Chapter 1. Introduction. The axiomatic approach versus heuristic

1.0. Crisis in Physics

A considerable number of prominent scientists says about the crisis in fundamental physics, which is reflected in the fact that the last 40 years in this field of science there are no new results (Smolin, 2006; Woit, 2007; Seth, 2007; Schroer, 2008; Schroer, 2009; Horgan, 1996; etc)..

So, well-known physicist Lee Smolin in his book (Smolin, 2006) notes:

"*The story I will tell could be read by some as a tragedy. To put it bluntly – and to give away the punch line – we have failed. We inherited a science, physics that had been progressing so fast for so ling that it was often taken as the model for how other kinds of science should be done. For more than two centuries, until the present period, our understanding of the laws of nature expanded rapidly. But today, despite our best effort, what we know for certain about these laws is no more than what we knew back in the* 1970*s.*

How unusual is it for three decades to pass without major progress in fundamental physics? Even if we look back more than two hundred years, to a time when science was the concern mostly of wealthy amateurs, it is unprecedented. Since at least the late eighteenth century, significant progress has been made on crucial questions every quarter century"…

Why is physics suddenly in trouble? And what can we do about it? These are the central questions of my book…".

The presence of the crisis is also confirmed by the philosophers:

(Popper, 1982) "*Today, physics is in a crisis. Physical theory is unbelievably successful; it constantly produces new problems, and it solves the old ones as well as the new ones. And part of the present crisis—the almost permanent revolution of its fundamental theories—is, in my opinion, a normal state of any mature science. But there is also another aspect of the present crisis: it is also a crisis of understanding.*

This crisis of our understanding is roughly as old as die Copenhagen interpretation of quantum mechanics. It is thus a little older than die original edition of The Lope of Scientific Discovery. In this part of die Postscript I have tried to make again a number of proposals intended to clarify what underlies this crisis of understanding".

The question arises about the causes of the crisis of fundamental science.

2.0. Which of our basic assumptions are wrong?

Although they use different terminology, physicists and philosophers converge to the same reason. Here is what Popper says (Popper, 1982):

"*In my view, the crisis is, essentially, due to two things:*

(a) *the intrusion of subjectivism into physics; and*

(b) *the victory of the idea that quantum theory has reached complete and final truth.*

Subjectivism in physics can be traced to several great mistakes. One is the positivism or idealism of Mach. It spread to the British Isles (where it had been originated by Berkeley) through Russell, and to Germany through the young Einstein (1905). *This view was rejected by Einstein in his forties* (1926), *and it was deeply regretted by the mature Einstein* (1950). *Another is the subjectivist* *interpre¬tation of the calculus of probability, which is far older and which became a central dogma of the theory of probability through the work of Laplace*".

Let us consider what the reasons are consistent with this in science.

Simplistically, we can say that science is a method of obtaining the answer to a question in order to gain some benefit for people.

Since Nature is only one, only one answer to each question must exist as well as one picture of each phenomenon. Such an answer is usually called true or correct. Methods that are used in order to obtain only one answers from Nature are named the methodology of science. In practice, methodology of science is a number of regulations.

The basis of methodology of scientific theory is nowadays a law (which conditionally can be named "**Francis Bacon** law of **science methodology**" (SEPh, 2003):

«Scientific community has taken that any theory is true, if it is in agreement with experimental results when these experiments are invariant with respect to the space, time, experimentalists, technical means and some other conditions».

In other words, to announce a verdict about the truth of the theory, the experiments should give identical results in Moscow, Los Angeles, on the Moon or Aldebaran; a hundred years ago, today, tomorrow, after a thousand years; by experimentalists from USA, Argentines, Mars or Venus; by means of any device, which is fit for a given experiment; and the results of the experiment must be mathematically processed and presented by known methods.

Assuming all of this, the Bacon law can be summarized as follows: "*The coincidence of theoretical results with experimental results is the truth in science*".

This law is regularly worked until the early 20th century. But, as the science development shows, there is some incompleteness in the Bacon law: this law says nothing about the method of construction of theory and about theory structure. As it turned out, the absence of this indication also leads to a crisis in science. In particular, we assume that one of the main causes of the current crisis is precisely this point. What grounds are there for such a statement?

Historically, there are two aspects of mathematics. Proof-based mathematics is not the only form (Davis and Hersh, 1982).

