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Beyond Objectivity: The Problem of the Thinker in the Context of Scientific Models

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ABSTRACT

The subjective experience of the "thinker" and the objective reality represented in scientific or technical models are in a complex interaction. The "objectivity" of scientific progress is accompanied by an inevitable subjectivity in the choice of a model in physics. This article examines the "thinker problem", which reflects the mental picture of the thinker, conditioned by his intuition, knowledge and experience and influencing his perception of reality and the models he constructs. The article substantiates the important role of the International System of Units (SI) used by the thinker in constructing a model. The Abelian structure of the SI and the finite amount of information contained in it dictate the limits of achievable accuracy in scientific research. However, the article argues that the thinker's freedom of choice in formulating a model is a necessary component of scientific progress. The article analyzes the contradictory interaction between this freedom and the desire to discover fundamental physical laws, while acknowledging the existence of limits to the accuracy of experimental measurements and the current lack of a generally accepted criterion for choosing the "most plausible" model. The article emphasizes the complex relationship between constructed models, experimental results and the philosophical position of the thinker, which obliges him to adhere to a strict methodological approach in scientific research.

Keywords: Model selection, Thinker's mind, Freedom of choice, Abelian group, International System of Units (SI), Uncertainty

1. INTRODUCTION: PERCEPTION OF REALITY USING MODELS

To understand the physical nature of the surrounding reality, scientists carefully develop the process of conducting an experiment in order to obtain initial data, empirical observations that serve as the basis for scientific knowledge. At the same time, the experiment itself is based on an already constructed model that reflects the thinker's ideas about the observed phenomenon. It can be argued that any model, in its essence, is an information channel between the object of study and the observer. In what follows, we will use the term "thinker", thereby emphasizing that during modeling (mental study of a phenomenon), no external influences are introduced into the object of study. Here, the "thinker" refers not only to an individual researcher, but also to a broader scientific community that shapes our understanding of the surrounding reality.

Obviously, the process of constructing a model is a creative mental act, a product of the human mind. Model construction is associated with the "thinker problem" in the study of physical phenomena. It follows that the act of choosing a model depends on the philosophical ideas of the thinker, as well as the prevailing scientific paradigms of the time. Two researchers, based on their own ideas about the object under study, can build two different models that differ from each other in a qualitative and quantitative set of variables and different mathematical dependencies between these variables. Both proceed from the assumption that their own model considers certain characteristics and reflects the object under study with high accuracy. Thus, a model, in addition to its function as an information channel, can be considered as a lens through which a thinker looks at a phenomenon, focusing his attention on certain features and potentially obscuring others. The value of choosing a model in physics is difficult to overestimate, since with its help, raw experimental data are structured into a framework of understanding, correct or incorrect, but allowing one to assert certain characteristics of the process under study. If the researcher is lucky, he manages to build a model that explains existing observations and predicts the future behavior of the system under study. In this case, the model is a reliable basis for formulating testable hypotheses, conducting further experiments and deepening the understanding of the observed phenomenon. For example, Newton's model of motion, revolutionary for its time, combined such concepts as force, mass and acceleration. Thanks to her, it became possible to calculate both the motion of the planets and the fall of apples within the framework of one theory. As scientific knowledge expanded and deepened, unique experimental stands were developed and scientists conducted increasingly precise experiments, the limitations of Newton's model became obvious. This paved the way for Einstein's development of the theory of relativity, which better considered new observations and united space and time into a single whole.

It is difficult to dispute the role and influence of the choice of model structure on the physical scientific understanding of the universe around us. At the same time, the technological advances in modern society would simply be unthinkable without models. The models used to understand the nature of electricity and magnetism, laid down by Maxwell, led to the development of electrical generators, transformers, and many other technologies in various fields of engineering. Likewise, the models in thermodynamics formulated by J. R. Mayer, James Joule, Pierre-Simon Laplace, Sadi Carnot, Rudolf Clausius, Walther Nernst contributed to the design of new efficient motors and power plants. In fact, the models that scientists create in physics form the basis for a wide range of practical applications, exerting a pervasive, albeit invisible, influence on everyday life in every corner of our Earth in countless ways. The following chapters discuss the construction of models in physics and their structure. The characteristics inherent in this process are considered, the features that characterize the thinker's freedom of choice in constructing a model, as well as the limitations imposed on accuracy, are clarified. The Abelian structure of the International System of Units (SI) is considered as the basis for constructing the most plausible model with the least uncertainty. Examples and case studies are presented to support the assertion that the "consciousness of the thinker" forms the image of the phenomenon under study that is perceived as reality. Finally, we emphasize the dynamic nature of scientific progress, where models are constantly being improved and questioned, which leads to a deeper and ever-evolving understanding of the world we live in. The article also discusses the phenomenon of scientific progress due to the continuous improvement of models, as well as the relationship between the constructed model, the experimental data, and the philosophical position of the observer/thinker.

