Reality as emergent phenomenon

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Abstract

In this article, I propose radical super-deterministic non-gauge hypothesis of emergent spacetime and matter, in which spacetime and matter are emergent properties of more fundamental entity. Properties of such more fundamental entity were analyzed, approach how to build emergent spacetime and matter with observable properties was proposed. It was shown how nondeterministic laws of quantum mechanics with gauge fields arise from super-determinism of underlying entity. The hypothesis of emergent reality (ER- hypothesis later), as shown in the article, is compatible with Special Relativity, General Relativity, Quantum Mechanics with Standard Model and cosmology. Quantum Mechanics was reformulated in background-independent form. Changes in equations of General Relativity are proposed in the article, same as changes to overall conceptual model of gravitation. Question is quantum gravitation exists is open mathematical question in ER-hypothesis and it can be solved by more detailed analysis of equations of ER-hypothesis. SU(3) symmetry was derived in ER-hypothesis and it was shown what Standard Model can be approximate solution of ER-hypothesis. ER-hypothesis unify all forces include gravitation; all forces are derived from one field.

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Introduction

Time is a phenomenon that each of us observe daily. But physics is still not able to understand what is time is. There is no evidence that time is independent phenomenon. Moreover, special and general theories of relativity established a dependency 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, is it possible to travel back in time.

There are some phenomena called as emergent. For example, second law of thermodynamic is one of emergent phenomenon. Properties of thermodynamic are based on underlying properties of individual atoms and molecules. However, equations of thermodynamic 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 based on more fundamental entity.

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 and it is possible to predict rate of decay.
2. We can predict probability of state of any object in future, with certain limitations, like not within gravitational singularity etc. In order to make such predictions, 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, in all non-accelerating reference frames.

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 velocity. 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 possible to predict on basis of state before.

Let's imagine that space-time-matter, satisfying all 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 model 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 emergent 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. 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, so there is no real freewill.

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, and such space-time-matter allow existence of sentient, such space-time-matter is exists, it is emergent reality. In such emergent reality sentient 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.

Later in the article, I will discuss nature of time in more details.

It is possible to notice what postulate of the hypothesis can be partially proven based on induction.

If, at some point of emergent time, human is able to think and feel reality of surrounding – he will be able to think and feel reality of surrounding at any other following moment of emergent time.

Proof:

ER-hypothesis describe world with exactly same physical laws and phenomena as we observe. If it cannot describe some observable phenomena, it means ER-hypothesis is not correct. So I assume here what ER-hypothesis is able to describe world with exactly same physical laws and phenomena as we observe. So if human would not be able to think and feel reality of surrounding at any other following moment of emergent time – it means physical laws and phenomena of our world prohibit to humans think and feel reality of surrounding. It directly contradicts to observations, humans are able to think and feel reality of surrounding.

So, the statement is proven.

Similar for first step of induction, what human (or sentient) belonging to such world can think and feel reality of surrounding at some moment of emergent time. If it is possible to build exactly same laws of physics in ER-hypothesis as in our world, it means what human will be able to be born, learn and start to think.

Postulate of ER-hypothesis is more philosophical than physical, so prove from above can be questioned based on different philosophical views. So I have to use postulate instead of theorem.

I will name underlying fundamental static system as Metauniverse.

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

In the definition, I use phrase “objectively existing”. The phrase means what something exists, and it can exist with or without observer, independently from observers. However, the term indirectly implies possibility of existence of observer. But observer who can observe Metauniverse cannot exists, because there are no any models of intelligent life without time. “Existence” also indirectly implies what something happens in time, some object exists and time changing. There is no time in Metauniverse, so it means Metauniverse exists not in typical meaning of existence. So “objectively existing” is not precise phrase here, but it looks as closest available. The phrase here means what Metauniverse exists without any possibility of being observed by any observer, and what word “existence” for Metauniverse is not imply any processes in time or time existence.

Metauniverse has some number of dimensions. Number of dimensions in Metauniverse in this article is not considered. This is one of many questions in the hypothesis that is left open for future. But Metauniverse should have at least 4 dimensions to include our reality. One dimension for time, three dimensions for space. All four dimensions are space dimensions with same properties; there is no time in Metauniverse. As would be shown later in the article, if Metauniverse have more than 4 dimensions, scalar field in Metauniverse should have different properties for other dimensions than for 4 dimensions subspace which include our reality.

In Metauniverse I suppose existence of scalar field. This means that there is an m-dimensional space V, in which there is a scalar field $f(x)$, where x is point in the space. I also expect that space of Metauniverse is a Euclidian space. Minkowski space of General Relativity arise as emergent space, described later in the article. 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, field is defined everywhere in space. 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. Value of scalar field is defined by values in neighboring points because there are no carriers of field in static 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

One of first questions which arise in static model of ER-hypothesis is – how, in some point of space-time, move from one frame of reference to another frame of reference, moving with different velocity? In order to answer it, it is necessary to make model containing space and time.

Initial model for n-dimensional emergent reality (n <= m, where m is number of dimensions in Metauniverse) is:

- one dimension represents emergent time
- n-1 dimensions forms emergent space, with n-1 dimensions.

In such model point of space will move along line representing time. Emergent space is perpendicular to line of time, because it consists from other dimensions then time.

It is not possible to represent velocity by increasing or decreasing rate of movement along time line. Any emergent object moving along time line at any rate would have exactly same changes of its state as object moving with any other rate.

“Moving along time line” here is not means what object really moving. Model of ER-hypothesis have no time, so there is no movement and no any processes in time. “Moving along time line” means consequent changes of state of object in consequent points on line of time. I mention here “object”. Later I will use “particle” instead of “object”. Definition and properties of particles, how they arise from one field of Metauniverse, are written later in the article.

Movement from one frame of reference in some point of emergent spacetime to another frame of reference can be obtaining by rotation of spacetime in this point of spacetime. It means rotating both emergent space and emergent time. So, time line after rotation would not be same as before rotation, similar for space. Time line after rotation will have angle to time line before rotation. As result, distance between points on the time lines will grow proportionally to time line length. So, velocity in model of ER-hypothesis was found.

State for any known to us object is depends on state of the object in past and state of objects and fields in some distance around the object in past, principle of locality; causality chains exists. In order to obtain similar properties from static Metauniverse, existence of mapping is necessary. I not use isomorphism here, because isomorphism here means what previous state fully defines new state. Mapping here

means what for each state of emergent spacetime-matter at some point of emergent time can be set another set of states of emergent spacetime-matter at some following point of emergent time and the set include all possible states for initial state. The set of following states should also contain probability of each set of states. So, the mapping produce probabilistic physics from super-deterministic Metauniverse. The mapping should be between states of space-matter in present to states of space-matter in future. Time in this case is vector perpendicular to space. Transition to reference frame with another speed is obtained by rotating spacetime, as described above. First, I will require mapping function to be single valued (isomorphic), later I will discuss multivalued functions of mapping.

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.

So, approach with algebra of states can work well, but, based how ER-hypothesis define states, it cannot be suitable everywhere. Algebra of states is not represents underlying physics, it is just good approximate solution which allows predicting distribution of states in future for limited amount of conditions.

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.

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, for inertial frames of references, mapping function must be same everywhere in spacetime. I not use “covariant” for laws of physics; the word is typically used in scientific articles. “Covariant” implicitly means that laws are changing covariant to metric tensor. But that if there are solutions for some reality with contravariant laws? I cannot exclude it, so I use “same everywhere in spacetime, for inertial frames of references” phrase instead.

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. Special Relativity limit maximum velocity to speed of light, it place limit of maximum angle of rotation.
2. Rotation cannot be made so that after one rotation time will points to past. But it not means that it is not possible to go to past after several rotations.

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 ER hypothesis, temporary definition of particle:

Particle – it is feature of scalar field of Metauniverse, which is stable at least for some emergent time and has invariant for rotations and interact in emergent spacetime with other particles as whole.

It means that some projection of scalar field of Metauniverse to emergent space, in vicinity of point x, 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. Particle should interact with other particles as whole as long as it is one particle, because if only part of particle interacts and other parts are not interacts, it means this parts are independent particles. Later in this article, the definition of particle will be expanded and modified; definition of elementary particle will be added. 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 scalar field on surface representing emergent space, 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 furthering weakening 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, part may be not belongs to emergent spacetime at all. Probabilistic function of mapping generates probabilistic laws of physics in corresponding emergent reality.

If mapping function is not single valued, it means that there is no isomorphism between states in past and future. Because same initial set of states can produce different set of states later. In quantum

mechanics it explained by probabilistic laws of nature, in ER-hypothesis I explains it as influence of factors external to spacetime and matter.

