "not mathematics".

Conclusion

An axiomatic deterministic theory of physics based on a single field is proposed. The theory, if true, allows to describe any physical phenomenon in any physical conditions.

In the theory model at the fundamental level there is no time and there is no dynamics. It is shown how space-time with matter and fields emerge in this model. It is shown that the anthropic principle emerges as a consequence of the theory. The causality principle is derived as a consequence of the main principles of the theory. All three Newton's equations are obtained as consequences of the theory and in the nonrelativistic approximation. Mass, energy and other concepts of mechanics were obtained. The Schrödinger equation is derived. An explanation of the nature of particle spin is proposed. It is shown that the maximum speed of interactions must be finite and be the same in all inertial systems. It is shown that the light speed and the maximum speed of interactions are exactly equal. A special theory of relativity with all its equations is obtained. The Klein-Gordon-Fock equations and, with some assumptions, the Dirac equations are obtained. Particles interaction is considered. There were given explanations of what virtual particles and quanta of field interactions are, and how renormalization works in quantum field theory. Seemingly fundamental interactions, such as strong, weak and electromagnetic are shown. Maxwell's equations are obtained, with some assumptions. It is shown that the standard model does not contradict the proposed theory. The nature of gravitation is considered. A strong equivalence principle is proved, all assumptions on which the general theory of relativity is based are proved. Based on this, it can be argued that the equations of the general relativity theory satisfy the theory of emergent space-time-matter. It is shown that gravity can not have quanta. Thus, this theory asserts that no theory of quantum gravity can exist. An explanation of the origin of the universe is proposed. An explanation is offered for the nature of dark energy and dark matter.

It is shown that mathematics, including logics, is a consequence of the equation describing the fundamental field. If the most fundamental level was described not by mathematics, but by something else, then instead of mathematics there would be consequences of this something else.

The theory is not fully completed. Many equations of the theory are not known yet. However, even in its current state, the theory makes it possible to combine the general theory of relativity and quantum mechanics. The theory, even in its current unfinished form, has the predictions, for example, such as the absence of a quantum of gravity. Thus, the theory is already falsifiable. I think that as the theory continues to work, new predictions of the theory will appear.

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