Our reality as emergent phenomenon

Andrey N. Smirnov

andreysxxxx@gmail.com

http://andsmi.blogspot.ru/

10 May 2015

Abstract

In this article, I propose new paradigm of physics. The paradigm leads to simple and unified picture of world. Such simplification and unification has cost of several key concepts of philosophy, including Being. I propose very radical hypothesis of emergent space-time-matter, in which space-time-matter are emergent properties of more fundamental entity. The hypothesis of emergent reality (ER- hypothesis later) shows how it is possible to find space-time-matter from a more fundamental, static field and space without time and matter. In the article, I show how it is possible to unify quantum mechanics and general relativity in one conceptual model, how to unify all existing forces. Changes in equations of general relativity are proposed in the article, same as changes to overall conceptual model of gravitation. New model of Big Bang is described and new cosmological model is proposed. New law for recession velocity was proposed, the hypothesis predicts what Hubble law is not applicable at large distance. ER-hypothesis predicts what Theory of Everything is non-gauge theory and cannot be based on space of states. The ER-hypothesis also describes possible parallel universes, propose way of theoretical finding of parallel universes, and way to calculate interactions between parallel universes. Theory of time is described in the article.

Keywords: TOE, hep-th, gr-qc, astro-ph

Introduction

Time is a phenomenon that each of us observe daily. But physics is still not able to understand what time is. There is no evidence that time is independent phenomenon. Moreover, special and general theories of relativity [2] establish a connection between time, space and gravitation. This suggests that time is not independent, and has relation with space and gravitation. We know properties of time. But there is no knowledge of why time flows, why time flows in one direction, are quants of time exists, why time is one-dimensional, it is possible to travel back in time.

There are some phenomena called as emergent. For example, gas is one of emergent phenomenon. Properties of gas are based on underlying properties of individual atoms and molecules. However, equations of gas can be considered practically independent from equations of atoms and molecules. Currently, our reality, our being, is considered as independent phenomenon. In the article I propose hypothesis which consider our reality, our being, as emergent phenomenon.

This article presents hypothesis of emergent space-time-matter (ER-hypothesis later in the article). This hypothesis considers space-time and matter as emergent properties of more fundamental entity. The fundamental entity includes everything objectively existing.

 If look at physical phenomena around us, they are characterized by several key features:

1. They are caused by something. There are causal links leading to what is happening. Currently there are no phenomenon known that would not fall under causal links. Some phenomena, like radioactive decay, have probabilistic nature. However, while for radioactive decay we cannot say what was direct cause of decay and we cannot predict exact moment of time of decay, but still radioactive decay can be considered as caused by creation of unstable nucleus.
2. We can predict probability of state of any object in future. In order to do so, we need to know current state of the object, and state of other objects in some distance around the object.
3. For some phenomena, we can predict behavior of objects in future only probabilistically. Quantum mechanics says that accurate prediction of state of quantum objects is not possible, we can predict only probability of states.
4. Laws of nature are same in all known space, and are not depends on reference frame.

How space-time can be built on static system?

If there is no time as fundamental phenomenon, it means that underlying structure of universe is completely static. Time in this case must be emergent phenomenon. Special theory of relativity establishes dependency between space, time and speed. It means that if time is emergent phenomenon, observable space is also emergent phenomenon. General relativity establishes dependency between gravitation and spacetime. It means that in order to find emergent spacetime, it is necessary to find gravitation as another emergent phenomenon. Quantum mechanics describes many quantum effects. It means it is necessary to find particles with quantum effects in scope of the hypothesis. All observable physical phenomena have causal relationships. As result, time should be built in such way so that phenomenon that occurred later on, would be predicted on basis of what it was before.

Let's imagine, space-time-matter, satisfying all the conditions above, was found on basis of static system. Can such space-time-matter describe reality, observable by us? If in such a world life is possible, can sentient being belonging to such world feel reality of surrounding and itself? These questions seem to refer to philosophy, as concept of Being is affected. However, different variants of answer to these questions provide different results in physics, so those questions are related to physics too. Postulate and main idea of this hypothesis is positive answer to these questions.

Occam's Razor helps in positive answer to this questions, since this hypothesis reduces number of independent phenomena and reduces significantly. Instead of various unrelated physical phenomena and independent space-time, this hypothesis suggests that all physical phenomena can be derived from one law of physics and suggests ways to find it.

If in such space-time-matter, found in static field, there is sentient, it will observe following:

- Time exists, and all events have causal relationships.
- There is past, present and future.

Why present time would exist? It may seem that in such system, time will pass immediately. However, it may be only from point of view of external observer. But external observer in this model cannot exist, because system includes everything objectively existing. Observer here can only be object, capable of self-awareness, and belonging to emergent space-time. If such observer will be in emergent time, it will observe changes of states of surrounding. Human thought - it is some change in state of particles and fields in man. Consequently, observer, who lives in emergent time, will also be able to think, provided that relevant physics of reality allows for intelligent life to exist. The speed of its thoughts will be

determined by rate of change of its states in time. In particular point in space-time, observer will always have same thought. If this hypothesis describes our Universe, it means that any human is, in some sense, immortal. Everyone exists forever, but when our present does not coincide with present of some other persons - they are not available to us. Also, number of human thoughts is limited by human lifespan. This hypothesis is not contradicts to freedom of human action. Anyone can do whatever he wants. However, desire of man to do something is caused by state of human body at some point in time. Therefore, one cannot wish for anything other than what was set by his state.

Postulate:

If in objectively existing static timeless system, which includes everything objectively existing, it is possible to find space, time and matter as emergent phenomenon, such space-time-matter is exists, it is emergent objective reality. If in such emergent reality is possible existence of sentient, it can feel, think, feel that it really exists, is in being.

Consequence of this postulate: for case when laws of physics of emergent reality allow intelligent life to exists, sentient belonging to such emergent reality will feel like being in space and feel the passage of time. He will feel emergent physical laws, laws of physics of fundamental static system will be deeply hidden from his feelings.

I will name fundamental static system as Metauniverse.

Metauniverse - objectively existing static timeless system which includes everything objectively existing.

Metauniverse has some number of dimensions. How many dimensions in Metauniverse in this article is not considered. This is one of many questions in the hypothesis that is left for future.

In Metauniverse I suppose existence of scalar field. This means that there is an N-dimensional space M, in which there is a scalar field $f(\vec{r})$, where $\vec{r}$ is vector in the space. In this article I do not propose equation of scalar field of Metauniverse, this requires further studies. I also expect that space of Metauniverse is a Hilbert space or pre-Hilbert space, in order to be able to determine distance between points. I expect that value of the scalar field at each point is determined by values of the field in neighboring points, and that equation of the scalar field is symmetric with respect to rotations. This effectively means that position, speed and properties of all particles at each point of time are determined by states in past, present, future and in areas not belonging to spacetime. In order to be able to predict distribution of states in future based on states in past, scalar field should have such properties. It means it should be possible to predict probability of states in some area of field with knowledge of states in another, non-intersecting, area of space of Metauniverse.

Our Universe, in context of this hypothesis, is one of emergent realities. This imposes some restrictions on possible topologies of Metauniverse. For emergent space-time-matter, therefore, it is necessary to find a way to find space, time and matter from these conditions.

Methods of finding spacetime and matter will be described in several iterations.