2. MODEL SELECTION

In all areas of physics, the process of modeling is part of scientific research: from the interaction of subatomic particles (Dunbar et al., 2012) to the movement of galaxies, from the movement of ions in the blood to the interaction of tectonic plates. In this case, experimental results are transformed into formulas that reflect specific physical laws (Galileo, 1638). The veracity of the resulting models depends on the art of model selection. This is not just a mechanistic approach, it is a process associated with human ingenuity, conditioned by the philosophical position of the observer and reflecting the delicate balance between the thinker's freedom of choice and his intuition (Nersessian, 2008).

2.1 Shaping Reality with Mental Images

The observer's mental picture is a product of existing knowledge and scientific paradigms, which plays a key role in the choice of model. One can imagine two physicists studying the motion of a swinging pendulum. One, adhering to the canons of classical mechanics, favors the effect of gravity pulling downwards on the tension of the string acting upwards (Newton, 1687). His model most likely includes mass, length, and gravitational acceleration. The other physicist, specializing in fluid dynamics, considers air resistance acting on the swinging mass (Anderson, 2016). Such a model may include drag coefficients and viscosity, along with the variables adopted in the first model. This situation is due to the mental picture of two different thinkers and emphasizes the subjective component of model selection.

Differences in the philosophical views of scientists determine the construction of models reflecting different characteristics of the phenomenon under study and the level of detail. The simple model of a swinging pendulum presented in school textbooks is based on an ideal case of a frictionless system (Goldstein, 2002). This is done to provide a simplified understanding of the mechanical principles involved in pendulum motion. However, for real-world applications where gradual deceleration of the pendulum is critical, a more complex model that includes friction may be required (Thornton & Marion, 2004). The trade-off between simplicity and complexity, influenced by the knowledge, experience and intuition of the thinker, determines the level of detail reflected in the model.

It is important to consider the modeling process from a historical perspective. Newton's mechanics has attracted many generations of scientists over many centuries. However, 200 years later, Einstein's theory of relativity completely changed scientists' understanding of gravity and space-time (Einstein, 1905). Thus, it can be argued that the mind of the thinker, which determines the choice of model, changes over time and adapts as scientific knowledge deepens and new discoveries in science and technology are made.

2.2 Creative Freedom of Research

Any field of intellectual activity, and certainly physics, develops and is based on the use of scientists' abilities, creativity and ingenuity. At the same time, as already noted, scientists retain a certain degree of freedom in choosing the direction of their research, even when observing the same physical object. For example, the propagation of light can be considered as a wave, effectively recording its interference and diffraction patterns (Feynman, 1963). On the other hand, a model based on light quanta confirms the existence of the photoelectric effect (Einstein, 1905). The models are different in their physical essence; however, they are legitimate and valid in their specific field of application and testify to the freedom that physicists have in choosing the most preferable representation for a particular phenomenon.

An obvious, although difficult to explain, fact is the ability of an intellectual to represent natural phenomena recorded in the form of mathematical symbols in a model that is outside the limits of observable reality (Bohm, 1952). For many decades, scientists have devoted thousands of articles to models that substantiate the existence of dark matter and dark energy, although they are still invisible, but follow from numerous cosmological observations (Dodelson, 2003).

At the same time, freedom is not an absolute narrative. It is appropriate to give the following example: a sculptor selects tools and materials at his own discretion, but his creation must satisfy certain aesthetic canons. Similarly, freedom in choosing a model is conditioned by established physical principles and restrictions and must also correspond to experimental observations. For example, the model of a perpetual motion machine, to which thousands of articles and patents are devoted, violates the fundamental laws of thermodynamics, and therefore is not viable. Similarly, a model of light propagation that contradicts the observed speed of light until another theory is created is incompatible with a huge array of experimental data (Govor et al., 2009).

2.3 Choice of Freedom and Evidence

A model is considered valid if its theoretical predictions agree with experimental data within the limits of the established uncertainty and it does not contradict existing laws. A new model, representing a previously unknown original idea, must satisfy two requirements (Longino, 2002):

1. The mathematical structure of the model, the functional relationships between the variables must not contradict the original theoretical assumptions (Bohm, 1952). The physical content of the model must not lead to meaningless or implausible conclusions.

