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Abstract.

In this paper we propose a particle model for the Higgs' condensate: we propose that this condensate is the set of (infinite velocity) non-local tachyons. We show that then there exists the anomalous geometrical diffraction (which contradicts to quantum mechanics). We show that there exists a universal time constant which defines the limits of the validity of quantum mechanics. We propose an experiment testing the existence of the anomalous geometrical diffraction. We proposed the dark energy conjecture which enables to make an estimate of the time constant. We assume certain ("Feynman") interaction between standard particle and the non-local tachyon. All this is related to the new (finite) form of the Feynman integral.

1. Introduction.

The basic idea of this paper is to study possible particle models for the Higgs' condensate and to look for some consequences. We proceed step by step:

- Bare Higgs' particles must be massive tachyons
- These tachyons must be non-local tachyons
- Higgs' condensate may be a set of non-local (infinite velocity) tachyons equidistant in time (time constant = τ_0)
- The granular (discrete) structure of the Higgs' condensate implies the existence of the anomalous geometrical diffraction in the time-like two slit experiment
- The interaction between standard particle and the non-local tachyon is described by the concept of the "Feynman" interaction (described in sect.7) and it is possible to show that the new Feynman integral converges to the standard Feynman integral when τ_0 goes to 0
- There are also other consequences: the origin of the randomness of quantum mechanics (QM).

The difference between the standard model and the model proposed here is the following. In the standard model the Higgs' mechanism is applied before the quantization on the classical level and the resulting theory is then quantized. In our approach we think on the situation before the spontaneous symmetry breaking (i.e. before the application of the Higgs' mechanism) and we ask: where are these bare Higgs' particles which are expected to make a Higgs' condensate?

In the standard model the Higgs' condensate give masses to other particles (through the Higgs' mechanism) etc. but the proper bare Higgs' particles disappeared from the standard model so that they were not quantized (the dressed Higgs' particles make a part of the standard model). The discrete (quantized) properties of the bare Higgs' particles are not taken in account.

In our approach we proposed the simple possible model for this quantized Higgs' condensate. Then we were looking for possible consequences. At the first place we obtained the existence of a geometrical diffraction in the time-like two-slit experiment (proposed already in 1989 in [6]). Existence of the discrete structure in the particle model of a Higgs' condensate implies that there should be fundamental limits on the universal validity of QM.

The estimate of the basic parameter τ_0 of our model is a difficult task. We formulate at first the dark energy conjecture (saying that the cosmological dark energy is represented by the Higgs' condensate). Using this conjecture we were able to arrive at some estimate of the order of τ_0. This (very rough estimate) makes possible to think on the possible experimental test of the existence of geometrical diffraction. We propose to do the experiment test of the possible existence of the geometrical diffraction.

In sect.2 we show that the bare Higgs' particles must be represented as nonlocal tachyons which are described in some details. In sect.3 we shall describe the proposed particle model for the Higgs' condensate as a set of non-local tachyons. In sect.4 se shall introduce our main topic – the anomalous geometrical diffraction in the time-like two hole experiment. In sect. 5 we propose the dark energy conjecture and using it we give an estimate of the basic time constant τ_0 which is a parameter of our model. In sect.6 we describe the possible interaction between standard particles and non-local tachyons and we describe the "physical Feynman integral". We also show here that in the limit where τ_0 goes to zero our model converges to the standard model. In sect.7 we give the complete derivation of the proposed model (without estimate of τ_0) which implies the principal limits for the validity of QM. In sect.8 we give a brief history of concepts of non-local tachyons and of anomalous diffraction. In sect.9 we give a summary.

2. Bare Higgs' particles as tachyons, space-time classification of particles and non-local tachyons

Quantum objects have, in general, two possible representations: the wave representation and the particle representation. These are considered as equivalent.

Our proposed model will be based on the particle representation[1]. Individual systems should be interpreted as particles.

Usually the analysis of the Higgs' sector is done in terms of the co-called Higgs' mechanism. The standard Higgs' mechanism uses the wave representation of quantum objects. We shall proceed in another way using the particle representation of quantum objects.

It is clear that the Higgs' Lagrangian is tachyon, since the sign of the mass term is negative. This is the situation before the spontaneous symmetry breaking, where bare Higgs' particles are considered. After the spontaneous symmetry breaking the dressed Higgs' particles will acquire the positive mass (this is well known). There arises a question what is the particle representation of the bare Higgs' particles. Such a representation will be the main objective of our model.

Thus the starting point will be the clarification of the concept of a tachyon objects in quantum theory. It will be shown that the unique possibility for bare Higgs' particles is to be non-local tachyons.

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[1] There exists also an argument for this choice. This is the probability model for quantum mechanics described in [1] and [2]. In this probability model for quantum mechanics it can be shown that particle properties can be attributed to individual systems, while wave properties can be attributed only to collectives (i.e. ensembles of particles).