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 $f(x)$ can be represented as

$$f(x) = \sum f_i(x) \quad (1)$$

then we can construct a reality by usage of one of $f_i(x)$ 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 follows 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 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 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, I need to find 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 non-predictable component.

In the article, I would name as non-predictable every phenomenon which is not possible to describe based on probability.

Non-predictable component in this case does not mean absence of causal relationship; it just means that causal links are deeply hidden from the corresponding emergent reality. At the moment, there are no experimental results which show existence of non-predictable phenomena in our Universe.

There is no phenomenon known with non-predictable behavior. Therefore most likely that non-predictable component is always zero or its influence is significant only at cosmological scale. 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 particles with Planck energies.

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

Particle - feature of scalar field of Metauniverse or its decomposition, defined in area belonging to emergent spacetime, which is exists at least for some emergent time and has invariant under rotations for some range of rotations as approximation, it interact in emergent spacetime with other particles as whole.

Additionally to already discussed, I added "*as approximation*". Why invariant, or symmetry to rotations, exists only as approximation I described later in the article, in Special Relativity part. In that would be shown what the approximation is not non-relativistic approximation, it's more complex.

Adding non-predictable part 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 non-predictable 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. What means "non-predictable part is much smaller than other parts of mapping function" is described later in the article, in "Time, Space and Matter" part.

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 for emergent 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
7. Discrete space, continuous time, continuous space of velocities
8. Discrete space, continuous time, discrete space of velocities

If SU(3) symmetry correctly describe particles as approximation, option #1 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. How SU(3) arise in ER-hypothesis is described later in the article, but attentive reader may notice what SU(3) symmetry is already described just not named.

In order to find which option describes our reality, it is necessary to solve equations of ER-hypothesis, proposed later in the article.

Interaction of past, present and future

According to ER-hypothesis, we live in static timeless Metauniverse, where time is emergent phenomenon. Field in Metauniverse is static, there is no preferred direction, and 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, from point of view of observer not going to past, is not possible. It not prohibits time machine however: if there is some process which allows for some world lines to go to past, from point of view of the world lines it may looks as they go to past. But from point of view of observer who not goes to past – nothing can go to past. Change of past is not possible, because Metauniverse is static.

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.

Any attempt to make change of past would not has any effect. It is because those attempts are already affected past, even before we decided to do it.

ER-hypothesis and Standard Model, SU(3) symmetry

Particles in any state should be same after rotation of spacetime, as approximation. How Special Relativity affect rotations is described later in the article. In our emergent spacetime, there are 3 spatial dimensions. It means what particles should allow rotation in 3 orthogonal directions. Matrix for rotation in 3 orthogonal directions in 4-dimensional space is 3x3, if ignore time. Time can be ignored for non-relativistic case. Only one field exists in Metauniverse, and particles with their state are such dimensional parts of scalar field which are preserved by rotations. Note what same part of scalar field may represent more than one particle for same spacetime. Determinant of matrix for rotation is always equal to 1.

Probability of some particle be in some state at some point of space in quantum mechanics is described by wave function. Wave function is function which uses complex numbers. Because ER-hypothesis is expected to describe our Universe, I can use rotations for wave functions.

So, wave function should also allow rotation of spacetime. It means what wave function should have symmetry to SU(3) group, as approximation and for smooth space without quants of space. Unitary because determinant of matrix for rotation is equal to 1, S because wave functions is based on complex numbers. Smooth space – because if space is not smooth it means there are no continuous rotations and Lie groups are not applicable for such cases.

In any SU(3) group it is possible to find SU(2) subgroups, similar for SU(2) it is possible to find U(1).

SU(3) symmetry directly leads to SU(3)xSU(2)xU(1) symmetry as approximation

So, ER-hypothesis predicts SU(3)xSU(2)xU(1) symmetry, similar to Standard Model.

There is no proposed equation of field of Metauniverse, search for the equation needs to be done with usage of reverse approach. It would be necessary to find such field which satisfies all constraints of ER-hypothesis. SU(3)xSU(2)xU1() symmetry is one of such constraints.

As result, I can conclude what Standard Model can be approximate solution of ER-hypothesis.

Loss of information about past

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

Can events, which already happened, be changed?

If non-predictable part of mapping function is non-zero, it is possible that we would see events different than they were at time when they happened. In this case, with distance from point of event will be accumulated non-predictable contribution. Chains of cause-and-effect relationships would be 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 guess that non-predictable 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, loss of information about past may be not observable under normal conditions.

It is necessary to solve equations of ER-hypothesis to be able to describe such processes, and is they exist.

In order to estimate effects of non-predictable phenomena, if they are exist, I add additional definition: time of half decay of causality.

Time of half decay of causality – it is duration of time when half of causality chains, existed at beginning, not exists at end of the time.

The definition is quite vague; because there is no exact definition of what is “causality chain” and how to calculate them. So the definition needs to be improved with future development of ER-hypothesis.

Metauniverse and emergent realities

Metauniverse, according to ER-hypothesis, is static timeless space containing scalar field $f(x)$. All others – particles, time, space and others – are emergent phenomena.

Our Universe is part of Metauniverse. Volume occupied by a 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.

Methods for determination of spacetime, described above in the article, 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 – it is all universes, which have intersection in space of Metauniverse with selected part of spacetime of universe.

If there are locally parallel universes, it not means 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.

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.

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 some another reality. Simplest possible solution is for interacting parallel universes. Maybe extraterrestrial sentient 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 there is end of time
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.

Therefore, in beginning, until time appeared, was (and it still exists in Metauniverse, but far from us) some state 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 and gravitation parts.

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 Euclidean space. 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.

Mapping function, described above, must have no noticeable non-predictable parts on all available now for study range of energies and values of gravitational field. It should be possible to describe properties of particles and their interaction in above range of conditions based on their states. In this case, their accurate equations should have a range of states as solution for SU(3) approximation, so Standard Model would be approximate solution of ER-hypothesis.

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.

Special Relativity and ER-hypothesis

Current experimental data shows what all laws of physics are same in all non-accelerating frames of references. So, in order to form time, all laws of physics should be same in all non-accelerating frames of references. Some physical laws like electrodynamics and Special Relativity, requires constant speed of light in all frames of references. It can be achieved by following model:

After each rotation, new maximum angle of rotation appears, from point of view of geometry of Metauniverse. It may be different then before rotations, but symmetric for rotation to any side. Speed of light must be not changed with change of maximum angle; speed of light depends not only on angle of rotation, but also on speed of time in Metauniverse (described more lately in the article). In such case, after making some amount of rotations in one direction, it should be possible to go to past, from

point of view of accelerating object. From point of view of observer who not change its velocity, accelerating object would not go to past, it would just increase its speed to not more than speed of light or maximum angle of rotations, may be after some rotation it will be seen even as decreasing its speed. Particles of light must map to particles of light in other frame of references, same for particles. But position of particles and their trajectory will change after rotation, and distance between trajectory of same particle but in different frames of reference may grow instantly over time. I want to highlight the result of ER-hypothesis – same particle in each point always go to different trajectories depending on angle of view. How to find types of functions which allow such model is unclear for me, I think some models from holography can be used here. So, it requires more research to find mathematics of described model. In equations of ER-hypothesis I will requires such properties from related functions, but functions are not found. Again, ER-hypothesis is new hypothesis with completely new mathematical model. No mathematics exists in ready to use for the model state. I think it is possible to find such equations, but their search will take quite a lot of time. And ER-hypothesis contains much more open questions; I more focused on creation of basis of ER-hypothesis than research in details each open question.

So, let's discuss the model in more details.

First, I will discuss possibility to go to past. If after each rotation (increase of speed) new maximum angle is allows to go beyond previous maximum angle, it means possibility to rotate to 180 degrees from first rotation, go to past. However, because Metauniverse in ER-hypothesis is static, it cannot be changed. So, attempt to change past with number of consequent accelerations should fail. However, from point of view of accelerating observer all should look as usual, same physical laws as before accelerating. So, if plan to make changes in past before accelerating, it should be possible to make them after accelerating. It looks as contradiction. The contradiction can be resolved, if add loss of information after rotating by big angle. Information should be fully lost if rotate to past, so original plans to change past would no longer be in effect. Should information be lost if accelerate object less than to past? There is no answer to the question now. ER-hypothesis leads to equations of ER-hypothesis, and the equations are expected to describe any space-time-matter for any reality. Equations of ER-hypothesis are proposed in the article, they can answer to the question but only after quite a big research. Loss of information – it is cases when some events, like interaction of particles, happened in one frame of reference but not happened in another frame of reference. So, after rotation of reference frame some particles may disappear or appear, positions of particles in Metauniverse may be changed.