Search for spacetime and matter

State for any known to us in our reality object depends on state of the object in past and state of objects and fields in some distance around the object in past. In order to obtain similar properties from static Metauniverse, existence of mapping is necessary. The mapping should be between states of space-matter in present to states of space-matter in future. I require function of mapping to be

unambiguous now, multivalued functions of mapping will be discussed later in the article. Time in this case is vector perpendicular to space. Transition to reference frame with another speed is obtained by rotating spacetime.

Set of states of space-matter at some point of time – it is minimal set of characteristics of scalar field in area corresponding that moment of emergent time, which is necessary to predict set of characteristics of scalar field in areas corresponding to future moments of time. Set of characteristics in future time should be minimal set of characteristics necessary to predict set of characteristics of scalar field in areas corresponding to more late time, etc. Such approach is somewhat similar to holographic principle [9], but it has different conceptual model.

With such approach, observable states from quantum mechanics are such characteristics from set of states of space-matter at point of time which forms algebra of states and related groups and operators. So, in order to predict distribution of probabilities of quantum states in future it is enough to know states in present.

So, approach with algebra of states can work well, but obviously it cannot be suitable everywhere. Algebra of states is not represents underlying physics, it is just good mathematical approach which allows to predict distribution of states in future for limited amount of conditions.

Later in the article I will explain what while such approach with space of states works, may be even in some modified way, it is possible to talk about emergent spacetime. For areas where such approach is not works – they are not belongs to our spacetime. However, there are transitional areas and transitional energies.

Mapping function is not just another algebra and related groups and operators. However, mapping function should use map of states in past or present to create distribution of states in future. So, algebra of states is part of mapping function.

Theory of Everything, in scope of ER-hypothesis, it is theory which will describe scalar field of Metauniverse and our reality in Metauniverse. It should answer – is our reality based directly on scalar field of Metauniverse or on some part of series.

ER-hypothesis predicts what Theory of Everything is non-gauge theory, and is not based on algebra of states. Algebra of states, for some conditions and areas, can be solution from Theory of Everything for limited amount of space and energies.

If states of some object are not described by mapping function, such object is not belongs to related spacetime, it is located outside of spacetime. In order for laws of physics to be same everywhere in spacetime, mapping function must be same everywhere in spacetime. Maximum angle of rotation is limited by two factors:

1. By properties of scalar field of Metauniverse. Field may limit applicability of mapping function to only a certain range of rotations
2. Rotation cannot be made so that after rotation time will points to past.

In our reality, state of any object at time t depends on state of space and matter within vicinity of c*t around the object at time t=0. However, existence of such mapping is not enough, it is necessary to be able to switch to frame of reference of moving bodies. Matter is also necessary. I will introduce, in scope of the ER hypothesis, temporary definition of elementary particle:

Elementary particle - feature of scalar field of Metauniverse, which is stable at least for some time and has invariant for rotations.

It means that some projection of scalar field of Metauniverse to emergent space, in vicinity of point $\vec{r}$, with some modifications, not changing features of projection of the field and preserving invariant of particle, must exist along vector of time for some time. Mapping function should map projection of field to similar projection belonging to later time. Later in this article, the definition of elementary particle will be expanded and modified. Movement of particle relative to point of emergent space - is change in distance in emergent space from particle to point where line of time comes from initial position of the particle. In order to be able to go to reference frame of moving particle, it is necessary to have same mapping function in reference frame of moving particle. Because if mapping function is different, this means that in case of change of velocity of particle begin to act different physical laws. Transition to reference frame of moving particle is rotation of spacetime. Emergent time is always perpendicular to local emergent space.

Mentioned above properties of mapping imposes certain restrictions on equation of scalar field of Metauniverse.

Approach to formation of emergent reality, described above, requires specific scalar field of Metauniverse. There is possibility to significantly reduce constraints to scalar field of Metauniverse. Instead of require from scalar field of Metauniverse ability of constructing continuous mapping function, it is possible to request to have this ability only in some points. In this case, space and time are discrete. Since spacetime of one reference frame is at angle relative to reference frame moving with another speed, this means that there is a minimum angle of rotation. Consequently, space of velocities also becomes discrete.

Above were described approaches that require single-valued mapping function. However, such function imposes lot of restrictions on original field. Of course, it leads to easier search for equation of scalar field of Metauniverse but I want to consider all possibilities. Mapping can be probabilistic, it means multi-valued function of mapping. This means that for same conditions of initial field mapping may be one of a plurality of possible values, in accordance with probability distribution function. In this case, laws of physics in emergent reality will also be probabilistic. Usage of probability function of mapping allows further weaken requirements for scalar field of Metauniverse. Probabilistic function of mapping does not mean that result of mapping cannot be predicted accurately. It can be accurately predicted with knowledge of function of scalar field of Metauniverse and boundary conditions. Boundary conditions, however, may be not belongs to emergent spacetime, part of them may belongs to future. Probabilistic function of mapping generates probabilistic laws of physics in corresponding emergent reality.

In order to get emergent reality, it is possible to use not scalar field of Metauniverse, but some decomposition of the field in series. In such case, mapping function should map not the field itself, but some function consisting of a set of related components of decomposition. For example, if scalar field of Metauniverse $f(\vec{r})$ at points of space can be represented as $f(\vec{r}) = \sum f_i(\vec{r})$, then we can construct a reality by usage of one of $f_i(\vec{r})$ or by a combination thereof. Point of space in such case may no longer be a point in Metauniverse, will occupy some volume, and may overlap in Metauniverse with other points of same space. At same time, points of space in related emergent reality would look like without volume, point-like.

I will make several definitions with the approach:

World line - curve that starts at some point in spacetime, and includes all following by time points.

World line is different for each frame of reference, i.e., through a single point in space passes so many world lines, how many rotations available. The curve is constructed by finding the closest following by time point belonging to same reality, then the nearest point to the found point, etc.

Distance between points in space belonging to same spacetime - is the number of points in the space located between them in the shortest curve for discrete solutions and the length of this curve for the case of continuous solutions.

Distance in time between points belonging to same reality - is number of layers of the space located between them for discrete solutions, and distance between spaces along world line of the selected point in the case of continuous solutions.

   With the approach described above, requirements for field of Metauniverse further reduced. However, there is a problem with beginning of world lines. If world line is infinite and is not closed, Metauniverse must also be infinite. With endless world lines, our Universe must also be infinite. However, this contradicts current data about history of our Universe. So, we need a way for emergence and completion of world lines.

   World line is based on ability of mapping function be same for entire reality. However, situation is possible when starting from a certain point of time mapping function cannot make proper mapping. It is possible that field of Metauniverse in such location have no anything unusual. If at some point of time mapping function cannot have correct mapping, in this point world line is terminated. Same is for beginning of world line. At some point, it becomes possible to use mapping function. At this point emerges spacetime and matter. However, emergence of one or more world lines does not mean appearance of new emergent reality. For forming a space of velocities it is necessary to be able to perform rotations of spacetime, and number or angle of rotations must be equal everywhere. At beginning of world line it can be possible what full range of rotations with usage of mapping function is not possible. At that point it is not possible to say that time and space exist. This is transitional space, phase of forming space, time and matter. If by moving forward on the world line it is possible to reach emergent reality - hence the beginning of the world line was birthplace of new reality. If the world line breaks before reaching emergent reality - hence the formation of new reality was unsuccessful. What will happen if one of world lines that make up reality suddenly disappears? For example, there is a small place with some feature of field not allowing using mapping function. World line in many cases can be continued even when mapping function gives incorrect results if add into mapping function indeterministic component.