There were proposed two particle models for tachyons:

(1) The standard tachyons, see for example [3]
(2) The no-local tachyons proposed in [4] and [5]

Now we shall describe the complete classification of possible space-time description of particles. We shall describe the free motion of particles, but the non-linear motion is, in general, such that at each point of the trajectory its tangent space is of the type described below.

The space-time classification of particles (here $\mathbf{x}, \mathbf{x_0}, \mathbf{v}, \mathbf{w}$ etc. are vectors from R^3 while t, t_0 are real numbers and $\mathbf{x}$, t are variables while $\mathbf{x_0}$, t_0, $\mathbf{v}$, $\mathbf{w}$ are parameters):

(i) The standard massive particle

$$\mathbf{x} = \mathbf{x_0} + \mathbf{v} (t - t_0) , \qquad \text{where } | \mathbf{v} | < c , \text{ and } c = \text{velocity of light}$$

(ii) The standard relativistic massless particle

$$\mathbf{x} = \mathbf{x_0} + \mathbf{v} (t - t_0) , \qquad \text{where } | \mathbf{v} | = c$$

(iii) The standard finite velocity tachyons

$$\mathbf{x} = \mathbf{x_0} + \mathbf{v} (t - t_0) , \qquad \text{where } | \mathbf{v} | > c$$

(iv) The standard infinite-velocity tachyon

$t = t_0$, $\mathbf{x} = \mathbf{x_0} + \lambda\, \mathbf{v_0}$, where $| \mathbf{v_0} | = c$ is a parameter, while $\lambda \in$ **R is a variable,** and t_0, $\mathbf{x_0}$, $\mathbf{v_0}$ are parameters[2]

(v) Non-local massive tachyons

$$t = t_0 + \mathbf{w} \,.\, (\mathbf{x} - \mathbf{x_0}) , \qquad \text{where } | \mathbf{w} | < 1/c$$

(vi) Non-local massless tachyons

$$t = t_0 + \mathbf{w} \,.\, (\mathbf{x} - \mathbf{x_0}) , \qquad \text{where } | \mathbf{w} | = 1/c$$

Note that the physical dimension of the standard velocity $\mathbf{v}$ is meter/second, while the physical dimension of the non-local tachyon velocity $\mathbf{w}$ is second/meter.

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[2] We obtain this form when we write $\mathbf{x} = \mathbf{x_0} + \lambda\, \mathbf{v_0} \,.\, (t - t_0)$, where $| \mathbf{v_0} | = c$ and $\lambda \to \infty$. If $t > t_0$ we obtain $| \mathbf{x} | \to \infty$ and this is a non-sense. Thus it must be true that $(t - t_0) \to 0$. Then for $\lambda = \lambda_0 (t - t_0)^{-1} \in \mathbf{R}$ we have $\mathbf{x} = \mathbf{x_0} + \lambda_0 (t - t_0)^{-1} \mathbf{v_0} (t - t_0) = \mathbf{x_0} + \lambda_0 \mathbf{v_0}$ (assuming $(t - t_0) \to 0$). The trajectory of this standard infinite-velocity tachyon is $\{(\mathbf{x}, t_0) \mid \mathbf{x} = \mathbf{x_0} + \lambda_0 \mathbf{v_0} ,\ \lambda_0 \in \mathbf{R}\}$.

Trajectories of particles (i) – (iii) are straight lines in R^4 . Trajectories of particles (v), (vi) are three-dimensional hyperplanes in R^4 .

Particles (i) – (iv) are observable. This is clearly true for the standard massive tachyons with the finite velocity | **v** | > c . This is also true for standard infinite-velocity tachyons[3].

Particles (v), (vi), i.e. non-local tachyons are **not observable** in any coordinate system, since their trajectory is non-local. (More details on this property can be found in [5]).

The non-observability of individual non-local tachyons is their **most important** feature. This implies that the large number of such particles **could exist**. This means that the individual non-local tachyon cannot be observed but the collective of many non-local tachyons could be, in principle, observed.

On the other hand, standard tachyons are observable, so that (up to now) their existence is excluded.

The Higgs' condensate is usually obtained and described using the Higgs' mechanism in the wave representation of quantum objects.

The particle description of the Higgs' condensate (as a condensate of bare Higgs' particles) must be done by the condensate of tachyons. But the standard tachyons cannot be used, since they are observable (but not observed). Thus the **non-local tachyons must be used** for the representation of the condensate consisting of bare Higgs' particles.

The problem to define the particle representation of the Higgs' condensate has to be solved . the solution consists in the representation of the condensate as a set of non-local tachyons (which are individually non-observable).

We have arrived at the basic consequences:

(i) The bare Higgs' particles must be represented as non-local tachyons
(ii) The Higgs' condensate is the set of non-local tachyons.