"*The mathematics of Egypt, of Babylon, and of the ancient Orient was all of the algorithmic type. Dialectical mathematics -- strictly logical, deductive mathematics -- originated with the Greeks. But it did not displace the algorithmic.In Euclid, the role of dialectic is to justify a construction-i.e., an algorithm. It is only in modern times that we find mathematics with little or no algorithmic content. [. . .] Recent years seem to show a shift back to a constructive or algorithmic view point*."

It turned out that this difference is also characteristic for physics of XX-XXI centuries. Richard Feynman caught the attention of physicists on this particularity . In a series of lectures "The Character of Physical Law " (Feynman, 1964), he analyzed these issues in detail. The following are typical excerpts from his book:

"*...there are two kinds of ways of looking at mathematics, which for the purpose of this lecture I will call the Babylonian tradition and the Euclidean or Greek tradition. In Babylonian schools in mathematics the student would learn by doing a large number of examples until establishing the general rule... Tables of numerical quantities were available so that they could solve elaborate equations.*

Under the Babylonian system, everything was prepared for calculating things out. But Euclid (under the Greek mathematical system) discovered that there was a way in which all of the theorems of geometry could be ordered from a set of axioms that were simple. The Babylonian mathematics is that you know all of the various theorems and many of the connections in between...".

The next step is then the guessing of physical equations, which, Feynman argues, facilitates the guessing of new physical laws in a way that common-sense feeling, philosophical principles, or models cannot.

Feynman (Feynman, 1964) argued that, "*In physics, we need the Babylonian method, and not the Euclidian or Greek method*."

The Babylonian tradition and the Euclidean or Greek tradition in the framework of physics and mathematics can be named "algorithmic approach" and "axiomatic approach"; following Karl Popper (Popper, 1982), they can be called "instrumentalism" and "realism"; recalling the T. Kuhn analysis (Kuhn, 1962), we can also name these methods "Babylonian paradigm" and "Greek paradigm"; or "neo-positivistic approach" and "classical approach" (Mach, 1897; Holton, 1968)).

In framework of "Babylonian approach" (see, for example, the mathematical cuneiform tablets of Mesopotamia, Egypt papyri, the Ptolemeus astronomy theory) the theory is formulated in the form of regulations, rules, recipes of calculations found in any way, including through trial and error or the method of fitting. It is clear that the number of these regulations, rules and prescriptions should be almost as great as the number of questions to be answered. Any mathematic apparatus can be invented here to obtain the result, without understanding its connection with other part of theory.

In contrast, according to "Greek approach" for each area of science must exist one of the equivalent systems of axioms, and all mathematic results of the theory must follow consecutively from this axiom system (for examples see the Euclid geometry and classical mechanics of Newton).

Although both approaches are not against the Bacon law, it is difficult to disagree with the fact that a scientific theory, which enjoys a huge number of practical recipes and instructions, found by means of trial and error method, contradicts to our intuitive understanding of the unity of the world picture (Planck, 1910).

"Is the physical picture of the world, only more or less an arbitrary creation of our mind, or, conversely, we have to admit that it reflects a real, totally independent from us, phenomena of nature? ...

If, on the basis of the above, I answer affirmatively this question, I am well aware that the answer lies in a certain contradiction with the direction of the philosophy of nature, which is headed by Ernst Mach and which now enjoys great sympathy among scientists. According to this doctrine, in nature there is no other reality other than our own feelings, and every study of nature is, ultimately, only the economical adaptation of our thoughts to our feelings, to which we come under the influence of the struggle for existence. The difference between the physical and mental is purely practical and conventional; i.e. the unique elements of world - this is our experience.

Although I am firmly convinced that in the Mach system, if it is consistently held, there is no self-contradiction, it seems to me no less significant that its value is, in essence, purely formal and does not concern the foundations of science. The reason for this is that the Mach system is completely alien to the most important attribute of any natural science research: the desire to find a permanent, independent of change of times and the people, world picture ...

The goal does not lie in the complete adaptation of our ideas towards our sensations, but in the complete liberation of the physical picture of the world from the individuality of the creative mind. This is a more precise statement of what I described above as the exemption from anthropomorphic elements.

When the great creators of the exact science - Copernicus ..., Kepler ..., Newton ..., Huygens…, Faraday, ... - introdused their ideas to science, surely none of these scientists have relied on the economic point of view in the fight against the inherited beliefs and overwhelming authority. The support of all their activities was the unshakable belief in the reality of their world view. In view of this undoubted fact, it is difficult to get rid of the fear that the train of thoughts of leading minds would be violated, the flight of imagination weakened, and the development of science would be fatally delayed, if the principle of economy of Mach really became the focal point of the theory of knowledge. Maybe it will actually be more "economical" if we give the principle of economy a more modest place?"

