THE 'PRIMARY IDEAL OBJECT' MODEL OF PHYSICS AND IMPLICATIONS FOR MODELS OF SPACE-TIME, THE 'PHYSICAL VACUUM', AND THE 'BIG BANG'

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The view presented here is based on author's concepts of `**Primary Ideal Objects**' (**PIO**) and **'Nucleus of a Branch of Science'** (**NBS**). PIOs are the basis for *ontological* physical models of reality. The **NBS** defines the PIO (like a system of axioms of geometry defines concepts of point, line and other its primary concepts). This view is connected with the statement that the development of physics is directed by Euclidean geometry as a sample of *a theory,* rather than by Bacon's empirical *method*. We first look at the work of Galileo Galilee and Isaac Newton. They created the *main* structure of *the branch* of physics that has remained at the core of all subsequent modern branches of physics. The secret of our approach consists in finding the *common structure* for all branches of physics at the model level. The '*mathematical', 'model', and 'empirical'* strata are distinguished in this structure. From this point of view some of the concepts of modern cosmology are analyzed.

1. Introduction

Why is the question "**What is physics?**" so difficult to answer? One of the typical answers to this question was given by H. William Koch [1], director of the American Institute of Physics. His answer, like so many other serious attempts to answer this question, leads to an *operational description* of the activities and methods used by a physicist rather than defining the fundamental nature of *physics*. This substitute for a '*definition'* of physics leads to statements like: *'Physics is what physicists do'*. The same situation is true for chemistry and biology.

I think that the reason for all these difficulties lies in the empiricist's definition of science as being derived by the subject. The majority of scientists and philosophers look at physics through different empirical models of science, whose roots lie in the empiricism of F.Bacon with its standard sequence:

Empirical facts ➔ **Empirical laws** ➔ **Theoretical laws** **(1)**

which I will call the **"Standard Empirical View".**

By the end of the 18th century D. Hume and I. Kant had already showed that the last step is impossible from inside the empirical logic. There are some branches of science, which for some time didn't go any further than the **empirical laws** step**.** However, some well-advanced branches of science emerged from this stage to the stage of **theoretical laws**. Thus D. Hume's critique of the "Standard Empirical View" from the point of logic was repeated in 20th century by K. Popper and supported by A. Einstein. T. Kuhn, and others did a new critique from the point of view of the *history of science*. The "Standard Empirical View" is still alive even though many of its elements have been broken by the severe critiques from philosophers of science. The reason for such a situation is the absence of a good alternative.

2. The PIO Model View

I want to suggest an ***alternative*** "**model view**" of physics. I assert that the popular view that 'physics is mainly an experimental science', is an overstatement in the same way that theoretical physics is viewed primarily as mathematical physics. Of course physics cannot exist without experiment and mathematics, but theoretical *ontological* models actually define the face of physics. My analysis of the works of Galileo, Newton, Maxwell, and other creators of *new branches of physics* [2] shows that the development of physics is directed by **Euclidean geometry** as the fundamental prototype of a scientific theory (supplement with engineering relationship between main theoretical objects and empirical material), rather than by Bacon's empirical method.

There are two very important common features in **geometry and physics**:

1. The existence of **two types** of **ideal objects**
2. **a) `primary ideal objects' - PIO** (such as the points, lines, and planes in *geometry* and the particles, fields, etc., in *physics*) and;

   b) `secondary ideal objects' (such as polygons in geometry and models of phenomena in physics);

2. The existence of **two types of definitions:** primary ideal objects' are **defined implicitly** within *the system of basic concepts (**notions**) for a specific branch of science* and; ‘secondary ideal objects’ are **defined explicitly** with the help of the primary ideal objects’

I call the ***'Nucleus of a branch of science'*** (**NBS**) the *minimal system of notions and postulates that define the appropriate system of basic **concepts***. In geometry its analogue is the system of axioms of geometry. The `'primary ideal objects' are at the center of a given branch of physics such as classical or quantum mechanics, electrodynamics, Special Theory of Relativity, and so on. One can find a standard division of these branches in contemporary theoretical physics.

'Particles' in Newton' mechanics, electromagnetic field in Maxwell's electrodynamics, quantum particle (electron, photon, and so on are its realizations) in quantum mechanics are the examples of PIO. These **PIOs** are the main concepts of every branch of physics. All theories of any branch of physics (theoretical models of phenomena) are made of these 'bricks'.

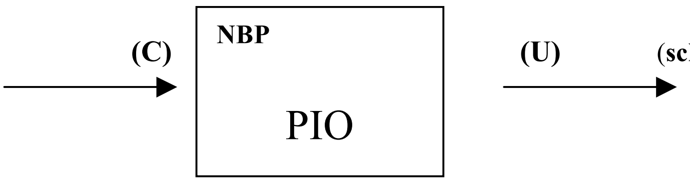
Historically the situation in physics developed in the same way as in geometry. After the appearance of non-Euclidean geometry, the initial or "primary" concepts of Euclidian geometry (such as point, line, and plane) became not obvious and began being defined **implicitly** within the system of axioms of geometry. In physics, Maxwell's electrodynamics played the role of non-Euclidean geometry.