We shall also assume that these non-local tachyons will be massive tachyons – see (v). This is based on the fact that the standard lagrangian in the Higgs' mechanism describes the massive non-local tachyons.

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[3] To see the locality of the infinite-velocity tachyon it is necessary to transform the coordinate system to another one. We shall consider the coordinate system moving with the co-linear velocity **V** , | **V** | < c . In this case the formula for the transformation of the velocity is simple **v'** = (**v** – **V**) / (1 – (**V**.**v** / c^2)) . For each velocity **v** , | **v** | > c , one can consider the new coordinate system with the relative velocity **V** = **v** . (c^2 / | v $|^2$) . We obtain that 1 – **V**.**v**/c^2 = 0 and then **v'** is infinite and collinear with **v** . This transform the finite velocity tachyon into the infinite-velocity tachyon and the inverse transformation transforms infinite velocity tachyon into the finite velocity one. For each infinite-velocity tachyon there exist coordinate systems such that the transformed tachyon has finite velocity and in this coordinate system it is localizable.

3. The particle model for the Higgs' condensate

Now we shall consider the particle model for the Higgs' condensate as a set of non-local tachyons. These massive non-local tachyons may have arbitrary form shown in the preceding section (v) (in general, they also can have non-linear trajectories).

We shall propose the simplest possible particle model for the Higgs' condensate. We shall use the following simplifications:

(i) We shall consider only "infinite velocity" massive tachyons, i.e. tachyons with $\mathbf{w} = \mathbf{0}$ having the trajectory

$$IVT(t_0) = \{ (\mathbf{x}, t) \mid t = t_0 , \mathbf{x} \in R^3 \} , \quad \text{where } t_0 \text{ is a parameter}$$

($IVT(t_0)$ = the trajectory of the infinite velocity tachyon at $t = t_0$.)

(ii) We shall assume moreover that these non-local tachyons will be separated by the same interval of time τ_0

$$\mathbf{C} = \{ IVT(k.\tau_0) \mid k \in \mathbf{N} \}$$

where $\mathbf{N}$ denotes the set of natural numbers and t=0 is the beginning of time in the standard model of cosmology.

The condensate **C** is the set of infinite velocity tachyons equidistant in time. The constant distance in time τ_0 is a universal constant of the model.

This is the simplest way how to represent the particle model of the Higgs' condensate. We shall call it the basic model for the Higgs' condensate. We shall use it, since it contains the basic ingredients of the particle model of the Higgs' condensate. We think that the main properties of the Higgs' condensate can be, in the lowest order, studied in this simplified model. In the next section it will be shown that the main feature – the anomalous diffraction – is present already in this model.

It is possible to consider the slightly more general model in which tachyons have still the infinite velocity (i.e. $\mathbf{w} = \mathbf{0}$) but times when these tachyons occur are not equidistant. We shall suppose that there are times moments $0 < t_1 < t_2 < \ldots$ in such a way that the distribution of times is governed by the Poisson distribution.

Then the condensate will have the following form

$$\mathbf{C} = \{ \, IVT(t_k) \mid k \in \mathbf{N} \, \}$$

where $\{ t_k \mid k \in \mathbf{N} \}$ is the sequence of times discussed above.

This is the situation which we shall call the Poisson model of the Higgs' condensate. Up to now we have two models, the basic one and the Poisson one. Both models use the non-local tachyons with the infinite velocity.

We shall assume that standard particles will be scattered by non-local tachyons from the Higgs' condensate, but that between two such scatterings they will move linearly (the first Newton's law). The form of the interaction between the standard particle and the non-local tachyon will be described below.

Thus we shall assume that

(i) Standard particles are scattered by the non-local Higgs` tachyon
(ii) Between two scatterings particles move linearly (this is the first Newton's law).

4. The anomalous geometrical diffraction and the time-like two hole experiment

There is a basic two-slit experiment in our model for the Higgs' condensate. But this is the time-like two-slit experiment (in the contrast to the standard space-like two-slit experiment) which gives the anomalous diffraction. The standard two-slit experiment will be referred as the space-like two slit experiment, which describes the typical quantum interference.

The idea of this time-like two hole experiment was presented in [6] and then in [7] and [9]. There are two holes, but they are in such position that the particle has to go through both holes – one after the other. This situation is clear from the diagram. A motion of particles is directed in the direction of the axis x. each particle must pass through the first hole and then through the second hole and only after this it can arrive at the screen.