In the article, I would name as indeterministic every phenomenon what is not possible to describe based on probability.

 Indeterministic component in this case does not mean absence of causal relationship; it just means that causal links deeply hidden from the corresponding reality. At the moment, there are no experimental results which show existence of indeterministic laws of physics in our Universe. If elementary particles have a size of quantum space, while adding indeterminism, we would have seen indeterministic behavior of particles. This is not observed. In order for behavior of particles do not become indeterministic, it is necessary for scalar field of Metauniverse to not allow indeterministic solutions or particle should consist of a large number of world lines. If particle composed of a plurality of world lines,

and this number is large enough, contribution of indeterminacy can be extremely small. Such a particle will also be able to survive disappearance of world lines and the emergence of new lines.

However, there is no phenomenon known with indeterministic behavior. Therefore most likely that indeterministic component is always zero. Or it differs from zero only in the places of formation of spacetime. At the moment, only candidates for such places are vicinity of black holes with strong gravitational field and vicinity of particles with Planck energies.

Scalar field of Metauniverse may not allow indeterministics solutions if, for all observable states, there is algebra of states with inner automorphism.

Above was given temporary definition of particles. Based on written above, modified definition:

Particle - feature of scalar field of Metauniverse or its decomposition, in field of spacetime, which is exists at least for some emergent time and has invariant under rotations for some range of rotations.

As can be seen from this definition, I do not distinguish fermions and bosons. I expect difference between them in their equations of state.

Adding indeterminism to mapping function leads to necessary for emergent physical laws to be resistant to small changes in mapping function.

Space of velocities is formed by all possible rotations of spacetime at which there is no change of probabilistic part of mapping function and indeterministic part is much smaller than other parts of mapping function (deterministic part and probabilistic part). Rotation of spacetime corresponds to transition to reference frame moving at different speed.

Speed of one reference frame relative to another - is function of number of rotations of spacetime for transition between reference frames. For continuous solutions - function of angle of rotation of spacetime, necessary for transition from one reference frame to another.

Accordingly, for discrete solutions of spacetime speed can vary only discretely. Observed velocity in corresponding reality is function of angle of rotation or number of rotations.

At any point in spacetime, there should be maximum angle at which it is possible to rotate the spacetime. Otherwise, using acceleration, it can be possible to go back in time.

Existence of maximum angle of rotation of spacetime means existence of maximum possible speed. In our reality it corresponds to speed of light.

Based on written above, there are several possible options of spacetime:

1. Continuous space, continuous time, continuous space of velocities
2. Continuous space, continuous time, discrete space of velocities
3. Continuous space, discrete time, continuous space of velocities
4. Continuous space, discrete time, discrete space of velocities
5. Discrete space, discrete time, continuous space of velocities
6. Discrete space, discrete time, discrete space of velocities

I think first option most likely describes our reality. The option implicitly means absence of quantum gravity, reasons described later in the article. If quantum gravity exists, in such case our spacetime is described by option 6.

I will add several notations:

Let $g(\vec{R})$ – is either scalar field of Metauniverse or function built from decomposition of scalar field Metauniverse $f(\vec{R})$. $\vec{R}$ – vector in space of Metauniverse.

I will note space of Metauniverse as M

Emergent space – such space V, $V \subset M$ where values $g(\vec{R})$ can be mapped to values $g(\vec{R})$ on another emergent space.

Let $\varphi(\vec{r})$ – is function of mapping of field $g(\vec{r})$ of one emergent space to field in another emergent space, where $\vec{r}$ – is vector in such space. I will write the function as combination of different parts:

$$\varphi(\vec{r}) = d(\vec{r})p(\vec{r})(1 + i(\vec{r},\vec{R})) \qquad\qquad (1)$$

$d(\vec{r})$ – deterministic part, $p(\vec{r})$ – probabilistic part

$i(\vec{r},\vec{R})$ corresponds to indeterministic part. $\vec{R}$ – is vector in space of Metauniverse. Dependency from $\vec{R}$ is necessary, because value of the function is not possible to find based on values of field $g(\vec{r})$ on emergent space. Corresponding emergent space simply have no information necessary to build the function.

Isomorphism is closest to describing the relationship of spaces belonging to different times. However, spaces are not isomorphic. In order to name the ratio of spaces I introduce concept of "partial directed isomorphism".

Partial directed isomorphism of spaces– is mapping of field of space L_1 to field on another space L_2. Mapping goes from bigger or equal by size volume of space L_1 to smaller or equal volume of space L_2. Closely located parts of space L_2 are mapped from closely located parts of space L_1. During reduce in distance between two parts of space L_2 related parts of space L_1, necessary for mapping, also become more close and converge in limit.

As I wrote above, it is possible that indeterministic part is zero everywhere, or zero everywhere except in neighborhood of black holes or near particles with Planck energies.

Based on written above, I will add definition of spacetime:

Spacetime - is set of ordered sets of partial directed isomorphic spaces built on Metauniverse. Mapping function must be, with exception of indeterministic part, identical for each of set of spaces. For each point of each of set of space must exist same number of possible rotations of space in which, with the exception of indeterministic part, mapping function is not changed. Number of possible rotations for discrete solutions should be same for all points of spacetime, total possible angle of rotation for continuous solutions must be same for all points. If make consistently two rotations, then it should be possible to perform a rotation and return to original reference frame or close to it. Order of spaces corresponds to time, spaces corresponds to space, set of rotations corresponds to space of velocities.

So, this definition does not allow world line to go to past. This means that in such a spacetime travel in own past is impossible. If some world lines goes to past – it would start to influence to itself more than once. And, from point of view of all world lines which not go to past – it is not possible.

However, this definition allows existence of closed spacetime, with closed world lines. If closed spacetime is seen in equations describing part of our Universe, such as in some solutions with black holes, such closed spacetime represent another reality, different from our reality.

Partial directed isomorphism of spaces is based on properties of scalar field of Metauniverse. Such field should have no selected direction. In such case, additionally to partial directed isomorphism must exists reverse partial directed isomorphism. In such case, first spacetime formed by the isomorphism corresponds to some universe, second, reversal, corresponds to another universe. I would name suh universe as anti-universe.

Anti-universe – it is universe with mapping function reversal to selected universe.

Interaction of past, present and future

According to the ER-hypothesis, we live in static timeless Metauniverse, where time is emergent phenomenon. Field in Metauniverse is static, there is no preferred direction, equations of field are invariant to rotations. It means every point belonging to past or present interacts with points in future. Also, it means future interacts with present and past. Because Metauniverse is static, it also leads to impossibility to go back in past, time machine is not possible. Another conclusion – inability to change past from present. Any states of objects in present are already have effect to past, and it is not possible to make states of objects to be incompatible with past.

Later in the article, it would be shown what distance l between points located on same position but at different time is described by equation, which is approximately equal to $l = ct$. Here c is speed of light, t is time difference between points. Distance in our spacetime may be not equal to distance in Metauniverse, and in such case distance L in Metauniverse $L = kl$, where k is unknown coefficient of proportionality. The coefficient, based on estimates of age of Universe, is equal to 1 (described later in the article)

If take two moments of time on Earth with 4 years difference between them, they are located at distance of 4 light years. It's about same distance as distance between Earth and nearest star near Sun, Proxima Centauri. Distance in 1 second corresponds to distance between Earth and Moon. It is possible to compare attempt to change past which was 1 second ago, with attempt to quickly change something on Moon without any instruments to do it. There are no lasers to send light beam from present to past, there are no even radio waves to send information. Attempt to change past from present can be somewhat compared to attempt to change something on Moon by movements of hands only. Movements of hands not change anything on Moon, but it has some, very small, impact on gravity fields and gravity waves. So, some impact exists. But attempt to make very small change of past by movements of hands or something similar, has no any effect. It is because those movements are already affected past, even before we decided to do it.