After 40 years, in 1952, E. Schrodinger even more clearly expressed dissatisfaction with algorithmic (Babylonian, neopositivistic) development of modern physics (Schrödinger, 1952):

(Quotes from Part I) "*The innovations of thought in the last o years, great and momentous and unavoidable as they were, are usually overrated compared with those of the preceding century; and the disproportionate foreshortening by time-perspective, of previous achievements on which all our enlightenment in modem times depends, reaches a disconcerting degree according as earlier and earlier centuries are considered… A theoretical science, where this is forgotten, and where the initiated continue musing to each other in terms that are, at best, understood by a small group of close fellow travellers, will necessarily be cut off from the rest of cultural mankind; in the long run it is bound to atrophy and ossify, however virulently esoteric chat may continue within its joyfully isolated groups of experts...*

The disregard for historical connectedness, nay the pride of embarking on new ways of thought, of production and of action, the keen endeavour of shaking off, as it were, the indebtedness to our predecessors, are no doubt a general trend of our time…

There is, however, so I believe, no other nearly so blatant example of this happening as the theories of physical science in our time...

There have been ingenious constructs of the human mind that gave an exceedingly accurate description of observed facts and have yet lost all interest except to historians. I am thinking of the theory of epicycles".

(Quotes from Part II) "*There is, of course, among physicists a widely popular tenet, informed by the philosophy of Ernst Mach, to the effect that the only task of experimental science is to give definite prescriptions for successfully foretelling the results of any future observations from the known results of previous observations.*

If our task is only to predict precisely and correctly by any means whatsoever, why not by false mathematics?"

3.0. Algorithmic mathematics vs. axiomatic

3.1. Why is the modern theory of elementary particles called the Standard Model?

Modern theoretical physics does not pretend to explain how something really happens in nature. Theoretical physics only claims that it can offer mathematical models that describe phenomena well, on the basis of which it is possible to make predictions, and then to test them experimentally.

Therefore, nothing restricts the mathematics that is needed for theoreticians to build models. For example, it is acceptable to use complex numbers if it turns out that with the help of complex numbers, it is possible to describe something that was not possible to describe with the help of real numbers; or, if it turns out that in order to describe the electrical and magnetic interactions of bodies it is convenient to introduce the notion of an electromagnetic field that is somehow "spilled" in space, then it is acceptable to do so. If it turns out that it is more effective as far as explanations and predictions are concerned, to use curved space-time to describe gravity, this is also acceptable.

The transition from one mathematical model to another does not necessarily have to be smooth, but can be accomplished abruptly. For example, we have a set of experimental facts that can not be described by the previous theory (say, classical mechanics). In addition it is not possible at a principled level; i.e., in classical mechanics there is simply no place for such phenomena. In this case we have to invent another mathematical formalism, in which the main role will be played by other objects.

For example, quantum mechanics is the kind of formalism that does not transition smoothly from classical mechanics, but is based on another basis. If some strange variants appear in the course of the development of a theory, they should be used if this mathematical model with its unusualness better describes the reality than any other models.

The same is true for the transition from quantum mechanics to quantum field theory. There, too, the rules of the game change: other objects become key-objects, and the formalism of working with them becomes more difficult. Most importantly, this theory should successfully describe and predict phenomena that could not be described by quantum mechanics.

In other words, modern theoretical physics does not represent an aggregation of knowledge in which all results follow consistently from a limited set of statements. It is rather a collection of disparate recipes – mathematical description models, poorly connected with each other and accepted by agreement by the majority of the scientists of the world.

Hence the name of the modern theory of matter: **Standard Model.**

Further we will examine the structure of the contemporary theory of elementary particles - Standard Model - and will note its “ Babylonian” difficulties.

4.0. Difficulties of quantum field theory

The quantum field theory (QFT), (in particular, in the form of the Standard Model (SM)), is the contemporary theory of elementary particles and their interactions. Its predictions agree with experiments. But it has very strange peculiarities.

The most peculiar features of quantum mechanics are quantum nonlocality, indeterminism, interference of probabilities, quantization, wave function collapse during measurement. They and some others are basic principles of quantum mechanics that are generally accepted and called “The Copenhagen interpretation” :

1.A system is completely described by a wave function,

2.The description of nature is essentially probabilistic. The probability of an event related to the square of the amplitude of the wave function.

3. The wave function represent the state of the system, which grows gradually with time but, upon measurement, collapses suddenly to its original size.