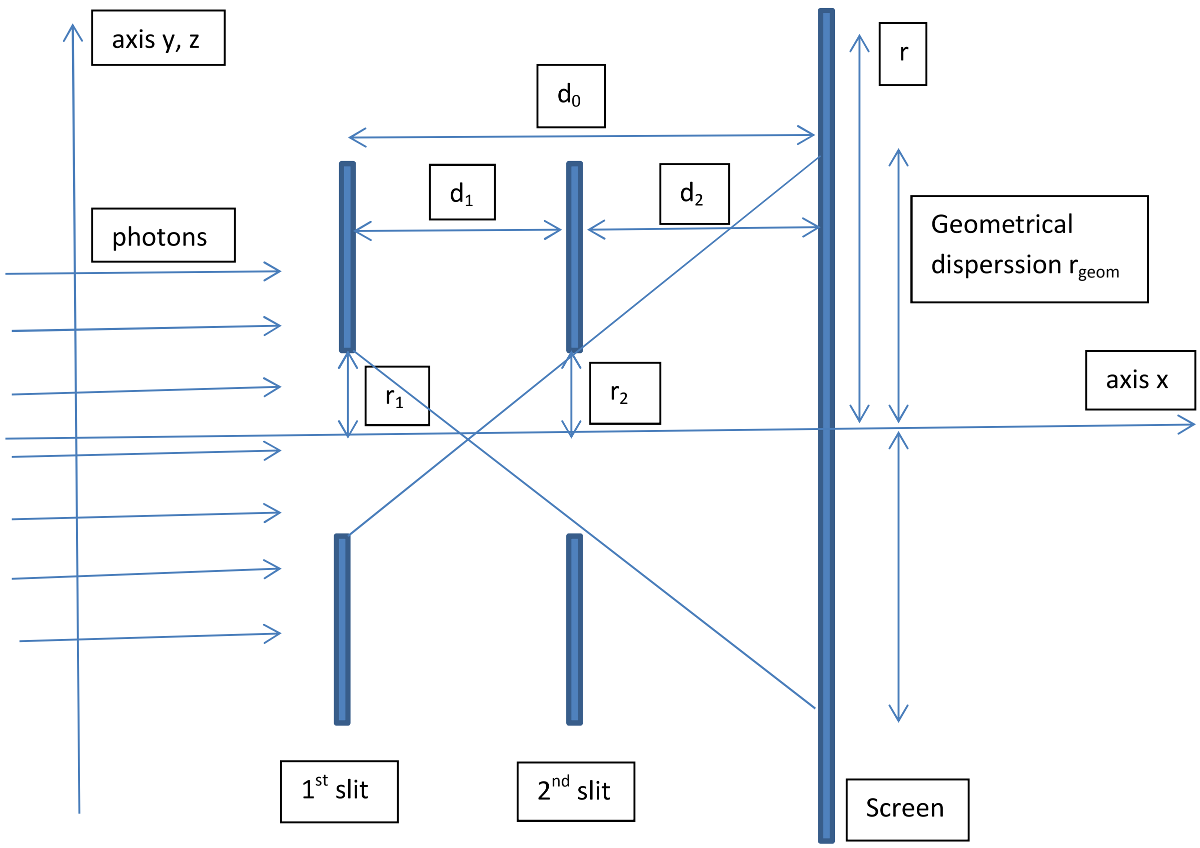

Diagram 1.

Let d_0 be the distance between the first slit and the screen. We shall consider this time-like two slit experiment done with photons. Then the time when the photon is inside the apparatus is

$$t_0 = d_0 / c.$$

If the time t_0 is bigger than τ_0 , then each photon will be scattered with some non-local tachyon during its passage in the apparatus and then after the scattering its trajectory will be unpredictable. The expected distribution of photons at the screen will be similar to the standard quantum mechanical distribution for the diffraction.

If, on the other hand, the time t_0 is smaller than τ_0, then some photons will be scattered (by some non-local tachyon from the particle model for the Higgs' condensate), while others will not be scattered. In the case when the photon will not be scattered with some non-local tachyon then its distribution will be the geometrical diffraction (we have assumed that between scatterings with non-local tachyons the photon moves linearly). In the case when the photon will be scattered the resulting distribution will be similar to the standard quantum mechanical distribution.

The probability of the first case (the photon is not scattered) will be $(1 - t_0/\tau_0)$, while the probability of the second case (the photon is scattered) will be t_0/τ_0.

Thus, in the case $t_0 < \tau_0$ the resulting probability distribution on the screen will be the weighted sum of considered distributions

$$f(r) = t_0/\tau_0 \,.\, f^{QM}(r) + (1 - t_0/\tau_0) \,.\, f^{geom}(r)$$

where $r = (y^2 + z^2)^{1/2}$, f^{QM} is the standard quantum mechanical distribution and f^{geom} is the distribution of the geometrical diffraction.

Our main result: in the situation when d_0 is sufficiently small one can expect the anomalous geometrical part of the diffraction in the time-like two holes experiment.

Let r_1 is the radius of the first hole and r_2 is the radius of the second hole. Let the distance between holes is equal to d_1 and the distance between the second hole and the screen be d_2 and let us suppose that these two distances are the same $d_1 = d_2$. Then the support of the geometrical distribution f^{geom} will be the ring at the screen with the radius $r_{geom} = r_1 + 2r_2$ and the intensity of the flow of photons through this ring will not depend on the wave length of photons.

