Spacetime and matter as emergent phenomena

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Abstract

A radical deterministic non-gauge theory of emergent spacetime and matter is proposed. In this theory it is assumed that spacetime and matter are the emergent properties of a more fundamental entity. It is shown what properties such a fundamental entity should possess. An approach is proposed to find emergent spacetime and matter with observable properties in such an entity. It is shown how the laws of quantum mechanics with non-deterministic results of measurements and with gauge fields appear in the deterministic model of a more fundamental entity. The proposed theory of emergent spacetime and matter (further ESTM theory), as shown in this article, is compatible with special and general theories of relativity, as well as with quantum mechanics and cosmology. Quantum mechanics was reformulated into background-independent one. The derivation of Schrödinger equation for quantum mechanics is given. It is shown how the Heisenberg uncertainty principle appears from the determinism of a more fundamental entity. Changes in the locality principle are proposed. Equivalence of inertial and gravitational mass is substantiated. The corrections to equations of the general theory of relativity, as well as the change in the conceptual model of gravitation, are proposed. The ESTM theory predicts the absence of a quantum of gravity. The ESTM theory unites all the fundamental forces, including gravity. All fundamental forces are derived from one field.

Introduction

In this article I develop the theory of emergent spacetime-matter [1]. Knowledge of 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, the known laws of physics allow for the existence of singularities, for example, inside black holes. Most consider these singularities as a sign that new physics begins near singularities. New laws of physics describing the state of space, time and matter are being searched for near these singularities. The 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 my knowledge, is first considered only within the framework of the proposed theory. This second option is that in some neighborhood of singularity space, time and matter do not transform into something unusual, but cease to exist. Moreover, since something inside this neighborhood of singularity affects its environment in spacetime, this something cannot be nothing. The question arises, what can be this something?

If this something does not contain spacetime and matter, it must be something more fundamental. But then, since it does not contain spacetime-matter but interacts with them, space, time and matter themselves must be derived from this something. Proceeding from this, spacetime-matter must be the emergent properties of this something. However, they cannot be defined everywhere, but only where there are suitable conditions for this.

Time is the phenomenon, which manifestations we constantly observe. Physics still does not know what time is, the existing description of time and its properties is phenomenological. Moreover, the special and general theories of relativity have established the relationship between time, space and gravity. This shows that time is not an independent phenomenon, but it is connected 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 time is unidirectional, whether there are time quanta, why time has one dimension and if 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.

At present, all the theories known to me in physics consider spacetime and matter as independently existing phenomena. But do they really exist on their own or are they the manifestation of something more fundamental?

This article presents the theory of emergent spacetime-matter (hereinafter referred to as ESTM theory). In this theory, space, time and matter are viewed as being emerged by the properties of a more fundamental entity. This fundamental entity includes everything that exists objectively.

If you look at the properties of physical phenomena, they are characterized by several key properties:

1. Physical phenomena are caused by something. There are cause-effect relations leading to what is happening. At present there are no known phenomena that do not fall under the cause-effect relationship. Some phenomena, for example, the decay of the unstable nucleus of an atom, are of a probabilistic nature. However, although it is impossible to predict the exact decay time for

such phenomena, it is possible to predict the probability of its decay. Thus, the decay of such an atom is still within the framework of the cause-effect relationship.

2. It is possible to calculate the probability of the state of any object at subsequent instants of time with some limitations, such as not near the gravitational singularity, etc. In order to make such a calculation, it is necessary to know the current state of the object and the current state of other objects at some distance from this object.
3. For some phenomena prediction of the state in subsequent moments is only probabilistic. Quantum mechanics claims that it is impossible to accurately calculate the state of an object in the future - one can only calculate the probability of states.
4. The laws of nature are the same throughout the observable space of the universe in all inertial reference systems.

How can spacetime be built on a system in which there is no time?

If there is no time as a fundamental phenomenon, it means that the entity on the basis of which the universe exists is completely timeless and has no changes. This entity cannot have any changes in time due to the fact that there is no time. It would be wrong to assert that the entity on which the universe exists is static. Static implicitly means that something does not change with time, but it does not apply to the case when there is no time. Time in this case must be emergent phenomenon. The special theory of relativity establishes the connection between space, time and speed. It follows that if time is a emergent phenomenon, the observed space is also emergent phenomenon. The general theory of relativity establishes the connection between gravity caused by matter and spacetime. It follows that in order to find emergent spacetime, it is necessary to find gravity and matter as emergent phenomena. Quantum mechanics describes many quantum phenomena. This means the need to find elementary particles with quantum-mechanical effects within the framework of this theory. The principle of uncertainty is an important part of modern physics. It is necessary to show how the uncertainty principle appears in the deterministic ESTM theory. The principle of locality is one of the cornerstones of modern physics. Therefore, the ESTM theory must contain locality, albeit in some modified form. All the observed physical phenomena have a cause-effect relationship. Hence, the emergent time must be constructed in such a way that the state of emergent spacetime and matter could be predicted on the basis of states at the previous moment of time. The resulting laws of physics in emergent spacetime should not contradict any well-established theory in its well-tested domain of applicability. Modern physics knows four fundamental fields. In ESTM theory spacetime and matter must be constructed using only one field. All fundamental interactions, including gravitational interactions, must be derived as emergent phenomena from this field.

Later in this paper I will show that ESTM theory satisfies all these conditions.

Imagine that spacetime and matter, satisfying all the conditions above, were found on the basis of the timeless entity. Can such a spacetime describe the universe that we observe? If life is possible in such a world, can an intelligent being belonging to this world think, feel the reality of the environment and itself? These questions seem to be related to philosophy, since the concept of Being is considered. However, without a positive answer to these questions, the attempt to build emergent spacetime based on the timeless entity does not make sense. This means that different answers to these questions lead to different results in physics. Consequently, these questions also apply to physics. The postulate and the main idea of ESTM theory is the positive answer to these questions.

Occam's razor helps to find the positive answer to these questions, since the ESTM theory significantly reduces the number of independent phenomena. Instead of many different physical phenomena, the

ESTM theory assumes that all physical phenomena, including spacetime itself, can be derived from a single-field model and suggests ways of finding them.

If in such an emergent spacetime, emerged from the timeless entity, there is a rational being, it will observe the following:

- Time exists and all phenomena have a cause-effect relationship.
- There is past, present and future.

Why will the present exist? It may seem that in such a system the time will pass instantly. However, this can only be from the point of view of the external observer. But an external observer in the model of this theory cannot exist because there is no time as a fundamental phenomenon and also because the entity that generates the Universe includes everything that exists objectively. The observer in this model can only be an object capable of self-awareness, and belonging to emergent spacetime. Human thought is some kind of change in the state of particles in a person in time. Consequently, the observer living in the emerged time will be able to think. The speed of his thoughts will be determined by the rate of change in the state of his state relative to other processes occurring in his emergent spacetime. At any particular point of spacetime the observer will always have the same thought. If this theory describes our Universe, it means that everyone is immortal to some extent. But this does not mean that every person exists at every moment of created time. Every person exists forever, but when our present time does not coincide with the present time of someone else - such time are inaccessible for us. Similarly, at any point in the present time, our current mind cannot communicate with itself in the past or the future. Also, the number of human thoughts is limited by the person’s life time. Any person can do whatever he wants within his capabilities. However, a person's desire to do something is caused by the state of the human body at some point in time. Therefore, no one can wish for anything other than what is prescribed by his state. This means that in the deterministic model of ESTM theory there is no real freedom of will.

In modern physics free will is based on the Heisenberg uncertainty principle. In this article I will show that the uncertainty principle does not contradict the determinism of this theory, it arises quite naturally from the deterministic model of this theory.

Postulate:

If in objectively existing timeless system which includes everything that exists objectively, it is possible to find spacetime and matter as emergent phenomena, and if such spacetime matter contains intelligent life, then such spacetime-matter exists and it is emergent spacetime-matter. In such a emergent spacetime-matter a intelligent being can think and feel that it really exists.

Consequences of this postulate: for the case when the laws of physics of emergent spacetime-matter allow the existence of intelligent life, a intelligent being from this spacetime will feel itself in space and feel time. It will feel the emergent laws of physics. The laws of physics of a fundamental timeless system will be deeply hidden from his sensations.

Later in this article I will return to discussing the nature of time.

It can be seen that the postulate of this theory can be proved by induction if we assume that ESTM theory allows us to build a model with the laws of physics completely identical to what is observed. If it is proved that this is impossible, it means that ESTM theory is incorrect. Thus, this means that the postulate of the theory, in principle, can be verified.

If at some point in the emergent time a person is able to think and feel the reality of the environment, then he will be able to think and feel the reality of the environment at any subsequent moment of time while he exists.

Evidence:

ESTM theory presumably describes the world with the laws of physics and phenomena identical to what we observe. If a person is able to think and feel the reality of the environment at some point in time and will not be able to think and feel the reality of the surrounding at any subsequent time, it means that the laws of physics in our world also do not allow a person to think and feel the reality of the environment at subsequent times. This directly contradicts observations: people are able to think and feel the reality of the environment.

Thus, this statement is proved, provided that the ESTM theory allows us to build the laws of physics completely identical to what is observed.

Similar situation is for the first step of induction - that a person belonging to emergent spacetime-matter with completely identical observable laws of physics will be able to think and feel the reality of the environment at some point in time. If in ESTM theory it is possible to build exactly the same laws of physics as in our world, this means that people will be able to be born, learn and start thinking.

The postulate of ESTM theory is largely philosophical, although it has physical consequences. Therefore, its proof can be displaced by using another system of philosophical views. Therefore, I use the postulate rather than the theorem. However, the postulate of ESTM theory can be verified by checking the predictions of ESTM theory. Therefore, if further development of ESTM theory allows experimental predictions to be made, and if the results of the experiments correspond to ESTM theory, this will call into question all systems of philosophical views that are incompatible with the philosophy of ESTM theory.

Usually the article on theoretical physics does not contain philosophy. However, due to the fact that ESTM theory touches the key moments of philosophy, such as Being, consciousness, etc., the philosophical component is an inseparable part of ESTM theory. Here the philosophy ends, although a little later we will have to return to it.

Now I will introduce a new definition - atemporal process:

Atemporal process is a process that takes place in the absence of time as a fundamental phenomenon and occurs in emergent spacetime.

With this definition all processes in our universe are atemporal processes, assuming that time is a emergent phenomenon.

I will call the fundamental timeless system a Metauniverse:

Metauniverse is an objectively existing timeless system that includes everything that exists objectively.

In this definition I use the phrase "objectively existing". This phrase means that something exists, and can exist both with the observer and without him. However, usually this term implicitly implies the possibility of existence of the observer. But an observer who could observe Metauniverse cannot exist, because it is not clear how an intelligent life can exist without time. "Existence" also usually implicitly implies that something is happening in time, some object exists in time. There is no time in

Metauniverse, so it means that Metauniverse exists not in the typical meaning of the word. So "objectively existing" is not a phrase accurately describing Metauniverse, but the closest available in meaning. This phrase here means that Metauniverse exists without any possibility of direct observation by any observer and that the word "existence" for Metauniverse does not imply any processes in time or the existence of time.

The space of Metauniverse has some number of dimensions. This number should be at least 4, so that Metauniverse can accommodate our Universe. The space of Metauniverse is not the same as the space of the Universe, the space of the Universe arises as emergent phenomenon from Metauniverse. I expect that the space of Metauniverse is Euclidean. The Minkowski space, corresponding to the general theory of relativity, arises in the derivation of emergent space from the Euclidean space of the Metauniverse. In Metauniverse I expect the existence of scalar field. This is a classic field without any quantum effects. This means that there is a scalar field described by the equation $f(x)$, where x is a point in Metauniverse space, and this field is defined everywhere in Metauniverse. I also expect that the value of this field at each point is determined by the values of this field at neighboring points and that the equation of this field is symmetric with respect to rotations - there is no dedicated direction. This means that the location, speed and properties of all elementary particles (they will be searched further in the article) at each instant of time is determined by states in the past, future, present and field values in areas not belonging to spacetime, if such areas exist. The value of the field at each point is determined by the values of the field at neighboring points, since there cannot be any carrier particles for interaction in the timeless Metauniverse. What is elementary particle and its states, is shown further in the article.