I think it is possible to mathematically prove inability to pass information from future to present. However, I decided to leave the the question open for future.

Loss of information about past

Past - it's all events that have already occurred.

Can events, which already happened, be changed?

If indeterministic part of mapping function is non-zero, it is possible. In this case, with distance from point of event will be accumulated indeterministic contribution. Chains of cause-and-effect relationships are modified. In this case, it is possible that in same frame of reference, at points separated by a certain time, events in common past will look different.

It can be interpreted as loss of information about past.

I expect that indeterministic part can be non-zero only at space where at least some world lines are emerging and terminating. Such behavior of world lines can be expected to be found at curved spacetime, with strongest effects near gravitational singularities and black holes, may be somewhere else. Therefore, variability of past is not observable under normal conditions.

Metauniverse and emergent realities

Metauniverse, according to ER-hypothesis, is static timeless space containing scalar field $f(\overrightarrow{R})$. All others – particles, time and others – are emergent phenomena. Space is vector space. The space have scalar product.

I guess that to describe our Universe, it is possible to use Hilbert space or pre-Hilbert space for Metauniverse space. Is space of Metauniverse Hilbert space or pre Hilbert space, I cannot say now, more research is needed.

Our Universe is part of Metauniverse. Volume occupied by universe in Metauniverse corresponds to sum of volumes of all spaces of universe since beginning of time until end of time, or until cycling of universe.

The above methods for determination of spacetime can provide several different solutions with different mapping functions. These solutions can cross in space of Metauniverse, or not overlap, or coincide exactly occupies same space of Metauniverse. It is also possible that in part of space of Metauniverse existence of spacetime is not possible and no reality exists in that place.

Each of these solutions corresponds, according to postulate of the hypothesis, to objectively existing reality.

I will introduce several definitions:

Multiverse – it is set of all universes, existing in Metauniverse.

Close universes – it is universes that have intersection in space of Metauniverse.

If universes are close to each other, it does not mean that particular region of spacetime of universe is close to region of another universe. Possibly, intersection happened billions of years ago, or it will happen in billions of years in future, or is happening in many mega parsecs away.

Locally parallel universes - all universes, which have intersection in space of Metauniverse with selected part of spacetime of universe.

If there are locally parallel universes, that does not mean that it is possible to interact between universes. For interaction between universes is necessary, but not sufficient, non-zero correlation between equations of particles belonging to the different universes.

Interacting parallel universes - universes, action in one of them may affect state in other universe, and vice versa.

There are some solutions[3] which allows closed time like curves. In ER-hypothesis, I interpret such solutions as interacting parallel universes. They are much smaller than our Universe, but they are separate universes.

If action from one universe to another universe will make rational being, in another universe such action will looks as consequence of its own physical laws and it would have independent from first universe causality links.

For each universe, always must exists anti-universe. Anti-universe is always interacting parallel universe, it is based on reverse mapping function. It is possible to say what time in anti-universe go in back direction in comparison with universe.

Recently, in fantasy become popular genre with parallel Earths located in parallel dimensions. According to ER-hypothesis, parallel Earths are possible, in case if accumulation of matter in one reality leads to accumulation of matter in another reality. Simplest possible solution is for interacting parallel universes. Maybe extraterrestrial sentients are very close, on parallel Earth?

Properties of our spacetime

There are several possible options of existence of Universe:

1. Time in Universe has a beginning but no end.
2. Time in Universe has a beginning and an end
3. Spacetime in Universe looped.
4. Time in Universe has no beginning and no end.
5. Time in Universe has no beginning but there is end of time.

All variants with infinite time assume infinite Metauniverse.

Modern experimental data show that time in our universe has beginning. It discards all options except 1 and 2.

In scope of the hypothesis, I see only one mechanism of generating a new reality - gravitational singularity, as described above.

Therefore, in beginning, until time appeared, was gravitational singularity where usage of same mapping function as now in our universe was impossible. Next, began formation phase of our Universe, which created space, time and matter. It is not possible to say how much time this process took, since time itself was also in phase of formation. Further development of the ER-hypothesis, understanding physics of Metauniverse, should allow studying formation of our Universe in details and even looking further before Big Bang, to where there was neither time nor space.
End of formation phase is not means end of formation of new spacetime and matter. It is still possible and, at least for spacetime, happens, described later in the article in cosmology section.

Our reality

In this part of article, I will describe how our reality looks based on the ER-hypothesis.

We are in static timeless Metauniverse. Metauniverse has scalar field, space is a Hilbert space, or pre-Hilbert. Field is not uniform everywhere, somewhere it is more, somewhere less, but equation of field is

same everywhere. Our universe exists in Metauniverse, formed on basis of one of variants of formation of spacetime and methods for quantization, described above.

Options with discrete space of velocities difficult to combine with fact that energy of quants of light use same value of Planck constant as for particles. Therefore, it is more natural to assume that quantization occurs on basis of scalar field of Metauniverse or its decomposition and space of velocities is continuous. Option with continuous spacetime looks for me more natural than option with discrete space. Additionally, this option has another advantage - it should be easier to find.

I assume that mapping function, described above, has no indeterministic parts on all available now for study range of energies and values of gravitational field. I assume what properties of particles and their interaction in above range of conditions, can be described based on their states. In this case, their accurate equations should have a range of states as approximate solution.

With these assumptions, appears algebra of Von Neumann to describe changes in states of particles in time, for available ranges of energies.

Gravitation warps emergent spacetime. Thus, gravitation does not affect character of interaction between particles on entire observed range of gravitational forces.

At same time, both quantum mechanics and general relativity, according to the ER-hypothesis, are approximate and have restrictions on their range of applicability.

Both quantum mechanics and gravitation are emergent phenomena of scalar field of Metauniverse.

Above, in the introduction, I described my vision, within the ER-hypothesis, how emergent time is perceived by sentient beings.
I consider our Universe as:

1. State in future for all spacetime, except transitional space of spacetime formation and termination, can be described based on state in present or past without indeterministic part. It means state in future can be described based on state in present or past either deterministic, or probabilistic.
2. Our spacetime-matter is based on scalar field of Metauniverse, not on one of its decomposition.
3. Distance between two points in emergent space by any curve is dependent on distance between the two points in space of Metauniverse for curve following curve in emergent space. Equation with the dependency will be described in gravitation part of the article.

Assumption #1 from above put some restrictions to equation of scalar field.

We know what it is possible to predict probability of future states based on states in past in some area. In order to predict state of some object at time t, it is necessary to know states of all objects and fields at t=0 at radius r = c*t around that object. Gravitation warp emergent spacetime, it means at any point of space, space is either flat or has some curvature. In each point of space, time is perpendicular to space. it means what at any point along world line it is possible to build distribution of probabilities based on states in past or present. The probability distribution would be same for all world lines belonging to same reality.

I assume equations of scalar field of Metauniverse are symmetric, no any chosen direction.