On the other hand, the intensity of f^{QM} inside the ring in the screen with the radius $r_{geom} = r_1 + 2r_2$ is small when the wave length of photons is sufficiently large (this intensity depends on the wave length of photons).

This is result of this paper: there is a non-zero intensity of the geometrical diffraction in our model non-depending (presumably) on the wave length of photons, while in quantum mechanics the total intensity through the above ring must go to zero when the wave length is large.

Now we shall describe this result in more quantitative terms. We define the ring D_r in the screen by

$$D_r = \{(x,y,z) \in \text{screen} \mid (y^2 + z^2)^{1/2} < r\}$$

Then we denote the number of photons passing through both holes and the ring D_r during the time interval $[t_0, t_0+T]$ by

$$N(t_0, T, d_1, d_2, r_1, r_2, r, \lambda)$$

This quantity can, in principle, depend on t_0.

Here λ is the wave length of used photons, r_1 is the radius of the first hole, r_2 is the radius of the second hole and r is the radius of the ring in the screen.

Then we define the intensity by

$$I(t_0, d_1, d_2, r_1, r_2, r, \lambda) = \lim_{T\to\infty} (1/T) \,.\, N(t_0, T, d_1, d_2, r_1, r_2, r, \lambda) \,.$$

Clearly this intensity does not depend on t_0.

Then the relative intensity is defined by

$$R(d_1, d_2, r_1, r_2, r, \lambda) = I(d_1, d_2, r_1, r_2, r, \lambda) \,/\, I(d_1, d_2, r_1, r_2, \infty, \lambda) \,.$$

This relative intensity shows which part of the total diffraction is ended in the disc D_r.

Now we shall also consider the same quantities but in quantum mechanics: N^{QM}, I^{QM}, R^{QM} which depend on the same parameters as N, I, R. These quantities can be calculated in QM.

The relation between our model and the standard quantum mechanics is given by the fact that the standard quantum mechanics is obtained when τ_0 goes to zero. But there exists a more interesting relation between our subquantum model and the standard QM.

Schrodinger equation in QM is first-order in time, i.e. the evolution depends only on the present state of the system. This implies that the relative QM-intensity does not depend on d_1 (assuming $d_1 > d_2$) and it also does not depend on r_1 (assuming $r_1 > r_2$). Thus

$$R^{QM}(d_1, d_2, r_1, r_2, r, \lambda) \approx R^{QM}(d_2, r_2, r, \lambda)$$

Assuming that $d_0 = d_1 + d_2 >> c.\tau_0$ one can expect that the subquantum model will be approaching the standard QM

$$R(d_1, d_2, r_1, r_2, r, \lambda) \approx R^{QM}(d_2, r_2, r, \lambda)$$

This shows that if $d_0 < c.\tau_0$ then the behavior of our model is not first-order (the evolution depends not only on the present state but also on the previous history) while if $d_0 >> c.\tau_0$ then the evolution is first-order and the influence of the history is vanishing. This conclusion was already obtained in [6].

Thus the main feature of our model is the fact that τ_0 is non-zero.

Our main prediction means that there is a non-trivial geometrical diffraction. This may be expressed in a way that there exist d_1 , d_2 , r_1 , r_2 , r , λ such that

$$R\,(d_1 , d_2 , r_1 , r_2 , r , \lambda) > R^{QM}\,(d_2 , r_2 , r , \lambda)$$

We can define the anomalous geometrical diffraction by

$$R^{anom}\,(d_1 , d_2 , r_1 , r_2 , r , \lambda) = R\,(d_1 , d_2 , r_1 , r_2 , r , \lambda) - R^{QM}\,(d_2 , r_2 , r , \lambda)$$

and then the above condition transforms into the condition

$$R^{anom}\,(d_1 , d_2 , r_1 , r_2 , r , \lambda) > 0 .$$

This formulas show clearly that our model is **strictly different** from the standard quantum mechanics if $\tau_0 > 0$ and it approaches the quantum mechanics when $\tau_0 \to 0$.

In the paper [7] this effect was called the concentration effect – this means that photons are more concentrated in the central part of the screen than in the QM case.

5. The dark energy conjecture and the estimate of the time constant τ_0

Now we come to the second main topic which is the estimate of the time constant τ_0 which is a parameter of our model. To find some estimate it is necessary to relate this constant of the model to some real physical phenomena. To do this we need some conjecture. This is related to the concept of the dark energy created in the cosmology.

Dark energy conjecture:

Our model for the Higgs' condensate is the model for the dark energy. I.e.