Why do I assume the existence of scalar field, and not say a vector field or some other? I'm trying to build a minimalistic model that would be able to describe our Universe. With scalar field it seems to be obtained. Thus, the use of more complex fields violates the minimalist approach of this theory.

Metauniverse has some amount of spatial dimensions, there is no time. The number of Metauniverse measurements is unknown, but later in the article it will be shown that there are arguments in favor of the fact that this number is more than four. Metauniverse must have at least 4 dimensions in order to be able to include our universe. One dimension for time and three dimensions for space. All these dimensions in Metauniverse are spatial dimensions and there is no time in Metauniverse.

I will add the definition of complete universe:

Complete universe is the inseparable emergent spacetime matter that has identical laws of physics at any point of emergent spacetime.

I will also add what is such a universe in terms of the proposed theory:

Universe is the complete universe at the given moment of emergent time.

Complete universe includes spacetime and matter throughout the existence of time in this universe. The observer in this complete universe at any given time can only observe the state of the universe at the moments of emergent time. Since the complete universes are based on emergent spacetime and matter, all complete universes are emergent.

According to this theory, our universe is one of the emergent universes. At any given time we can only observe the state of the universe at some point in time. Accordingly, it is necessary to find the spacetime and matter corresponding to the observed phenomena from the described properties of Metauniverse.

Later in this article I will use the word "universe" basically in the meaning of complete universe. For cases where this will mean the universe, it will be clear from the context. The word "Universe" with a capital letter means the universe to which we belong.

Search for spacetime and matter

One of the first questions that arise in the timeless model of ESTM theory: At some point in emergent spacetime how can we move from one frame of reference to another, which is moving relative to the first frame of reference? In order to answer this question, we need a model containing space and time.

The initial model of emergent spacetime with n dimensions, where n <= m. Here m is the number of dimensions of Metauniverse.

- One dimension represents the emergent time
- n-1 dimensions form emergent space with n-1 dimensions.

In such a model, the points of emergent space will move along the line representing time. The emergent space is perpendicular to the time line wherever it is flat.

To begin with, we need to find how time can be found in this model.

In the equations of physics time is a parameter of evolution of the system. Therefore, it is necessary to find what can be the parameter of evolution in emergent space-matter - this will be emergent time.

Recalling the properties of nature described above, the proposed method for searching the emergent time in a timeless Metauniverse:

1. We draw an arbitrary non-self-intersecting 3-dimensional (for the search for a 3-dimensional space) hypersurface in the space of Metauniverse.
2. We draw one more non-self-intersecting 3-dimensional hypersurface. This hypersurface must not intersect with the first hypersurface.
3. So, there are two hypersurfaces. We need to find at least some objects on them. All this is a scalar field. Accordingly, objects on a hypersurface are all possible expansions of scalar field by some bases. I will return to the question of possible expansions in the paper, while I note that these expansions are not obliged to follow everywhere the same lengths of hypersurface. This means that in different areas of the same hypersurface the expansion of the field can go along different lengths. The following is the example of explanation. For the Fourier series expansion this can be written as: $f(x) = \sum_{i=-\infty}^{+\infty} \hat{f}_i \, e^{-i\omega k_l(x)x}$. Here $k_l(x) = l_e/l_M$ is the coefficient specifying the ratio between the distance between two closely spaced points l_e в in emergent space and the distance l_M between the same points along the hypersurface in the space of Metauniverse. Because of the different value of this function in different areas of hypersurface representing the emergent space-matter at a certain moment in time, the inner curvature of spacetime appears in emergent spacetime. I will return to this issue later in the article for a more complete description.
4. Now we are looking for whether it is possible to predict the probability of the state of at least some objects on the second hypersurface based on their state on the first one. Did we get any opportunities? If not, then go to the first step. Otherwise - perfectly, these 3-dimensional hypersurfaces can be considered as potential candidates for emergent space, and the distances

between the nearest hypersurface points can be vectors, possibly representing the emergent time [not quite so, it will soon become more complicated]. Time, as described above, is what sorts the processes and allows us to describe the subsequent state on the basis of the previous state. So time is evolution parameter of the equations. That's how the potential emergent time here is described, it provides exactly such functions.

5. Two hypersurfaces are still not enough to talk about emergent spacetime. [Here I describe only the continuous emergent spacetime. The discrete emergent spacetime is a more complex case, described later in the article]. Spacetime must be continuous, so there must be a set of hypersurfaces between the first two. Any point between these first hypersurfaces must belong to some other hypersurface. On each of these internal hypersurfaces it should be possible to predict the state of the same objects, albeit with some probability, as on the second, for the same formulas. The requirement of the ability to predict by the same formulas leads to the same emergent physical laws on all hypersurfaces at all moments of emergent time. Then after the second hypersurface it is necessary to build further ones (until we can do that) with the same emergent laws of physics. If this happens, it is still a candidate for the fact that emergent spacetime is found. Coming back to time. Time in this case is represented by a curve which vector at each point is either perpendicular to hypersurface or has the largest angle where the hypersurface is curved. In order to maintain the same physical laws, it may be required that in different areas of hypersurface the length of the time vector representing the unit of time is different. In this case, the curvature of emergent spacetime will be determined not only by the curvature of hypersurface, but also by the slowing/acceleration of time and, taking into account the above described, the contribution from the change in the ratio of length in emergent space to the length in Metauniverse.

What is obtained is still not a full-fledged emergent spacetime, but some principles are shown how it can be found. We need additional properties – we need to find movement. For movement we need to find the speed.

It is impossible to imagine the speed by increasing or decreasing the speed of movement along the time line. Any emergent object moving along the time line with any speed of time will have exactly the same changes of its states as the object moving with another speed along the time line. Thus it turns out that this is the same object.

"Movement along the time line" here does not mean that there are some objects that move in the space of Metauniverse. There is no time in ESTM theory of Metauniverse, therefore in Metauniverse there is no movement and no processes in time, only atemporal processes. " Movement along the time line" means a successive change in the state of the object at consecutive moments on the line of emergent time. Now I use the word "object", but later I will use the words "elementary particle" instead. The definition and properties of elementary particles and how they appear from the scalar field of Metauniverse are described later in this article.

The transition from one frame of reference to another, moving with respect to the first, can be accomplished by rotating the spacetime at the point of spacetime where the transition occurs. This means turning both the emergent space and emergent time. It follows that the time line after the turn will not be the same as before turning (and similarly for space). The time line after the turn will have some angle with respect to the time line before the turn. As a result, the distance between points on these time lines will grow in proportion to the length of the lines. This behavior corresponds to the speed. Thus, the speed in the model of ESTM theory is found, and it is the angle of rotation of the spacetime.

The state of any object known to us depends on its state in the past and the state of objects and fields in some neighborhood of this object in the past. There are cause-and-effect relationships. In order to obtain such properties from the timeless Metauniverse, it is necessary to have a matching function. Matching function here means that for any state of elementary particles in some area of emergent spacetime there is a set of states of the area of emergent spacetime at each subsequent time and this set includes all possible states for the initial state with their probabilities. First, I'll look at the matching function with a single value and then I'll look at matching functions with many values.

This approach with the matching function can work well, but, given how this matching function is introduced, probably it is not possible to use this matching function everywhere. While this approach with the matching function works, you can talk about emergent spacetime-matter. For those areas of Metauniverse where such an approach does not work, these areas do not belong to this emergent spacetime. However, transitional areas and transient energies can exist, described further in the article.

If the state of an object cannot be described by the same matching function as for other objects belonging to some emergent spacetime, then such an object does not belong to this spacetime, it is outside this spacetime. Such an object can belong to another spacetime, if it can be described by matching function for spacetime, or does not belong to any spacetime. In order for the laws of physics to be identical in all inertial systems in emergent spacetime, the matching function must be the same in all inertial frames of reference. Let me remind you that objects here mean all possible constructions from the expansion of scalar field of Metauniverse on emergent space. The metric of emergent space can differ from the metric of the hypersurface representing the emergent space (this will be shown later).

The maximum angle of rotation of spacetime corresponding to the maximum possible speed is limited by several factors:

1. Properties of scalar field of Metauniverse. The field can limit the applicability of matching function to some range of rotations. The special theory of relativity says that the maximum possible speed is the speed of light, which imposes the limit on the maximum angle of rotation.
2. Turns must support cause-effect relationships.
3. The turn should not be such that after the turn the time will point to the past which was before the turn. But this does not mean that it is impossible to turn into the past by several successive turns (it will be considered further).

In our Universe the state of any object at some point in time depends on the state of space and matter around this object at any previous point in time. However, the presence of matching function is not enough, we should be able to move into a moving frame of reference. Consequently, the elementary particle after the rotation must remain itself, although it is possible to change the state. I will present the temporal definition of an elementary particle (later it will be refined):

Elementary particle is such a part of the expansion of scalar field of Metauniverse in emergent space, which is stable for at least some emergent time, has the invariant for rotations and interacts in emergent spacetime with other elementary particles as an integral unit.

This means that part of some expansion of the scalar field in emergent space in the vicinity of some point with some modifications that do not change the properties of the part of the expansion and preserve the invariant for rotations, must exist along the time line during some length of the time line. The matching function must be able to predict the future state of a particle based on its state and the state of other surrounding particles at some distance in the present. Elementary particle must interact with other particles as an integral unit, since if only a part of elementary particle interacts and the other parts do not interact, it means that these parts are separate elementary particles. Later in this article the definition of an elementary particle will be expanded and changed.

In the definition of an elementary particle there is the requirement of the invariant for rotation. It is clear that for scalar field with the above properties $\oint \frac{df(\vec{r})}{\overrightarrow{dr}} \overrightarrow{dr} = 0$ for any closed curve. The question arises, how can such an invariant exist at all? The answer to this question is proposed in the section where the special theory of relativity is considered.

The approach to formation of emergent spacetime-matter, described above, imposes a lot of restrictions on the properties of the scalar field of Metauniverse. It is possible to significantly reduce the restrictions on the scalar field of Metauniverse. Instead of requiring the scalar field of Metauniverse to construct a continuously defined matching function, it is possible to require that the matching function be discrete, defined only at certain points. In this case emergent spacetime also becomes discrete. Since the spacetime of one frame of reference is at an angle with respect to the reference frame moving with some speed relative to the first system, it means that the discreteness leads to the presence of a minimum rotation angle. Accordingly, the velocity space also becomes discrete.

The approach described above uses the matching function with a single-valued matching function. However, such a function imposes many restrictions on the scalar field of Metauniverse. Of course, this leads to simplification of the search for the equation of the Metauniverse scalar field, but I want to consider all possibilities. Matching function can be probabilistic, which means a multi-valued matching function.

This means that for identical values of the scalar field in emergent space, matching can be on a set of different values in accordance with the probabilistic matching function. The use of probability matching function allows us to further weaken the requirements for the function of the scalar field of Metauniverse. The probability matching function does not mean that the result of the comparison cannot be accurately predicted. The result can be accurately predicted by knowing the scalar field function and knowing the boundary conditions. Moreover, the boundary conditions may not be available in emergent spacetime-matter, part of them may not belong to emergent space, and some may not be reflected in the particle states.

I'll add several definitions:

World line is the line that starts at some point in emergent spacetime and which includes all points that follow in time.

World lines differ in different frames of reference, i.e. through one point in the space of Metauniverse there are as many world lines as there are turns available.

With the approach described above, the requirements for the scalar field of Metauniverse become weaker. However, there is a problem with the beginning of world lines. If the world line is infinite and not closed, Metauniverse must also be infinite. With the infinite world line time in our Universe must also be infinite. However, this contradicts the cosmological data on the history of our universe, that time in the universe has the beginning. Thus, we need to find a way for the emerging and completion of world lines.