Photons and gluons are always traveling at speed of light. So, they always have maximum possible angle to vector of time, other type of particles have less angle. The angle for photons and gluons is equal to angle representing speed of light. After rotation of frame of reference, surface in Metauniverse, corresponding to speed of light, will be different than before rotations. So in one frame of reference particles with speed of light belong to one surface, in another frame of reference, after rotations – to another surface, their positions in Metauniverse changing by rotations. If rotate frame of reference, once or several times, and next rotate back to original position (if it is possible without exceeding speed of light), particles and their positions must be same as before rotations. Same applies to particles which not travel with speed of light. So there is loss of information after rotation of frame of reference, and there is change in direction of speed of particle after rotation of frame of reference. As result, physical vacuum for any frame of reference should be full of elements of particles, the particles are not exists in this frame of reference but exists in some other frame of reference. It is possible what the elements of particles still can interact with usual particles, so they can be responsible at least for part of virtual particles in physical vacuum. I would name as element of particle case when in some frame of reference,

corresponding to particle-size area in Metauniverse, there is particle, and there is no such particle in same area of Metauniverse belonging to our frame of reference and same reality.

Proposed above behavior is looks as not falsifiable, because it cannot be directly observed. Any hypothesis which cannot be falsified cannot be considered as scientific hypothesis. However, while ER-hypothesis predicts there is no way to directly observe the behavior, there is ability to test other predictions and falsify ER-hypothesis.

Such behavior, with inability to directly observe some phenomenon, is inherent part of any super-deterministic hypothesis. The behavior cannot be directly observed, so it is not directly falsifiable, but it can be tested and falsified by comparing other, observable, predictions of super-deterministic hypothesis with experiments.

Speed of light is same everywhere in non-accelerating frames of references. Speed of light, with approach described above, it equal to:

$$c = v_t * tg(\alpha) \quad (2)$$

v_t – speed of time in Metauniverse, α – angle between vector of time and light. The angle α is same to all directions around vector of time. However, speed of time may change and, as result, the angle will change together with speed of time. Another result of the equation is: distance between two points in emergent space is equal to distance between same two points in Metauniverse over surface of emergent space. Speed of light is speed in emergent space. Emergent space is perpendicular to vector of time. So hypotenuse of resulting triangle is located opposed to angle between speed of time and speed of light.

So, scalar field should have quite specific properties, described above, to support Special Relativity in ER-hypothesis.

Loss of information during rotations means ER-hypothesis cannot be gauge theory; there is no group of local transformations for entire range of rotations. However, it not means what local transformations not works for some range, but such transformation will be approximate. So, instead of Lie algebra for rotations it is necessary to use functional equations for rotations not be able to calculate without approximations.

If angle of speed is much smaller than 2π, in such case loss of information may be neglected. So, in order for SU(3) to be applicable, it is necessary to have following condition:

$$\alpha \ll 2\pi \quad (3)$$

Described above behavior not means what SU(3) symmetry must break for relativistic cases, but it means SU(3) is approximate model. Another conclusion is – quality of SU(3) symmetry depends on angle of speed of light. Later, in gravitation part, was shown what the angle is not constant. How it affects quality of SU(3) symmetry and laws of physics is discussed later in the article.

Special Relativity contains relation between time intervals in different frames of references. Such relation cannot be obtained in ER-hypothesis directly from geometry. The relation imposes another restriction to scalar field of Metauniverse.

Time, Space and Matter

There are many definitions of time. Most of them says what time is phenomenon completely independent from observers, and it exists both when observers exists and not exists.

In ER-hypothesis, we exists in static timeless Metauniverse, there is no time as phenomenon on level of Metauniverse. Time appears as emergent phenomenon. But is such time exists without observers? Without observer, it cannot be measured. Without observers, emergent time is just mathematical abstraction. So time and any effects of time without observer cannot be experimentally tested, and, as result, it becomes question of philosophy. My opinion is: without observer time is not exists unless observer appeared at some more late emergent time. Only intelligent life can be observer. So, time exists only if related emergent reality contains intelligent life.

Similar is for space. Space, as emergent phenomenon, exists only if observers exist in related emergent reality.

Matter is also emergent phenomenon, and it not exists without observers.

Intelligent life cannot exists without causality, when events in past affecting events in present. At least, as far as I know, nobody proposed models of intelligent life in physics without causality.

As result, definition of time:

Time – subjective ordering of set of emergent space-matter which support causality chains

Subjective is because time is not exists without observer. Each moment of time contains different space and matter. Each state of space-matter at following moment of time should be, at least partially, be based on state in previous moment of time, in order to support causality chains. State of space-matter at following moment of time can be not fully based on state at previous moment of time, as long as it allows existing for some causality chains. Causality chains should exists for long enough time to allow arising of intelligent life, otherwise related reality would not have intelligent life at it means such reality have no observer. Without observer at some point of emergent space-time, reality is not exists.

So, if laws of physics contain non-determinism, it should be small enough to allow existence of intelligent life.

In this part of article it is easy to notice what ER-hypothesis is based on non-realistic philosophy view with eternalism, because one of its consequences what spacetime and matter are not exists independently of our mind. However, I think what the hypothesis is closer to critical realism than anti-realism, because it contains entities independent from mind. It is field of Metauniverse. More precisely, mind is dependent on the scalar field but the field is not dependent on mind.

Holographic principle of ER-hypothesis

Metauniverse in ER-hypothesis has no time, so it not contains any particles, except in emergent realities. As result, there are no force carriers for field, so each value of field in point of space of Metauniverse should be defined by values of field in neighboring points. I will name it as holographic principle of ER-hypothesis.

Holographic principle of ER-hypothesis is incompatible with Holographic Principle of String Theory. Reason is not only because ER-hypothesis have no strings, but also because boundary of region in ER-hypothesis include not only past, but future too. Also, particles in ER-hypothesis are just some emergent

objects based on field of Metauniverse, and knowledge of state of particles is not sufficient to fully describe state of field inside region.

Holographic principle of ER-hypothesis may lead to interesting conclusion: full information about entire Metauniverse and all its realities exists in any region of Metauniverse. Such conclusion may be valid in case of smooth function of field of Metauniverse, probably some other restrictions are required.

Locality in ER-hypothesis

All known interactions in our Universe are local, with speed of light as limit to speed of interactions. There is also quantum entanglement which seems as have faster speed of information movement than speed of light.

Locality in ER-hypothesis is achieved with SU(3) symmetry. All particles must conform SU(3) symmetry, and none of particles may have speed above speed of light. All particles interact between each other only with usage of other particles or directly without violation of locality. As result, there is locality.

However, ER-hypothesis not prohibits faster than light interactions if they involve particles with macroscopic size. In case of particles with big size, particle interacts as whole and, as result, it corresponds to interaction with faster than light speed.

Gravitation interaction may not have field carriers at all; it can be just mathematical function which provides ordered set of emergent spaces which support specific kinds of particles and causality. But because there are no any observations what gravitation interact at speed above speed of light, such function also must support locality. Curvature of spacetime in such case is caused by function of gravitation to support causality and locality.

About possibility of direct interaction between particles without violation of locality.

There is open question. Is it possible to build universe based on particles with violation of locality and make the universe be able to support causality chains and intelligent life? If it is not possible, it explains reasons of locality in our Universe.

Physics of Planck energies and new fundamental forces

Adding Special Relativity to ER-hypothesis, as described above, leads to conclusion what SU(3) may be only approximate symmetry. It may be applied to get some knowledge about physics of ultra-high energies up to and include Planck energies.

As it was described above, SU(3) symmetry is approximation. Photons, similar to other particles, change its path in every point in case of rotation of point of view. Here arise problem with SU(3) approximation – if some particles have ultra-high energies and they travel near photons, they must be near same photons after rotations and at about same distance, if rotation goes for small angles. At same time, if rotation is big enough, it should be possible to rotate to frame of reference where the particle is not moving and photons are travelling at their speed of light. Particle at Planck energy have Compton wavelength equal to Schwarzschild radius and can be black hole. It means black hole in case of if particle move with such energy and usual particle in case if rotate and move to frame of reference where particle is not moving. It means what such particle cannot be same in different frame of references – and it means breaking of SU(3) symmetry. As result, it put limits on validity of particle based approach. Also, it is not possible to say what particle based approach breaks after certain energy or corresponding angle. More probable what differences from particle based approach would slowly accumulate depends on angle of rotation.