- **(i) The particle representation of the dark energy is the set of non-local tachyons**
- **(ii) These non-local tachyons are the bare Higgs' particles from the Higgs' condensate**

Let us immediately remark that our model of the Higgs` condensate fulfils the basic requirement that the dark energy is everywhere in the universe and it is not localized: this is the direct consequence of the fact that our particle model for Higgs` condensate is composed from the non-local massive tachyons with the zero tachyon velocity **w** = 0 .

Let us remark the following: it is clear that our model for the Higgs' condensate is non-relativistic. But the standard limit of the model ($\tau_0 \rightarrow 0$) goes to the standard model of quantum mechanics which is relativistic (see Sect. 8) and thus for the time interval much greater than τ_0 predictions of our model are close to predictions of the standard model (see Sect. 8).

The breaking of the relativistic symmetry in our model is not created by the theory but by the distribution of the matter (in fact, the distribution of non-local tachyons from the Higgs's condensate) in the universe. Thus this breaking of the relativistic symmetry is the spontaneous symmetry breaking created by the real distribution of the mass in the universe. The recovery of the relativistic symmetry in the limit $\tau_0 \rightarrow 0$ is clear, mainly from the Feynman integral described below in Sect. 8.

For us this conjecture is extremely important since it is then possible to estimate the density of the Higgs' condensate.

We know already that the density of the dark energy is (approximately) 25 larger than the density of the standard mass. This means that the dark energy density is approximately one order greater than the standard energy density.

Now we shall also assume that the distribution of the energy into particles will be similar for standard energy and for the dark energy. This make possible to estimate the constant τ_0 from our model.

Let us choose the space unit δ_0 in such a way that the density of the standard mass will be such that it gives (in the mean) the one standard particle in the volume of the dimension δ_0^3.

Now we can estimate the value of δ_0. It is known that the approximate value of the baryonic mass density is (approximately) one baryon in the meter cube in the universe. But there are many other particles different from baryon (photons, neutrinos, leptons etc). We would like to estimate that there are, say, 10^{12} particles in the volume of meter cube. This implies that we can take $\delta_0 = 10^{-4}$ meter = 100 microns. The corresponding value of $\tau_0 = \delta_0 / c$ will be of the order $\tau_0 \approx 10^{-4} * 10^{-9}\ \delta_0$ second = 10^{-13} second = 100 femtoseconds (we set approximately $c = 10^9$ meter/second). If one considers the situation with $\delta_0 = 10^{-5}$ meter = 10 microns then we obtain $\tau_0 \approx 10$ femtoseconds.

Thus our estimate is

$$\tau_0 \approx 10 \text{ femtoseconds .}$$

This corresponds to the value of δ_0 that will be (approximating $c \approx 10^{-9}$ meter/second)

$$\delta_0 = 10 \text{ microns.}$$

To make the proposed time-like two holes experiment with the parameter

$$d_0 = d_1 + d_2 \approx 10 \text{ microns}$$

is (in principle) possible.

Our proposed experiment:

To do the time-like two holes experiment with d_0 of the order 10 microns and $r_1 = r_2$ of the order 5 microns and to look for the anomalous geometrical diffraction.

6. The interaction between the standard particle and the Higgs' non-local tachyons and the physical Feynman integral

We assume that the standard particle moves linearly between moments of the scatterings with non-local tachyons from the Higgs' condensate. This piece-wise linear trajectory will be parametrized by positions at times of scatterings (plus the initial and final moment of time)

$x_0=x(t_0)$, $x_1=x(t_1)$, … , $x_{n-1}=x(t_{n-1})$, $x_n=x(t_n)$, denoted as $\{x_0, x_1, \dots, x_n\}$

where $t_0 \in [\, s\tau_0 , s\tau_0 + \tau_0)$[4] , $t_n \in (\, (s+n-1)\, \tau_0 \,,\, (s+n)\, \tau_0\,]$ for some s and n and then $t_k = (s+k)\, \tau_0$, $k = 1, .., n-1$.

The corresponding velocities are $v_k = (x_{k+1} - x_k) / \tau_0$, $k = 0, \dots, n$, i.e. $x_{k+1} = x_k + v_k \tau_0$.

In the interaction with the non-local tachyon the velocity of the standard particle is changed. The velocity is changed in such a way that the resulting new velocity will have the uniform probability distribution independent from the preceding velocity

$$\Pr [\, v_k \in (v, \Delta v) \mid v_{k-1} \,] = \alpha\, \Delta v \ , \quad v \in R, \ \ \Delta v > 0, \ \ \alpha > 0 \, .$$

Probability distribution of the position will be

$$\Pr [\, x_{k+1} \in (x, \Delta x) \mid x_{k-1} \,,\, x_k \,] = (\alpha/\tau_0)\, \Delta x \quad , \quad x \in R, \ \ \Delta x > 0, \ \ \alpha > 0 \, .$$

This type of interaction will be called the Feynman interaction since this interaction is the base of the Feynman integral. Then we obtain for the propagator Prop $(x_0, t_0 \,;\, x_n, t_n)$ the standard formula

$$\int \exp i\, A\, (\{x_0, x_1, \dots, x_n\})\, dx_1 \dots dx_{n-1}$$

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[4] $x \in [a, b)$ means that $x \geq a$ and $x < b$.

where $A(\{x_0, x_1, \ldots, x_n\})$ is the standard action for the piece-wise linear trajectiory $\{x_0, x_1, \ldots, x_n\}$.