World line is based on the ability of matching function to be the same at the entire emergent spacetime. However, the situation is possible when from a certain point the matching function cannot work. If at some point in Metauniverse the matching function cannot be correctly applied, world line ends at this point. Similar situation is the beginning of the world line. At some point it becomes possible to use the matching function. Potentially, at this point there is emergent spacetime-matter. The emerging of one or several world lines does not mean the emerging of emergent spacetime-matter. In order to form the velocity space, it is necessary to be able to rotate the spacetime over the whole range of velocity space. At the beginning of the world line it may be that the full range of turns is not available. At this point it is impossible to say that time and space exist. This is the transient space, the phase of formation of spacetime and matter. If while moving along the world line it is possible to reach the emergent universe, it means that the beginning of this world line comes from the place of the emergence of a new emergent universe. If the world line is interrupted before the universe is created, it means that the formation of the new universe was unsuccessful. What would happen if one of the world lines that make up the universe ends? For example, in some area of Metauniverse space, the matching function produces inaccurate results. In many such cases the world line can be continued even when the matching function gives incorrect results if the unpredictable component is added to matching function.

In this article I call unpredictable any phenomenon that cannot be predicted on the basis of states at the previous moment of emergent time, albeit probabilistically.

Unpredictable component does not mean the absence of cause-effect relationships. It simply means that the cause-effect relationships are deeply hidden from the corresponding emergent spacetime-matter. At the moment, I do not know any experimental results that show the existence of unpredictable phenomena in our universe. Therefore, it is entirely possible that the unpredictable component is always exactly zero, or it effects significantly only on cosmological scales. Or it differs from zero only in places of formation of spacetime. At the moment, possible candidates for such places are the neighborhoods of gravitational singularities and particles with Planck energies.

Above a temporary definition of elementary particle was given. Based on what was written above, the definition changes as follows:

Elementary particle is such a part of the expansion of the scalar field of Metauniverse in emergent space, which is stable for at least some emergent time, has an approximate invariant for rotations and interacts in emergent spacetime with other elementary particles as integral unit.

In addition to what has already been described, I added "approximate". On the one hand, as described above, the invariant must be exact. On the other hand, it is not clear how to construct such an invariant in the model with the scalar field of ESTM theory. It looks like an internal contradiction. In the section on special relativity it will be shown that, on the one hand, the invariant is exact, and on the other hand that it is also approximate.

It may seem that the invariant must be exact and not approximate. In accordance with Noether theorem, continuous symmetries lead to conservation laws. If the invariant for rotations is inaccurate, this can lead to violation of some conservation laws, namely the law of conservation of angular momentum. Later in the section on SR it will be shown that inaccurate invariant does not necessarily lead to violation of conservation laws, it can be constructed so that it will be perceived as accurate.

Adding of unpredictable part to matching function leads to the necessity for emergent physics laws to be resistant to small changes in matching function.

At any point of emergent spacetime there must be a maximum angle at which it is possible to rotate the spacetime. Otherwise, changing the speed could turn into the past.

The existence of the maximum rotation angle of spacetime means the existence of the maximum possible velocity. In our universe this corresponds to the speed of light.

Based on the above, there are several possible options for emergent spacetime:

1. Continuous space, continuous time, continuous velocity space
2. Continuous space, continuous time, discrete velocity space
3. Continuous space, discrete time, continuous velocity space
4. Continuous space, discrete time, discrete velocity space
5. Discrete space, discrete time, discrete velocity space
6. Discrete space, discrete time, continuous velocity space
7. Discrete space, continuous time, continuous velocity space
8. Discrete space, continuous time, discrete velocity space

At the moment, all the experimental data show the lack of discreteness, which means that variant 1 describes our Universe. This option means no quantum gravity (the reasons for that will be described later in this article).

The search for spacetime does not end here, since there are a number of unresolved issues. I will continue the search later in the article. But first I will consider a number of other issues.

Interaction of past, present and future

According to ESTM theory, we live in timeless Metauniverse. Time in our Universe is emergent phenomenon. The scalar field of Metauniverse does not change due to the fact that there is no time. In Metauniverse there is no preferred direction, and the field equations do not depend on the direction.

This means that any point belonging to the past or the present interacts with the future. Also, it means that the future interacts with the past and the present. Because Metauniverse is timeless, it also means that the past cannot be changed. From the point of view of the observer who belongs to emergent spacetime the time machine is impossible. However, this does not completely prohibit the time machine. If there is a process that allows some world lines to go into their past, for example to be closed, then from the point of view of the observer, who does not belong to such lines, nothing can go to the past. In more detail this will be analyzed in the part where the special theory of relativity is considered.

Any states of objects in the present have already affected the past, it is impossible to make the state of objects incompatible with the past. Any attempt to change the past will not lead to any changes in the past. The reason is that these attempts have already been taken into account in the past, even before we decided to do them.

Loss of information about the past

The past is all those events that have already occurred.

Can events that have already occurred change?

It is possible if the unpredictable part of the matching function is different from zero. In this case, depending on the distance, the contribution from the unpredictable component will accumulate. Cause-effect relationships in this case will change with time. It is possible that in the same frame of reference, at points separated by time, emergent events, events in the general past may look different.

This can be interpreted as the loss of information about the past.

I suppose that the unpredictable part can be essentially nonzero only where any world lines are formed and completed. This behavior of world lines can be assumed near gravitational singularities and perhaps somewhere else. Therefore, loss of information about the past may not be available for observation under normal conditions.

It is necessary to solve the equations of ESTM theory in order to be able to describe such processes and to find out whether they exist.

In order to describe manifestations of unpredictable phenomena (if they exist) I will add a new definition:

The half-life of causality is the time interval during which half of the cause-effect relationships existing at the beginning will not exist at the end of the time interval at a given rate of cause-effect relations violation.

This definition is rather vague. There is no precise definition of what a cause-effect relationship is and how these relations should be calculated. Therefore, this definition needs to be improved in the process of further development of ESTM theory.

I will write the equation for the half-life of causality:

$$\tau_{caus}(V,t) = \frac{N(V,t)}{dN(V,t)/dt}$$

Here τ_{caus} is the half-life of causality at time t, N is the number of cause-effect relationships at time t in some area V, $dN(V,t)/dt$ shows how quickly cause-effect relationships are lost in time t. In this equation it is necessary to somehow take into account the cases when cause-effect relationships go from the allocated volume of emergent space to the neighboring volumes, as well as how they come from the outside. I think these problems can be solved further with future development of ESTM theory.

Is there a loss of information about the past in the normal conditions of the Earth? In other words, how accurately is it possible to predict the state of the system in typical terrestrial conditions based on its state and the state of its entire environment?

In order to try to answer this question, we can recall that the law of conservation of energy is based on the Noether theorem and the homogeneity of time.

Observational data show that at cosmological times the energy of visible matter is not conserved. In order to solve this problem there is a concept of dark energy, which is responsible for the accelerated expansion of the Universe. Adding dark energy allows you to keep the uniformity of time.

Within the framework of the proposed theory of emergent spacetime-matter, an alternative explanation is possible on the source of energy for the observed accelerated expansion of the Universe. If we assume that there is a nonzero unpredictable part in the equations, this leads to the fact that the system will cease to be symmetric with respect to time transfer. As a result, there will be a violation of the energy conservation law. In order for the result of this violation to coincide with observations, it is necessary that the average effect of this violation is not zero and leads to the desired result.

I think that we can try to estimate the average value of the unpredictable part, but I leave it for the future. So far the result of this part of the article is that the equations of this theory can contain some unpredictable part. Let me remind you once again that the unpredictable part is unpredictable only from the point of view of information available at some point in time. From the point of view of Metauniverse there is no unpredictability.

Expansion of scalar field and elementary particles

In one of the sections above I mentioned that all objects in emergent spacetime are some expansions of the scalar field of Metauniverse on the hypersurface representing the emergent space. The above also described what results it should lead to. Taking into account everything written, I will analyze the expansion of the scalar field in more detail.

To begin with, there is some hypersurface L, and at each point on this hypersurface the scalar field of Metauniverse has some value. I assume that the contribution of one elementary particle can be represented as part of some expansion of the field on the surface L:

$$u(L,\vec{r}) = \sum_{i=-\infty}^{i=+\infty} u_i w_i(L,\vec{r},\vec{r}-\overrightarrow{r_u}) \quad (1)$$

In this equation w_i is the i-th function by which the expansion takes place, u_i is some kind of factor, $u(L,\vec{r})$ is the value that this sum gives at the point $\vec{r}$, that belongs to surface L, $\vec{r}$ and $\overrightarrow{r_u}$ vector of Metauniverse, $\overrightarrow{r_u}$ is a point on surface L with respect to which the expansion for the given particle is the most symmetric. In order to find the distance between the points $\vec{r}$ and $\overrightarrow{r_u}$ on surface L we must also use the L function.

Do we need to sum this equation from minus to plus infinity?

Adding the restriction to the values of i means the imposing of restrictions on the length of waves for particles. One of such limitations can already be seen – it is Planck energy. For the wavelength that corresponds to it, it is impossible to build the invariant to rotations of spacetime. Thus, a restriction on the possible values of i appears. On the other hand, the restriction to the maximum wavelength does not look so obvious. It can be said that there is hardly any sense in considering the wavelengths larger than the size of the Universe, and here is another limit on the possible values of i. I think that the maximum size of waves can be further restricted, but it is still unclear how. If we assume that characteristic length for the function w_i depends on i, then it means restrictions on the minimum and maximum values of i. For those functions w_i, where the dependence of the length of characteristic wave can both increase and decrease with increasing i, it means excluding ranges of values i where characteristic wavelengths of the function w_i do not fit within the range described above.

Thus, it is necessary to change the summation over i to summation from $iMin$ to $iMax$. For brevity, in the equations below I will basically write that the summation goes over i, without mentioning the summation boundaries.

Since I assume that the function of the scalar field of Metauniverse does not have any distinguished directions, then in the case of a plane surface L for isolation of one particle in the expansion of the field there should exist the point with respect to which this expansion is symmetric. In case the surface is curved, the symmetry in the expansion disappears, but we can talk about the point where the expansion is closest to symmetry. In case of a plane surface, when the expansion is symmetric and independent of direction, the dependence on $\vec{r}$ disappears from the equation and the dependence on $\vec{r} - \overrightarrow{r_u}$ remains:

$$u(L, \vec{r}) = \sum_i u_i w_i(L, \vec{r} - \overrightarrow{r_u}) \tag{2}$$

Also, the basis of expansion and the functions w_i can differ for different types of particles. I denote the type of the particle as p, so the basis of expansion for particle of type p is the set of all functions w_{ip}. Thus, the contribution to the scalar field from particle of type p:

$$u_p(L, \vec{r}) = \sum_i u_i w_{ip}(L, \vec{r}, \vec{r} - \overrightarrow{r_u}) \tag{3}$$

At the same point there may be nonzero parts from the expansion of different elementary particles. This means that the value of the scalar field at each point must be a sum of different particles plus perhaps some part that does not lead to the formation of emergent elementary particles:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum u_k(L, \vec{r}) \tag{4}$$

Here $u_k(L, \vec{r})$ is the value of the expansion of the field from k-th particle at the point $\vec{r}$, belonging to surface L, $f(\vec{r})$ is the value of the scalar field of Metauniverse. $f_{ext}(\vec{r})$ is the part of the value of the scalar field which does not lead to formation of emergent elementary particles.

The summation is over all elementary particles present on hypersurface L, which means summation over all elementary particles available at some time in the corresponding universe.

Taking into account the fact that different types of particles can exist, this equation can be rewritten as:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} u_{ikp} w_{ip}(L, \vec{r}, \vec{r} - \overrightarrow{r_{kp}}) \tag{5}$$

Here u_{ikp} is the coefficient of field expansion for the k-th particle of type p, A is the number of different types of elementary particles, $\overrightarrow{r_{kp}}$ is the point of greatest symmetry of expansion for the k-th particle of type p. Summation over k proceeds in case there are particles of a given type from 1 to N_p) the total number of particles of type p.