2. The predictions of the model, the accuracy of the results of theoretical calculations of the variables used must be within the error limits caused by the experimental uncertainty achieved in natural measurements (Nersessian, 2002). It is a well-known fact: the model for planetary motion developed by Johannes Kepler is confirmed by centuries of astronomical observations (Kepler, 1609) of the orbits of the planets around the Sun.

Although the quantitative agreement between theory and experiment and the explanation of the main mechanisms of the phenomenon allow us to assume the appropriateness of the chosen model, its ability to offer unexpected, previously unpredicted results (Nersessian, 2002), which can be verified in experiments (Longino, 2002), is considered no less important. It is appropriate to recall the kinetic theory of gases. This model, confirmed by experiments (Bohm, 1952), on the one hand, agrees with the known experimental data on gas pressure, diffusion and temperature changes, but also predicted new phenomena: the dependence of viscosity on temperature. At the same time, although existing models are attractive from the point of view of the achieved closeness of theoretical calculations and experimental data, there is always the possibility of refining the model, revising it or replacing it. For example, Bohr proposed a model that successfully explains the structure of simple elements but is difficult to apply to the behavior of more complex atoms (Bohm, 1952). This served as an impetus for the development of a quantum mechanical model, which offered a more accurate and detailed picture of the atomic structure (Bound, 1988). That is why the process of choosing a model structure should be viewed as an iterative process, constantly adapting to new information.

2.4 Necessity of Using Evidence and Laws

The cornerstone in constructing a model is the condition of observing the laws of conservation of energy and momentum (Feynman, 1963). If this condition is met, at least the apparent consistency of the study of any physical phenomenon or technological process is ensured. In addition, a carefully developed experimental plan, along with the use of advanced mathematical methods for processing the obtained experimental data, allow us to assume that the model with theoretical predictions is justified and verified (Longino, 2002).

In this chain of successive stages of studying an object, an important role is given to the International System of Units (SI) (BIPM, 2019). The structure of the SI is based on seven basic variables (length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity). The use of SI allows us to hope that the models constructed by scientists and engineers are formulated in one common language (BIPM, 2019). The use of a standardized SI ensures an objective comparison of the results of various research groups and helps to strengthen international cooperation in scientific research (International system of units, 2023). In addition, the use of fundamental constants in the SI, such as the speed of light in vacuum, the electron charge, the electron mass, Planck's constant and the fine structure constant, provide a fixed interval within which different models can be used. These constants act as anchors, ensuring consistency and minimizing ambiguity in the interpretation of physical phenomena (International system of units, 2023; Mohr, 2012). To summarize the above stages of the model formulation process, it should be noted that the mind of the thinker, shaped by existing knowledge, scientific paradigms, conditioned by his knowledge, experience and intuition, determines the initial choice of the model structure. This is an apparent freedom to explore different points of view and indulge scientific curiosity. However, this freedom is not absolute; it has limitations and certain boundaries. The chosen model must ultimately correspond to the established physical laws and experimental observations. The framework outlined by the known physical laws and the results of natural observations can, to a large extent, guarantee that the proposed model does not contain contradictions and reproduces the observed object correctly enough. It is hard to deny that the freedom of decision-making of the thinker, associated with the existing paradigms in modern physics, allows us to improve our understanding of the universe.

3. SI STRUCTURE – ABELIAN GROUP

Any scientific research involves building a model that, according to its developers, best reflects the phenomenon under study, which depends on a large number of factors. One of these factors, which is practically not paid attention to, is the influence of the chosen system of units. Many scientific articles (Longino, 2002) have studied the interaction between the point of view of the thinker and existing scientific paradigms when choosing a model. At the same time, this article pays special attention to the mathematical structure of the system of units. With its help, researchers select variables that are significant from their point of view for building a model.

In what follows, we will consider only the International System of Units (SI), which has the structure of the Abelian group, due to its widespread use in science and technology. At the same time, similar reasoning can be used when discussing other systems of units, such as the GSS, the British system or the Planck system.

3.1 The Appropriateness of the SI in Formulating Models

For centuries, studies have used various units of length: feet, meters, cubits. Pressure has been measured in pounds per square inch (psi), and in other studies, in the atmosphere. In such a situation, it is extremely difficult to make comparisons between experiments and, ultimately, to build a unified scientific understanding.

