Low Energy World 1

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In this paper we will consider some possible scenario of the universe formation. We will start from the basic optimization principle that defines the ground state of the world and will derive some features of such a world, including the origin of time and necessity of universal speed, possible reason of existing of three generations of building blocks and their conjugates, symmetries and their violations and finally some cosmological consequences like inflation stage and accelerating expansion of the universe.

keywords: Fractal space; time; universal speed; gravitation; symmetries; inflation; universe accelerating expansion

1. INTRODUCTION

First lets specify the scope of the discussion. A simple picture one could imagine is the following: our world is made out of some building blocks, that could be particles, fields etc, that are contained in some frame, which we call space-time. Namely this frame will be the main subject of the paper. We assume that at high energy density the space could be very different from what we observe now, for example it can have an arbitrary number of dimensions and the time in its common meaning may simply be absent. The idea behind the study is that there is some certain ground state where the world, independently on initial conditions, will always arrive when the energy density becomes small, in other words, when the world gets cooled down. We will try to derive the properties of this ground state and describe phenomena accompanying the transition to it. Due to the limited size of the paper we will omit not essential detailes with the hope to continue the discussion in following publication(s).

2. OPTIMIZATION PRINCIPLE - LOWEST RADIX ECONOMY

To illustrate the basics of the following consideration lets imagine digital computer memory which is needed to accommodate some range of numbers, for example from 0 to 999 in the decimal counting system. In this system elements with 10 states will be needed for representation as well as three of such elements, corresponding to 3 digits. In total 3 elements with 10 states each will have 30 hardware states. In the binary system 10 digits with 2 states for each one is enough to cover the same range, in total 20 hardware states are needed; the system on the base 1000 in turn will require 1000 states. It becomes clear, that the number of hardware states will depend on the choice of the counting system base. For arbitrary number A the required number of hardware states needed for the representation of all numbers in the range from 0 to A can be written as

$$r = n \cdot \log_n(A), \tag{1}$$

where n is the base of the counting system. This expression has a minimum at $n = e$ ($e = 2.71828...$, Euler number). For the computer we can choose binary or ternary counting system [1] in order to get the most economical solution. Above exercise is one of the cases of a more global rule known as a lowest radix economy principle (see for example [2]). An attempt to use this principle as variational method in quantum mechanics can be found in [3]. Our model is based on the idea, that the space itself, namely the number of space dimensions in the ground state, obeys the lowest radix economy principle to provide the maximum allowed variety of states by minimal means. In this case we get the same relation (1) with the optimum at $n = e$ dimensions.

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3. E-DIMENSIONAL SPACE, SMALL AND LARGE DISTANCES

In the nature, where we have practically infinite amount of degrees of freedom, the rule of e dimensions at the ground state could be precisely fulfilled. For the moment we will postpone the discussion of e-dimensional fractal space properties, but emphasize one interesting feature of it: if we put some pointlike probe charge in this space or put there any other pointlike source with typical long-distance field, then a self energy will not contain UV divergent loops and can be calculated at zero distance limit without any renormalization procedure. Generally speaking, this statement is valid for any space with number of dimensions less than 3 (where one has a logarithmic divergence of the field energy integral at zero distance). Examples of fractional approach to quantum physics can be found in the literature (see for example [4] and references therein).

From the other side for e-dimensional space we have a problem with infrared long distance divergence. For massless particles field energy integral has a divergence at infinity. For very high matter/energy density one can neglect long distance effects, but with decreasing density due to the space expansion, contribution of field integrals at long distances become more and more important. In order to avoid an infinite field energy contribution to the total energy, the space has to change itself at long distances, adapting to the nearest amount of dimensions, where field integrals are converging at infinity, namely exactly to 3 dimensions. So we arrive to the following picture: the space at the ground state (low energy, low density) has to have e dimensions at small distances and three dimensions at large distances.

4. TIME AND UNIVERSAL SPEED, SPECIAL RELATIVITY

Now lets pay attention to the large distances and also recall that the basic rule still requires e dimensions. The meaning of that is: in addition to 3 dimensions we need some extra dimension, that one can add to 3 spatial dimensions in order to reduce effectively the full dimension of the system to e. Note that this new dimension of course is closely connected to spatial 3 dimensions and transforms together with them.