In such case it means it is possible to not only predict probability of future states based on present, it is possible to predict probability of present states based on past, present and future.
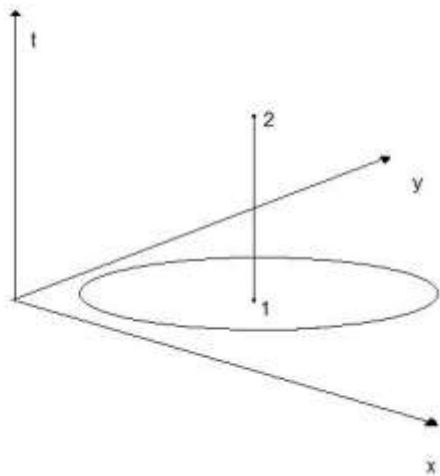
Picture 1. The picture illustrate it is possible to predict probabilities of states in future at point 2. In order to do it, it is necessary to know states at areas with radius $r = ct$ around point 1, where point 1 have same values of (x,y) as point 2, and t is difference in time between points 2 and 1. The picture have 2 spatial axis x and y, and one time axis t.
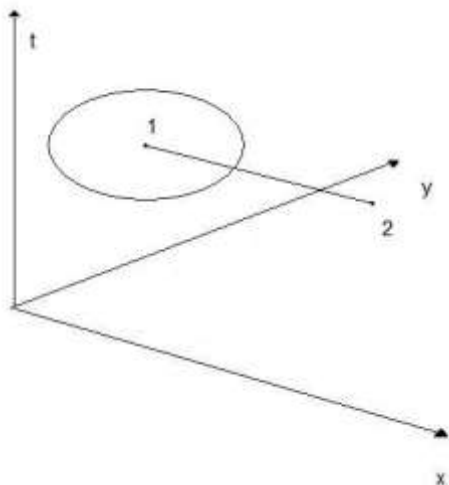
Picture 2. The picture illustrate it is possible to predict state at point 2, belonging to present, based on states in past present and future in other area. The picture have 2 spatial axis x and y, and one time axis t.

Point 1 on picture 2 have (x, y, t) coordinates (0, y1, 0). Point 2 on picture 2 have (x, y, t) coordinates (x2, y1, 0). Area around point 1 have x=0.

It means distance between the points is equal to time difference $t = x_2/c$

Next, I would use light-like invariant interval from Special Relativity. I can use Special Relativity because, as it written in the article, ER-hypothesis is fully compatible with Special Relativity.

$s^2 = y^2 - c^2 t^2$. For light-like interval s=0. So, $y = ct = c\frac{x_2}{c} = x_2$

Symmetry of properties of scalar field of Metauniverse to rotations allows using equation from picture 1, modified to rotations. So, in order to predict distribution of probabilities of states at point 1 at present, it is enough to know states of objects and fields at area

$$x=0, (y - y_1)^2 + c^2t^2 \leq x_2^2 \qquad (2)$$

Special Relativity and ER-hypothesis

In order to form time, all laws of physics should be same in all frames of references. So, if some laws, like electrodynamics, need constant speed of light in all frames of references, speed of light must be constant. It corresponds to same mapping function everywhere in spacetime. Same mapping function everywhere in spacetime is one of requirements of ER-hypothesis to mapping function. So, ER-hypothesis is consistent with Special Relativity. Thermal time hypothesis[1] shows possible relation between C*-algebra of states, inner automorphism and time. ER-hypothesis also has same algebra of states to form spacetime, but it goes much further, ER-hypothesis explain how such algebra is formed and where it can be applicable, and how it can be possible to describe areas where approach with space of states is not possible. Thermal time hypothesis shows how time can be dependent on state changes. In ER-hypothesis, observable state changes caused by movement of emergent matter in emergent space in emergent time.

Gravitation

General relativity [2] treats gravitation as warp of spacetime by mass. ER-hypothesis treats gravitation similarly, as warp of emergent spacetime by mass.

What is mass in ER-hypothesis?

Every particle has some gravitational mass. So, gravitational mass should be something universal. Also, all particles with non-zero rest mass have inertial mass, and inertial mass is equal to gravitational mass.

Most suitable source for both gravitational and inertial masses I see gradient of scalar field, and consider gradient of scalar field as mass later in the article.

With such assumption, scalar field has such properties, what each area of space with gradient of field has mass

$$m = \int g\left(\frac{df(\vec{r})}{d\vec{r}}\right)d\vec{r} \qquad (3)$$

m is mass in area, integral over entire area, g – it is unknown function which gives mass from gradient of scalar field, $f(\vec{r})$ – it is scalar field of Metauniverse, $\vec{r}$ – vector in emergent space.

So, scalar field of Metauniverse should have such properties, what deviation of gradient of the field in emergent spacetime from line should require applying force.

Particles are created from scalar field of Metauniverse or its decomposition to some series and exist some time. It means general relativity adds some restrictions on scalar field of Metauniverse. Relation between scalar field of Metauniverse and emergent spacetime is described above.

Due to fact that particles change spacetime, is that if will be big enough number of particles - there can be problems with spacetime and world lines. At some point, continuing of spacetime would be impossible. At that point, there is gravitational singularity. Close vicinity of gravitational singularity is

place for massive formation of spacetime and for some formation of matter. There may emerge and terminate world lines, and particles.

Gravitational singularity does not mean that at point of singularity Metauniverse also has singularity of scalar field. It does not even mean that in these places value of scalar field of Metauniverse is higher than average.

During search for spacetime, one of condition of spacetime was – all laws of physics should be same in all space. It allows using equivalence principle from GR. As result, General Relativity is fully describe gravity, according to ER-hypothesis. ER-hypothesis, however, predicts what cosmological constant is not constant and predicts value of cosmological function. It is described later in the article, in cosmology part.

So, equation of gravity for ER-hypothesis:

$$G_{\mu\nu} + \Delta(t, v_t)g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{4}$$

$\Delta(t, v_t)$ is cosmological function and its value and its incompatibility with existing cosmological models will be described later in the article. v_t – distance in Metauniverse corresponding to 1 second in related frame of reference, speed of time in Metauniverse.

GR predicts what time in areas with high gravitation ticks slower than time in areas with low gravity. It means what emergent space have to pass less space in Metauniverse to tick 1 second in areas with high gravity than in areas with low gravity. So, length in Metauniverse, corresponding to one second, v_t decreasing in areas with high gravity and increasing with areas with low gravity. It is possible to assume what $v_t = c$ for case when tensor T=0, and $\Delta(t, v_t) = 0$. As result

$$v_t = kc\frac{dt}{dt_z} \tag{5}$$

dt – change of time in presence of mass and with cosmological function, dt_z – how time will change if, in same point, tensor T=0, and $\Delta(t, v_t) = 0$, k – some unknown linear proportionality coefficient, value will be found later in the article. So, such equation set dependency between distance passed in Metauniverse and unit of time.

Same applies to distance in emergent space. With usage of same logic,

$$dl_M = k * dl\frac{dt}{dt_z} \tag{6}$$

dl_M – distance in Metauniverse, dl – distance in emergent space.

I will add definition of normalized distance.

Normalized distance – it is distance in Metauniverse between points belonging to emergent spacetime, by some curve belonging to emergent spacetime.

So, normalized distance by some curve between two points p1 and p2, both belonging to same emergent space is:

$$l = \int k * dl\frac{dt}{dt_z} \tag{7}$$

Integral goes over selected curve from point p1 to point p2.