Is it possible to make particle based approximation more precise?

Answer to the question requires research of properties of model of ER-hypothesis. Exact solution can be found from equations of ER-hypothesis, equations are derived later in the article. But solving equations of ER-hypothesis seems as much more complex than find at least some properties of model of ER-hypothesis which relates to symmetry and symmetry breaking.

So, without the research it is possible to make only guess. My guess, not proved by any calculations, is:

It is possible to improve quality of particle based approach for ultra-high energies, below Planck energies, if add more fundamental forces based on higher level symmetry.

In such case, laws of physics would consist from laws of physics related to different symmetries.

It can be written as:

$$L_c = \sum_{i=0}^{p} L(SU(i)) \quad (4)$$

Where $SU(i)$ – group of symmetry for i, L – laws of physics resulting from such symmetry group, L_c – cumulative law of physics which describe particles with best possible approximation. For i=0 special case, SU(0) means not Lie group but gravitation. Note – as I already discussed in the article, because particles represents only parts of scalar field, any laws of physics which are based on particles and their states can be only approximation.

Such approach is similar to expansion in terms of Taylor series or other series, but applied to laws of physics. Also, any i>3 is not means what exists some additional (compacted or no) dimension. It is just another part in expansion in series of symmetries.

With the approach any part for i>3 represents new, undiscovered yet, fundamental force. Value of p is unknown; it can be as high as infinity.

Is the guess correct or no, can be found based on further research of properties of model of particles in ER-hypothesis.

Gravitation

During description how to find spacetime from scalar field, I mentioned what emergent laws of physics must be same for all spacetime and for all frames of references. It is possible what in some cases emergent spacetime will be curved, because there are no solution with non-curved spacetime in some areas of Metauniverse. As result, we would observe curved spacetime.

Curved spacetime is not something new, General Relativity use curved spacetime to describe gravitation. So, I would assume what curved spacetime is responsible for gravitation, similar to General Relativity.

Why gravitational mass is equal to inertial mass is open question, it is necessary to find way how to calculate both of the masses to be able to find answer.

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 can be impossible. At that point, there is gravitational singularity. Close vicinity of gravitational singularity is place for massive formation of spacetime and for 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 or lower than average, it just means there is no solution which support same causality. May be decomposition into series stop to works?

During search for spacetime, one of condition of spacetime was – all laws of physics should be same in all emergent space, for inertial frames of reference. It allows using equivalence principle from General Relativity which says same. So, I can use General Relativity for ER-hypothesis. However, some changes are necessary to made to General Relativity.

General Relativity predicts time dilation – time in areas in stronger gravitational field tick slower than in areas with smaller gravitational field. In order to get same for emergent spacetime, it is necessary for speed of time be higher in areas with stronger gravitation fields than in areas with smaller gravitational field. In such case events in stronger gravitational field would looks slower from point of view of observer in smaller gravitational field.

Speed of time – it is length in Metauniverse corresponding to unit of time in some point of emergent spacetime.

It is possible to write equation to set dependency between speeds of times depending on time dilation. Observer in smaller gravitational field during time dt_1 passes same distance as observer in stronger gravitational field during time dt_2 which corresponds to time dt_1. So, speed of time v_1 for first observer should be different from speed of time v_2 for second observer.

$$l = v_1 dt_1 = v_2 dt_2 \tag{5}$$

As result:

$$v_1 = v_2 \frac{dt_2}{dt_1} \tag{6}$$

Speeds of time are different proportional to relative time dilation.

Such approach partially changes intrinsic character of spacetime curvature of General Relativity to combination of extrinsic and intrinsic curvature of spacetime. Also, it allows using absolute value of speed of time to compare with any other point, include other universes. Without such interpretation of time and speed of time, time dilation is something one reference frame has relative to the other in the same universe and using it as absolute value does not make sense, there is no time dilation for comoving observers at different time of Universe. With adding absolute value of speed of time, appears time dilation between comoving observers belonging to different time of Universe.

Cosmology constant is usually interpreted as dark energy. It is possible to interpret it as existence of particles with some mass with negative value, which repel each other, which is evenly spread in Metauniverse.

All current cosmology models predicts that Universe had origin, and was interactions between all areas in past. Low difference in cosmic microwave background shows that Universe had nearby no differences initially.

In order to add it to model of ER-hypothesis, simplest way is to consider our Universe as three dimensional surface of four dimensional hypersphere. Surface of hypersphere have curvature. So, it is necessary to add $K(t, v_t)$, function of extrinsic space curvature due to curvature of surface of

hypersphere, to equations of General Relativity, near cosmological constant. Hypersphere is similar to de Sitter space, and for de Sitter space part related to curvature is equal to $\frac{3}{R^2}$. For hypersphere, $K(t, v_t)$ can be calculated from radius of hypersphere.

$$K(t, v_t) = \frac{3}{\left(R(t)\right)^2} = \frac{3}{\left(R_0 + \int_0^t v_t(\tau) d\tau\right)^2} \quad (7)$$

R_0 in the equation is initial radius of Universe, when spacetime emerged (discussed later in the article), $v_t(\tau)$ is speed of time at time τ. Integral goes from beginning of time to current time.

So, equation of gravity for ER-hypothesis:

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

Δ is cosmological constant, v_t – speed of time.

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. Based on it, speed of time $v_t = const$ for case when energy-momentum tensor T=0 and exists cosmology constant Δ. As result

$$v_t = v_0 \frac{dt_z}{dt} \quad (9)$$

dt – change of time in presence of energy-momentum tensor and cosmology constant, dt_z – how time will change if, in same point, energy-momentum tensor T=0. v_0 is constant, speed of time with energy-momentum tensor T=0. So, such equation set dependency between distance passed in Metauniverse and unit of time.

So, equations of General Relativity with changes from ER-hypothesis transforms to system of equations:

$$\begin{cases} G_{\mu\nu} + (\Delta + \frac{3}{\left(R_0 + \int_0^t v_t(\tau) d\tau\right)^2}) g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \\ v_t = v_0 \frac{dt_z}{dt} \end{cases} \quad (10)$$

What would be value of emergent spacetime curvature if energy-momentum tensor is zero, $\Delta > 0$ and $R(t) \to \infty$?

Well, equations above will give non zero curvature equal to $\sqrt{\Delta/3}$

How the non-zero curvature arise? It may looks as contradiction to extrinsic nature of space curvature. However, I not propose that curvature in General Relativity is only extrinsic, part of curvature is intrinsic. And next question is – what represents intrinsic curvature, what is source of the curvature?

In order to answer to the question, it is necessary to solve proposed in the article equations of ER-hypothesis. It is possible to propose potential approaches to solution in order to show what intrinsic curvature is not contradict to ER-hypothesis. Below I wrote one of possible approaches, and I think at least one another approach can give same result.

As was shown above, speed of time in ER-hypothesis must grow with growth of gravitational field. So, if energy density is not dispersed in Universe fully uniform, will be areas with growth of speed of time and decreasing of speed of time. As result, space of Universe would not be flat, resulting in intrinsic part of curvature. Mass in Universe is not evenly spread – there are particles, and there is vacuum between particles. Even if spread particles fully evenly over space, still would be areas with growth of gravitational potential, with approaching to particle, and with decreasing of gravitational potential. So, emergent spacetime is always not flat on micro level due to existence of dark energy. If average module of spacetime curvature would grow with time, it is possible to get same behavior as we observe.

So, emergent space belonging to same moment of time can be like sinusoid, with amplitude growing with time.

Quantum gravity is discussed later in the article.

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.

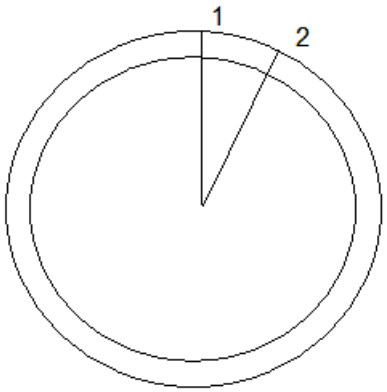
In ER-hypothesis, in order to achieve:

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

Simplest solution is to conclude what our Universe is three dimensional surface on four dimensional hypersphere.

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 absence of spacetime and matter. Description of the state requires usage of full equations of ER-hypothesis, state based approach with usage of space and time cannot works. So, any parts of field in such states directly interact, regardless of distance, there is no horizon problem. As result, size of Universe at formation epoch becomes unclear in ER-hypothesis. In order to find it, it is necessary to solve proposed equations of ER-hypothesis for such case. However, the size still should be small in comparison to current size.