The SI, based on seven base units (meter, kilogram, second, ampere, kelvin, mole, and candela), allows a wide variety of derived variables to be constructed on its basis, all related by rigorous mathematical relationships. The advantages of the SI are obvious: it facilitates collaboration between researchers, each of whom can confidently use the results of others.

Consider two groups studying the electrical conductivity of different materials on different continents. If their results are presented in the same SI unit, then the presented results, obtained using different experimental equipment, can be analyzed and compared objectively. This reflects the critical element inherent in SI, which minimizes the influence of the researcher's subjective interpretation of the obtained results and makes them more reliably reproducible (BIPM, 2019). Due to this characteristic of SI, compared models constructed by different thinkers can reflect all sorts of points of view, while remaining within the framework of objective observation of the surrounding world.

3.2 The SI Structure – Abelian Group

A number of articles (Menin, 2017; Laszlo, 1964; Arovas, 2023) prove that the SI structure, including the base variables and their derivatives, can be represented as an Abelian group (AG). AG is a set of elements (in this case, the total number of base units and derived variables in the SI) that satisfy five properties: closure, associativity, identity, inversion, and commutativity (Artin, 1991). Taking this circumstance into account leads to a situation where the mathematical properties of AG affect the method of constructing models and calculating the achievable minimum accuracy of the model:

1. Closure is the unification of any two units in the SI, which leads to the emergence of a new unit related to the SI. For example, the unit of speed is expressed as meters/second.

2. Associativity is the order in which units are combined. The equation $(a \cdot b) \cdot c = a \cdot (b \cdot c)$ is valid for any combination of a, b, and c. Associativity ensures that the dimension of the variable being sought depends only on the physical quantities included in the formula, and not on the order of the variables in the formula. For example, the magnitude of kinetic energy $E = \frac{1}{2} mv^2$ remains unchanged when the units of mass (kg), velocity (m/s), and the coefficient ½ are interchanged.

3. Identity is the presence of a "unit" element, denoted by 1. In the SI, the number 1 serves as the identity element $1 \cdot u = u \cdot 1 = u$. Multiplying a quantity by 1 confirms its magnitude without changing its nature. Models may include dimensionless constants or scaling factors that do not affect the overall structure of the units. 4. Inversion means that for every unit in the SI there is a corresponding reciprocal unit which, when combined, gives the identity element 1. The reciprocal of the meter (m) is (m^{-1}), the reciprocal of the second (s) is (s^{-1}), and so on. For example, in the equation for acceleration $A = F/m$, where F is the force, m is the mass, and A is measured in newtons ($kg \cdot m/s^2$). The dimension of the final result is expressed as m/s^2, which corresponds to acceleration.

4. Commutativity means that the order in which units are multiplied does not affect the final result. In other words, $a \cdot b = b \cdot a$ for any two SI units. For example, the work done by a force F acting through a displacement d can be expressed as $W = F \cdot d$. The commutative property guarantees that the dimension $W = d \cdot F$ will give the same result.

The Abelian group properties of the SI guarantee that measurements made according to given formulas are self-consistent and unambiguous. This ensures a clear and understandable expression of physical relationships in scientific models.

3.3 The Impact of the Abelian Nature of the SI on Model Construction

The revealed structure of the SI, which is an Abelian group, has a huge influence on researchers when constructing a model. The mathematical structure has such properties as closure, associativity, commutativity, inversion, and identity. These properties help maintain objectivity when choosing a model. In an Abelian system, the final result is less susceptible to the subjective views of the researcher, which allows for the establishment of objective criteria for comparing models formulated by developers with different experience, knowledge, and intuition.

The theoretical foundations of dimensional analysis were laid by Buckingham and Guchman in the early 20th century. This method helps researchers verify the veracity of a model by identifying potential errors. By analyzing the dimensionality of each variable included in the model equations, physicists and engineers can be sure that all terms of the equations have the same dimensions, and the final result is a meaningful value. The Abelian properties of the SI variables make this process visual. Closure ensures that all possible combinations of SI variables result in meaningful dimensions in the system. Associativity and commutativity ensure that the order in which variables are placed in formulas does not affect the outcome of dimensional analysis. In essence, the Abelian structure ensures that dimensional analysis is a reliable tool.

Scientific progress stimulates the search for new experimental data based on unique measurement methods in all areas of science and technology, which in turn encourages thinkers to revise existing and propose new models of physical phenomena. In this context, special importance is attached to the Abelian properties of the SI, which ensure that new units can be easily integrated into the existing structure. History is full of examples of this. Thus, the creation of quantum mechanics led to the emergence of new units such as the Planck constant

(h) and the electronvolt (eV), used to formulate phenomena at the atomic and subatomic level, different from our everyday experience.