Suppose that there are two distinct points on hypersurface L. The question arises: do hypersurfaces that correspond to a state at any time point in time coincide? In order for them to coincide, it is necessary that the speed of time, namely the length in Metauniverse corresponding to a unit of time at a given point, coincide for both points. If the speed of time is different, the hypersurfaces will also differ.

Assume that there are three points on hypersurface L and the distance between the first and second points along the hypersurface is equal to the distance between the second and third hypersurfaces. Does this mean that the distance in emergent space between these points will also be the same? It is not clear why this should be so. But then it means that the expansion needs to be changed.

Where the length in Metauniverse, corresponding to a unit of length in emergent space, is greater than elsewhere, then the functions w_i should take this into account. This means that the distance between $\vec{r}$ and $\overrightarrow{r_u}$ should correspond to the distance between these points in the emergent space, and not in the space of Metauniverse. In addition, there should be a dependence on the speed of time $\overrightarrow{v_t}$ at point $\vec{r}$. So at different speeds of time in different areas the amplitude can differ in order to achieve the same effect.

Adding the dependence from $\overrightarrow{v_t}(\vec{r})$ leads to equation

$$u_p(L, \vec{r}) = \sum_i u_i w_{ip}(L, \vec{r}, \overrightarrow{v_t}(\vec{r}), l(\vec{r} - \overrightarrow{r_u}), c) \tag{6}$$

Where $l(\vec{r} - \overrightarrow{r_0})$ is the function that returns the distance between two points$\vec{r}$ and $\overrightarrow{r_u}$ in the corresponding emergent space, c is the maximum velocity of the particles.

Here the question arises: how locality is achieved in this approach and why the dependence on the maximum particle velocity c is added to equation 6. Locality can be provided by assuming that $\overrightarrow{r_{kp}}$ corresponds to the intersection of the world line corresponding to zero velocity and hypersurface L, and this line passes through the point of the greatest symmetry of the particle at the instant of time

$$\Delta t = l(\vec{r} - \overrightarrow{r_{kp}})/c \tag{6.1}$$

earlier. Here c is the maximum velocity of the particles corresponding to the speed of light in our Universe. If universes are possible without limiting the maximum speed, then this corresponds to infinite maximum speed and $\Delta t = 0$. O It should be noted that if there is maximum velocity of particle motion, then it must be the same in all frames of reference, since all reference frames in ESTM theory are equal, and there is no dedicated frame of reference. This means that in equation 6 it is necessary to add the dependence on the maximum speed c.

Thus, the value of scalar field at point $\vec{r}$:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} u_{ikp} w_{ip}(L, \vec{r}, \overrightarrow{v_t}(\vec{r}), l(\vec{r} - \overrightarrow{r_{kp}}), c) \tag{7}$$

here $\overrightarrow{r_{kp}}$ satisfies the equation 6.1.

What does the distance function relate to? As the length unit increases, the effect of the corresponding functions w_{ip} accumulates longer. This means that the amplitude u_{ikp} of this function can be smaller. Since the effect accumulates longer, it also means that the distance function is related to time-velocity function. This means that there must be some invariant connecting the length function and time-velocity function. I will denote it as h:

$$h(l, \overrightarrow{v_t}) = const \tag{8}$$

It is not yet clear whether this invariant is connected somehow with the speed of light.

These equations are not yet final. Further in the article they will be changed relatively to cosmology.

Now we need to add here the multiply mentioned matching function. The state-based matching function at any time gives the state at subsequent times. Taking into account equation 7 and the approximation of plane emergent space and neglecting the finiteness of the maximum velocity of particles described by equation 6.1, the state Ψ at any instant of time can be written as vector in the state space consisting of the values u_{pik} and $\overrightarrow{r_{pk}}$ for all particles in the considered area. This means that the matching function (I will denote it as U) takes the state vector from one value to another and in the above-mentioned approximation of plane emergent space and nonrelativistic energies, so it is the operator:

$$\Psi(t + dt) = U\Psi(t) \quad (9)$$

Thus, operator U transforms the state vector into another state vector, so it is the linear operator.

The next question that arises: whether operator U is a single-valued or multivalued function? When describing above the process of searching for emergent spacetime it was mentioned that one can try to use a multi-valued matching function that must contain the probability of each state. Taking into account the requirements for information preservation and the fact that probabilistic transformation leads to loss of information, I conclude that operator U can only be a single-valued function. Thus, an additional condition is imposed in the search for emergent spacetime.

If there is loss of information, this equation turns into:

$$\Psi(t + dt) = U\Psi(t) + P(\dots) \quad (10)$$

Here $P(\dots)$ is unpredictable part, and the ellipsis means a set of unknown parameters on which this function depends.

At the creation/destruction of particles the state vector changes the number of elements. I think that the transition is not instantaneous, there are some transient processes. So far, it is impossible to describe these transient processes, because for that we need to investigate the properties of the function of the scalar field of Metauniverse.

Metauniverse and emergent universes

According to ESTM theory, Metauniverse is a timeless space containing scalar field $f(x)$. Elementary particles, time, space, which we observe – these all are emergent phenomena.

Our Universe is a part of Metauniverse.

The methods of finding spacetime-matter, described above, can lead to several different solutions. The domain of definition of these solutions may intersect in Metauniverse, may not intersect, and some solutions can be defined for the same areas of Metauniverse. It is possible that no solutions are defined for some areas of Metauniverse.

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

Here are several definitions:

Multiverse is the set of all universes defined in Metauniverse.

Close universes are universes that have intersections in Metauniverse.

Close universes do not mean that a particular area of spacetime of one universe intersects with the domain of another universe. The intersection could have happened billions of years ago or forward, or many megaparsecs from this area.

Locally parallel universes are all universes that have intersections in the area of Metauniverse space with the allocated area of spacetime of some universe.

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

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

If the action for influencing another universe produces a rational being, the consequences of such actions in another universe will look like consequences of their own physical laws and will have cause-effect relations independent of the first universe.

Not so long ago fantasy became popular in the fantasy genre with parallel worlds. 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 intelligent beings are very near on the parallel Earth?

Spacetime properties of our Universe

Does time in our universe have beginning and end? There are several possible options and I will list them all:

1. Time in the Universe has beginning but has no ending.
2. Time in the Universe has beginning and ending.
3. Spacetime in the Universe is closed.
4. Time in the Universe has no beginning and no ending.
5. Time in the Universe has no beginning but has ending.

All variants with infinite time mean the infinite space of Metauniverse.

Modern astronomical data show that time in our universe has the beginning. This discards all variants except 1 and 2.

Accordingly, at the beginning, before emergence of time, there was (and still exists in Metauniverse, although far from us) some state where the use of the same matching function as it is now was impossible. Then, in some area of Metauniverse, the phase of formation of our Universe began, at the end of which our spacetime and matter appeared. It is impossible to say how long this process took, since time itself in this phase was in the formation stage. Further development of ESTM theory should allow us to study in detail the stage of formation of the Universe and even see what was before the Big Bang, when there was neither time nor space.

Completion of formation phase does not mean the cessation of formation of new space and matter. Formation is still possible and, at least for space, it still occurs (it will be described further in the article in section concerning cosmology and gravity).

Our Universe

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

We are in timeless Metauniverse. Metauniverse has scalar field defined in the whole space of Metauniverse. The space of Metauniverse is Euclidean. The equation of the scalar field is the same everywhere. Our Universe exists in Metauniverse, it was formed on the basis of one of the variants of spacetime formation and the quantization methods described above.

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

Emergent spacetime can be curved. In this case gravity appears. Gravity does not change matching function for particles. Gravity provides the uniformity of matching function where matching function would otherwise not be applicable. Emergent spacetime is curved so that matching function is unchanged.

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

Both quantum mechanics and gravity are emergent phenomena.

Time, space and matter

There are many definitions of time. All the definitions which I know say that time is the phenomenon completely independent of observers - it exists in the presence of observers and when observers do not exist.

In ESTM theory we exist in timeless Metauniverse. There is no time in Metauniverse, the time we observe is emergent phenomenon. But is there such a time without observers? Without an observer it cannot be measured. Without an observer the time in ESTM theory model is just a mathematical abstraction. Time and any effects in a possible emergent spacetime cannot occur without an observer. Is it possible to consider that a possible emergent universe, in which there are no observers, exists? It seems that this question is related to philosophy.

My opinion: the universe does not exist if it does not have an observer over all possible emergent time. Only a rational being can be an observer. Thus, the universe exists only if rational life appears in it at some point in emergent time. Without an observer a possible universe remains a mathematical abstraction.

Rational life cannot exist without cause-effect relationship. As far as I know, at the moment there are no models of intelligent life without cause-effect relationships.

From one point of view, time is the parameter of evolution of equations, as described earlier in the article. From another point of view and given the above, time is such a subjective ordering of a multitude of matter-spaces that support causality. This means that spacetime-matter is subjective and is not objective - it depends on the observer and does not exist without the observer.

Time is subjective because it does not exist without an observer. Each moment of time contains a different state of space-matter. Each state of space-matter at each moment of time must be based, at least in part, on the state of space-matter at previous points in time, in order to maintain cause-effect relationships. The state of space-matter at subsequent times may not be completely based on the state at previous points in time, provided that they allow the existence of at least some cause-and-effect relationship. Cause-and-effect relationships should exist long enough to allow the emergence of intelligent life. Otherwise, the corresponding universe will not have rational life and, as a result, will not have the observer. If the universe does not have the observer at any time of emergent spacetime, such a universe does not exist and remains a mathematical abstraction.

It follows that if the laws of physics contain an unpredictable part, it must be small enough to allow the existence of intelligent life. This means that in any universe there must exist at least one area of space V that has suitable conditions for the development of intelligent life and for which the half-life of causality is greater than the minimum half-life required for the emergence of intelligent life:

$$\exists V, V \rightarrow SAS\,,\;\; \tau_{caus}(V) \geq \tau_{min}\; \forall\, t_{begin} < t < t_{end},\, t_{end} - t_{begin} > \tau_{min} \qquad (11)$$

here τ_{caus} is the half-life of causality, τ_{min} is the minimum half-life of causality at which the formation and existence of intelligent life is possible. Such a condition must be fulfilled in this area on the entire spacetime gap related to the formation and existence of intelligent life, from time t_{begin} and to t_{end}. The designation $V \rightarrow SAS$ in this equation means that other conditions in this volume should allow the emergence of intelligent life and self-aware structures.

I expect what with further development of ESTM theory, new equations will be added to equation 11. Additional equations are necessary to allow existence of intelligent life.

In this part of the article it is easy to see that ESTM theory is not based on philosophical realism. This is due to the fact that one of the consequences of this theory is the impossibility of existence of spacetime-matter regardless of our consciousness. Spacetime-matter is the product of our consciousness. The proposed theory contains entities independent of our mind, namely the field and space of Metauniverse. More precisely, consciousness depends on the scalar field of Metauniverse, but the field itself does not depend on consciousness.

ESTM theory and anthropic principle

The anthropic principle [2] [3] was proposed for the scientific explanation why there is a number of non-trivial relations between the fundamental physical parameters in the observable Universe necessary for the existence of intelligent life. There are different formulations; usually weak and strong anthropic principles are outlined.
The anthropic principle of participation formulated by John Wheeler is the variant of the strong anthropic principle is [4]:

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

In ESTM theory the anthropic principle of participation is the direct consequence of the main theses of the theory.