Picture 1. Illustrate expansion of our Universe, projection of hypersphere of Universe in Metauniverse to two dimensions. Inner circle is Universe at time t1, outer – Universe at time t1+dt

Experimental data shows that cosmology constant is constant with good precision. It can be interpreted as existence of constant dark energy density in entire Metauniverse.

General Relativity, with adding of extrinsic curvature, needs adjustment. Because FLRW metric is analytical solution of General Relativity, it means changes in equations of General Relativity will also affect FLRW metric, FLRW metric would not be analytical solution of modified equations of General Relativity.

If mass density in Universe is close to density of closed space, proposed equations of General Relativity will give inflation phase. It happens because speed of time in ER-hypothesis is absolute value, not relative. After inflation phase, extrinsic space curvature drops to near zero and metric becomes FLRW metric, for case when

$$\Delta \gg \frac{3}{\left(R_0+\int_0^t v_t(\tau)d\tau\right)^2} \tag{11}$$

Speed of time in ER-hypothesis have absolute value, it is not something relative. So, if density of early Universe is close to solution with closed Universe without presence of extrinsic curvature, speed of time will be much higher than current speed of time, resulting in inflation phase. Inflation phase in current cosmology models must be short due to horizon problem. But in ER-hypothesis, due to its super-determinism, horizon problem is not so restricting. So, inflation phase, when speed of time was much higher than current speed of time, can take more time in ER-hypothesis.

Possible argument against slower rate of inflation phase than rate predicted by current widely accepted theories is close to uniform distribution of matter in visible part of Universe. However, these models are based on statistics of ensembles of independent particles. In case if radius of Universe R_0 when spacetime emerged was not zero, there is no need to require locality prior to the radius. Particles, same as spacetime, are not existed before the radius, so locality is not applicable for the case.

About comparison with experimental data.

Latest observations show that space curvature is zero with good precision, and cosmology constant is constant with good precision. It is equivalent to case described above when spacetime become FLRW metric. ER-hypothesis predicts that somewhere in past space curvature must be bigger than now. Problem is – when space curvature was big? It can happen it was big even before Universe become transparent to light. So, ER-hypothesis is not contradicts to observations. However, cosmology part of ER-hypothesis needs further improvement.

This part of article, about cosmology, can be much bigger in size. However, my main goal in the part is to show compatibility of ER-hypothesis with experimental data, and I leaving further development of cosmology in ER-hypothesis for future.

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 emergent spacetime. Gravitational force plays big role in building 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 has quantum effects, it affects at some point of spacetime, and not does any effects for some other time. And it has 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 is no any evidence what either time or space has quants. Equations of quantum mechanics are valid only if time is smooth, non-quantified, parameter.

If there are quants of time or space, SU(3) symmetry will be approximate even for non-relativistic case, because Lie algebra assume continuous range of transformations.

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 them if spacetime consists of quants of spacetime? So, further study of mathematical model of ER-hypothesis and proposed equations would allow understanding is quantum gravity exists in our Universe if ER-hypothesis is valid.

Physics of early Universe

In one of previous parts was shown what quality of SU(3) symmetry, same as quality of particle based approach, depends on angle of speed of light. In gravitation part, it was shown that the angle can become smaller in strong gravitational field.

Direct result of it – it is possible to conclude what quality of SU(3) symmetry for particles was better in early Universe, in case if early Universe had strong gravitational field. Same can be applied for SU(3) symmetry in strong gravitation fields. Can it result in differences in SU(2) or U(1) part? I will leave the question open, more research of math of ER-hypothesis is necessary to answer the question.

Also, in one of previous parts I did guess what laws of physics can be represented as sum of laws of physics from many symmetries.

If the guess is correct, such additional symmetries also would be affected, and energies corresponding to their interactions may decrease. It is open question, left for future.

Kinds of particles

I wrote definition of particle above, but that was not considered yet – it how interaction between particles allows to form different kind of particles.

Let's consider case. There is solution of scalar field, emergent spacetime and set of particles. Some types of particles interact with some types of particles, and not interact with some types of particles. Question is: how many emergent realities will create such solution?

Reality is based on ability to support causality chains. So, if take some type of particle, it can participate only in causality chains where it can interacts, directly or indirectly. Direct interaction – it is case when the type of particle can directly affect other type of particle. Indirect interaction – it is case when the type of particle cannot directly affect other type of particle, but it can affect some other, third, type of particle, it can affect another particle etc.; resulting in impacting second type of particle. So, reality can contains only such kind of particles, which can interact between each other, directly or indirectly. . If some type of particle cannot directly or indirectly interact with some other type of particles, it means they cannot participate in same causality chains. So, if there is type of particles which cannot directly or indirectly interact with some other type of particles, they belong to different realities, even if equation of emergent spacetime is same for them. So, there are kinds of particles, and each kind of particles

belongs to separate reality. Inside each kind of particles, any two types of particles can directly or indirectly interact.

I will name set of kind of particles as:

$$P = \{p_1, \dots., p_m\} \quad (12)$$

It is kind of particles P consisting of m types of particles p_i

I will write condition that any two types of particles from same kind of particles can directly or indirectly interact as:

$$\forall\ (p_i, p_k)\ \exists\ (p_i \leftrightarrow\ p_k), p_i \in P, p_k \in P \quad (13)$$

Notation $p_i \leftrightarrow\ p_k$ means here direct or indirect interactions. In case of indirect interactions, it means it is possible to find such chain of interactions between types of particles p_i and p_k that it would result in change of particle of type p_k

Interaction can be only between particles belonging to same reality. It means we cannot observe intermediate states of particles creation/destruction. Particle in intermediate state, when particle is being born from some collision or another event, is not belongs to our reality. Only when it transforms to one of particles belonging to our reality, it can interact with other particles.

So, from point of view of emergent spacetime, particles creation/destruction happens immediately. It is one of reasons why operators of creation/destruction of particles in Standard Model are able to works.

What are kind of particles from point of view of symmetries?

Above was shown what particles must conforms to SU(3) symmetry. However, it can be possible what several SU(3) symmetries can be built along same vector of time. In such case it will lead to different SU(2)xU(1) symmetries too. It is possible, for example, in case if equation of scalar field can be equal to sum of two functions with low correlation.

States of particles

Scalar field of Metauniverse has no states, it just have value in each point of space. Particle in model of ER-hypothesis is just feature of scalar field with some properties. As discussed in Special Relativity part, particle is not bound to some trajectory. In one frame of reference particle can have one trajectory, but in another frame of reference – it can have different place in Metauniverse and different trajectory, and distance between trajectories for same particle but belonging to different frame of references may grow instantly over time.

Particle can have some state. State for particle is defined by its position, scalar field and function of particle.

Particle has some position in frame of reference. The position, most likely, is not point like, particle occupy some volume. If some volume contains particle, it not means it cannot contains other particles, for same frame of reference. Particles must be defined by their functions of particles.

Function of particle must be defined in space of Metauniverse, and it should tell can particle exist in some specific region of Metauniverse. Particles may occupy big region of Metauniverse and resulting emergent space. For example, experiments with double-slit shows that electron has properties of both wave and particle. In ER-hypothesis, it can be explained as electron has size equal to maximum size

where wave function is not zero. It not contradicts to experiments where it was measured that size of electron is less than some small value. Here arise two different sizes: one size is size where function of particle shows non-zero presence of electron, another size is how particle behave in interactions. First size can be found as area where wave function of electron, from quantum mechanics, is non zero. Second size can be measured in experiments. In order to predict second size, it is necessary to solve equations of ER-hypothesis. Function of particle must be defined on entire spacetime. So it should not be dependent on emergent space or emergent time. However, in order to use the function, must be necessary to use emergent spacetime. I will name function of particle as:

$$a(x) \tag{14}$$

How function of particle may work in emergent spacetime? Such function should help to describe state of particle and position of particle, in probabilistic way and with support of causal chains. In quantum mechanics, there is wave function which describes state of particle and position of particle. If function of particle will produce wave function, then it would be possible to describe state of particle and position of particle, in probabilistic way. Because position and trajectory of particle is depends on frame of reference, it means that the wave function must depends not only on scalar field, but also on emergent spacetime.

So:

$$\psi_{e,i}\left(x_e, \left|\vec{t}\right|\right) = \psi_i(a_i, x, f, L, \vec{t}) \tag{15}$$

$\psi_{e,i}$- wave function in emergent spacetime, equal to wave function of quantum mechanics for particle p_i, ψ_i – wave function for particle p_i in Metauniverse, x_e – position in emergent space, $\left|\vec{t}\right|$ – module of time, a_i – function of particle for particle p_i, x – position in Metauniverse, f – function of scalar field, L – function of emergent space, $\vec{t}$ – function of emergent time.