In the last decade, the FIQ method has been proposed to construct a model of a physical phenomenon or technological process with the least uncertainty (Menin, 2017). It is based on the use of the concept of "a variable containing a finite amount of information." This term can be applied to any physical variable. In FIQ, the Abelian nature of the SI is combined with the concept of "complexity" as applied to the system of units. This allows one to calculate the amount of information contained in the SI and the constructed model. Comparative uncertainty, introduced by Brillouin in the seventies of the 20th century, is proposed as a universal criterion for assessing the plausibility of the model and calculating the minimum relative uncertainty. The effectiveness of the FIQ method has been tested in various fields of science and technology, including measuring physical constants and the speed of sound, studying electric discharge in water, developing an optimal cold storage system, combining the Landauer principle and the Bekenstein limit, etc. (Menin, 2022; Menin, 2021; Menin, 2017; Menin, 2019; Menin, 2023). The acceptability of the FIQ method for quantum mechanics will require additional scientific research in the future.

3.4 On the Limits of the Thinker's Influence

Created by the intellectual efforts of an international consortium and having the structure of an Abelian group, the SI has the property of representing laws of nature that do not depend on the subjective worldview of the scientists-thinkers.

The SI is a complex system in which many different variables can be connected or linked to each other by various functional dependencies.

The Abelian nature of the SI fixes these variables and the relationships between them in a strict mathematical structure. This fact allows us to assert that the physical laws discovered do not depend on the philosophical position of a particular thinker. It follows that the SI acts as an objective lens through which scientists understand the surrounding reality (Bohm, 1952).

One can imagine that at one end of the Earth the thinker measures distance in cubits and time on a sundial, while at the other end the researcher uses centimeters and seconds. In two disparate measurement systems, these scientists can discover Newton's laws if they transform the measurement data into the SI structure. Thus, the SI provides a common and understandable basis for every researcher to combat various counterproductive concepts. Although quantum mechanical phenomena contrast with the classical understanding of mechanics, the use of the SI allows formulating models and successfully predicting experimental results. Reliance on the SI has an important methodological aspect, when the focus is inside the triangle formed by objectivity, subjectivity and common sense, and not concentrated on one end of the triangle. This provides a theoretical basis for action and at the same time allows creativity and intuition to express themselves.

4. MODEL SELECTION: THE ROLE OF FREEDOM IN SCIENCE

The previous chapters have considered issues related to finding a balance between the thinker's freedom to propose ideas and the restrictions on formulating the structure of the model. However, at present, no generally accepted order, criterion or set of rules for constructing a model has been proposed. In each specific case, the thinker has his own original thinking, depending on accumulated knowledge, acquired experience and innate intuition, which leads to the idea of a creative process of model selection.

This chapter will consider the role of freedom of choice in science. Specific examples of model selection in different areas of physics will be considered. This will show how the intuition, experience and knowledge of the thinker can influence the conduct and decision-making in the course of scientific research.

4.1 The Thinker's Responsibility for Choosing Appropriate Models

There is no area of the natural world that physicists have not explored. This freedom comes with the responsibility to ensure that the chosen model is not just an intellectual exercise to increase one's h-index and earn a significant salary, but an instrument that faithfully represents the observed phenomenon (Bohm, 1952). This responsibility includes the following requirements:

1. Internal consistency: the formulated model cannot contain inconsistent assumptions in the initial conditions and mathematical formulations that lead to absurd or ridiculous conclusions (Bohm, 1952). For example, when studying the motion of planets around the Sun, the model cannot include any violations of the law of conservation of energy and momentum.

2. Empirical consistency: theoretical calculations for measuring a particular objective function must correspond to the uncertainty calculations achieved during experiments (Nersessian, 2002). In the event of a deviation of the calculated data from the observation/measurement results, the model should be reformulated. For example, the early idea that the Universe is limited, and the Earth is stationary at its center led observers to a model that could not accurately predict the position of the planets in the sky. Understanding this contradiction served as an impetus for the creation of a completely new model. It was based on the fact that the Sun is located at the center of the Universe, and the Earth performs at least two types of motion: annual around the Sun and daily around its axis; the stars are stationary relative to the Sun.