Thus the "secondary" physical objects are defined through the "primary" physical objects explicitly. The most difficult task is to define the "primary" physical objects**.** We can do it **only implicitly** with help of ***'Nucleus of a branch of science'*** (this situation takes place in other sciences too)**.**

Before describing the ***'Nucleus of a branch of science' for physics,*** I want to say something about a very evident but yet important point. The **two types** of ideal objects **-- `primary' and 'secondary'** lead to the existence of **two types of work in science.** The **first** is the '**creative**' one (we designate it by **'C'**). It is the most interesting for us since it represents the creation *phase* of new "primary (fundamental) ideal objects» and, accordingly, a new branch of physics (or other science). It gives a **sense** to a new `primary ideal objects' (such as quantum particle or electromagnetic field).

The s**econd** type of work involves the ‘utilization’ of the PIO**.** This **'utilizing'** phase (we designate it on Sch.1 by '**U**') takes the newly created "primary (fundamental) ideal objects" and uses them for modeling-explanation and constructing-prediction of various natural phenomena. In the history of science these phases are fixed as various answers to the question: What is the goal of **science, "to explain" or only "to describe"** natural phenomena? For the most part the creators of new branches of physics—G. Galilee, J. Maxwell, N. Bohr, and A. Einstein (in his early work) proclaimed the "*descriptive*" approach.

There is nothing absolutely new in such distinction. It is common to both *A. Einstein’s division* on **`principle'** and **`constructive'** theories and *T. Kuhn's division* on **'anomalous'** and **'normal'** science. However usually in the analysis of science only the latter 'utilizing' case is considered. We will concentrate on the 'creative' phase.



(**scheme 1**)

The *'nucleus of a branch of physics’ has* a very clear structure common to all branches of physics. It consists of three parts: **preparatory (P), theoretical (T),** and **measurement (M)** (Sch.2)**;**

P	***T***	***M***

(scheme 2)

This scheme is very close to the one that Fock used in his dispute with Bohr for the description of experiment[i] [3]. The experiment requires a 'utilizing' phase and any experiment exists only in connection with the theory, without the theory one can say about an observation only. The theoretical part, **T**, consists of **mathematical** (**Math) stratum** and **ontology model (Mod) stratum** illustrated in ‘scheme 3’.

The latter includes the **physical system (A)** composed as a rule of one (the particle in Newton's mechanics) or two (charged particle and electromagnetic field in Maxwell's electrodynamics) primary ideal objects, and the **states** of the system (**S_A (t)**) at time t. There are external action **F** (external forces and so on), and an interaction between `primary ideal objects' in many-particle systems either. The whole structure gives the representation of **motion as a transition** *in time* from one state to another. 'Time' plays a special role and is different from the other measurable quantities (observables), though in thermodynamics its role plays temperature or other parameter.

(T):
Math: –EM–>
↑ ↓
Mod: $(F)S_A(t_1)$ $S_A(t_2)$

(scheme 3)

The transition in *time*[ii] from one state to another itself is defined with the help of the **Math-stratum,** which contains the mathematical representatives of the elements of Mod-stratum and the **equation of motion** (EM), which integrates all the elements of the Math-stratum and forms a mathematical representation of motion as a transition in time from one state to another. The equation of motion defines the dynamical or "**diachronical"** qualities of the system, and also its "**synchronical**" qualities (the range of states of the system).

I want to emphasize that **all these concepts are defined in common and implicitly!**

All the elements of the Model stratum must have a **realization in empirical material**. This is fulfilled with the help of the **preparatory** (P), and **measurement** (M) parts. The physical system and its initial state are created in the preparatory *part*. The measurement part contains the standards and procedures of comparison with it for every measurable quantity[iii] (e.g. distance, velocity, mass, etc.).

The very important feature of scheme 2 is the non-theoretical character of **P** and **M** parts. It is the comparison with a standard (gauge), not the interaction between a measured system and a device, that makes the essence of the measurement. The P-T and T-M borders can be moved, but the comparison with a standard cannot be removed. The standards are not the 'phenomenon' and 'subject' of the theory. The latter is a very important feature of the model. When one forgets this, then paradoxes arise like Schrodinger's Cat' or the 'reduction (collapse) of Wave Function' [4].

The 'secret' of this view consists in finding the common structure for all the main branches of physics at the model level. The various branches of physics (e.g. classical and quantum mechanics, electrodynamics, etc.) differ by the substance filling these mutually connected concepts: the physical system, its states, their mathematical images, the equations of motion, the 'measurement' standards and the procedures defining the measurement and preparation process. This approach gives an inconvenient view for 'understanding' the place of mathematics and measurement in physics. This is true especially for quantum mechanics, the theory of relativity and modern cosmology.

Returning to the question **"What is physics?"** we can say that the "model view" (described by schemes 1-3) defines the physics not through its subject, but throughthe **types of models**, which it uses. Thus physics is characterized by the **model of motion as a transition in time from one state** of physical system **to another** and by two **archetypical models**, which are used for making models **of `primary ideal objects'**. The 1st is a Newtonian model of particles in vacuum and forces. The 2nd is Descarte's model of a continuous fluid (the models of fields and waves are derived from it). This **model of physics** permits us to represent the fundamental ideas of all main branches of physics.

3. «The PIO Model View» and 'Understanding' in Physics»

The 'model view' gives an answer to another hard question. One of Heisenberg's papers was named [5] **«What is the concept of "understanding" in Physics?»** In this paper he discussed what the word "understanding" means in theoretical physics.