Field of Metauniverse

Metauniverse in the ESTM theory has no time and does not contain any elementary particles. Spacetime-matter are emergent phenomena. Accordingly, for the scalar field of Metauniverse there are no carrier particles for interaction. The value of the field at each point of Metauniverse in this case should be determined by the values of the field at the neighboring points

Particles in the ESTM theory are emergent objects based on the scalar field of Metauniverse, and knowing the state of such particles is not enough to completely describe the state of scalar field. The states of elementary particles are expansion coefficients in functions for a particle and the set of states of elementary particles do not provide complete information about the state of scalar field of Metauniverse in the corresponding area. Also, these eigenvectors must correspond to functions w_{pi} from equation 6.

The fields of Metauniverse do not change in time due to the fact that there is no time, so there cannot be any carrier particles for interaction. This leads to the conclusion that the field values at the point are determined only by the field values at the surrounding points.

This leads to the following: if there is any closed surface S in Metauniverse, the value of the field inside any point in the area surrounded by this surface is determined only by the field values on this surface, $f(S)$.

This means that there is function $g(x, S, f(S))$ that unambiguously finds the value of scalar field of Meta–universe at the point x o of the surrounding surface S, where the field value on the surface is f(S):

$$f(x) = g(x, S, f(S)) \tag{12}$$

It can lead to an interesting conclusion: complete information about the entire Metauniverse and all emergent universes exists in any area of Metauniverse. Such a conclusion may be true under the condition of smoothness of the scalar field function for Metauniverse (additional conditions are possibly required).

Observation

The main source of information about the reality surrounding us is observation. How observation can be described from the point of view of ESTM theory?

Observation can only be done by an observer. If state Ψ characterizes the state of the system at some point in time, then in order to describe the observation from this state it is necessary to select the state of the observer Ψ_{SAS} and the state of the observed object Ψ_{obs} . Taking into account equation 9, this leads to the fact that the result of observation is described by a certain linear operator.

The Schrodinger equation

Equation 9 describes the evolution of the system in time in the approximation mentioned. Laws of physics, as was written before, should be always same. It means should exist symmetry for time translation. This means that the operator U preserves the scalar multiplication, i.e., it is unitary.

If in equation 9 dt=0, then $U = I$, where I is the unit operator.

Further, I assume that function Ψ differentiable, which means the continuity of spacetime. Therefore, we can write the following:

$$\Psi(\mathrm{t} + \mathrm{dt}) = \Psi(\mathrm{t}) + \mathrm{d}\Psi(\mathrm{t}) \tag{13}$$

On the other hand,

$$\Psi(\mathrm{t}) = I\Psi(\mathrm{t}) \tag{14}$$

Then

$$\Psi(\mathrm{t} + \mathrm{dt}) = (\mathrm{I} + \mathrm{dU})\Psi(\mathrm{t}) \tag{15}$$

The equation can be shortened:

$$\mathrm{d}\Psi(\mathrm{t}) = \mathrm{dU}\ \Psi(\mathrm{t}) \tag{16}$$

dividing by dt:

$$\frac{d\Psi}{dt} = \frac{dU}{dt}\Psi(\mathrm{t}) \tag{17}$$

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

$$\frac{d\Psi}{dt} = A\Psi(\mathrm{t}) \tag{18}$$

What I actually got is Schrodinger's equation up to a multiplier. Let us recall how the Schrödinger equation looks:

$$ih\frac{d\Psi}{dt} = \widehat{H}\Psi \tag{19}$$

I should note that it is quite easy to get equation 19 from equation 18. To do this, we must remember that unitary operator can be represented through Hermitian operator. For Hermitian operator the following is met:

$$U = e^{iH} \tag{20}$$

Where U is the unitary operator. Substituting eq. 20 in eq. 18 we get, up to multiplier, equation 19. The presence of Planck constant in eq. 19 indicates that Planck constant is somehow connected with the expansion functions.

I recall that the law of conservation of energy, according to Noether's theorem, follows from the homogeneity of time. In ESTM-theory, time is homogeneous, this is evident from the way it is sought. Consequently, equation 18 must contain the law of conservation of energy and there, in some form, there must be a description of energy. In equation 19, energy is described by the Hamiltonian $\widehat{H}$, and the law of conservation of energy is fulfilled in it. Thus, this can be considered as an additional argument in favor of the fact that equations 18 and 19 coincide.

The Schrodinger equation is nonrelativistic. Equation 18 is also nonrelativistic, since equation 6.1, which determines the dependence on the speed of light, is not taken into account.

The Schrodinger equation describes spinless particles.

I will derive the equation for particles with spin in the future. It seems that it is rather easy if we assume that one particle can be represented by more than one set of expansion functions. One set for spinless particles, two sets for particles with spin ½, etc.

Uncertainty principle

The Heisenberg uncertainty principle is one of the fundamental properties of quantum mechanics. It may seem that the uncertainty principle is incompatible with the deterministic model of ESTM theory. In this part of the article I will show that the uncertainty principle does not contradict with ESTM theory.

The description of derivation of the uncertainty principle is described in many textbooks on quantum mechanics. The main property that leads to the uncertainty principle is the wave function and non-commutative operators for measured values, such as location and momentum. I am not going to copy the derivation of the uncertainty principle; it is enough to note that the ESTM theory contains the Schrödinger equation, so that all the mathematics of quantum mechanics can be used. As a result, ESTM theory leads to the uncertainty principle despite the fact that it is a deterministic theory.

The uncertainty principle in the ESTM theory is the manifestation of wave properties of elementary particles.

ESTM theory and gauge theories

Gauge theories have proven themselves successful in describing fundamental interactions and particles, with the exception of gravity. The standard model is the gauge theory.

ESTM theory allows us to construct gauge theories, since it contains both the wave function and the Hamiltonian operator. Thus, one can use the entire formalism of gauge theories, although with the different interpretation.

Speed of light

According to the ESTM theory, in order for the emergent universe to be brought into being it is necessary that there was an observer in it. The question arises: is it possible to construct such a emergent spacetime in which there would be no restriction on the maximum speed of elementary particles and in which life is possible?

I guess that's impossible. If this assumption is true, then all emergent universes must contain a maximum speed limit and, accordingly, a special theory of relativity. The value of the maximum speed can be different in different emergent universes.

If there is a maximum speed of particles motion for some universe, then it must be the same in all reference systems in the universe, because there is no dedicated reference system.

Further, according to the special theory of relativity, the maximum speed corresponds to the speed of light.

This means that the speed of light is the derived value and should be determined by the equation of scalar field for Metauniverse and the set of expansion functions $\{w\}$ for the field in emergent space from eq. 7:

$$c = c(f, \{w\}) \tag{21}$$

In order to explain the origin of the speed of light, one can look at typical mathematical functions. For example, we can take function $f(x, y) = (x-1)^2 + (y-1)^2$

draw an oriented straight line through the point (1,1), then begin to move it in parallel for the increased distance. In this case, the values of this function on the line will increase consecutively. There is something like the propagation of a signal with the successive distancing of a straight line.

In the example above the values of the function are symmetric with respect to rotations. Values of the function of the Metauniverse scalar field cannot be symmetric with respect to rotations, although the function itself, as I assume, is symmetric. Therefore, it is necessary to solve the complications arising in this connection, which is done in the next section.

Special theory of relativity and ESTM theory

Modern experimental data show that all laws of physics are the same in all inertial reference systems. Accordingly, the emergent spacetime must provide these properties. Some laws of physics, such as electrodynamics and SR, require the same speed of light in all inertial reference systems. This can be done using the following model:

After each turn corresponding to transition to the new reference system, a new maximum rotation angle appears. This angle may differ from the angle before the rotation, but must have the same values for rotating in any permissible direction. The speed of light should not vary with the change of the maximum angle of rotation - the speed of light is determined not only by the value of rotation angle, but also by the speed of emergent time (described later). In such a model, it is possible by successive rotations corresponding to successive accelerations to get into one's own past from the point of view of the accelerating object. At the same time, the observer being in a fixed reference system should see another situation. From the point of view of such an observer, the accelerating object does not fall into the past, it will accelerate its speed but its speed will never exceed the speed of light. Quanta of light in the reference system before the rotation must correspond to the quanta of light in the reference system after the rotation, similarly for other elementary particles. After rotation the surface of the cone corresponding to the speed of light will differ from the surface of the cone before rotation. Quanta of light move at the speed of light and should be on this cone. Consequently, the location of the particles and their trajectory will change after the rotation, and the distance between trajectories of the same particle in different reference systems will constantly grow in time. I want to emphasize this result of ESTM-theory - the same particle at each point goes along trajectories that depend on the viewing angle. It is not yet clear for me how to find the types of equations that allow such behavior. I think that some holography models may be used. So, further research is needed here to find the mathematics of the model described. In the equations of ESTM theory I will require such properties from the corresponding functions, but the functions themselves have not yet been found, only their properties have been found. Again, the ESTM-theory is a new theory with a completely new mathematical model. As far as I know, there is no mathematics suitable for describing the model of ESTM theory without further refinement. I think that sooner or later the functions of ESTM theory can be found, but this search will take quite a long time. The ESTM theory contains many other open questions; In this article I'm trying to build only the basis of the ESTM theory. A complete construction of this theory is impossible within the framework of one article.

Now, I am going to consider this model in more detail.

First I am going to consider the possibility of getting into past. If after each rotation (corresponding to the speed set in relation to the previous reference system) the new maximum angle allows you to go further than the previous maximum angle, this means that it is possible to turn 360 degrees and turn into your own past by successive turns. However, since the Metauniverse in the ESTM-theory is timeless, the past cannot be changed. Therefore, the attempt to change the past must be unsuccessful. However, from the point of view of the accelerating observer, everything should look like usual, and the laws of physics should be the same as before acceleration. Therefore, if you plan to make any changes in the past before the acceleration begins, it should be possible to make them after getting into the past. It looks like a contradiction. But this contradiction can be solved if we add the loss of information during the turns. The information must be completely lost when one gets into his own past, hence no plans created before getting into the past will be preserved. Loss of information is the case when some events occurred in one reference system but did not occur in another reference system. This means that after moving to another reference system some particles may appear or disappear and the positions of the particles can change.

Photons and some other elementary particles always move at the speed of light. This means that they always have the maximum possible angle with respect to time vector, and other particles have a smaller angle. For photons the angle is equal to the angle corresponding to the speed of light. After turning the Metauniverse surface corresponding to the light cone will be different from the cone before the rotation. So in one reference system, particles with the speed of light are on one surface and in the reference system after turning - on another surface. Their location in Metauniverse changes when turning, some particles may appear after the turn and some may disappear. If you rotate spacetime once or more times and then turn back to its original position (if possible without exceeding the speed of light), the state of the particles and their positions should be exactly the same as before the first rotation. The same applies to particles that move at a speed of less than the speed of light. Thus, there is loss of information during the rotation of spacetime, corresponding to the transition to another reference system. I note that the described behavior means that the symmetry to rotations is an approximation.

The loss of information described above cannot be directly measured, since the observer also loses information when moving to another reference system. However, although ESTM theory predicts that loss of information cannot be directly observed when moving to another reference system, it can potentially be indirectly tested on the basis of other predictions of ESTM theory.

The similarity of the laws of physics in all inertial reference systems looks quite naturally in the ESTM theory. This is due to the fact that the laws of physics of emergent spacetime for each of the universes are based on the same matching function. For identical initial conditions the matching function should give the same results because of the symmetry of the Metauniverse scalar field function with respect to rotations.

The speed of light is the same everywhere in all inertial reference systems. The speed of light for the model described is:

$$c = v_t * tg(\alpha) \tag{22}$$

v_t is the speed of time in Metauniverse, α is the angle between the time vector and the light. The speed of time can change and, as a result, this angle will change along with the speed of time. The speed of light is the speed in the emergent spacetime. The emergent space is perpendicular to time vector where it is not curved. So the hypotenuse of the resulting triangle is opposite the angle between the speed of time and the speed of light.

Thus, the scalar field must have rather specific properties, described above, in order to combine special theory of relativity and ESTM theory.