3. Predictive power: experimental confirmation of the proposed model does not mean its ultimate truth. We can only talk about the fact that the experiment and theory do not contradict each other. The model should not only provide results that are consistent with experimental data, but also reveal the mechanisms of the phenomenon being studied, as well as predict new effects that have not been observed before and can be tested in practice. The process of building a model is iterative: the emergence of new data from experiments and the desire of scientists to better understand a physical phenomenon lead to continuous updating of the model and even its rejection in favor of more detailed models.

4.2 Freedom and Constraint in Model Selection

The scientific community is widely discussing the alarming topic of falsification of research results and the impossibility of reproducing the results published in a large number of research articles. This confirms the fact that, unfortunately, many scientists, in pursuit of fame and privileges in their scientific careers, violate not only ethical standards, but also the delicate balance between their freedom of choice of model and the established framework of responsibility for the results presented. Without seriously preparing the material, in a hurry, a significant number of researchers publish "raw" materials. In order to achieve real success in physics, one should adhere to at least the following recommendations, minimalist in requirements:

1. Use established principles: when formulating a new model of an already known technological process or a previously considered phenomenon, when constructing a model of a process or physical object that were previously unknown or discovered, first of all, it is necessary to be guided by the already known laws of conservation of energy, momentum, angular momentum. These laws are universal constraints, according to which any model must be built. If these principles are violated in a model, for example, perpetual motion machines, it cannot but arouse suspicion (Weinberg, 2010).

2. Rely on previous "giants": the existing success in the development of previous models and theories can be very useful in the development of new concepts and models. After Newtonian classical mechanics gained worldwide recognition, it became clear over time that it has limitations and its predictions at the atomic level do not work. This situation led scientists

to the need to introduce new principles and laws. The success of previous theories sharpened the interest of researchers in quantized energy states, which served as the basis for the development of quantum models (Klauder, 2023).

3. Be open to new ideas: the success of physics in all areas of human activity is based on the intellectual creativity of scientists and the advancement of new, unconventional ideas. There are many examples from the history of science to support this thesis: from the geocentric view of the world to the heliocentric model, from divine creation to Darwin's theory of evolution, from classical mechanics to Einstein's theory of relativity, from the witch Doctor of Medicine to the elucidation of the structure of DNA by Watson and Crick in the early 1950s. All these achievements revolutionize scientific thought (Kuhn, 1962). Thus, the thinker, maintaining a balance between the freedom of choice of the model and the recognized established knowledge, can and should expand the study of new ideas, even if these ideas go beyond the established paradigms (Neurach, 1955; Relativity, 2022).

4.3 Examples of Model Choice in Different Areas of Physics

This chapter will present several examples of model choice that manifests itself differently in different areas of physics.

4.3.1 Planetary Motion

It is convenient to trace the process of model choice using the history of astronomy. In proposing the geocentric model, astronomers in Egypt and Greece placed the Earth at the center of the universe and proposed a complex system of epicycles to account for the retrograde motion of the planets. The model was very complex and did not match observations, which led to confusing adjustments.

Nicolaus Copernicus, aware of the discrepancies between the predicted and observed positions of the planets, proposed the heliocentric model in the 16th century (Tegmark, 2017). Although the heliocentric model was initially controversial, it simplified the explanation of planetary motion, had excellent explanatory power, and was consistent with empirical observations. Later, the works of Johannes Kepler (Kepler, 1609), who proposed elliptical orbits, and Isaac Newton, who discovered the law of universal gravitation, demonstrating the importance of the choice of model by the thinker, changed the physical understanding of planetary motion. They proved that a new idea can, given previous experience, provide more accurate and reliable forecasts.

The last hundred years have not been marked by outstanding discoveries related to astronomy. However, the models of planetary motion continue to improve. This is evidenced by the discovery of LIGO, which confirmed the existence of gravitational waves and confirmed the ideas of Einstein's general theory of relativity and improved the scientific understanding of planetary motion, especially in strong gravitational fields (Copernicus, 1543; Abbott et al., 2016).

The use of the latest Webb telescope made it possible to look into the deepest corners of space, discover thousands of exoplanets, and think about the correctness of scientific ideas about the formation and dynamics of the observed planetary systems. It is obvious that new discoveries and accumulation of additional experimental data initiate the formulation of new models (Einstein, 1915).

4.3.2 Blackbody Radiation

At the end of the 19th century, the problem of ultraviolet catastrophe was the focus of attention of the scientific community. This problem, arising from the concept of classical physics, for example, the Rayleigh-Jeans law, about a continuous energy spectrum, was in contradiction with the observed distribution of energy over different wavelengths: the peak of energy emission is reached at a certain frequency, after which it decreases. The obvious discrepancy between the existing theory and the obtained experimental data required the creation of a new model and its theoretical justification (Mayor and Queloz, 1995).