There isn't one simple answer. We can find many examples that speak in favor of the idea that **"understanding" in physics is constrained by the process of building of an ontological model**. Planetary motion, the turbulent motion of fluids, and superconductivity are all examples demonstrating that the feeling of "understanding" of a phenomenon appears after building an ontological physical model of the 'phenomenon'. The same idea can be seen in his statements: "We have understood a group of phenomena when we have found the right concepts for describing these phenomena". Or: "By constructing simplified models and by demonstrating that these models do show the characteristic features of the phenomena, we convince ourselves that the concepts are correct (e.g., in the theory of superconductivity), that we have "understood" the phenomena".

Based on such an understanding of "understanding" in physics, we absolutely disagree with popular statements like 'nobody understands quantum mechanics', which one can hear from very prominent physicists. We suppose, that the reason for such a lack of understanding is the usage of **inadequate** for the description of quantum phenomena using classical **notions**. The *incomprehensibility* of certain quantum phenomena from a classical viewpoint becomes evident in paradoxes such as the "wave-particle dualism" arising in descriptions of quantum mechanical phenomenon (e.g. movement of electron) using the classical language of particles and waves. Particles and waves are in fact *alternative concepts* in classical physics. The same kind of situation arises if one attempts to describe electromagnetic waves with the concepts of Newtonian mechanics. If one could describe new phenomena within the framework of older concepts, then why should we make a new branch of physics?

The *incomprehensibility* in abstract descriptions of nature is the starting point for the physics of 20th Century[iv]. The *incomprehensibility* can be transformed into a new PIO and new branch of Science (which establish a context for the PIO) after some complex theoretical work is done. In 1925-1926, the "wave-particle dualism" in the formulations of A. Einstein and L. de Broglie was such a starting point for the transformation of *incomprehensibility* into a 'comprehensible' new PIO – the 'quantum particle', [2, 6].

Let's consider how we *define* our "understanding" in various branches of physics using the ***concept of a particle*** for example. What does one need to know in order to 'understand' what is meant by a 'particle' in classical Newtonian mechanics or in the relativistic mechanics of Einstein or in non relativistic quantum mechanics? What are the number of questions that need to be answered before an 'understanding' can be formed? Why is the concept of a 'particle' in quantum mechanics so fundamentally different? We suppose that the '*understanding'* of fundamental concepts such as the 'particle', is connected with the *depiction* of an ontological physical model.

This 'depiction' is formed by the *answers* to three main questions:

1) what are states of a particle?

2) what is a **'type' of motion** of the particle (e.g. what are the mathematical images of a particle and its states and the *'equation of motion'*)?

3) what are ***measurable quantities, standards and measurement procedures?***

The 'answers' to these questions give ***implicit definitions*** of the particle.

1) A ***particle*** is characterized by its ***state 'type'***. The state is given by the values of its spatial 'location' (or 'position'), $\boldsymbol{x}$, and it's momentum $\boldsymbol{p} = m\boldsymbol{v}$ (for particle mass, **m**, with velocity, v) at a given *time* 't', in Newtonian and relativistic mechanics. In quantum mechanics it is characterized by the distributions of the *probabilities* of values of these (and/or other) *parameters* while taking into account the property of the *complementarity* (in the sense defined in [4]).

2) The **'type' of motion** of the particle is characterized by the *'motion equation'* (e.g. 'classical' (Newton), 'relativistic' (Einstein), or 'quantum' (Schredinger)) which is connected to a physical system (object) and its states through their mathematical images. These images are represented by the '*Lagrangian*' or '*Hamiltonian*' **for the system** in 'classical' and 'relativistic' mechanics, the '*Hamiltonian operator'* in non relativistic quantum mechanics; wave function or pair (x,v) **for states** in quantum and classical or relativistic mechanics)

3) The measurement procedures differ for the three branches of mechanics. They are based on the concept of invariant **hard body** (e.g. the 'standard meter') in classical mechanics, an invariant '**hard' velocity of light** in relativistic mechanics, and on **Born's postulates** in quantum mechanics (see [4]).

4. Epistemological Context of the "Model View"

The PIO model view leaves some epistemological questions about PIO's origin open. These are concerned with the relationship between 'theory' and 'reality' in physics.

At the end of the 19th century we find two popular opposing viewpoints about this relationship. Max Planck formulated them during his debate with the followers of E. Mach. He said: «What is in fact the physical picture of the Universe? Is this picture an expedient, but essentially arbitrary, creation of our intellect, or should we accept that it reflects real, observer independent, natural phenomena?»

Planck believed that the outside world is something independent from us and that the phenomena confronting us are 'absolutes'. These absolute elements (meaning universal constants and related laws–A.L.) are independent of any human or other thinking entity, and is what we call reality. Copernicus, Kepler, Newton, Huygens, Faraday, ... all based their investigations on a firm belief in the reality of their picture of the Universe.... This answer is to some extent in contradiction with the tendency in natural philosophy promoted by E. Mach, which is presently very popular with natural scientists. He believed—said Planck—that … any study of nature is, in the long run, only an economic accommodation of our thoughts to our sensations» [7]. The *'constructivism'* of E. Mach was a variant of answer to Hume's critique of the **"Standard Empirical View" (1).**

Today these positions are named **'realistic empiricism'** (or 'science realism') and **'constructive empiricism'** [8]. Briefly the first supposes that the result of scientist's work is the **discovery** of 'something unknown', which already exists in Nature (similar to the discovery of new lands in Geography). Their aim is to find the **'truth'**, which is understood as the '*correspondence to facts'* independent of scientists' activity (i.e. theoretical concepts are looked as 'facts' existing in Nature independent of scientists' activity). The **'constructive empiricism'** supposes that the result of scientist's work is not discovery but **invention**. Accordingly they put some form of **effectiveness** as a criterion for choosing among different theories (e.g. Mach's 'economy of thinking').