In order to understand better the properties of a resulting space, let's consider a square of invariant line element, an interval, in Cartesian coordinates of flat space $(x^1, x^2, x^3, ..., x^N)$ of some dimension N:

$$\Delta s_N^2 = \sum_{i=1,N} (x_2^i - x_1^i)^2$$

It is easy to notice that for points, separated by unit distance in every space coordinate, the value of such an interval is numerically equal to the space dimension N:

$$\Delta s_N^2 = N, \quad \text{if} \quad (x_2^i - x_1^i)^2_{i=1,N} = 1 \tag{2}$$

Now we consider 3-dimensional space, where $\Delta s_3^2 = (x_2^1 - x_1^1)^2 + (x_2^2 - x_1^2)^2 + (x_2^3 - x_1^3)^2$ and add a new, 4-th dimension, which effectively reduces the 3-D space to e-D. According to assumption (2), it should be done the following way:

$$\Delta s_e^2 = (x_2^1 - x_1^1)^2 + (x_2^2 - x_1^2)^2 + (x_2^3 - x_1^3)^2 - c^2 \cdot (x_2^4 - x_1^4)^2$$

with the coefficient $c^2 = 3 - e \approx 0.28172...$ It is obvious, that the above expression (with reverse sign) coincides with the definition of the Minkowski space $\mathcal{M}$ metrics, if the fourth coordinate x^4 is time and coefficient c is the speed of light. Consequently, the metric signature of the resulting space is the Lorentz group $O(3,1)$ and transformations between inertial frames are Lorentz transformations.

In further discussion we will call the above described 4-th dimension "time". It is worth to note, that since this new dimension is in fact the bridge between precisely defined e-D space and 3-D space, the natural unit for it is also precisely defined and the ratio of space units to time units has a dimension of speed and has a special eigenvalue, the world constant, universal speed. Later on we will call this constant the "speed of light". Clear, that it appears together with time.

5. GENERAL RELATIVITY

It is worth to emphasize that the flat 3-D space will take place asymptotically, when energy density is approaching zero. Following the above discussion one may assume, that for non-zero energy densities some transition situation occurs: the dimension of the space is slightly below 3-D while the time already exists, maintaining the overall dimension to be e-D. It could be written the following way:

$$ds^2 = a^2 \cdot (ds_3)^2 - c^2 \cdot (dt)^2$$

where a^2 - scale factor, that may be dependent on time $a^2 = a^2(t)$

$$ds^2 = a^2(t) \cdot (ds_3)^2 - c^2 \cdot (dt)^2 \tag{3}$$

Now we got the Friedmann-Lemaître-Robertson-Walker (FLRW) metric, which is a standard model of modern cosmology. Here ds_3^2 doesn't depend on time and ranges over 3-dimensional space of uniform curvature, that is, elliptical space, Euclidean space or hyperbolic space. $a(t) = 1$ today is a standard normalization. Factor c is constant in general relativity.

In our model we assume that 3-dimensional space of uniform curvature is mathematically equivalent to the fractal space of the dimension r directly defined by the curvature. Then the term $a^2 \cdot (ds_3)^2$ becomes $(ds_r)^2$ with $e < r(t) < 3$ evolving together with world expansion. The speed of light is not a constant anymore, being zero at maximum curvature corresponding to e-D space and reaching maximum for the flat Minkowski space. Note, that we have no singularities in our model, since the space curvature cannot exceed that of e-D space.

Assuming that the curvature of our world space is small and the deviation from Minkowski metric is already not significant, we conclude that our space should be elliptical, the speed of light is practically constant and almost equal to its asymptotic value and the residual curvature is equivalent to the gravity, which is described by Einstein equations.

So we have now the following picture: 3-D space, time and the speed of light at large distances, which is already quite similar to what we see in the nature, and some strange purely spatial e-dimensional space with no time and speed of light at small distances. The last one looks very unusual from the point of view of our experience.

6. UNCERTAINTY PRINCIPLE

Here we should draw attention to the fact that, being observers, we can only see these small distances from the point of view of large distances, where we have 3 spatial dimensions and time. Doing our measurements at smaller and smaller scale, we enter the region where time does not exist, it becomes undefined, uncertain. Thus we essentially arrive to the uncertainty principle, although in some unusual form.