If the angle of the speed of light is much less than 2π, then the information loss at each turn can be small. They can be small under the following condition:

$$\alpha \ll 2\pi \tag{23}$$

The behavior described above does not mean that the symmetry to rotations is not applicable for relativistic cases, but this means that it is the approximation. Another consequence is that the symmetry accuracy depends on the angle of the speed of light. Further in the section on gravity I will show that this angle is not constant. Its effect on the accuracy of this symmetry is discussed later in this paper.

The special theory of relativity contains a connection between time intervals in different reference systems. This connection in the ESTM theory cannot be derived directly from geometry. This connection imposes an additional constraint on the scalar field of Metauniverse.

Now I will write what was described above as the equations.

The average value of the 3-vector R of position and speed of the particle with the wave function ψ:

$$\langle R\rangle = \int \psi^* R\psi dr \tag{24}$$

The same from the point of view of another reference system:

$$\langle R\rangle_1 = M\langle R\rangle = M\int \psi^* R\psi dr \tag{25}$$

$\langle R\rangle_1$ is the 3-vector from the point of view of another reference system, M is the transformation matrix. M is calculated based on the special theory of relativity.

The same 3-vector can be calculated as:

$$\langle R\rangle_1 = \int \psi_1^* R_1\psi_1 dr_1 \tag{26}$$

ψ_1 is the wave function of a particle in this reference system.

I should note that the wave function of the particle is determined by the coefficients u_{pik} from equation 7.

As it was described above, the particles after rotation are not in the same position as before the rotation. This means that there is a difference between the position predicted by the special relativity and the actual position. Thus, the difference module between 4 vectors is greater than zero:

$$|M\int \psi^* R\psi dr - \int \psi_1^* R_1\psi_1 dr_1| > 0 \tag{27}$$

for the case when the reference systems do not coincide. I will designate this difference as function θ:

$$\theta(v, \beta, \{w\}, L, \vec{v}_t) = |M\int \psi^* R\psi dr - \int \psi_1^* R_1\psi_1 dr_1| \tag{28}$$

$$\theta(v, \beta\ , \{w\}, L, \vec{v}_t) > 0\ if\ v > 0 \tag{29}$$

This function depends on the speed v of another reference system; angle β corresponds to the speed of the particle at a given point of emergent spacetime. I should note that this angle can be different at different points in emergent space. L is the function that describes the emergent space, $\vec{v}_t$ corresponds to the speed of time at a given point in a given reference system. Both of these functions will be described in more detail later in the article in the section devoted to gravity. Function θ can also depend on some other parameters. If they exist, they can be found in the course of further work on the ESTM theory.

This difference cannot be measured experimentally, it is forbidden by the determinism of this theory. In order to measure this difference, the experimenter needs to accelerate and move to another reference system. But in the process of acceleration the experimenter's data about where he expects to see the particle will change so that they become consistent with the new reference system. In ESTM theory there are no completely independent events, as all events are connected. Accordingly, the transition to a new reference system leads to a slightly modified but completely self-consistent picture.

Thus, although symmetry is only the approximation, from the point of view of the observer in emergent space this symmetry is exact one. As a result, Noether's theorem is still applicable to symmetry to rotations, which allows the corresponding conservation law to exist.

Changing past and future

In previous part was shown what change of velocity also change events. Particles may disappear or appear, change their velocity etc. Our Earth rotating around Sun so it continuously change velocity. As result, it means what our past, if the theory correct, is also changing. So past is not something which happened and will never change. Similar is for future – rotation of frame of reference also change future. So, both our past and future continuously changing.

Locality in ESTM theory

All known interactions in our universe are local; the speed of light is the restriction on the speed of interaction. There is also quantum entanglement phenomenon that looks like instantaneous transfer of information at the speed greater than the speed of light. There are interpretations of this phenomenon, which do not lead to violation of locality.

Locality in ESTM-theory is achieved by means of equation 6.1. All elementary particles should satisfy symmetries to rotations, and none of the particles should have the speed above the speed of light. All particles interact with each other only using other particles without violating locality. The maximum speed for all particles is the speed of light. This is the locality in the ESTM theory.

I should note that the ESTM theory does not prohibit instantaneous interactions at a distance if at least one of the interacting parts is a macroscopic particle. In case of particles with this size, the particle interacts as a whole and, as a result, it corresponds to instantaneous transfer of information. The quantum entanglement phenomenon can thus be interpreted as the destruction of macroscopic particle consisting of two elementary particles.

Gravitational interaction cannot have carrier particles for interaction at all; it can be just a mathematical function that finds the emergent space with the necessary properties. Since all the known experimental data show that gravity interacts with the speed of light, such a function must also support locality. The curvature of spacetime in this case is caused by the need to observe causality and locality.

Locality, which is achieved in the manner described above, is not complete. This means that although from the point of view of the emergent spacetime, elementary particles in the interaction look like observing locality properties, however, in any emergent spacetime there are no truly independent events. This is due to the fact that in Metauniverse any point of space affects all other points of space.

Possibility of direct interaction between the particles without violating the locality principle.

This is an open question. Is it possible to build a universe based on the particles interacting in violation of locality principle? I should recall that any universe should support cause-effect relations and intelligent life.

Metric of inscribed hypersurface

In ESTM theory at each instant of emergent time one can construct a hypersurface corresponding to this instant of time. The question arises, what is the metric of this hypersurface?

As shown by S. Hocking, J. Ellis [5, p. 55], it is impossible to construct an inscribed hypersurface in the Euclidean space with the Lorentz metric. Is this the problem for the ESTM theory?

If we look at how this impossibility is justified, we can see that it is implied that this hypersurface is common for all reference systems. As explained in the section devoted to SR above, in ESTM theory it is not the case. The transition to another reference system also includes rotating the hypersurface. Thus, after the transition to another system, the hypersurface will be different. The possible problems with this rotation, as described above, are solved by eq. 28.

Thus, the described impossibility of constructing an inscribed hypersurface having Lorentz metric in the Euclidean space is not applicable to the ESTM theory.

Now the question arises: What is the curvature of emergent space at the indicated point on hypersurface representing the emergent space?

In order to answer this question, we need to use equation 7. This equation shows that an equal distance in emergent space between two neighboring points can mean different distance in space of Metauniverse. Similarly, the same time interval can mean different distances in Metauniverse if the speeds of time are different. This means that the curvature of emergent space at any given point depends on the point at which the comparison is made.

It can be seen that in order to construct the connection between the curvature of space and the relative speeds of time and length of space, an equation can be constructed, but I leave it for future.

Gravity - part one

In the section where I described the process of searching for emergent spacetime in scalar field I wrote that the laws of physics should be the same in all inertial reference systems. It is possible that in some cases the spacetime must be curved in order to ensure this uniformity. As a result, this leads to curved spacetime.

I should note that the curvature of spacetime is not equal to the curvature of hypersurface representing emergent space in Metauniverse. In the curvature of emergent spacetime the change of the speed of time, which will be described later in this section of the article, also participates.

The curved spacetime is not something new - the general theory of relativity uses the curvature of spacetime for describing gravity. Therefore, I will assume that the curved emergent spacetime is responsible for gravity, similar to the general theory of relativity.

The next question to be solved is whether the equations of gravity of this theory coincide with the equations of the general theory of relativity. In order to answer this question, I will show that the equality of the inertial and gravitational mass is the consequence of ESTM theory. I have already shown the constancy of the maximum speed in all reference systems, and I will show that the gravitational equations should not contain the energy-momentum tensor of the gravity field. Proceeding from what was shown below I conclude that the equations of gravitation predicted by the ESTM theory coincide with the equations of the general theory of relativity. Einstein's equations are based on two postulates: the principle of equivalence and uniformity of the speed of light in all inertial reference systems. An important feature of these equations is the absence in the equations of the energy-momentum tensor of gravitational field.

Because gravity is emergent phenomenon caused by the field of Metauniverse, and elementary particles are expansions of the field, it means velocity of gravity is equal to maximum possible velocity of particles. For our Universe, it means speed of light.

Gravity changes the speed of bodies, bending spacetime, which leads to rotation of hypersurface representing the reference system where the body is at rest. Acceleration of the body, as described in the article above, is also reduced to rotation of hypersurface representing the reference system where the body is at rest. But then it means that it is impossible to distinguish which force acts on a sufficiently small body - gravitational or inertia force. Consequently, the inertial and gravitational masses are equal.

The need for curvature of spacetime is caused by the changes in the scalar field. Elementary particles participate in the expansion of scalar field by bases. But gravity itself does not participate in these expansions - it is the function of them. But this means that gravitation does not affect itself, the energy-momentum tensor of gravitational field must not exist in the equations of gravity.

Since the mass curves spacetime, then with a sufficiently large mass problems with spacetime and continuation of world lines can arise. At some point, the continuation of world lines can become impossible. At this point, the spacetime gap begins, which corresponds to gravitational singularity. These gaps are not required to have zero size in the emergent space, although inside they do not contain the emergent spacetime-matter. So there is the difference from the predictions of the general relativity theory which says that the matter in the center of a black hole must contract to a point. The prediction, which is different from the predictions of other theories, is good (in addition, the singularity is also eliminated), but I cannot imagine how it can be verified experimentally, as information from black holes is not transmitted to the outside.

The area of emergent space near the spacetime gap is the area of formation and completion of world lines. Particles may appear and disappear here.

The spacetime gap, caused by strong gravitation, does not mean the gap of the Metauniverse space. This does not even mean that in this area the values of scalar field of Metauniverse are greater or smaller than the mean values. This only means that there is no solution that allows us to extend the world lines of emergent spacetime to the area of the gap.

Although the ESTM theory interprets gravity in a manner similar to the general relativity theory, it requires some changes in the general relativity.

The general relativity theory predicts the slowing down of time - time in the areas with strong gravitational field is slower than in the areas with weaker gravitational field. In order to obtain the same behavior, it is necessary that the speed of time be the higher the stronger the gravitational field is. In this case, the events in the stronger gravitational field will look slower from the viewpoint of the observer in the weaker gravitational field.

The speed of time is the length in Metauniverse corresponding to the unit of time at the corresponding point of emergent spacetime.

One can find the equation of relationship between the speed of time and the time delay. An observer in a weaker gravitational field in the time interval dt_1 passes through Metauniverse the same distance as the observer in a stronger gravitational field in a time dt_2. Thus, an equation is obtained for the speed of time v_1 for the first observer and the speed of time v_2 for the second observer:

$$l = v_1 dt_1 = v_2 dt_2 \tag{30}$$

This implies:

$$v_1 = v_2 \frac{dt_2}{dt_1} \tag{31}$$

It follows that the relative speeds of time differ in proportion to the relative time dilation.

This approach partially changes the internal nature of the curvature of spacetime. It also allows the use of the values of the speed of time to compare relative time dilations between different time points. Without adding the speed of time comparing the time dilation between observers at different time intervals does not make sense. In the approach of ESTM theory such a comparison makes sense.

I should add that the speed of time can explain the inflation phase of the early Universe. If the speed of time in the first moments of the early Universe was large enough, the emergent space could grow very rapidly. Since the speed of time increases with the growth of gravitational field, this means that gravity at the first moments of time of the universe should be very strong.

In ESTM theory both space and time are emergent by the atemporal processes taking place in the Metauniverse. As a consequence, in addition to the intrinsic curvature of spacetime, corresponding to a change in the speed of time, there can be an extrinsic curvature. The extrinsic curvature may be caused by the fact that the average curvature of the hypersurface representing the universe space in Metauniverse has a nonzero mean curvature. Such extrinsic curvature can be zero only if hypersurface of the emergent space of our Universe in Metauniverse has zero mean curvature. However, modern cosmological data say that the Universe has the beginning. This means that some time ago the Universe was much smaller than now. This means that the Universe is expanding - the area of hypersurface representing the Universe is growing. This means that on cosmological scale the hypersurface of the Universe space may has nonzero curvature. Thus, the Universe can have a nonzero extrinsic curvature, which can be greater than zero because the Universe expands, and this curvature may change in time. Thus, the extrinsic curvature must be a function of something. In order to take this curvature into account in general relativity equations, it is necessary to add extrinsic curvature Δ_{ext} to the equations of the general theory of relativity in addition to the cosmological constant Δ:

$$G_{\mu\nu} + (\Delta + \Delta_{ext})g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu} \qquad (32)$$

This change does not contradict the experimental data for the entire observable history of the Universe:

$$\Delta \gg \Delta_{ext} \qquad (33)$$

Δ_{ext} is not the constant, it is a function that depends on unknown parameters. I think that one of such parameters may be the age of the Universe. Without a more detailed mathematical model of ESTM theory it is impossible to predict the function of extrinsic curvature. However, we can make a few guesses.