It seems to me that it is important to distinguish between two pairs of oppositions: 1) **realism (**which stands on discovery and truth) and **constructivism (**which stands on invention and effectiveness) on one hand and 2) **rationalism** (which begins with ideas) and **empiricism** (which begins with observations) on the other hand.

The majority of scientists and philosophers are empiricists and stand on these two variants. But 'empiricism' cannot decide some fundamental epistemological problems [2]. On the other hand, analysis of the 'logic' involved with the creation of a new branches of physics, demonstrates that a **constructivist alternative** [2, 6] is possible.

We can see it in creation of Galileo' s theory of falling bodies. If we look at his original texts, we'll find, that his arguments were not generally based on empirical observation (as F. Bacon taught), but on his theoretical belief that «*nature* tries to use the simplest and the easiest means in all of its devices... Therefore, when I note that a stone set in motion and falling from a considerable altitude acquires more and more velocity, should not I assume, - he continues, - that this increment takes place in the simplest form? If we examine the phenomenon more closely, we will find that there is no simpler incrementation than *uniform...»* [9]. Galileo's physical reasoning is well demonstrated in his long digression «about bodies falling in vacuum» on the «first» day of his *Discourses* and in the problem of a thrown body (the «fourth» day). First of all the law of motion is presented, namely, that bodies fall at a constant acceleration (on the "third" and "fourth" days, and they fall at equal velocities on the "first" day), and as a result of mental experiments, the three aspects of the process are separated, viz., body, vacuum, and medium. The concept of body is invariable (evidently because the moving stars, which had been discussed by astronomers since ancient times, have clearly defined images), and the elements of the physical model to be formed are a vacuum and a medium (while Aristotle's medium is the source of motion, Galileo's medium is the cause of deviation of real motion from the ideal one he introduced). In fact, Galileo introduced the vacuum as the ideal medium, in which the 'ideal' and the 'real' fall of a body is the same. Then he looked at this model like an **engineer** at a project and linked his vacuum to the real material by introducing such `structural elements' as smooth ramps and other structural components. Thus Galileo introduced an **engineering approach** into physics via his *Discourses*[v].

We call our philosophical position the **«constructive rationalism».** This theme goes through **Galileo and Newton** up to modern physics, and it is opposite to the track of the modern philosophy of science originating in the ideas of **F. Bacon**. It is constructive on the phase of the creation of new primary ideal objects, but doesn't differ from the realistic one in its use since primary ideal objects are artificial, but real (as bricks, of which the buildings are made) (see [2, 6][vi]).

5. Model View of Relativistic Gravitation Theory[vii]

Let's look through the model view at the theories of Einstein and two of its alternatives: the 'gravitation field' (Logunov et. al.) and the 'ether'.

<u>Einstein's theory of gravitation</u>

Einstein's **model** of curvature of space-time is the extension of his special theory of relativity. Two things were changed in **special theory of relativity** (STR) in comparison with classical physics. The **first** is the change in the main 'length' standard. The 'hard' *velocity of light replaced the 'hard' meter*. As consequence it leads to a relativity of simultaneity, distance, and time intervals. The **second** change is in the form of the equation of motion (EM). It is distinguished with the help of a method, which we call the *"starting classical system"* method. It is widely used in 20th century physics (in quantum mechanics and statistical physics [2; 4]).

According to this method the classical Lagrangian is constructed for the **'starting'** classical model of bodies (particles), then after a procedure, which uses Einstein's postulates, the classical Lagrangian is transformed into the non-classical Lagrangian.

$$\begin{array}{ccc} L_A^{cl} & \longrightarrow & L_A^{noncl} \\ \uparrow & & \uparrow \\ A^{cl} & & A^{noncl} \end{array} \qquad \textbf{(scheme 4)}$$

Thus, the non-classical mathematical representation is confronted with the **starting** classical system. As a result, one gets the transformation of the classical model into a non-classical one (with non-classical behavior) through the mathematical stratum indirectly.

As a result we can state that no radical changes occur in the 'model stratum' (Scheme 3) for the special theory of relativity in comparison with the classical one (in contrast to quantum mechanics with its 'complementarity principle' [2, 4]): there are the same particles and its states, but the ‘movement’ character changes radically.

Really, how is a particle or field characterized in our 'model view'? The characterization is done by specifying the ‘states’ associated with the particle or field. This state can be given by ‘position’, ***x,*** and ‘momentum’, ***p,*** for particles (or by the values of the magnetic, ***H,*** or electric, ***E,*** fields for the electromagnetic field). They are the same in Newton's and Maxwell’s ‘classical’ physics and in Einstein's ‘relativistic’ physics. But the particle’s ‘movement’ or ‘trajectory’ is ruled by different equations of motion depending on whether a ‘classical’ (Newton&Maxwell's) or ‘relativistic’ (Einstein's) description is required. As a result the same particles (bodies) and electromagnetic field move in classical and relativistic physics in the same phase space, but with different way of changing their states (motion) ruled by different motion equations.