In this way we have obtained the physical Feynman integral as a result of the Feynman interaction of a particle with the non-local tachyons from the Higgs' condensate. We call this formula the physical integral since it is a result of a concrete physical process and not only certain mathematical formula.

This physical Feynman integral is finite, since the time step $\tau_0 > 0$ is fixed. The mathematical Feynman integral is obtained as a limit $\tau_0 \to 0$. In this way we obtain that our subquantum theory converges to the standard quantum mechanics if $\tau_0 \to 0$.

Thus in the limit $\tau_0 \to 0$ we obtain the standard quantum theory.

But we have obtained much more:

- We have obtained the physical base for the standard quantum theory
- The fixation $\tau_0 > 0$ makes the (infinite) renormalization theory not necessary – of course, there may exist a finite renormalization procedure, but the infinite renormalization is not needed
- The terms of the first order in τ_0 will be the subquantum corrections to the standard quantum theory

7. The complete logical derivation of the proposed model

Our model was developed and analyzed above. In this part we shall give the almost pure logical derivation of our model. This derivation shows that our model is not an arbitrary invention but it is a result of the strict logical process. Of course, this means that this model is not only an interesting invention but it is an (almost) consequence of known facts and previous results.

(i) In papers [1] and [2] it was shown that Quantum Mechanics (QM) can be considered as an applied probability theory – but not the applied classical Kolmogorov probability theory but the applied new probability theory called extended probability theory ([1]). This implies that the wave properties can be attributed only to ensembles of systems while the particle properties can be attributed to individual systems (and in some cases also to ensembles). This means that every individual elementary quantum object must be considered as a particle.

(ii) From the form of the Higgs' Lagrangian it is clear that the bare Higgs` particles must be massive tachyons.

(iii) Bare Higgs` particles are not observed so there is only one possibility that the bare Higgs` particles are massive non-local tachyons (see the classification above) – non-local tachyons are non-observed but also non-observable, i.e. they can exist in arbitrary large number.

(iv) The particle representation of the Higgs` condensate must have a form of a set of non-local tachyons.

(v) The simplest possible particle model for the Higgs` condensate is the model proposed above in the Sect. 3 where non-local massive tachyons have the zero tachyon velocity ($\mathbf{w} = 0$) and they are equidistant in time.

(vi) The interaction between the standard particle (e.g. some photon) and the non-local tachyon is described by the concept of the "Feynman" interaction introduced in the Sect. 7. This form implies that the standard Feynman integral is a limiting case of our model when τ_0 goes to zero. The particle representation of the Higgs` condensate is considered as a background and the back reaction of the condensate is neglected.

(vii) The anomalous geometrical diffraction in the time-like two slit experiment is the direct consequence of the particle model for the Higgs` condensate. In fact, any $\tau_0 > 0$ is good. This implies that our model is different from QM.

(viii) The existence of a universal time constant $\tau_0 > 0$ is the consequence of the particle model for the Higgs` condensate.

Thus the sequence of logical arguments implies that $\tau_0 > 0$ and that QM is not true in such small time intervals. The basis of this argument is the priority of the particle representation, i.e. the quantization of the Higgs' condensate. This is our logical argument that QM is not an absolutely true theory. Briefly: the particle model of the Higgs' condensate *implies* $\tau_0 > 0$ and this *implies* that QM is not an absolute truth and should be replaced by the subquantum mechanics with $\tau_0 > 0$. In other words: the absolute validity of QM implies the impossibility of the discreteness (or the quantization) of the Higgs' condensate.

The estimate of the basic time constant τ_0 **needs** more assumptions, namely the Dark energy conjecture and other hypotheses concerning the structure of the dark energy. Thus the estimate of τ_0 cannot be considered as a purely logical consequence of the previous results.

Of course, the existence of the anomalous geometrical diffraction directly contradicts to QM. This implies that our model cannot be considered as a part of QM and must be considered as a sort of some subquantum theory. This is a logical consequence of (vii) and this conclusion does not depend on the value of the time constant τ_0 – it is sufficient that $\tau_0 > 0$.

(The fact that $\tau_0 > 0$ is the consequence of the granularity – quantization – of the particle model for the Higgs` condensate. In the standard model of the Higgs` condensate the dark energy is continuously distributed and $\tau_0 = 0$.)

We have shown that the main part of our model is a **logical consequence** of the previous results, but the estimate of the time constant τ_0 requires also other assumptions.