4. Heisenberg's uncertainty principle: it is not possible to know the value of all the properties of the system at the same time; those properties must be described by probabilities.

5. Wave-particle duality. An experiment can show both the particle-like and wave-like properties of matter; in some experiments both of these complementary viewpoints must be invoked to explain the results, according to the complementarity principle of Niels Bohr.

6. Since measuring devices are essentially classical devices, it can measure only classical properties.

These peculiarities can not be explained on basis of quantum theory. Copenhagen interpretation describes the nature of the Universe as being much different then the world we observe.

The question arises, what grounds exist for the adoption of these concepts? It turns out that there are no bases, apart from the general agreement of physicists. As Niels Bohr (Bohr, 1962) said:

"*After a short period of ideological disorder and the disagreements, caused by short term of restriction of "presentation", the consensus about replacement of concrete images with abstract mathematical symbols, for example as , has been reached. In particular, the concrete image of rotation in three-dimensional space has been replaced by mathematical characteristics of representation of group of rotation*".

Many physicists have subscribed to the instrumentalist (or, according to R. Feynman, Babylonian) interpretation of quantum mechanics, a position, which is often equated with denial all interpretation. It is summarized by the sentence "Shut up and calculate!".

"*While expounding as the undisputed leader of the Copenhagen school, his peculiar mixture of positivism, realism, and existentialism, Bohr unfortunately did not anticipate the long-range effects of his teachings on future generations of physicists who lacked the philosophical training or the sophistication required to distinguish between subtle philosophical nuances and their gross over-simplifications. Such physicists condensed Bohr's entire philosophy into simplified enunciations of the principles of complementarity, wave-particle duality and the purportedly "classical nature" of the "apparatus," and simply ignored the rest. Indeed, what Karl Popper calls the "third group of physicists," who emerged right after World War II and soon became the overwhelming majority, is described by him as follows*(Prugovecki, 1992):

"*It consists of those who have turned away from discussions [concerning the confrontation between positivism and realism in quantum physics] they regard them, rightly, as philosophical, and because they believe, wrongly, many younger physicists who have grown up in a period of over-specialization, and in the newly developing cult of narrowness, and the contempt for the non-specialist older generation: a tradition which may easily lead to the end of science and its replacement by technology*." (Popper, 1982, p. 100).

4.1. What does the algorithmity of modern theories lead to?

Briefly and meaningfully about this peculiarity of QFT spoke one of the creators of SM, the Nobel laureate Murray Gell-Mann. (Gell-Mann, 1981):

"*Quantum mechanics, that misterious, confusing discipline, which none of us really understands but which we know how to use. It works perfectly, as far as we can tell, in describing physical reality, but it is a 'counter-intuitive discipline', as social scientists would say. Quantum mechanics is not a theory, but rather a framework, within which we believe any correct theory must fit.*"

According to (Anthony, 1985): "*The quantum mechanics ... says nothing about the nature of the particles, forming the Universe, and about forces, which operate between them. More likely, it is the* *set of rules, with help of which it is possible to find, what will take place according to the given dynamic theory under certain conditions*"

Steven Weinberg in his book "*Dreams of the Final Theory* (1993) Chap. 4."Quantum Mechanics and Its Discontents" writes:

"*A year or so ago, while Philip Candelas (of the physics department at Texas) and I were waiting for an elevator, our conversation turned to a young theorist who had been quite promising as a graduate student and who had then dropped out of sight. I asked Phil what had interfered with the ex-student's research. Phil shook his head sadly and said, "He tried to understand quantum mechanics."*

In his "*Lectures on Quantum Mechanics* (2nd ed., 2015), Ch. 3 : General Principles of Quantum Mechanics" he explained this remark in more detail:

"*My own conclusion is that today there is no interpretation of quantum mechanics that does not have serious flaws. This view is not universally shared. Indeed, many physicists are satisfied with their own interpretation of quantum mechanics. But different physicists are satisfied with different interpretations. In my view, we ought to take seriously the possibility of finding some more satisfactory other theory, to which quantum mechanics is only a good approximation"*

It is necessary to recognize that such structure of theory is completely acceptable for the technical applications. But at the same time, for this reason, SM does not answer many questions that are entitled to be asked by any inquisitive mind (in framework of the QFT the answers are either separate postulates, or claims that our ability to know the micro-world is limited due to some of its features).

Among these, for example, are: what is the origin of the mass; why fundamental particles - electron and quarks - don't have size (i.e., are point); why the wave function has not a physical sense.