That's why we can say that **Minkowski's 4-dimensional space-time is a form of the mathematical representation** in Math-stratum connected with the relativistic **motion equation**. H. Reichenbach was right when he suggested that the famous statement by Minkowski, «that after Einstein's special theory of relativity one cannot speak about space and time separately», was wrong. This is a surprise for the majority of physicists who were taught that SR, with its great emphasis on Minkowski's space-time, is the real *physical theatre*[viii].

The SR is the basis for the Einstein's next step, which is the General Theory of Relativity (GTR). He introduced a new description of **gravitation** using the *curvature of space-time* instead of Newton’s *gravitational force*. But what is this the *curvature of space-time?* Is it a new ontological model or a mathematical object?

The **model of force (or field)** rests on the idea of a "natural ("free") motion" of a *test body* and of the "departure" of the test body from this "natural motion". Then ‘force’ (or field) appears as the *source or cause* of this departure in the motion of a particle.

Einstein's model of the curvature of space-time can do without introducing the idea of "departure" of the ‘natural motion’ of a test particle, and hence of a related field. It can deal with the ideas of complicated "natural" motion of the test body in the presence of massive bodies (and energies) directly. The famous **geodesic** in the 4-dimensional space-time of Riemann with the alternating curvature (which is a function of the mass-energy distribution in space-time) is the *mathematical image* of this complicated "natural movement" of a body.

What is a *gravitation field* in GTR? We suppose that there are two different concepts of gravitation field. The *first* is the *field of curvature of space-time* (or metric tensor). This field is the departure of plane ('flat') 4-dimensional Minkowski space-time. The *second* is "*Newton-Maxwell" force field* which is a union of Newton's concept of gravitational force and Maxwell's concept of short-range action via a field. Physicists, working in GTR, often take the first one as gravitational field. We suppose that it is only a mathematical image of the second. This is a result of analysis of the formulation and type of solutions to problems specifically related to experiment, the analysis which is concentrated on the P-T and T-M borders of scheme 2. Everything that belongs to the model stratum is revealed then.

The entire procedure is outlined as follows. One begins with a ***starting*** classical system of chosen bodies (or condense matter) and massive bodies and energies as sources of gravitational field in ordinary 3- dimensional space in a moment of ordinary time. Next one constructs a corresponding *mathematical image* of it in the GTR, i.e. in the language of Riemann's 4-dimensional space-time to get the corresponding equation of motion. **The result is always represented in the language of the motion of bodies and fields in ordinary 3-dimensional space** as functions of ‘ordinary’ time. This is the demand of the *'nucleus of a branch of science'* of GTR where the *state* of a body is characterized by the usual 3- dimensional values. The state of gravitational field is defined through accelerations and its spatial derivatives in 3- dimensional space. Thus the type of the system is like in electrodynamics.

This moment was finely fixed in the question posed by S. V. Mein (noted Russian biologist with a very wide range of interests) to the participants of one astrophysical conference: "**You are all very well to discuss all of your questions in 4-dimensional space-time, but why in the beginning and in the end do you always talk about stars that are some parsecs away at some given time?**" We find the same situation in descriptions of specific GTR phenomena such as *gravitational collapse* and *gravitational waves*. Gravitational collapse is described as 'process of hydrodynamic compression under action of its own gravitational force' in *ordinary space.* Gravitational waves are described as an 'alternating gravitation field, which is radiated by moving with acceleration masses … like electromagnetic radiation' [10]. You can hear from the theorist that gravitational waves are 'ripples of *curvature of space-time'.* But in the description of gravitational waves since the sources for these ‘waves’ one says about the motions of ‘classical’ binary star systems rotating in *ordinary space and time*. When one describes a ‘detector’ for these gravitational waves, it usually involves the relative motion of two 'classical' test bodies also moving in *ordinary space and time.*The statement that all measurements are to be expressed in classical language is a lame excuse, because there are procedures of measurement expressed in the language of 4-dimensional space-time of Riemann [11]. The potential of human language and thought to be very rich and the concept "classical" is changed with time. A bright example – history of concept of electromagnetic field. The same we'll say about the statement that 3-dimensional space images are approximation and simplification of complex real 4-dimensional space-time situation. It isn't an approximation because there are no limitations on accuracy. The relationship between **4-dimensional space-time and ordinary space and time** isn't the relationship between ontological model and its corresponding 'empirical' practices. It is the relationship between the mathematical image and the model image.

A source of the described above inconsequence (which is unnoticed by the majority of physicists) lies in putting equality between Einstein's *curvature of space-time* and of *curvature of ordinary space* as in Clifford's natural philosophy model.

In 1876 the prominent mathematician, V. Clifford, announced a new model (naturphilosophy program) based on the *curvature of ordinary space* instead of forces and particles [12]. It was seen as ontological program. But the intent of this novelty was directed at the struggle with the idea of the *material ether.* If we compare it with models of fields after Maxwell, which suppose no material substance, then the difference between field and Clifford's *curvature* model begins to disappear. Both of them are based on some "departure". This is represented by the "departure" of the test body from the "natural motion" (in the model of a field), and the "departure" of 'flat' Euclidean space, which is called the *curvature of space*. The latter "departure" (of *curvature of space) can be easily* interpreted as a field of some known or unknown "force". Through it the gravitational wave is the movement of such curvature of space and vice versa. Clifford's model had no obvious advantages over the field models and was forced out by the latter.