The other important consequence is the fact that the particle model for the Higgs' condensate can explain the **physical origin of the indeterminism** (randomness) of quantum mechanics. Thus the source of the indeterminism of QM is not the God, but the interaction with the non-local tachyons from the Higgs' condensate. Thus randomness of QM is not an axiomatic definition (as it is usually supposed) but a consequence of the physical state of universe, i.e. of the particle structure of the Higgs' condensate.

8. A brief history of non-local tachyons and of the anomalous diffraction

The concepts of the non-local tachyons and of the anomalous diffraction in the time-like two slit experiment were developed in a series of papers but in a slightly different form than in the present paper. We shall describe the relation of these previous papers to the present paper.

- The first publication on non-local tachyons was [4] in 1979 where the starting point was the QM based on real quaternions instead complex numbers. There was shown that such QM should describe tachyons and it was also shown that the classical approximation of these tachyons must be described as hyperplanes from Sect. 3 (v). This was the first appearance of the idea that the trajectory of a freely moving tachyon should be the 3-dimensional hyperplane and not the 1-dimensional line.
- The second paper on non-local tachyons was [5] in 1983 where more structure to the quaternion QM was given and the classical approximation was analyzed in more details. There was clearly stated that the classical tachyons should be described by hyperplanes (in general by the space-like 3-dimensional sub-manifolds in R^4).
- In the paper [6] in 1989 the structure of the background formed by non-local tachyons was used as an assumption. This was the first paper where the time-like two slit experiment was proposed and the hypothesis of the anomalous diffraction was proposed. The anomalous diffraction was considered inside (the quantum analog of) the Ornstein-

Uhlenbeck stochastic process which describes the more detailed version of the Brownian motion. In this process the phenomenon of the anomalous diffraction occurs.
- But the analysis of the Ornstein-Uhlenbeck process is much more complicated than the basic subquantum model proposed here. Nevertheless the time-like two slit experiment and the anomalous diffraction were for the first time proposed in [6], moreover the universal time constant was also introduced in this paper.
- In the paper [7] (2001) the originally linear theory developed in [6] (free systems without any interaction) was generalized to the non-linear theory containing the possible interactions. In many cases the effects proposed in [6] are in [7] mathematically (at least partially) analyzed.
- The time-like two slit experiment was fully described and analyzed in the paper [9] in 2004. There was proposed the more detailed form of this experiment.

9. Conclusions.

We shall divide this section into parts: starting points, conjectures, the proposed experiment, results and the discussion.

Starting points (hypotheses based on serious arguments)

- Non-local massive tachyons as a particle representations of bare Higgs' particles – see sect. 2
- The Higgs' condensate as a set of infinite velocity non-local tachyons equidistant in time – see sect. 3
- The interaction between the standard particle and the non-local tachyon as a Feynman's interaction (i.e. a base of a Feynman integral) – see sect. 7

Conjectures

- Dark energy conjecture: the proposed model for the Higgs' condensate is the model for the cosmological dark energy – see sect. 5
- The indeterminism of QM conjecture: the indeterminism as a consequence of the interaction of standard particles with the non-local tachyons from the Higgs' condensate – see sect. 8

The proposed experiment

- The time-like two holes experiment – see sect. 4

Results

- The particle model for the Higgs' condensate (sect. 3)
- The anomalous geometrical diffraction in the time-like two holes experiment (sect. 4)
- The dark energy conjecture and the estimate of τ_0 (sect. 5)
- The physical Feynman integral (sect. 7)
- The standard limit of the proposed new theory (sect. 7)
- The logical deduction of the fact that $\tau_0 > 0$ – this implies that QM is not absolutely true (sect. 8)

The discussion

- The basic input is the discrete (quantized) structure of the Higgs' condensate – instead of the continuous representation of the condensate in the Higgs' mechanism in the Standard model
- The second basic input is the idea of the Higgs'condensate as a set of infinite velocity non-local tachyons equidistant in time
- The third input is the dark energy conjecture saying that the Higgs' condensate represented as a set of non-local tachyons represents the dark energy – i.e. that the particle content of the dark energy should be represented as a set of non-local tachyons
- The forth input is the idea that all indeterminism of QM originates from the interaction of standard particles with non-local tachyons from the Higgs' condensate
- In general, we believe that the quantized (i.e. discrete) structure of the Higgs' condensate is an important element in quantum theory
- The estimate of τ_0 makes possible to think on real experimental testing of the existence of the geometrical diffraction

Main conclusions (as consequences of our assumptions):

- The particle model for the Higgs' condensate
- The existence of the time constant τ_0
- The existence of the anomalous geometrical diffraction in the time-like two-slit experiment
- Dark energy conjecture
- The existence of limits of the universal validity of QM given by $\tau_0 > 0$
- The "physical" Feynman integral with $\tau_0 > 0$

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