Max Planck, a venerable scientist of his time, proposed an idea that was in complete contrast to the existing view of the process of energy emission by a material object. The famous formula E=h ν, where E is the energy, h is Planck's constant, and ν is the radiation frequency (Rayleigh, 1900), meant that the energy of electromagnetic waves is not emitted or absorbed continuously, but is transmitted in the form of discrete units called quanta. The formula became a symbol of the birth of quantum mechanics. It served as an impetus for the formulation of new ideas and models. Albert Einstein received the Nobel Prize for explaining the photoelectric effect, confirming the need to develop a new model whose theoretical predictions coincide with experiment. In turn, Planck's formula dramatically changed the approach of scientists in other fields of science. Through the efforts of Niels Bohr and his associates, a model was developed to describe the spectral lines of hydrogen (Planck, 1900).

These discoveries were followed by a whole series of new discoveries, ideas, and the construction of models of previously unpredicted phenomena: the interaction of elementary particles, the discovery of the Higgs boson (Bohr, 1913), the development of quantum field theory, successful calculations of the behavior of quantum systems at low temperatures with unprecedentedly small measurement uncertainty (Aad et al., 2012; Gemmer et al., 2009).

All these achievements emphasize the iterative and ongoing process of developing new models, confirming the importance of choosing a model and the responsibility of a thinker in shaping a scientific worldview.

4.3.3 Climate Modeling

When modeling climate, scientists and engineers must consider a large number of influencing factors that can be measured with a large difference in uncertainty. Currently, the Earth's climate system is described by general circulation models (GCMs), which are designed not only to predict climate change but also to develop policy decisions by the international community. Given the incredible complexity of these models, researchers use sophisticated mathematical methods coupled with computers of enormous performance and memory. GCMs include many sub models to detail the overall picture of the climate, including:

1. Atmospheric dynamics models based on the equations of hydrodynamics and thermodynamics include the study of the movement of air masses considering the interaction of wind patterns, temperature and humidity. These models are based on the fundamental equations of hydrodynamics and thermodynamics. Particular attention in their development is paid to the accuracy of forecasting weather conditions and long-term climate trends to cover a wide range of different atmospheric states (Bloch, 2005).

2. Ocean circulation models aim to simulate the flow of water masses in the world's oceans and their interaction with the atmosphere, considering the heat and salinity of the oceans, temperature gradients, salinity and the Coriolis effect. Satellite observations and ocean buoy data are used to improve the accuracy of these models (Palmer, 2008).

3. Radiative transfer: The radiative transfer model studies the processes of absorption, emission and scattering of radiation by the Earth's surface and atmosphere. These models provide a more complete understanding of radiation for understanding the energy balance of the planet, predicting temperature changes, understanding the greenhouse effect, and reducing uncertainties in climate forecasts (Frame & Stone, 2012).

4. Land-atmosphere-ocean interaction models aim to deepen our understanding of complex feedback mechanisms including the relationships between vegetation and soil moisture with atmospheric moisture and temperature, and ocean currents with coastal climate. The accuracy of the models is improved by using data from satellite images and land-based observations (Bony et al., 2015).

All of the above climate models can vary in complexity and resolution. Models with a large number of variables and high resolution allow researchers to clarify fine details of physical processes, while requiring very powerful computing resources. Conversely, in simple models, the detail of the studied climate processes deteriorates, although the power of the required computers can be reduced. This determines the need to maintain a balance between the choice of more accurate models and the computing power used:

1. Simplification of complex processes in climate modeling is associated with a decrease in the number of variables considered - parameterization - due to existing computational limitations. An example of this operation is the GCM technique used in the study of cloud formation and convection. In this case, model calibration is used to increase parameterization, including adjusting the model variables to improve consistency with observed climate data. This ensures that the models provide realistic results (Pitman et al., 2009).

2. The currently unavoidable, significant uncertainty in climate forecasts is due to the complex and changeable structure of the climate system. To solve this problem, ensemble modeling is used, which consists of implementing/running several simulations that differ in initial conditions and the number of variables in the model. This makes it possible to predict some finite range of possible future climate conditions and improve the reliability of model climate forecasts (Mauritsen et al., 2012).

Climate modeling is an example of model selection and maintaining a complex balance involving the integration of detailed physical processes, calibration and parameterization of models against observational data, and management of computational limitations. Climate models are constantly being refined, which helps improve the understanding of climate dynamics.