Thus we suppose that serious changes in STR and GTR take place in measurement procedures and equations of motion. There are no radical changes in the ontological model which remains the same as in classical physics where the motion of an object in ordinary space and time along with the concept of 'acceleration' as a departure of 'natural' 'free' movement is 'caused' by a force field. The '*curvature of space-time'* exists in mathematical stratum as mathematical image of "Newton-Maxwell" gravitational field model.

We suppose that P. Marzkes' '*project of a direct mesurement*' in the 4-dimensional space-time of Riemann [11] confirms our idea of **'*curvature of space-time'*** in modern physics as a **mathematical object only**. This method is highly speculative and difficult to realize experimentally. At this time it has not been realized anywhere as therefore cannot compete with simpler approaches using the 4-dimensional *curvature of space-time* as the mathematical image for the "Newton-Maxwell" gravitational field ontological model. This competition takes place because of principle of equivalence of frames of reference under acceleration and homogeneous gravitational field.

Though Einstein's GTR is the leader among relativistic theories of gravitation, it still has some serious problems and unanswered questions.

Some questions arise in connection with the Big Bang scenarios modeled with Einstein's theory of gravitation, such as the problem of the 'borders of laboratory' as well as the problem of specifying the proper procedures for any 'measurement' process.

Under the **problem of 'borders of laboratory'** I mean that an experiment as the basis of science of the New Age means artificial borders of a laboratory environment.

The borders may be very large but they do exist, and it is a principal moment. The 2^{nd} law of thermodynamics is defined on the working body of ideal heat engine which has borders. However, the Universe as a whole is principally without borders in this sense and we cannot be sure that the Universe doesn't need a new **Primary Ideal Object**' and new Branch of Science. Why do we suppose that it can be described by a set of 'laboratory' sciences such as thermodynamics, GTR (which is a generalization of classical mechanics), et al?

It seems to me that the concrete consequence of this general trouble manifests itself in one self-discrepancy, which can be seen in the scenario of the Big Bang. On one hand, the latter is based on the theory of relativity. The latter is based on the statement that one has to account for all the procedures of measurement in every physical theory. On the other hand, when we get closer to the 'singularity point' in the 'time-reversed' scenario of the Big Bang we have no atoms and nuclei. How does one define the procedures for the measurement of distance and time when you have no atoms and nuclei present?

6. Logunov's "Relativistic Theory of Gravitation"

Now let's look at **Logunov's "relativistic theory of gravitation**" (**RTG**) [13], which in his words combined "Poincare's idea of the gravitational field [14] as a Faraday – Maxwell physical field with Einstein's idea of a

Riemannian space-time geometry in the framework of the **special theory of relativity** (**STR**), which describes events both in inertial and in non-inertial reference frames.

This theory is fundamentally different from the Gilbert–Einstein equations since they retain the notion of an inertial coordinate system, and forces due to gravity are fundamentally different from those due to inertia, as the former are generated by a physical field… A question of physics proper… must be answered with the aid of experiment… but the question arises as to which experimental facts are necessary unambiguously to characterise geometry. I believe such facts to be the fundamental laws of energy – momentum and angular momentum conservation ... – Logunov says. It is precisely these facts that lead to pseudo-Euclidean space-time geometry as the simplest one. This means that in establishing the structure of the Space-time geometry, it is reasonable to proceed not from selected experimental facts (e.g. light propagation and test body motion) but from the basic physical principles deduced by generalising numerous experimental findings which characterise different forms of matter" [13].

"RTG is based on the special theory of relativity, which means that Minkowski space (a pseudo-Euclidean space-time geometry) is the fundamental space for all physical fields, including the gravitational field. This proposition is necessary and sufficient for the laws of conservation of energy – momentum and angular momentum to be valid for matter and gravitational field taken together". "According to this theory, a homogeneous and isotropic universe develops in a series of alternating cycles, from high to low density, and cannot be anything other than flat. The theory predicts the presence of a large amount of latent mass in the universe and prohibits the existence of 'black holes' (whose 'existence' hasn't had a direct 'experimental' confirmation as yet is not an established fact – A.L.). Also, the theory explains all observable events so far known to occur in the solar system." [13].

Logunov takes the laws of conservation as 'fundamental' in his RTG instead of Einstein's 'principle of equivalence' between inertial and gravitational masses. Why not? If we remember the logic of Newton's work, he created the laws of dynamics and the law of gravity together for one task: to create a theory from which all three Kepler's laws of planet's motion can be derived. Thus Newton's laws of dynamics and the law of gravity are intimately connected, and the proportionality between inertial and gravitational masses is its result. This proportionality in the models of gravity of Newton and Logunov doesn't mean Einstein's equivalence principle. For them "forces due to gravity are fundamentally different from those due to inertia" [13].

Thus the question is still open. "The special theory of relativity had a strong experimental background, among which the Michelson-Morley experiment was only a small element. This was not at all the case for the general relativity theory that is a synthesis of special relativity and gravitation. Among the possible hypotheses, Einstein has chosen some of the simplest but many other choices were also possible and various theories, among which that of Professor Logunov, are in competition with the general relativity." – said by Prof. C. Marchal at this Workshop in his resume of review of experiments on this subject [15]. The most part of physicists will not agree with him. The majority of physicists uses Einstein's theory of gravitation and get many results. Sometimes they compare their results with results of alternative theories [16] to show their absolute superiority. Of cause today Einstein's theory of gravitation is more "progressive" "investigation program" (in I. Lakatos's terms) but who knows the future?