Quantum gravity is discussed later in the article.

Quantum mechanics

Set of states of space-matter at some point of time – it is minimal set of characteristics of scalar field in area corresponding that moment of emergent time, which is necessary to predict set of characteristics of scalar field in areas corresponding to future moments of time. Set of characteristics in future time should be minimal set of characteristics necessary to predict set of characteristics of scalar field in areas corresponding to more late time, etc.

With such approach, observable states from quantum mechanics are such characteristics from set of states of space-matter at point of time which forms algebra of states and related groups and operators. So, in order to predict distribution of probabilities of quantum states in future it is enough to know states in present. It leads to probabilistic laws of physics in related emergent realities and to quantum mechanics.

Such approach can lead to fully deterministic physics in emergent realities. However, in order to achieve it, it should be possible to predict values of scalar field of Metauniverse in area a1 based on values of the field in another area a2. Also it should be possible to rotate area a2 and it still should be possible to predict values at least in part of area a1. My guess – only trivial solutions allows it, and our Universe is not looks as something trivial. So, probabilistic laws of quantum mechanics come from ER-hypothesis in quite natural way.

In quantum mechanics, events are probabilistic in nature. In the ER-hypothesis it is possible if mapping function is probabilistic. In this case, based on information in corresponding spacetime it is impossible to predict how event occurs at next time, other than with some probability. This does not mean that it is impossible to predict what will happen in next moment, but full information that would allow to do it, is outside of space-time.

Elementary particles have size much smaller than distance that they can pass over its lifetime. This means that their behavior is described by solution of (unknown yet) equation for large distances. This behavior resembles solitons. Difference is that solitons are propagated in time and space. Particles, according to ER-hypothesis, it is just a feature of static scalar field. I will name such behavior as solitoid.

Solitoid - is feature of static field or its decomposition into series, retains its structure, possibly only at certain points or intervals of space, at distances much greater than its size in emergent space.

Accordingly, particles are solitoids that are valid on space-time.

Should particles continuously be defined on spacetime? Or maybe they exist some small segment of spacetime, next they are converted into something else, next they reappear again? First seems most logical, but second cannot be excluded now. Looking at equations of solitons, I think that first is most likely.

Properties of particles and their interactions observable by us, depends on unknown equation of scalar field and equations of particles.

I assume that at least properties of part of particles in certain range of speeds and properties of their interactions can be described on basis of states.

Quantum mechanics and Standard Model describes particles and their interaction/transformation on basis of transitions between states and space of states.

Therefore, if particles can be described on basis of states, there is possibility of such equation of scalar field of Metauniverse and such equations of state of particles that Standard Model would be particular case for some range of conditions. So, it put some restrictions on scalar field of Metauniverse and to equations of particles. In order to be compatible with quantum mechanics and Standard Model, equations of particles and equations of ensembles of particles should allow using states to calculate its behavior at least for some range of conditions. States, in such case, is something like eigenvalues of equations of particle and ensembles of particles. I know eigenvalues relates to algebra and I expect differential equation for particles. So, state is not eigenvalue from some algebra, but some characteristic value of differential equation on long distance under some conditions.

With such approach, Quantum Mechanics is approximate model build on space of states from characteristic values of particles and ensembles of particles. Precision of the approximate model is good enough to be precise on all our typical conditions.

So, ER-hypothesis is compatible with quantum mechanics and Standard Model.
However, if states are just some characteristic values of equations of particles, it means there are cases when state-based description is not suitable. It means Theory of Everything cannot be gauge theory. Below in article there is part of the article, describing conceptual model of ER-hypothesis at Planck energies. It describes vision of ER-hypothesis for physics of Planck energies and very first moments of Big Bang.

Grand Unification Epoch and Planck Epoch. Big Bang.
Above, states of quantum mechanics were described as characteristic values of differential equations of particles and ensembles of particles. Let's see how such description will work at Planck scale energy.

During approach to Planck energy, first I expect splitting of states. Next, if continue to increase energy, space of states will start to consists of discrete space of non-discrete, continuous, states. At that energy, quantum mechanics will fail. I think with some modifications QM still would be able to explain processes at such energy level. However, if increase energy more – all states should combine into one continuous state and theories based on space of states will be unable to predict anything. At that moment of time, particles, both fermions and bosons, will disappear. Instead of many particles, will be one wave-like entity without discrete states.

Current theories of Big Bang says what our Universe started from singularity. Next started Planck Epoch. During Planck Epoch gravity was as strong as other 3 forces. Next Planck Epoch transformed to GUT Epoch, due to some reasons. During the transformation, gravity separated from other forces. After GUT epoch, strong force separated and started electroweak epoch. Electroweak epoch and following epochs are described by well verified physics theories.

I propose another epochs for Big Bang, sorted by time.

1. Pre-time epoch, epoch before time appeared. During that epoch, it is impossible to find any world lines which existed at that epoch and still exists. In order to describe state of scalar field of Metauniverse, it is necessary to use full equations of the field; approach with state-based description is not works. So, at that epoch, there are no any forces – because there is no space and no time. I would name state of matter during that epoch as non-spacetime matter. It is final

state of matter under high pressure or high energies, it can withstand any pressure and any energies. I think such state of matter is exists inside black holes.

2. Formation epoch. It starts at emergence of first world line belonging to our reality, finished at beginning of time. Begin of time started with full formation of space of velocities. Formation of space and, possibly matter, is still happens. It is because predicted cosmology function, calculated later in the article, is above zero. As for formation of matter, ER-hypothesis in its current state is not predicts it, but it is not prohibit formation of matter too. So, the epoch started before beginning of time, and finished at t=0, t is time. During the epoch, time, space and matter not existed, were in process of formation. The epoch happened not at t<0, time not existed during the epoch. Particles not existed during the epoch, because in order to describe them it is necessary to use full equations of scalar field of Metauniverse. Description based on space of states is not works. Big Bang started at the formation epoch.

3. Epoch of continuous states, space of states is discrete. Started when it became possible to distinguish particles and describe them based on space of states. Approach with space of states will encounter big problems here. But probably with additional modifications, QM/QFT still would be able to have predictive power on that energy. Its moment when first particles appeared. Started at t=0, with start of time and space.

4. Epoch of states split. Approach with space of states, with some modifications, still should be able to work.

5. Next started epoch of separate states.

Formation epoch have no gravity, no time, no space, no matter. Later, in epoch of continuous states, gravity, with formation of space, became separate force. So, it is epoch when gravity is not separated yet from other forces, but it not existed. In such case it corresponds to Planch epoch.

Without math model of scalar field of Metauniverse and our reality, I cannot say what is corresponding to GUT epoch, and is GUT epoch and related unification possible at all.

Methodologies of GUT theories require calculation of different gauge constants and VeV vacuum expectation value, for energies above 246 GeV.

However, with conceptual model of epochs described above, I see no need to look for ways how to calculate them; they are not exists to my model.

About formation of quarks, electrons etc. Without math model, I cannot describe formation of particles in numbers, just describe it on qualitative level.

Conceptual model of current theories of Planck epoch: it is ideal gas of some particles with high energies, gravity unified with other forces. Theory of Everything, with such approach, should answer how vacuum expectation value is affected by gravity, resolve Planck temperature issue etc.

ER-hypothesis's conceptual model of Planck epoch: moment of time when time started, happened exactly at t=0. Before, time not existed. Later, gravitation become separate force.