Can ψ_i, wave function of particle in Metauniverse, be common for all particles? I think it is quite probable. But more likely I think there are two wave functions: one for particles travelling with speed below speed of light, and second for particles travelling with speed of light. It is because such types of particles have significant differences.

Same approach as for kind of particles can be applied to states. Particle with some state must be able to interact with particles with any state, directly or indirectly. If for some particles in some states there is no direct or indirect interaction, it means such states belong to different realities.

So, additionally to kind of particles, for each particle must exists set of states allowing interaction:

$$\forall \left(p_i(St_m), p_k\left(St_j\right)\right) \exists \left(p_i(St_m) \leftrightarrow p_k\left(St_j\right)\right), p_i \in P, p_k \in P, St_m \in St(p_i), St_j \in St(p_k) \tag{16}$$

$p_i(St_m)$ – particle of some type in state St_m, $p_k(St_j)$ – particle of some kind in state St_j, $St(p_i)$ – set of states for type of particle p_i, $St(p_k)$ – set of states for type of particle p_k

States may be not only discrete, but they can be continuous.

Looking at equation above, seems as it is possible existence of particles which contains many sets of states belonging to different realities.

What if several particles are close enough to each other, and start to behave as particle, interact with other particles as whole?

In such case it is new particle based on superposition of origin particles, because it satisfies to definition of particle. If such particle is broken in result of interaction, new particles appear instead of one particle and they must have separate states. So, other parts of same particle will know particle is broken immediately, regardless of size of such particle.

Particle, which can be described as some superposition of other particles, is not elemental particle. However, if particle is superposition of other particles, such particle still must interact as whole. So other particles may become noticeable only after destruction of such particle.

Definition of elementary particle:

Elementary particle – it is particle which cannot be described as some superposition of other particles.

So, Eq(16) describes not only elementary particles, but also cases when particle consists of superposition of many other particles.

Elementary particle may have many generations of particle. Each generation must have same properties. I think it can be achieved if function describing particles on scalar field allows scaling. Probably something like

$$\begin{cases} a_2(x) = a_1(2 * x) \\ \quad \ldots\ldots \\ a_n(x) = a_1(n * x) \end{cases} \tag{17.1}$$

a_1 – function describing first generation of some particle on scalar field, x – point in Metauniverse, a_2 – function for second generation, a_n – function for n-th generation.

If look at photons, length of wave for each new generation of photons (with growth of frequency) decreasing. So, another case is also may be possible:

$$\begin{cases} a_2(x) = a_1(x/2) \\ \quad \ldots\ldots \\ a_n(x) = a_1(x/n) \end{cases} \tag{17.2}$$

With such approach, photons of different energies are different generations of same kind of particle.

I will write equation for particle consisting of elementary particles:

$$a_{p_i}(x) = a(\{p\}, \{c\}) \tag{18}$$

$f_{p_i}(x)$ – function of particle p_i, consisting from set of elementary particles $\{p\}$ with their corresponding functions of particles. Elementary particles may combine into one particles under different initial conditions, and it may result in different properties of resulting particle. So, $\{c\}$ – is set of all conditions affecting resulting particle.

May atom be one particle, consisting of multiple electrons and core from protons and neutrons? Electrons are not emitting energy during being bound in atom. There is good explanation in quantum mechanics why electrons are not emitting in the case. But if look at the explanation, it looks quite phenomenological without explaining internals. If atom is one particle, it interacts as one particle until it is broken by some interactions and there is also no problem with energy emission. Probably it can be measured, I not sure about experimental possibilities for the case.

If some elementary particles can combine into one particle which can be long in space, it can explain quantum entanglement. So, it is possible explanation of quantum entanglement.

Nature of scalar field

One of question which was not discussed above is: what is scalar field of Metauniverse?

It is possible to make some guesses; I not have definite answer now.

One possibility: what is the field is unknown, we just assume it exists and use equations to find its properties and resulting emergent reality with our laws of physics. If solving of equations of ER-hypothesis with this approach will result in success, it would means the question will be left open for future.

Another possibility: there is no scalar field as field; such behavior is provided by space tension, compression and extension. In such case space must be able to compress and extend under pressure. Metauniverse, in such case, is static space, and any region inside Metauniverse may be under pressure from other regions of Metauniverse.

Both possibilities described above, not change equations of ER-hypotheses, which are written below in the article. However, equation of scalar field, for first case, will be different from equation of space compression/extension for second case.

Emergent reality, equations of ER-hypothesis

In previous parts of the article, I described idea of ER-hypothesis, next checked is ER-hypothesis compatible with known physics. I proposed changes to some theories, to make them compatible with ER-hypothesis. Some equations were proposed for some parts of ER-hypothesis. All of above created ground to build mathematical model of ER-hypothesis. Predictive power comes to physical hypothesis only with mathematical model, without mathematical model hypothesis can give only very rough conceptual vision. In this part of article, I will write equations for ER-hypothesis.

So, exists scalar field $f(x)$, where $x = \{x_1, .., x_n\}$ is point in n-dimensional Euclidean space. Value of field in any point is determined by values in all other points of Metauniverse.

Our current knowledge about physics of Universe says what three forces in Universe have particles, carriers of interaction. Electromagnetic force has photons as carriers of interaction etc. One exception is gravitational force, particle-carrier of the interaction is not found as of now. Field is Metauniverse is static, so no any carriers of interactions are possible. It limits interaction to only one case – when field in some point is interacts only with points near.

So, it leads to: if there is some closed surface S in Metauniverse, value of field inside any point of region surrounded by the surface is determined only by values of field on surface, $\varphi(S)$. In this region it is necessary to find emergent spacetime with matter.

So, it means exists function $g(\vec{r}, S, \varphi(S))$ which gives value of field in point x belonging to region surrounded by surface S, where value of field on surface is $\varphi(S)$:

$$f(x) = g(x, S, \varphi(S)) \tag{19}$$

Next, current physics is based on particles. So, it is necessary to find particles. Particles, belonging to some reality, must interact only with particles belonging to same reality, except cases when interactions with other realities will not change probabilistic causal relationships. If some particles will interacts with

other reality in such way what it would break causal relationship, and it means it is not emergent reality, emergent reality must support causal relationships. If probability to interact with other realities is same everywhere, causal relationships are not affected by such interaction. Observations show what physical vacuum have some properties, typically explained by vacuum energy and existence of virtual particles. I propose another explanation of vacuum energy and quantum foam. Particles, belonging to our reality, interact with scalar field, and interact in such way what the interaction looks as interaction with some virtual particles. Field of Metauniverse in place of interaction may not contain anything like such virtual particle, just result of interaction looks as interaction with such particle.

As I wrote above, particle – it is some property of field of Metauniverse which exists some time along world lines and have slowly changing invariants-like for rotations. So, it is possible to describe particle by function. Such function should have values of field over some region as input, and provide value 1 in regions where field looks as the particle and 0 if field is not looks as the particle. So, such function can be based on correlation between form of particle and scalar field, in each point.

Each reality contains some number of functions of particles.

$$\mathrm{A} = \{a_1, \dots a_i, \dots a_N\} \tag{20}$$

it is set of all function of particles for reality containing N different types of particles.

Some of particles always travel at same speed, like photons. Such particles can have different energy, but all other properties are same regardless of energy. It can be explained by scaling of functions of particles. So, each function of particles can form series of particles with same properties and different only by energy. Note: can form not means will form, it depends on functions. Example of such particles is photons and gluons. Different generations of leptons and quarks can be explained by same. But here arise question: why there is only three generation of leptons and quarks, what prevent fourth generation? May be there are more generations, and we just not observed bigger generations due to much higher energy of particles belonging to forth and consequent generations? In order to answer it, it is necessary to solve equations proposed in the article.

Behavior of particles depends on their state in past. So, in order to predict their future states it is necessary to find first emergent time and space. So, function of particle depends not only on scalar field, but also on emergent space and time. As result, particle after rotation of spacetime may be in different place than before rotation. So, wave function of particle looks as:

$$\phi(a, x, f(x), \overrightarrow{v_t}, L) \tag{21}$$

Where f is values of scalar field, a – function of particle, x – point in Metauniverse, $\overrightarrow{v_t}$ – vector of emergent time, L – corresponding emergent space.