7. Ether Theories

It is interesting to note that an **Ether Theories of Gravitation** can be built, which is compatible with some of the most important current experimental facts, perhaps even with all of them [17]. The starting point for these Ether Theories is the "*Lorentz-Poincare ether theory*". In this theory, "the ether is an *inertial frame* in which Maxwell's equations are valid and such that any material object in this frame undergoes a 'real' Lorentz contraction if it *moves* through the ether….

The Lorentz-Poincare ether theory may be criticized only for the very reason that makes it physically equivalent to standard special relativity, namely the indetectability of the ether: thus, any inertial frame may be indifferently choosed as the ether. This may lead to Einstein's 1905 opinion, according to which "the introduction of the luminiferous ether will insofar appear superfluous". But special relativity does not involve gravitation. Therefore, the experimental support of special relativity does not, as such, provide much constraint on the theory of gravitation: one may define a very large class of "relativistic" modifications of Newton's gravity, by the condition that any of them should *reduce to special relativity when the* gravitational field cancels… If one defines in this way the "relativistic" character of a theory of gravitation, nothing forbids that a such theory may have an *a priory* privileged reference frame – thereby violating not only the explicit form of the principle of relativity…, but its very spirit" [17].

The *physical reason* to search for such an "ether theory of gravitation" comes from a number of *motivations*. The first is the wish to reconcile quantum physics with the theory of gravitation («quantum mechanics and quantum field theory were built in *flat space-time* which requires a preferred time coordinate» [17]). «Moreover, quantum theory shows that what we call "*vacuum*" is endowed with physical properties (cf. the 'Casimir effect', …), thus making some form of 'ether' likely» [17]. The second is the desire to resolve the difficulties in General Relativity such as; (i) the singularity occurring during gravitational collapse and (ii) the need for '*dark matter'* in order to explain the peculiar motions of stars in galaxies.

In the Ether Theory of Gravitation [17]: "The gravitational force is tentatively interpreted as Archimedes' thrust in the fluid ether" in scalar ether theory of gravitation. "The average motion of that fluid defines a preferred reference body or "macro-ether", which plays the role of the Lorentz-Poincare rigid ether… The Lorentz-Poincare ether is one particular inertial frame for the flat metric γ^0…. Three-dimentional body (manifold) "macro-ether", denoted by M, is the set of the world-lines "x^i= Const = a^i (i=1, 2, 3), x^0 arbitrary". Thus each point of M may be defined by a 3-vector $\mathbf{x} \equiv (x^i)$. The ratio $t \equiv x^0/c$ is called the "absolute time" where c is a constant (the velocity of light)" 17].

Thus in the model stratum for all three models above, we have a body in the classical 3-dimensional space. Minkowski's and Riemann's 4-dimensional space-time is a form of mathematical representation in the Math-stratum. Many scientists and philosophers say that the 4-dimensional space-time is an ontological physical model in model stratum, as it was treated in the investigation program of Clifford. But the analysis of the experimental and theoretical realizations of Einstein's theory of relativity and its many-dimensional children shows that they are made in Math-stratum only, at least until now.

8. 'Virtual' Particles and the Vacuum

In modern cosmology many scenarios for the initial state of the Universe use concepts from Quantum Field Theories (QFT). Some of the central concepts of QFT, such as **'virtual' particles** and **'the vacuum'** appears analogous to the above situation with the concept of 4-diventional space-time. To analyze it let's consider these concepts on the example of a quantum electrodynamics (QED), which is the 'mother' of all Quantum Field Theories (QFT). Let's consider its general scheme.

The initial model is the model of "free" quantum particles (fields), i.e. particles (fields) with the interactions between themselves neglected. These particles (electrons, positrons and photons) are considered PIOs. These PIOs are the foundation of many-body physical systems that are aggregates of particles. The values of the energies and the momenta of all these particles can be used to describe the collective state of a system. A **system** with no particles is called the **vacuum**.

The model is then modified by the secondary quantization and the aggregates of the particles are transformed into states of a new system such as one electron-positron-photon field. The total physical description of the state of a system composed of *electrons, positrons, and photons,* is defined by the distributions of the occupation numbers for the various particle energies and momenta (i.e. $n_{e^-}(E, p)$, $n_{e^+}(E, p)$, and $n_\gamma(E, p)$ respectively). Change in the *numbers* of these three types represents the state change described by the QED model for the system. The main process in the QED model is the transition from an *initial* to a *final* configuration state for the entire system.

The **state** of such system with $\mathbf{n_{e-} = n_{e+} = n_\gamma = 0}$, which has minimum energy, is called the **vacuum state** of the system. Therefore the vacuum is transformed from a type of a system in the initial model into the type of a state of QED-system.

The **Math-Stratum** of the QED model for the system and its states is based on the **secondary quantization representation**. The Lagrangian or Hamiltonian for this system represents a *mathematical image* of the physical system and takes the form of 'creation' and 'annihilation' operators. The action of these operators on the *vacuum state* changes the particle *numbers* (e.g. n_{e-}, n_{e+}, and n_γ) in what is called the 'creation' or 'annihilation' of particles (this depends on the increase or decrease in the numbers). The state of a many-particle system cannot be simply reduced to an aggregate of states of one-particle systems from which it is composed. In the QED model, this fact is reflected in the use of a *time ordering procedure* for the one-particle creation and annihilation operators.