Behavior of particles at high energies, from highest to smaller, is described above at description of proposed epochs. One of such epoch is correspond to Planck energy.

Cosmology of ER-hypothesis

According to many observations, our Universe is isotropic on large scales, and is expanding. In order achieve isotropic Universe, many cosmological models says what our Universe started from some very small or point like volume, next started inflation phase.

In ER-hypothesis, in order to achieve:

1. Entire Universe have single source
2. Universe is expanding

it is necessary to conclude what our Universe is surface of hypersphere.

Speed of time v_t – it is how big distance in Metauniverse corresponds to one second in our Universe.

However, even normalized distance may differ from distance between points in Metauniversefor same curve, like $L = kl$. L is distance in Metauniverse, l is normalized distance, and k – some constant of proportionality. Later in the article I would use k=1, because it is more simple and because there is no evidence it is different from 1. Later in the article will be calculation of age of our Universe. That calculation give same result as other models only if k=1, it is another argument to assume k=1.

Universe is started from small hypersphere, and growing in Metauniverse. So, process of formation of new space is still happens, everywhere with positive curvature of space.

Expected state of matter before Big Bang is non-spacetime matter. Non-spacetime matter not belongs to our spacetime, and description of the state of matter requires usage of full equations of scalar field, state based approach with usage of space and time not works. So, any parts of matter in such states directly interacts, regardless of distance, there is no horizon problem[4]. As result, size of Universe at formation epoch become unclear in ER-hypothesis. However, it still should be small.

I will use R_0 as notation for radius of hypersphere of Universe after formation epoch.

Time since Big Bang can be calculated with usage of Hubble constant.
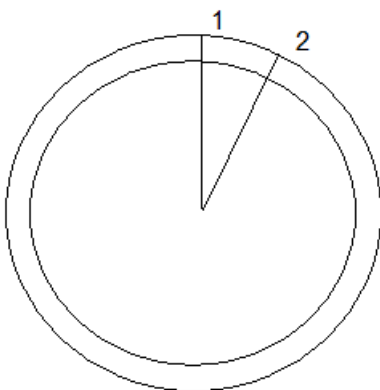
Picture 3. Illustrate expansion of our Universe, projection of hypersphere of Universe in Metauniverse to two dimensions. Inner sphere is Universe at time t1, outer – Universe at time t1+dt

Total length of projection of Universe to two dimensions is $L = 2\pi R(t)$

R(t) – radius of hypersphere at moment t.

Length between any two points on hypersphere $l(t) = \alpha R(t)$

I do assumption what distance between points in Metauniverse by curve following emergent space is either equal or proportional to distance in emergent space, the assumption was described above in the article.

α – angle between points.

Distance between two points grows with speed

$$v = \frac{dl(t)}{dt} = \alpha \frac{dR(t)}{dt} = \alpha v_t \tag{8}$$

If use, for simplicity of calculation, $v_t = const$, $R_0 \ll R(t)$,

In such case $R(t) = v_t t$,

t is time since start of time in Universe.

$$v = \alpha v_t = \frac{l(t)}{R(t)} v_t = \frac{l(t)}{v_t t} v_t = \frac{l(t)}{t} \tag{9}$$

Hubble law[6] says what at current time $v = H_0 l(t)$

H_0 – value of Hubble constant at current time.

Hubble law is not compatible with ER-hypothesis, because the law is based on FLRW metric[7].

FLRW metric is analytical solution of equations of general gravity with cosmological constant. ER-hypothesis predicts what cosmological constant change over time, so it should be named as cosmological function. However, it is possible to notice what prediction of ER-hypothesis at current cosmic time is same as Hubble law prediction, for cases when distances are relatively small, $L \ll \frac{c}{H_0}$

As result, I can use measured value of Hubble constant for my calculations.

If t is current time,

$$v = H_0 l(t) = \frac{l(t)}{t} \tag{10}$$

So, age of Universe is approximately

$$t_0 = \frac{1}{H_0} \tag{11}$$

The result is similar to many other cosmology models. I will use t_0 notation later in the article for current age of Universe. If coefficient of proportionality between normalized distance and distance in Metauniverse will be different from k=1, result would be different by k times. So, it support choice of k=1.

Next, I want to find how law for recession velocity changes in time, for ER-hypothesis.

According to equation above,

$$H_0 = 1/t_0 \tag{12}$$

So, coefficient of proportionality change over time by equation

$$H(t) = \frac{1}{t} = H_0 \frac{t_0}{t} \tag{13}$$

t_0 – current age of Universe, H_0 – value of Hubble constant at current time, t – time.

Previous calculations was done with assumptions: $v_t = const$, $R_0 \ll R(t)$. I will try to estimate how it change over time without that assumptions.

So,

$$H(t) = \frac{v_t(t)}{R(t)} = \frac{v_t(t)}{R_0 + \int_0^t v_t(\tau)d\tau} \tag{14}$$

$v_t(t)$ can be calculated from modified equations of general relativity.

Hubble law establishes dependency between distance passed and recession velocity. Typically, we know velocity by Doppler effect and it is necessary to estimate distance by velocity, with assumption what its mostly recession velocity. The law was tested on relatively short distances [8], up to few hundreds megaparsecs away. For such distances, Hubble law is approximately equal to law of recession of ER-hypothesis. However, there are cases when distance is much bigger. I would calculate dependency between distance passed and recession velocity for light.

$$v = \int_{t_1}^{t_0} dl * \frac{1}{t} = c \int_{t_1}^{t_0} \frac{dt}{t} = c(\ln(t_0) - \ln(t_1)) = c * \ln(\frac{t_0}{t_1}) \tag{15}$$

Because for light distance passed $L = c(t_0 - t_1)$

$$v = c * \ln\left(\frac{t_0}{t_0 - \frac{L}{c}}\right) = c * \ln(\frac{1}{1 - \frac{L}{ct_0}}) \tag{16}$$

So, law of dependency between recession velocity and distance passed is:

$$L = \frac{c}{H_0}\left(1 - \frac{1}{e^{\frac{v}{c}}}\right) \tag{17}$$

It is for case when $v_t = const$, $R_0 \ll R(t)$.

Hypersphere is similar to de Sitter space[5]. Cosmological constant in GR equation for the case is:

$$\Delta(t) = \frac{3}{(R(t))^2} = \frac{3}{(R_0 + \int_0^t v_t(\tau)d\tau)^2} \tag{18}$$

Because radius of curvature grows with time, it means value of cosmological constant changing. So, instead of cosmological constant should be cosmological function, value is dependent on age of Universe.

Cosmological constant is approximately equal, for $v_t = const$, $R_0 \ll R(t)$ to

$$\Delta(t) = \Delta_0 \frac{t_0^2}{t^2} \tag{19}$$

Δ_0 – value of cosmological constant at current time. It is possible to estimate value of the constant, assuming $v_t = c$, c is speed of light, and $R(t_0) = ct_0 = \frac{c}{H_0}$

$$\Delta_0 \approx 3\frac{H_0^2}{c^2} \tag{20}$$

So, equations of general relativity with changes from ER-hypothesis:

$$G_{\mu\nu} + \frac{3}{\left(R_0 + \int_0^t v_t(\tau)d\tau\right)^2} g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{21}$$

$$v_t = c\frac{dt}{dt_z}$$

t – age of Universe from point of view of observer in related point.

It is easy to notice what $\Delta(t) > 0$ for any t.