Lets start from time-energy uncertainty relation in Mandelshtam [5] formulation (see also in [6]):

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2} \tag{4}$$

Typically Δt here is associated with lifetime of some state while ΔE is a natural linewidth of this state (or mass width for unstable particles). We will treat this relation to be valid for *real* time and introduce in the expression (4) some elementary volume $\Delta V = \Delta x \cdot \Delta y \cdot \Delta z$, namely:

$$\frac{\Delta E}{\Delta V} \cdot \Delta t \cdot \Delta V \geq \frac{\hbar}{2}, \quad \text{or} \quad \Delta t \cdot \Delta x \cdot \Delta y \cdot \Delta z \geq \frac{\hbar}{2\rho_E},$$

if we use $\rho_E = \Delta E/\Delta V$ - some characteristic energy density, "vacuum energy". Thus we include in the uncertainty relation not only the Fourier conjugate pairs of variables, like position and momentum, or in different formulation, non-commutative pairs of operators, but all space-time variables together.

Taking into account handbook statement that quantum mechanics can be directly derived from uncertainty principle, we come to the statement that simple purely spatial e-dimensional space for us, as external observers, looks like very rich and complicated quantum mechanics. At this point we can also make the following conclusion: if this model is correct, time, speed of light and quantum mechanics (at least in the form of wave mechanics) are all the properties of low energy and low density universe ground state and do not exist at high energies.

7. TRANSITION DISTANCE

An additional observation comes from the evaluation of the pointlike charged probe self energy integral. It is obvious that the result depends on the characteristic distance, where the transition between two cases (e-D and 3-D) occurs. Too small characteristic distance leads to divergence at zero distance, too large characteristic distance - to the rise of the long distance part of the integral. At some particular transition length the self energy integral has a minimum. The hypothesis is that the careful analysis of the transition region and self energy integral minimum will allow to introduce another word universal constant, namely the Planck's constant, which thereafter can be used in the uncertainty principle formulation.

8. THE THIRD PRINCIPLE

In the above described picture we had used two basic principles: maximum phase space by minimum means (we got e-D space as a consequence of it) and long distant field energy minimization (transition distance to 3-D space, time and light speed). Now lets have a closer look at e-D space itself. To visualize it one can try to imagine a standard 3-D coordinate system with somehow "reduced" or "shortened" dimensions. There is some ambiguity how we can do it: either we "shorten" all 3 dimensions simultaneously, keeping the symmetry of our fractal space, or we treat these dimensions individually, keeping overall constraint that the sum of these dimensions should be equal to e. In the last case we arrive to the concept of asymmetric fractal space. In support of such a possibility we can try to imagine smooth transition between 3-D and 2-D spaces when we have almost reach 2-D space: the next small step will give us only two "full" dimensions, so this "almost 2-D" space will have 2 complete dimensions plus something "small" with obvious asymmetry. In the following considerations we assume that our e-D space is asymmetric with all dimensions being different. We do not know yet what basic principle is behind the exact choice, but from the discussion below it seems like it should be a really universal principle that works always and everywhere, distributing individual dimensions in e-D space the very certain way. We can call it here "the third principle", leaving the choice of better name for the future explorer. Now we are almost ready to make the next step. Lets recall that we had logarithmically divergent mass integrals for pointlike charges in case of 3-D space and finite mass for the space with dimensions less than three. Note that for the smaller space dimension the mass is smaller. Lets try to apply the similar idea to the individual dimensions and some one-dimensional objects, eigenstates, corresponding to these dimensions. Such objects are considered in string theory, but as far as we know, the fractal space and moreover an asymmetric one, had never been explored there.