Then the **interaction** is introduced by some *transformation* of the Lagrangian (or Hamiltonian) in which some classical analogies and some presumptions about *symmetry* are used. Then (in the result) an equation of motion is represented in QED by *series of perturbations* with a constant of interaction $\boldsymbol{\alpha = 2\pi e^2/hc = 1/137}$.

The very popular '**Feynman Diagram'** technique is used to create a *visual representation* of the equation. Every member of the series is the product of the 'creation' and 'annihilation' operators. Each operator is pictured as a 'line' in the Feynman graph. The end lines, which are connected with the initial "free" particles, are called 'real' particles and the other, which represent the interaction are called 'virtual' particles. It is a very convenient mnemonic rule for operation with series of perturbation (generally speaking 'infinite'). Thus 'virtual particles' are the result of using the method of successive approximations in the Math-stratum only.

One of such an infinite series of perturbations with no free ends is called the 'vacuum part'. Often it is connected with the image of clouds of 'created' and 'annihilated' virtual particles. Other infinite series of perturbations, which have one free end of a definite type, are called electron or photon 'propagators'.

Then one goes back to the system constituted of particles.[ix] However, unlike the classical models, the particles in relativistic quantum mechanics demand the subsidiary model of 'physical' vacuum, which interacts with the 'physical' particles[x]. Such 'physical' vacuum is like ether (or environment). However, there is no spontaneous creation of particles[xi], and **'virtual particles' exist only as mathematical objects**, mathematical language for description of interaction between quantum particles and vacuum, and between quantum particles in QED (and QFT). Nevertheless, figurativeness of mathematical language of graphs and 'virtual' particles provokes to wrong (falls) interpret them as ontological models.

Conclusion

Returning to the question **"What is physics?"** and **"What is 'understanding' in physics?"** we can say that the answers to these questions are based on ontological physical models, which form the main part of physics. The "model view" (describe by schemes 1-3) defines physics through the **types of models**, which it uses. The **model of motion as a transition in time from one state** of physical system **to another** (and by ‘archetypical’ models) is used for making models **of `primary ideal objects'**.

The 17th -18th centuries gave two such archetypical models: the Newtonian mechanics model of particles in vacuum and forces (with possible long-range action between particles in vacuum), and the continuous fluid model which was born in ‘natural philosophy’ of Descartes (a model of short-range action) which was then developed further in the hydrodynamics of Euler. The latter gave birth to the models of fields and waves. The 20th century saw the birth of relativistic physics and some new archetypical models such as *4-dimensional space-time*, *curvature of space-time* (instead of *forces*), *'virtual' particles,* and the *'physical vacuum'*. Our analyses showed that all these images belong to mathematical stratum only while physicists still continue to use the old ontological models of particles, continuous fluids, fields, waves in ordinary space and time (at least so far).

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[i] We agree with the three-part structure, but not with his conception as a whole.

[ii] Time in dynamics plays a special role as a 'measurable' value defined by a 'clock'. There are different attempts to consider time as a phenomenon [18], which may be a subject of theory. Usually the authors do it self-contradictorily without understanding that the theory they use for 'time' is based on a non-theoretical concept of time. The S. Hitchcock's model of time presented at this Workshop provides some first steps toward a "theory of time" [19] with the interesting possibility of avoiding such self-contradictions by treating 'time' as a form of *information* originating in 'Feynman Clock'. This is a very difficult task. In my opinion it is far from a final solution yet.

[iii] We try to use term 'measurable quantities' instead of conventional 'observables' to stress the difference between a phenomenon which is *observable* (the subject of theory) and *'measurable quantities*' which are observable but cannot be the subject of theory.

[iv] Just as in early physics of 17-18th century a new branch of physics was born from solutions to concrete problems (e.g. falling bodies, planetary motions, and so on), not from paradoxes or *incomprehensibility.*

[v] In addition, Galileo finally made observations 'objective', and thus gave rise to a modern experiment. Experiment and measurements are separated from the individual and his sensations and are reduced to the description of procedures. Only this objective approach allows the use of devices to amplify knowledge, the same as mechanical devices (lever, pulley, etc.) intensify force. This intellectual revolution was not easy, and this can be seen in how difficult it was for Galileo to prove that the telescope could be used for astronomical observations. Many of Galileo's results were forgotten later during the long quiet post-Newtonian period, and N.Bohr had to do most of this work from scratch.

[vi] The concept of "realistic rationalism" of the Cartesian (Descartes) type, where PIOs come through intuition, are compatible with our PIO model view too.

[vii] The model view of quantum mechanics can be found in [4].

[viii] L. Mandelshtam even insisted on renaming 'Relativity theory' in 'theory of space and time'.

[ix] In such a picture the models of QED (and QFT) are 'auxiliary' and are displaced in the mathematical stratum. QED-model can become the base model if it is connected with observables directly.

[x] The Casimir effect and Lamb shift of spectral lines are classical examples of it.

[xi] The 'physical' vacuum in the model stratum is a stationary state where the spontaneous creation of particles is impossible, i.e. a vacuum remains a vacuum 'in time' [20, v. IV-2, c.14].