If write same based on values on surrounding surface S, it would be:

$$\phi(a, x, g\big(x, S, \varphi(S)\big), S, \varphi(S), \overrightarrow{v_t}, L) \tag{22}$$

Emergent space can be defined by equation, where for each point x of Metauniverse, for set of functions of particles and for time, it should return zero if point x belongs to emergent space for specific moment of time:

$$L(x, f, S, \varphi(S), \mathrm{A}, \overrightarrow{v_t}) = 0 \tag{23}$$

$\overrightarrow{v_t}$– it is vector of time in Metauniverse. The vector is necessary, because in some point can be lots of emergent spaces with different vectors of times. It is not too complex to use equations of General Relativity with changes from ER-hypothesis to write this equation in approximation without quantum effects.

Using same approach as in equation above for writing function of emergent time:

$$\overrightarrow{v_t}(x, f, A, L) = 0 \quad (24)$$

L – emergent space, $\overrightarrow{v_t}$ – speed of time, vector.

Space of velocities is formed by rotations of spacetime. So, must exists function Vr for rotations, rotating spacetime by specified angle,

$$L^* = Vr(L, \vec{\gamma}, x) \quad (25)$$

x –point of rotation, L – emergent space, belonging to same moment of time, $\vec{\gamma}$ – vector containing angle and direction of rotation, L^*– emergent space after rotation. This function of rotation is somewhat resemble metric tensor, it transform surface of emergent space to another surface. As was shown in Special Relativity part, events in spacetime have no invariant to rotations; they have only near-invariants, slowly changing during rotations. So algebra of groups is not applicable as exact solution here. However, as was shown above, Lie groups and SU(3) symmetry can be applicable as approximate solution.

Next, it is necessary to add support of Special Relativity.

Speed of light is same in all non-accelerating frames of references. So, with usage of Eq(2), the condition can be written as:

$$|\overrightarrow{v_t}(x, f, A, L)| * tg(\alpha_l(x, L)) = c \quad (26)$$

Here $|\overrightarrow{v_t}(f, \mathrm{A}, L, x)|$ is module of speed of time in point x, $\alpha_l(x, L))$ is angle between vector of time and light, in point x. The angle may be calculated, in case if all functions known, as angle between vector of time and path of photons represented by their function ϕ_c

The equation is valid for our reality. Is it applicable to other realities? Looks as unlikely, more likely it would be

$$|\overrightarrow{v_t}(f, A, L, x)| * tg(\alpha_l(x, L)) = const \quad (27)$$

for other realities. Such analog of Special Relativity can work in other realities if solution of functions of particles of ER-hypothesis on emergent space for such realities would be hyperbolic partial differential equations, wave like. If some other type of equations would be solution for some reality, Special Relativity can be not one of physical laws of such reality.

Equations of Maxwell, other equations with speed of light limit, are hyperbolic partial differential equations. So, solution of equations of ER-hypothesis for particles can be hyperbolic partial differential equations on emergent space.

All particles in our Universe travel at speed not higher than speed of light. So, angle between vector of time and trajectory β_i of particle for function ϕ_i should not exceed such angle α_l for light.

$$\beta_i \leq \alpha_l \tag{28}$$

As I wrote above, in Special Relativity section, rotations of spacetime must lead to loss of information in case if rotation exceeds some angle. Loss of information can be defined as relative number of events, which happens in one emergent spacetime, and not happens in another emergent spacetime, rotated by some angle. So, adding function $Ev(L, L^*, \gamma)$ – relative number of events which have velocity corresponding to angle γ, which happened in space L and not happened in space L^*, which is rotated to space L by directed angle $\vec{\beta}$, where $\beta < \alpha$, angle α correspond to velocity of speed. Loss of information should not be big, otherwise casual relationships will be affected in such way what information cannot be collected, and life would not be possible. So,

$$Ev(L, L^*, \vec{\gamma}) = \theta(\vec{\beta}, \vec{\gamma}) \tag{29}$$

Where $\theta(\vec{\beta}, \vec{\gamma})$ is unknown function, it limits loss of information after rotation. It can be rewritten as:

$$Ev\big(L, Vr(L, \vec{\beta}, x), \vec{\gamma}\big) = \theta(\vec{\beta}, \vec{\gamma}) \tag{30}$$

Rotating to some angle, next rotating back should produce zero loss of information:

$$Ev\big(L, Vr(Vr\big(L, \vec{\beta}, x\big), -\vec{\beta}, x), \vec{\gamma}\big) = 0 \tag{31}$$

Combining equations together, system of equations of ER-hypothesis:

$$\begin{cases} L(x, f, A, \overrightarrow{v_t}) = 0 \\ \overrightarrow{v_t}(f, A, L) = 0 \\ |\overrightarrow{v_t}(f, A, L, x)| * tg\big(\alpha_l(x, L)\big) = c \\ \beta_i \leq \alpha_l \\ L_r = Vr(L, \vec{\gamma}, x) \\ \forall \left(p_i(St_m), p_k\big(St_j\big)\right) \exists \left(p_i(St_m) \leftrightarrow p_k\big(St_j\big)\right), p_i \in P, p_k \in P, St_m \in St(p_i), St_j \in St(p_k) \\ \psi_{e,i}\big(x_e, |\vec{t}|\big) = \psi_i\big(a_i, x, f, L, \vec{t}\big) \\ a_{p_i}(x) = a(\{p\}, \{c\}) \\ Ev\big(L, Vr(L, \vec{\beta}, x), \vec{\gamma}\big) = \theta(\vec{\beta}, \vec{\gamma}) \\ Ev\big(L, Vr(Vr\big(L, \vec{\beta}, x\big), -\vec{\beta}, x), \vec{\gamma}\big) = 0 \\ f(x) = g(x, S, \varphi(S)) \end{cases} \tag{32}$$

Interaction of particles with such approach can be found by following approach, if all functions, include scalar field, is known:

1. In some frame of reference, with usage of set of functions of particles, find all particles everywhere in emergent spacetime
2. Interaction of particles is found: just look at how particles behave from point of view of emergent spacetime.

If look at equations above, there is no any isomorphism between emergent spaces belonging to different times, not even speaking about diffeomorphism. So, lots of math typically used by physics is not applicable to the equations, seems as only functional analysis applicable to them.

The system of functional equations above is very generic. In order to make them usable, it is necessary to find function of scalar field $f(x)$. If function of scalar field, Eq(19), was known, in such case laws of physics in our reality can be found by finding of particles with Eq(32). We observe only emergent

spacetime and matter, so problem for solving is much more complex than find emergent reality from known function of scalar field. First it is necessary to find equation of scalar field from our observable laws of physics, and only next find equations of particles, space and time from scalar field, expecting increase of our knowledge of emergent laws of physics as result.

How it can be done?

I think first it is necessary to solve problem of finding emergent spacetime with causality for general case. Solution of the problem will limit possible types of equations of scalar field and types of Eq(30), and it can give hints how to solve opposite problem of finding equation of scalar field from emergent spacetime.

After finding possible types of equations for Eq(32) it would be necessary to find which types would allow to have hyperbolic partial differential equations as solutions on emergent space for particles, at least as approximate solution for small angles of rotations. Maxwell equations and many other equations are hyperbolic partial differential equations; such types of equations are wave-like and can have constant speed of light. So, it can limit possible types of equations even more.

After identifying possible type of equation, it would be necessary to find how to build equations for scalar field to get lagrangian of Standard Model as approximate solution for Eq(30) at least for small angles $\beta \ll \alpha(x, L)$ and energies. Small angles because at higher angles may become significant effect of loss of information during rotations. I wrote approximate solution because solution can contains more elements in lagrangian than Standard Model. General Relativity should arise too, as solution for emergent spacetime.

Looks as solving of equations of ER-hypothesis is complex problem and it will require quite a lot of research. I leave the question open for future.

Arguments against ER-hypothesis

Scientific arguments against ER-hypothesis

In this part, I will try to summarize expected arguments against ER-hypothesis and answer to them.

I expect several main types of arguments:

1. Universe cannot have static underlying structure. Just look around, there is motion, there is time. This hypothesis directly contradicts to our feelings.
2. ER-hypothesis predicts following behavior for some phenomenon. Experimental results differ from predictions of ER-hypothesis.
3. Is function of scalar field, satisfying all requirements of ER-hypothesis, can exists?

I will try to answer to these arguments here.

First, I will answer to argument #1, about contradiction of ER-hypothesis to our feelings. I think the argument is not scientific; it is just expression of philosophical bias. Any scientific hypothesis should be considered based on its predictions, not based on how well it fits to common sense. Nature has no any obligations to respect common sense of humans.