9. THREE GENERATIONS

If we suppose that our asymmetric e-D space is somehow built by 3 "shortened" dimensions of different "length", then we can imagine exactly 3 sets of 1-dimensional eigenstates, corresponding to each of these dimensions. Since all 3 quasi-dimensions are different, 3 sets will be very similar to each other, except of their masses. The set, corresponding to almost "full" dimension, will be the heaviest one, the set belonging to the "shortest" dimension, will get the smallest masses. Due to the constraint, that the sum of all quasi-dimensions is equal to e, there should be some limitation, namely that the "shortest" dimension cannot be smaller than $e - 2$ and relevant masses cannot be smaller than a certain low limit. Using the string theory idea that these one-dimensional eigenstates are in fact universe building blocks, elementary particles, we come to the picture where we need 3 generations of particles having different masses. Constraint on the sum of three quasidimensions to be equal to e should lead to some relationship between generations masses. To summarize, the formalism of string theory in asymmetric fractal space with overall dimension e seems to be the key to understand the world.

10. ANTIPARTICLES, C, P, T AND CPT SYMMETRIES

It is obvious, that out of three orthogonal vectors of different lengths one can construct two coordinate systems: the left-handed one and the right-handed one. Similarly, one can imagine our quasi-dimensions in e-D space being arranged either left- or right-handed way. That gives us an additional degree of freedom and our three generations split into two kinds: left-handed and right-handed ones. Obviously we would like to declare them as particles and anti-particles. Considering relevant symmetries, we can easily introduce P, left-handed and right-handed symmetry, C - particle-antiparticle symmetry, and, since time is a bridge between asymmetric e-D and symmetric 3-D spaces, also T-symmetry. For obvious reasons, C, P and T symmetries are closely connected to each other. Due to the symmetry of 3-D space, combined CPT symmetry is always conserved, while violations of C, P and T symmetries are possible under certain conditions and have clear geometrical interpretation.

11. COSMOLOGY

Now lets consider cosmological consequences of the above described picture. Here we would not say practically anything about the initial hot stage. Space could have an arbitrary number of dimensions; time and speed of light were not defined. At some point, energy became low enough, so our system fell down into its ground state, namely asymmetric e-dimensional space. Three generations of particles had been created. Due to the fluctuations, some regions of the resulting space accidentally acquire left-handed orientation, other regions became right-handed. According to orientation, these regions were enriched either by particles or antiparticles. Further cooling and expansion of the world led to the creation of 3-D space, time and speed of light at large distances. At that moment, that one can call "the end of inflation era", we have our time zero. Since that moment the history of the world had a fork in its development: left-handed regions all together start to move in time in one direction, right-handed regions move in opposite direction in time. Clearly, the inhabitants of one of universe parts will observe particle-antiparticle asymmetry. The complimentary part of the universe, "anti-universe", from their point of view will lay in the past. If, as in our case, time zero was approximately 13.8 billion years ago, this anti-universe is there, but 27.6 billion years ago, moving backward in time. It is interesting that imaginary travel back in time will allow us to reach time zero point and then the second branch of the time fork. Inflation era and "Big Bang" are not accessible. The above described scenario should have some observable consequences. We have already mentioned baryon asymmetry. Second, remnants of regions with extraneous chirality which departed from our part of the universe at time zero, could develope themselves into vast spaces containing no visible matter. So called "voids" in the observed universe large scale structure could be good candidates for such objects. Recent large volume simulation of the evolution of the universe (for example [7]) are compatible with the assumption, that fluctuations at early stage of universe formation do not dilute, but instead give rise to the structure we observe today.

In addition, gravitational field at time zero was defined by the simultaneous presence of both universe and anti-universe parts. Disappearance of anti-universe regions will manifest itself only with delay, within event horizon. It means that their contribution to the effective gravitational field in the universe will consequently diminish in time. In case, if our universe is expanding, one will experimentally observe an accelerating expansion. At least qualitatively it explains manifestation of "dark energy", a great mystery of today's physics. To access the problem quantitatively, one needs a detailed simulation of universe evolution with double initial mass and delayed gravitational potentials .

12. CONCLUSIONS AND OUTLOOK

In this paper we presented the model, describing possible scenario of the world formation. Starting from the lowest radix economy principle, we derive some properties of the universe ground state which in many aspects are similar to those we observe in our world, including necessity of time, speed of light, Minkowski metric, gravity, 3 generations of particles and antiparticles, C, P, T symmetries and their violations and also some cosmological effects. Due to the large scope of issues presentation is mainly limited to the ideas and qualitative explanations leaving details apart. Clear that intensive studies are still needed to develope the model further.

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