We do not know the physical meaning of quantization; uncertainty principle of Heisenberg; a wave-particle dualism; non-commutativity of dynamic variables; the operator form of QM; statistical interpretation of wave function; phase and gauge invariance; four-dimensional world; Pauli exclusion principle;

The theory does not explain elementariness of the charge; the charge and fine structure constant values; the "charges" of weak and strong interactions; universality of electron charge; existing of plus and minus charge of the particles; particle spin; helicity; the existing of different kinds of particles: intermediate bosons, leptons, mesons, baryons; and why other particles don't exist; confinement of the quarks; the stability and instability of the elementary particles; existence of particles and antiparticles; spontaneous breaking of symmetry; zittertbewegung; etc.

We do not know the physical sense of the mathematical characteristics of Dirac's electron equation: why the spinor equation does contain two equations, and the bispinor - four equations? Why into the Dirac equations the matrices are used, which in the classical theory describe the rotation? Why do the Pauli and Dirac matrices form groups? Why the mathematical theory of groups is the basis for the search for invariants of physical theories? Why there are many equivalent forms of the Dirac electron equation that transform into each other through formal transformations of matrices and the wave function? Etc..

The understanding of the fact that "quantum mechanics is not a theory, but rather a framework, within which we believe any correct theory must fit", cause the desire to construct within the framework of existing theory the completely axiomatic theory of elementary particles.

4.2. Is it possible to move to a different paradigm?

A question arises, of whether the contemporary quantum field theory is already on that stage, when it can be formulated axiomatically (Smilga, 2001):

"*In his well-known popular lectures R. (Feynmann, 1964) reflects on the way physical theories are built up and distinguishes two such ways or, rather, two stages in the process of their construction: (i) the "Babylonian" stage and (ii) the "Greek" stage.*

It is not difficult to guess that the term "Babylonian" refers to ancient Babylon and the corresponding physical theory is just, geometry. A Babylonian geometer (the words "mathematician" or "physicist' were not yet coined) knew many facts about circles, triangles, and other figures, and his understanding was not purely empirical because he could also relate different such facts with each other… In other words, his theory described the observed experimental facts well and had direct practical applications.

Our Babylonian colleague was lacking, however, a, consistent structured system in which a set of basic simple facts are chosen as axioms and all others are rigorously derived as theorems… Feynman writes that a modern physicist is a Babylonian rather than a Greek in this respect: he does not care too much about Rigor, and his God and ultimate Judge is Experiment.

Strictly speaking, this is not quite correct. Some branches of classical and also of quantum physics have now quite reached the Greek stage.

Regarding … quantum field theory in general, we are living now in interesting times when we go over from the Babylonian to the Greek stage."

Therefore, we can not exclude an opportunity of existence of other paradigm, which are not breaking the mathematical apparatus of quantum mechanics, but give the essentially other theory. "Is it possible to make differently?" - the analysis of this question from known followers of de Broglie (Andrade and Loshak, 1972) leads to following statement of a question:

"*From the point of view of the sensible scientific approach, here there is no talk about whether postulates of the Copenhagen school correct or false are. The discourse goes simply about that any philosophical postulates have itself no evidential force, even if their logic connection with quantum mechanical calculations was perfect and the great discoveries on its basis were made. Hence, we should set for ourselves a problem: to establish, whether it is possible, proceeding from other postulates, to construct other interpretation of quantum mechanics and, thus, to come to the theory, which are distinct from those, which we know, and bringing new results. In other words, whether it is possible to make differently or even better?*

From the most general point of view this question seems quite pertinent and it would be very much desirable to answer it so that, since no way should remain without use, the similar enterprise will justify the efforts, spent for it ".

As examples of successful physical axiomatic theories serve, e.g., Newton's mechanic and classical electrodynamics. In these theories on the basis of several postulates (or, which is the same, axioms) all formulas, necessary for calculating of the physical values in these area of science, are derived.

We propose as such a theory to consider the axiomatic **nonlinear theory of elementary particles (NTEP)**. In framework of this theory, it can be shown that all the peculiarities of modern quantum field theory arise due to the fact that it is artificially treated as a linear theory. The mathematics of the nonlinear theory in the linear approximation is identical to the mathematics of existing QFT .

At the same time, all abovementioned features of modern quantum field theory in the nonlinear theory have a natural physical explanation and do not require artificial interpretations. Moreover, it appears that all the items of the Copenhagen interpretation are a mathematical consequence of the theory itself, thus,. justifying Andrade and Loshak's hope.

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