About argument #2. It can be serious argument, but at current state of ER-hypothesis, ER-hypothesis cannot make any measurable predictions. There are predictions related to cosmology, but they easily show same data as experimental data, they predict FLRW metric as approximate solution. So, in order

to make real arguments here, it is necessary to solve equations of ER-hypothesis first or at least find some predictions based on the equations.

About #3. I cannot say for sure what such function can exists, some research is necessary to answer the question. However, I can say what it is not possible to say what such function cannot exists without additional research. Research related to analysis of existence of such function is outside of scope of the article; probably it will be in one of following articles.

Of course, I cannot predict all types of scientific arguments against ER-hypothesis, so I tried to answer only most expectable types of arguments.

Non-scientific arguments against ER-hypothesis

Just recently I received feedback on ER-hypothesis: “This work is simply not physically sound.”

After some thinking, I understood it can be quite common perception of the hypothesis. So I decided to answer to such argument.

I consider such argument as non-scientific. Such argument simply means what any person, who says it, is sure what his philosophical view of Nature is true and sure what ER-hypothesis cannot be true because it contradicts to his philosophical view of Nature. May I see where it was proved? I have read many debates about realism vs anti-realism in Internet, and I have not seen any mentioning what realism was proved to be true.

It is very unusual when scientific theory directly use ontological view to derive its equations. ER-hypothesis is based on eternalism. If look at postulate of ER-hypothesis and look how spacetime and matter was derived, it is easy to notice what ER-hypothesis was derived directly from eternalism with only few additional assumptions. However, there is nothing in ontology which prohibits deriving of physical theories directly from ontological ideas.

May be ER-hypothesis requires too much changes in philosophical view of Nature and there is alternative which is not requires so many changes? Well, may I read any hypothesis which is not requires so many changes and which unify all forces? There are theories like String Theory, Loop Quantum Gravity etc., and some thinks they can unify all forces. But where is result with unification? It is not exists, as of now. ER-hypothesis, on other side, proposes simple and easy unification. The unification is easy to explain and understand, but only if one is ready to seriously consider the hypothesis instead of insisting on his philosophical views.

I understand it is possible what ER-hypothesis is wrong. But only scientific arguments should be used in science to prove what something is wrong, philosophical views should not be reason for rejections of new scientific ideas.

Open problems of ER-hypothesis

There are many open questions in ER-hypothesis. Some were mentioned above. In this part I describe some addition interesting questions and problems.

Is particle today same as year ago?

Cosmology model of ER-hypothesis is based on hypersphere. All particles belonging to same moment of emergent time must be able to interact between each other, directly or indirectly. But there is no condition what same particles must be able to interact with same types of particles as they were long

time ago, like soon after Big Bang. So here arise open question – are particles today same as they were year ago?

If particle today is not same as it was year ago, it can be used to explain non-zero cosmology constant.

Energy of vacuum

Many experiments shows what vacuum have energy. Vacuum usually described as filled with virtual particles. How to get same in ER-hypothesis?

Looks as it can be achieved if mapping function will produce similar effects. But why effects looks as interaction only with known types of particles? It is not clear, more research is necessary to understand it.

Applying ER-hypothesis to some known problems

Information and black holes

There is loss of information in black hole in current widely accepted theories.

There is no any loss of information in ER-hypothesis. Information may leave our spacetime, but it still exists in Metauniverse, just not available for us.

Conclusions

The proposed ER-hypothesis has two parts: philosophy and physics. So, I think it is better to split conclusion part into two sections: philosophy part and physics part.

Conclusions, philosophy part

ER-hypothesis gives new interpretation of Being and removes real freewill from human. The hypothesis is super-deterministic hypothesis, so it gives no real freewill to humans. The hypothesis proposes answer to one of big philosophical questions, how reality and our feelings relates between each other.

Being in ER-hypothesis is emergent phenomenon, it happens over static timeless Metauniverse.

Is model of ER-hypothesis fits into long term philosophical trend?

Some time ago accepted theory was Ptolemy theory, where Earth was in center of Universe and Sun orbited around Earth. Human was in center of Universe, animals were apart from humans.

Later, erosion of centered role of human in Universe begins. Earth begins to rotate around Sun, and Sun become center of Universe. Next it was found Sun is just one out of billions of other stars, and Sun rotates around center of Galaxy. Darwin has shown humans have same origin as other animals.

Currently, role of human in Universe is still high. It is high mostly because of freewill conception – that human is free to do everything.

So, in science and philosophy there is long term trend to reduce role of human in Universe. ER-hypothesis removes human's freewill and reduce role of human in Universe, and it fits to long term trend in science and philosophy.

Philosophy of ER-hypothesis may looks as far from beautiful, because it so diminishing role of human. It reduces conscience of human just to epiphenomenon. However, Nature has no any obligations to respect human's feelings.

Conclusions, physics part

ER-hypothesis is built upon one scalar field, so it unifies all elementary forces.

I see main power and main achievement of the hypothesis in simple conceptual model unifying Standard Model and General Relativity, resulting in set of equations for ER-hypothesis. The equations, if ER-hypothesis is valid, should be able to describe all physical processes include undiscovered yet. The hypothesis looks as is able to explain all observable forces and phenomena from one point of view. The unification is done based on one underlying field, so all observable fields and forces are emerge from that field. Main problem of ER-hypothesis – cost of the unification. The unification is at cost of most core concepts of philosophy.

Only one assumption was done during writing of the hypothesis. The assumption is postulate of ER-hypothesis. Also, I did some guesses but none of them is critical for ER-hypothesis.

In the article I described what ER-hypothesis leads to SU(3) symmetry as approximation, so it is possible to conclude that Standard Model can be approximate solution of ER-hypothesis.

I described how to explain Special Relativity in ER-hypothesis, and how it leads to SU(3) symmetry breaking.

General Relativity is included into ER-hypothesis, some changes to equations of General Relativity were proposed.

Main weakness of the hypothesis now – lots of open mathematical questions. They need to be resolved to make the hypothesis usable for calculations.

Another weakness of ER hypothesis – there are no analytical solutions of equations of ER-hypothesis. I think it is quite expected, initially, for any hypothesis which goes beyond well-known area of gauge theories build on space of states. Equations of ER-hypothesis are set of functional equations, so they are complex and not easy to solve.

Certainly, the proposed hypothesis is very radical; it affects core concepts of philosophy. However, this hypothesis is also promise 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 ER-hypothesis. 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 during search for analytical solutions for equations of ER-hypothesis.

ER-hypothesis makes some predictions, but none of them can be measured. It makes some changes in General Relativity in part related to cosmology, but probably there is no difference between FLRW metric and predictions of ER-hypothesis after Universe becomes transparent to light. However, ER-hypothesis proposes simple explanation of inflation phase of early Universe.

Loss of information after acceleration is not observable; such observation is prohibited by super determinism of ER-hypothesis.

Such problem, with small amount of new predictions, is mostly because ER-hypothesis is compatible with Special Relativity, General Relativity and Standard Model. However, number of predictions may grow after deeper analysis of proposed equations of ER-hypothesis.

Problem with observable predictions is not means that ER-hypothesis cannot be falsified. ER-hypothesis can be falsified if would be proven that equations of ER-hypothesis have no solution satisfying all conditions mentioned above, or if solution of equations of ER-hypothesis will be unable to correctly explain some phenomenon. ER-hypothesis is candidate for Theory of Everything, so it should describe all physical phenomena under any physical conditions.

If ER-hypothesis is valid, finding of equation of scalar field from our observable laws of physics would allow finding equations of particles, space and time from scalar field. As result, it can increase our knowledge of laws of physics and it would lead to measurable predictions, possibly it would result in discovering new phenomena.

List of predictions of ER-hypothesis:

- ER-hypothesis predicts SU(3) symmetry breaking.
- ER-hypothesis predicts what FLRW metric is incorrect at first moments after Big Bang, and inflation phase can take more time than predicts current theories. Also, if inflation phase took more time, it means what statistics for high scales is differing from statistics for our observable conditions.
- Parallel universes are predicted. Also, ER-hypothesis predicts ability of interaction between some, but not all, parallel universes.
- ER-hypothesis predicts that past cannot be changed, but not prohibit travel to past

Other results of the hypothesis:

- ER-hypothesis is able to explain General Relativity and Standard Model from one point of view and with usage of one only field.
- 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 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, solving its equations, should allow looking even further before Big Bang, to where there was neither time nor space.
- New interpretation of Quantum Mechanic was proposed
- New interpretation of quantum entanglement was proposed.