Cosmological constant and dark energy

Experimental observations show [6] [7] that the Universe is expanding, and that cosmological constant in the Einstein equations is nonzero and is a constant.

Cosmological constant is usually interpreted as the manifestation of dark energy responsible for the accelerated expansion of the Universe.

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

How does cosmological constant affect the expansion of scalar field on a hypersurface? Is modification of equation 7 needed?

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

If the entire extension is caused by the extrinsic curvature of hypersurface of 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 function of emergent distance depend on the extrinsic curvature, resulting is the invariable intrinsic curvature caused by cosmological constant, or extrinsic curvature does not play an important role.

If the extrinsic curvature does not play an important role, then the question is how expanding emergent space on hypersurface with zero mean curvature can be obtained. Equation 7 contains the emergent distance function. If with increasing age of the Universe this function for points with the same distance in Metauniverse produces an increasing distance, then by selecting a function one can obtain the expanding emergent space on hypersurface with zero mean curvature. Thus, it looks logical that the amplitude of the expansion function will also decrease in time. Thus, in equation 6 it is necessary to add a dependence on the age of the universe t:

$$u(L,\vec{r},t) = \sum_i u_i w_{ip}(L,\vec{r},t,\overrightarrow{v_t}(\vec{r}),l(\vec{r}-\overrightarrow{r_u},t),c) \qquad (34)$$

Thus, the equation for scalar field expansion can be rewritten as:

$$f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A}\sum_{k=1}^{k=N_p}\sum_{i=iMin}^{i=iMax} u_{ikp}w_{ip}(L,\vec{r},t,\overrightarrow{v_t}(\vec{r}),l\left(\vec{r}-\overrightarrow{r_{kp}},t\right),c) \qquad (35)$$

Cosmological constant is thus a function of the ratio of the average emergent distance between points at subsequent time intervals:

$$g = g\left(\frac{<l(t+dt)>}{<l(t)>}\right) \qquad (36)$$

This function looks as quite easy to find, but I leave it for future.

Because gravity is

It may be necessary to introduce a change to equation 8. Since according to equation 35 the functions of the set $\{w\}$ begin to depend on the age of the Universe, the invariant can also depend on the age of the Universe. It is not possible to say this unambiguously, since both functions of equation 8 depend on the age of the Universe. Perhaps, the invariant is such that this dependence in both functions leads to the fact that the invariant does not depend on the age of the Universe.

Dark matter

Equation 35 contains the part $f_{ext}(\vec{r},t)$ which does not lead to the emergence of elementary particles. If this value somehow affects the metric of emergent spacetime, it can explain the effects observed from the dark matter.

Quantum gravity and ESTM theory

When one talks about quantum gravity, he usually talks about the quantum properties of gravity.

The question arises whether gravity can have a particle-carrier of gravity?

Given the definition of elementary particles and taking into account the description of gravity above, gravity cannot have a particle-carrier of gravity. Thus, the ESTM theory predicts that graviton does not exist.

Gravity - part two

Above we proposed changes in the equation of the general theory of relativity. But is it possible to derive the equations of gravity directly through scalar field? This will be done in this section. However, in order to use the resulting equations for calculations they need to be considerably detailed.

Emergent space can be defined by the equation where for each point x of Metauniverse for a set of functions of the field expansion into elementary particles {w} and for time it must return zero if the point x belongs to emergent space for the specified moment of emergent time:

$$L(x, f, \{w\}, \overrightarrow{v_t}) = 0 \quad (37)$$

$\overrightarrow{v_t}$– is the time vector that also contains information about the current value of emergent time. It is the vector and not the scalar value of time that is needed, since at any point in the space of Metauniverse there can be a set of emergent spaces with the same set of expansion functions but with different directions of time. L is the function that returns zero if the point x belongs to emergent space for the specified value of time vector - it is not the Lagrangian operator.

I use the similar approach for writing the equation for time:

$$\overrightarrow{v_t} = \overrightarrow{v_t}(x, f, \{w\}, L) \quad (38)$$

L is the emergent space, $\overrightarrow{v_t}$ is the vector of time.

Accordingly, the equations of gravity:

$$\begin{cases} L(x, f, \{\mathrm{w}\}, \overrightarrow{v_t}) = 0 \\ \overrightarrow{v_t} = \overrightarrow{v_t}(x, f, \{\mathrm{w}\}, L) \end{cases} \quad (39)$$

These equations must lead to emergent space described by equation 32 and must create the Minkowski space of the general theory of relativity. Both functions in eq. 39 are unknown. In order to use these equations in calculations they need to be detailed.

These equations of emergent space and time can contain discontinuities in continuous solutions and areas where spacetime is not defined. This means that either in such areas there is no emergent spacetime, or in case of discontinuity there is no connection between the areas of spacetime with the same laws of physic.

Nature of scalar field

One of the questions that has not been discussed is what is scalar field of Metauniverse, why does it exist and where did it come from?

At the moment, I do not have the answer to this question.

We can say that the nature of this field is unknown, assume that it exists and use equations to find its properties. If ESTM theory is confirmed, it will be necessary to start thinking about the nature of this field.

Emergent spacetime and matter, equations of ESTM theory

In the previous sections of this article I described the basic idea of ESTM theory, showing that ESTM theory does not contradict known well-established theories. For some theories changes were proposed. Some equations were proposed for certain parts of ESTM theory. All the above creates a foundation for building a mathematical model of ESTM theory. In this section of the article the equations of ESTM theory are combined into a single system of equations.

So, there exists a scalar field $f(x)$, where $x = \{x_1, .., x_n\}$ is a point in the Euclidean space of Metauniverse with n-dimensions. The value of the field at each point is determined by the values of the field in the surrounding points.

Modern physics says that the three fundamental forces in our universe have carrier particles for interaction. Electromagnetic interaction has photon as carrier particles for interaction, and so on. Of the four known interactions the exception is gravitational interaction. Carrier particles for interaction were not found for it. The scalar field of Metauniverse does not change in time due to the fact that there is no time, so any carrier particles for interaction are impossible for it. This limits the impact of Metauniverse field only to one case - when the field at a point affects only neighboring points.

This leads to the following: if there is some closed surface S, in Metauniverse, the value of the field for any point inside the area surrounded by this surface is determined on the basis of the field values on the surface, $f(S)$. This leads to eq. 12.

Further, as was written above, it is necessary to find the expansion of scalar field of Metauniverse over elementary particles. This leads to eq. 35. If in some area of Metauniverse it is possible to find more than one expansion satisfying all conditions, then these sets of expansions refer to different emergent universes. Particles from different universes do not interact with each other, although some correlations between them are possible.

The particles interact in space and time. This means that emergent time and space should be found. Equation 39 imposes certain restrictions on emergent time and space.

The locality of all phenomena is observed. This leads to equation 6.1 and to the addition of the dependence on the maximum speed c to equation 35.

Next, we need to add the special theory of relativity.

Equation 22 says that in the ESTM theory the speed of light, determined by eq. 21, is always a constant. Equations 28 and 29 explain how the speed of light can be a constant and not lead to inconsistencies in the equations.

All particles in our Universe move at a speed not exceeding the speed of light. Consequently, the angle β between the time vector and the trajectory of the particle should not exceed the angle α_l corresponding to the speed of light:

$$\beta \le \alpha_l \quad (40)$$

By combining the equations I get the system of equations of ESTM theory:

$$\begin{cases} L(x, f, \{\mathrm{w}\}, \overrightarrow{v_t}) = 0 \\ \overrightarrow{v_t} = \overrightarrow{v_t}(x, f, \{\mathrm{w}\}, L) \\ c = c(f, \{w\}) \\ c = v_t * tg(\alpha) \\ \beta \le \alpha_l \\ \theta(v, \beta, \{w\}, L, \vec{v}_t) = |M \int \psi^* R \psi dr - \int \psi_1^* R_1 \psi_1 dr_1| \\ \theta(v, \beta, \{w\}, L, \vec{v}_t) > 0 \text{ если } v > 0 \\ f(x) = g(x, S, f(S)) \\ f(\vec{r}) = f_{ext}(\vec{r}) + \sum_{p=1}^{p=A} \sum_{k=1}^{k=N_p} \sum_{i=iMin}^{i=iMax} u_{ikp} w_{pi}(L, \vec{r}, t, \overrightarrow{v_t}(\vec{r}), l(\vec{r} - \overrightarrow{r_{pk}}), c) \\ \exists V, V \to SAS, \ \tau_{caus}(V) \ge \tau_{min} \ \forall \ t_{begin} < t < t_{end}, \ t_{end} - t_{begin} > \tau_{min} \\ \Psi(\mathrm{t} + \mathrm{dt}) = \mathrm{U}\Psi(\mathrm{t}) + P(\dots) \\ h(l, \overrightarrow{v_t}) = const \\ \tau_{caus}(V, t) = \frac{N(V,t)}{dN(V,t)/dt} \end{cases} \quad (41)$$

Interaction of particles with each other, provided that all functions and boundary conditions are known, can be found as follows:

1. In the corresponding reference system we can find all the particles everywhere in the selected area of emergent spacetime
2. The interaction of particles is found - it is enough to see how they change their state in emergent time

The system of functional equations written above is very much generalized. In order to make it suitable for calculations, it is necessary to find a scalar field function $f(x)$. If scalar field function (eq. 12) was known, then in this case the laws of physics in our Universe could be found by finding the exact equations of gravity and expansion functions for particles. We observe only the emergent spacetime-matter, so the problem with the solution is much more difficult than finding the emergent universe from the known function of scalar field. First we need to find the equation of scalar field of Metauniverse from our observable laws of physics. And only then we can find the equations of particles, space and time from scalar field equation. As a result of this approach, I expect an increase in knowledge about the physics of the Universe.

How can this be done?

I think that first it is necessary to solve the problem of finding the expansion of scalar field into elementary particles and emergent spacetime with support of causality. The solution to this problem is likely to impose limitations on the types of possible equations, which can give clues how to solve the inverse problem of finding scalar field from emergent spacetime.

It seems that solving the equations of ESTM theory is a challenging complex problem, which will require a lot of research.

Is the initial singularity in the Big Bang needed?

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

In ESTM theory the visible homogeneity of the Universe can be tried to reach without the initial singularity. To do this it is sufficient that during the phase of spacetime formation there were approximately the same conditions everywhere in the forming spacetime. Before the beginning of the formation of spacetime the emergent physical laws are inapplicable.

How many dimensions are there in Metauniverse?

One of the questions that arises when trying to understand the structure of the Universe is why the Universe has four dimensions (three spatial and one temporal).

Ehrenfest [8] showed why the number of spatial dimensions equal to three is the most suitable. If there are more than 3 dimensions atoms cannot exist. In case there are less than three dimensions, the motion would always occur in a limited area. Only with is the number of dimensions is equal to three both stable finite and infinite motions are possible.

Proceeding from the described above and using the anthropic principle of participation, it can be argued that the Universe has four dimensions because this very number of dimensions is necessary for the existence of intelligent life. Perhaps it is impossible to build emergent universes with a large number of dimensions because of the impossibility of the emergence of intelligent life in them.

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

Arguments against ESTM theory

Scientific arguments against ESTM theory

In this section I will describe the anticipated objections to ESTM theory and I will try to reply to them.