Also, for case when $v_t = const = c$, $R_0 \ll R(t)$, it may be rewritten to:

$$G_{\mu\nu} + \frac{3}{(ct)^2} g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{22}$$

t – age of Universe.

Cosmological constant can be interpreted as energy density of vacuum. For case with cosmological function, of course it still can be interpreted as slowly decreasing energy density of vacuum. However in model of ER-hypothesis it looks purely as geometrical function.

In ER-hypothesis, while changes to EFE are small, but there is big change in conceptual model of general relativity. Curvature in general relativity is intrinsic. ER-hypothesis proposes conceptual change and adds cosmological function as extrinsic curvature. Also, at least part of intrinsic curvature of GR in ER-hypothesis becomes extrinsic. It is interesting to analyze the changes in conceptual model of general relativity in more details, but I decided to leave it for future.

Existing cosmology models are based on FLRW metric. However, the metric is based on constant value of cosmological constant. So, ER-hypothesis is not compatible with FLRW metric, same as with all cosmological models based on FLRW metric.

Quantum gravity and ER-hypothesis

During search for spacetime, I required mapping function to be same everywhere in emergent spacetime. It can be written in another way: all laws of physics must be same everywhere in spacetime. Gravitational force plays big role in identifying emergent spacetime. Our spacetime may be smooth only if gravitational force is also smooth. If gravitation force has quants, both emergent time and space should consists of quants of spacetime. Reason – if gravity have quantum effects, it affect at some point of spacetime, and not do any effects for some other time. And it have quant of spacetime as result. Similar for space of velocities – if there are quants of gravitation, space of velocities must be discrete. As of now, there are no any evidence what either time or space has quants. Equations of quantum mechanics are valid only if time is smooth function.

Possible argument how quantum gravity can exists in model of ER-hypothesis: quants of spacetime are exists, but our experimental abilities are not allows discovering them. I see possible counter-argument in ER-hypothesis. Laws of physics should be same everywhere in spacetime. Is it possible to achieve if spacetime consists of quants of spacetime? I have no mathematical prove, but I guess it is either not

possible, or it limits possible functions to level when they will become incompatible with observed laws of physics. So, further study of mathematical model of ER-hypothesis, holography-like functions, would allow to tell us is quantum gravity exists in our Universe if ER-hypothesis is valid.

Current state of ER-hypothesis

I see main power and main achievement of the hypothesis in simple conceptual model unifying quantum mechanics/QFT and General Relativity. The hypothesis, on conceptual level, is able to explain all observable forces and phenomena from one point of view.

Main weakness of the hypothesis now – mathematical model is weak, there are equations only for limited amount of cases. I think it is quite expected, initially, for any hypothesis which goes beyond well-known area of gauge theories build on space of states. However, even existing mathematical model of the hypothesis allows making calculations for some cases and allowing doing measurable predictions. So, the hypothesis can be experimentally verified.

Certainly, the proposed hypothesis is very radical; it affects core concepts of philosophy. However, this hypothesis is also promise very radical reduction in number of independent phenomena. Occam's razor for this case shows the hypothesis can be correct.

ER-hypothesis proposes way to combine all known fundamental forces, including gravitation, within framework of a unified theory of everything. In addition, ER-hypothesis explains nature of time. This hypothesis introduces only one new entity, scalar field of Metauniverse. I also propose method how, based on the field, it is possible to describe our reality. The hypothesis removes independent concepts of time, space and matter. Numerous magic constants, quantum mechanics and Standard Model contains many of them, is also expected to be removed in scope of further development of the hypothesis. This hypothesis could be called Theory of Everything, if the hypothesis contains equation of scalar field of Metauniverse. At same time, I think that this hypothesis contains comprehensive set of interpretations and models for finding Theory of Everything.

List of predictions of ER-hypothesis:

- ER-hypothesis predicts how recession velocity law change with time
- ER-hypothesis propose changes to equations of General Relativity
- ER-hypothesis propose way how to mathematically prove possibility of absence or presence of quantum gravity
- ER-hypothesis predicts what FLRW metric is incorrect, and all cosmology models based on FLRW metric are also incorrect
- ER-hypothesis predicts no-spacetime matter. State of matter, when spacetime is not exists. It is hard to name such state as matter, because matter exists only together with spacetime. However, it is most suitable name which I found. Matter in such case can withstand any pressure and any temperature. Such matter is expected inside black holes, and, possibly, it can exist in center of neutron stars.
- ER-hypothesis predicts what Theory of Everything is non-gauge theory and it cannot be based on space of states
- Loss of information about past. It means past of object can looks different at different times. It is expected only near gravitational singularities and black holes and for particles with Planck scale energies.

- Approach with space of states, used by quantum mechanics, is expected to be broken near gravitational singularities, near black holes in strong gravitational fields and for particles with Planck energies. It is hard to name it as new prediction, because Planck energy is obvious limit for quantum mechanics. What is new – ER-hypothesis explains why and how approach with space of states will be broken and propose way to discover how to calculate behavior of particles at Planck scale energies. The prediction allows to make estimations how particles will behave at high energies.
- Parallel universes are predicted. Also, ER-hypothesis predicts ability of interaction between some, but not all, parallel universes.
- ER-hypothesis predicts what travel to past is not possible

Other results of the hypothesis:

- ER-hypothesis contains theory of time as one of parts
- ER-hypothesis proposed model of formation of spacetime, include model of formation of time and space during Big Bang. The hypothesis describes formation phase, during the phase both time and space not existed, they were in process of formation
- Further development of the ER-hypothesis should allow to look even further before Big Bang, to where there was neither time nor space.
- The ER-hypothesis is able to explain, on conceptual level, GR and QM/QFT from one point of view.
- Was proposed quite natural way how to unify, on conceptual level, quantum mechanics/QFT and General Relativity.

References

1. Von Neumann Algebra Automorphisms and Time-Thermodynamics Relation in General Covariant Quantum Theories, A. Connes, C. Rovelli,Class.Quant.Grav. 11:2899–2918, 1994.

2. Einstein, Albert (1917), "Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie",Sitzungsberichte der Preußischen Akademie der Wissenschaften: 142

3. Kurt Gödel (1949). "An Example of a New Type of Cosmological Solution of Einstein's Field Equations of Gravitation". Rev. Mod. Phys. 21 (3): 447.Bibcode:1949RvMP...21..447G. doi:10.1103/RevModPhys.21.447.

4. An Exposition on Inflationary Cosmology, Gary Scott Watson, Dept. of Physics, Brown University

5. Riess, A. et al. (September 1998). "Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant".The Astronomical Journal 116 (3): 1009–1038. arXiv:astro-ph/9805201.Bibcode:1998AJ....116.1009R. doi:10.1086/300499.

6. de Sitter, W. (1917), "On the relativity of inertia: Remarks concerning Einstein's latest hypothesis", Proc. Kon. Ned. Acad. Wet. 19: 1217–1225

7. Lemaître, Georges (1927), "Un univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques", Annales de la Société Scientifique de Bruxelles A47: 49–56

8. Riess, A. et al. (September 1998). "Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant".The Astronomical Journal 116 (3): 1009–1038. arXiv:astro-ph/9805201.Bibcode:1998AJ....116.1009R. doi:10.1086/300499.

9. Bousso, Raphael (2002). "The holographic principle". Reviews of Modern Physics 74 (3): 825–874. arXiv:hep-th/0203101