I expect several basic types of arguments:

1. The Universe cannot be based on timeless entity. It is enough to look around - there is movement and there is time. This theory directly contradicts our sensations.
2. ESTM theory predicts a specific behavior for some phenomenon. The experimental results differ from the predictions of ESTM theory.
3. Can scalar field function exist that satisfies all the requirements of ESTM theory?
4. ESTM theory does not contain the Standard Model.

I will try to reply to these objections.

First, I will answer to argument No. 1 about the contradiction of ESTM-theory to our sensations. I believe that this argument is not scientific; it's just an expression of philosophical views. Any scientific hypothesis should be evaluated on the basis of its predictions and not on the basis of how well it corresponds to "common sense". Nature has no obligation to conform to human common sense.

Concerning the argument No. 2, it can be a serious argument, but under the current state of ESTM theory it have only several measurable predictions, such as absence of quant of gravity, speed of gravity equal to speed of light and validity of equivalence principle.

Concerning argument No. 3, I cannot argue that such a function exists exactly, but more research is needed to answer this. However, I can argue that without additional research it is impossible to say that such a function cannot exist.

Concerning argument No. 4 - yes, I would like to derive the Standard Model from ESTM theory at once. It does not work, because the mathematics of the theory is not yet sufficiently developed. However, the future development of the theory can solve this problem. The mathematical model of ESTM-theory is improving as time goes by, so it in the future is will be possible to find a solution to this problem.

ESTM theory does not have hidden parameters at the level of elementary particles.

Of course, I cannot foresee all possible scientific arguments against ESTM theory, so I tried to reply to only the most expected arguments.

Non-scientific arguments against ESTM theory

Some time ago I received the following feedback on ESTM theory from the editor of one of the journals in physics: "This work is simply not physically sound".

After a moment's thought, I realized that this can be a fairly frequent perception of this theory. So I decided to reply to this review.

I think that this opinion has nothing to do with science. This view simply means that anyone who claims so is convinced that his philosophical vision of Nature is true and therefore ESTM theory is wrong as it is contradictory to one’s vision. Can I ask where and when this philosophical vision has been proved? I read a lot of discussions on the Internet about realism and anti-realism and I did not see any mention of the fact that realism was proved.

The situation when the physical theory directly affects philosophical questions is very unusual, but nothing prohibits such theories in the ontology of science.

Perhaps the ESTM theory requires too many changes in the philosophical vision of the world and there is a simpler alternative? Well, can anyone give me the name of any theory that does not require such significant philosophical changes and which integrates all the fundamental interactions? There are such theories as string theory, loop quantum gravity, etc., and some think that they can integrate all interactions. But where is the result of such integration? At the moment it does not exist. ESTM theory suggests simple integration of all fundamental interactions. This theory is easy to explain and understand, but only if one is willing to seriously consider the ESTM theory and its philosophy, and not to insist on his philosophical views.

I understand that ESTM theory may turn out to be wrong. However, only scientific arguments and not philosophical views should be used for its refutation.

Application of ESTM theory to some known problems

Information and black holes

In modern widely accepted theories there is black hole Information loss problem.

There is no information loss in ESTM theory. Information loss is possible only in emergent spacetime, but this information remains in Metauniverse, although it is not accessible to us.

The singularity in black holes, predicted by the general theory of relativity, is a spacetime gap in ESTM theory. This gap occupies a nonzero size in the surrounding emergent space. Outside this gap it is impossible to continue the emergent spacetime. In order to describe what happens beyond the boundaries of the gap, it is required to use the complete equations of ESTM theory.

Conclusion

The proposed ESTM-theory has two components - philosophical and physical. Therefore, I will divide the conclusion into two parts, the philosophical part and the physical part.

Conclusions - philosophical part

ESTM theory offers the new interpretation of Being. According to this theory, man has no real freedom of will. This theory is completely deterministic, so people do not have free will. The theory offers an answer to one of the great questions of philosophy, namely, how spacetime and our sensations are related.

To what extent does the model of ESTM theory correspond to long-term trend in the development of philosophy?

Some time ago, the most common theory was the Ptolemy's theory, where the Earth was in the center of the Universe, and the Sun revolved around the Earth. Man was in the center of the Universe and animals considered to be separate from man.

Over time, the breakdown of the central role of man in the Universe began. The Earth began revolving around the Sun and the Sun became the center of the Universe. Then it was discovered that the Sun is just one of the billions of stars, and the Sun revolves around the center of the Galaxy and there are billions of galaxies. Darwin showed that man has common ancestors with other animals.

Thus, in science and philosophy there is a long-term tendency to reduce the role of man in the Universe.

At present, the role of man in the Universe still remains quite high. This is mainly because of the concept of free will - that man is free in his actions.

In ESTM theory the human mind is the epiphenomenon emergent by Metauniverse.

Consequently, in relation to Metauniverse, man's role is much smaller than in modern theories in relation to the Universe.

However, in addition to reducing the role of man in Metauniverse to the level of epiphenomenon, ESTM theory has a directly opposite component to the role of man in the Universe. This component makes the role of man in the Universe exceptional and again, as in the time of Ptolemy, puts man in the center of the Universe.

According to ESTM theory, space, time and matter are subjective and they do not exist independently of the observer. Moreover, they are emergent by the observer. Thus, the absolutely exceptional role of man and other intelligent beings (if any) in the Universe is that the mind generates the Universe.

In Marxism there is a so-called basic question of philosophy. It is usually formulated as follows: "What is primary - spirit or matter?". My answer to this question has already been formulated and substantiated above. Choosing between consciousness and matter, consciousness is primary. However, consciousness is also emergent phenomenon, although it is a step higher than matter.

Considering a person from the point of view of Metauniverse, a person and his consciousness exist forever. Although it is not clear how true it is to talk about eternity in relation to the entity in which there is no time. However, in the Universe which is the emergent entity man exists some finite time.

The question arises: what is the real age of the Universe, how long has it been in Genesis?

The answer to this question is to answer the question of how long ago the mind has appeared in the Universe.

According to Darwin and the theory of evolution, man originated from animals. As far as I know, none of the animals, including primates, has the mind. If we assume that man is the only intelligent creature in the Universe, then the Universe appeared when the first person gained intelligence.

As far as I understood from Wikipedia, there is a consensus among paleoanthropologists that the first person gained intelligence not more than 1 million years ago. This means that the Universe is not older than 1 million years old. Before that, the Universe did not exist because of the absence of observers. I will denote the state of the Universe when it exists only potentially as pre-existence. This means that before the emergence of intelligent beings the Universe was in the state of pre-existence. In this case, various estimates of the age of the Universe, such as 13.77 billion years, etc., answer the question of how far one can hypothetically extend the cause-effect relations in the possible past. However, the existence of the Universe requires the observer, therefore, the estimates that do not take into account observers refer to the total duration of the existence of the Universe in Genesis and the time of its pre-existence, when the Universe existed only potentially.

It is possible that the periods of existence of intelligent life in the Universe were replaced by periods when there was no intelligent life. In this case, the Universe was in Genesis only when there was an intelligent life. In between, the Universe was in pre-existence, it existed only potentially.

ESTM theory also offers an answer to philosophical question - what is the beginning of the beginning and the cause of causes?

Considering this question from the point of view of ESTM theory, it does not make sense. The rationale is according to this theory causality is emergent phenomenon and does not exist at a more fundamental level of Metauniverse.

Thus, the answer to the question "what is the beginning of the beginning and the cause of causes?": The question does not make sense.

Conclusions - physical part

ESTM theory is built in one scalar field from which space, time and matter are derived. Thus, all the fundamental interactions are integrated.

In my opinion, the main achievement of this theory is a simple conceptual model that allows combining quantum mechanics with the general theory of relativity. If ESTM theory is true, its equations are able to describe any physical processes, including those that are not yet discovered, under any physical conditions. This theory offers a way of explaining all the fundamental interactions from a single point of view. This integration of interactions is based on one initial classical non-quantum field. Thus, all the fundamental interactions and elementary particles with their quantum effects arise from this field. The main problem of ESTM theory is the philosophical result of this integration, which affects the most fundamental concepts of philosophy.

All processes that occur in emergent spacetime are considered to be atemporal processes in ESTM theory.

It is shown how the Schrödinger equation is derived within the framework of ESTM theory. It is shown that Heisenberg uncertainty principle is also derived from the ESTM theory, despite the fact that ESTM theory is a deterministic theory.

I showed how the special theory of relativity and the principle of locality can be explained within the framework of ESTM theory.

The general theory of relativity is included in the ESTM theory. It is shown that the equations of gravity predicted by ESTM theory coincide with the equations of the general theory of relativity. The equality of the inertial and gravitational masses was substantiated. Some changes in the equations of the general theory of relativity were proposed.

Now the main weakness of this theory is a set of open mathematical questions. They will have to be solved in order to make the equations of the theory suitable for calculations. There are no analytical solutions to the equations of ESTM theory. I assume that initially this is quite expected for any theory that goes beyond the well-researched field of gauge theories. The equations of ESTM theory are a set of functional equations - they are complicated and it is not easy to find their solution.

The proposed theory is explicitly radical and it touches upon the key concepts of philosophy. However, this theory also promises a radical reduction in the number of independent phenomena. Occam's razor for this case shows that this theory may turn out to be correct.

ESTM theory offers a way of integrating within its model all the fundamental interactions, including gravity. Also this theory explains the nature and properties of time. ESTM theory adds only one entity - Metauniverse with scalar field. I also suggest a method of describing our Universe based on this field. This theory removes the concepts of independent space, time and matter. I also expect that a lot of constants, quantum mechanics and the Standard Model will be derived as a consequence in the process of searching for analytical solutions for ESTM equations.

ESTM theory proposes some changes in the general theory of relativity in the part related to cosmology. It is possible that there is no difference between the LCDM model and the predictions of ESTM theory at the whole interval after the Universe has become transparent to light. However, ESTM theory offers a simple explanation of the inflation phase of the early Universe. At the same time, it is not clear whether the Big Bang concept with its initial singularity is needed at all. Within the framework of ESTM theory one can see the possibility of obtaining a visible homogeneity of the Universe without its initial small size.

Explanations of the nature of dark energy and dark matter were offered.

Information loss was predicted when moving to another reference system, which is not available for observation. Such an observation is forbidden by the determinism of ESTM theory and the absence of completely independent events.

Such a problem with a small number of new predictions is caused mainly by the fact that this theory is compatible with SR, GR and quantum mechanics. However, the number of new predictions may start growing with a deeper analysis of the equations of ESTM theory.

ESTM theory is a candidate for the theory of Everything, so it must be able to describe any physical phenomenon under any physical conditions.

If ESTM theory is correct, finding the scalar field equation from the known laws of physics will allow us to find the equations of particles, space and time from the scalar field. As a result, it can improve our knowledge of the laws of physics and can lead to measurable predictions and possibly to the discovery of new phenomena.

List of predictions of ESTM theory:

- ESTM theory predicts that the FLRW metric is not applicable to the first moments after the Big Bang (if it existed at all).
- The existence of parallel universes was predicted.
- ESTM theory claims that the past cannot be changed
- ESTM theory predicts that graviton does not exist, gravity has no quants
- Speed of gravity equal to speed of light
- Equivalence principle is valid
- Our past and future are continuously changing

Other results of this theory are the following:

- The anthropic principle of participation is the direct consequence of this theory. Thus, the problem of fine tuning of the Universe is solved.
- ESTM theory can explain the general theory of relativity and quantum theory from a single point of view and using only one fundamental field.
- ESTM theory proposes changes in the equations of the general theory of relativity
- ESTM theory contains the theory of time as one of its parts.
- ESTM theory offers the model of spacetime formation, including the model of spacetime formation in the first moments of the Universe. This theory describes the phase of formation, during which time and space do not exist, but are in the process of formation.
- The further development of ESTM theory and the solution of its equations can allow one to look at what was before the emergence of the Universe when there was neither time nor space.
- A new background-independent interpretation of quantum mechanics was proposed.

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