4.3.4 String Theory

String theory has a history of 65 years. The idea was first formulated by Gabriele Veneziano in 1968 and was later developed by many physicists, including Green, Schwartz and Witten. Debates about its feasibility, usefulness, legitimacy and practical value do not subside. The fundamental difference between string theory and classical models that represent particles as point objects is that its building blocks are one-dimensional "strings" vibrating at certain fixed frequencies. These strings manifest themselves as different particles, allowing us to present a unified description for the known fundamental forces and particles. The assessment of the significance of this theory varies from one pole as "speculative, lacking experimental verification", to the other - as "mathematically elegant and promising" for the unification of the general theory of relativity and quantum mechanics, including three fundamental forces: electromagnetic, weak and strong nuclear forces.

In reality, there are problems in string theory that require solutions:

1. The reason for the unceasing attention to string theory is its mathematical harmony. It allows us to expand the Standard Model of particle physics, representing particles not as material points, but as vibrational states of strings. This, in turn, allows us to describe various interactions on both quantum and cosmological scales (Eyring et al., 2016).

2. Potentially, it is assumed that string theory allows us to unify gravity with the three fundamental forces, putting it forward as a candidate model for the Theory of Everything. This approach fundamentally distinguishes it from quantum field theories. The multidimensional structure of this theory, postulating additional spatial dimensions, claims to be the only way to incorporate gravity into a unified theory. However, the current lack of experimental verification casts doubt on the possibility of expanding observable space to many dimensions beyond the three known ones (Green et al., 2012).

3. String theory faces legitimate and significant criticism. This is explained by the lack of any experimental confirmation. It is impossible to achieve the energies at which string effects can be observed with modern particle accelerators. In addition, the so-called "string

theory landscape" assumes of the existence of many possible universes with different physical laws, which leads to a complete lack of demonstrable predictions.

4. String theory is subject to serious criticism due to the lack of any experimental confirmation. This is explained by the current impossibility of increasing the power of modern particle accelerators to observe string effects. In addition, the so-called "string theory landscape" suggests many possible universes with different physical laws and more than 20 spatial dimensions compared to the known three. Thus, string theory does not withstand the falsifiability test, which is one of the important methods for testing the theory (Polchinski, 2005).

5. In the absence of experimental confirmation of string theory, scientists are focusing their efforts on indirect evidence of its validity. The following directions have been proposed for this: studying the microwave background radiation, searching for signs of extra dimensions, and studying the effects of entropy and quantum gravity in black holes. Researchers believe that improving observation technologies and the likelihood of new discoveries in the field of high energies in the future will shed additional light on the justification of string theory (Brown & Susskind, 2022; Auffinger, 2022).

Further theoretical developments and, possibly, experimental results in the future may allow us to evaluate the merits of this theory with elegant equations for practical application.

4.3.5 Particle Physics: The Standard Model

In 1960, Sheldon Glashow formulated the foundations of the Standard Model (SM) in an attempt to unify the electromagnetic and weak interactions. The modern form of the SM was given by the works of Steven Weinberg and Abdus Salam (1967), who included the Higgs mechanism in this theory and demonstrated the possibility of unifying electromagnetic, weak and strong nuclear interactions into a single structure. The proposed SM was obtained as a result of outstanding intellectual activity of scientists, demonstrating a complex process of model selection.

The uniqueness of this theory lies in the developed gauge invariance, which describes the symmetries, interactions of elementary particles with each other and ensures the invariance of the basic laws under transformations. Due to this characteristic, it is possible to derive/formulate the conservation laws observed in nature. In addition, the SM predicted the existence of new particles, now discovered: quarks [55], leptons, gauge bosons. An obvious success of the SM and a confirmation of the reliability of the SM (Bohr, 1913) was the discovery of the Higgs boson with a mass of about 125 GeV, which occurred at the Large Hadron Collider (LHC) at CERN in 2012, an event that became a triumph of the intellectual work of researchers, the theoretical foresight of scientists and their experimental ingenuity (Maldacena, 1998; Friedman et al., 1991).

The achievements and successes of the SM are not diminished by the shortcomings that have not yet been eliminated. The SM does not yet include the gravitational force, dark matter and dark energy, which make up a huge part of the mass and energy of the Universe. To eliminate the shortcomings, such innovations as supersymmetry and grand unified theories have been proposed. However, no new experimental confirmation has been obtained (Higgs, 1964).

Efforts to improve the SM model resemble an iterative cycle: hypothesis - prediction - experimental verification. The lessons learned from this series highlight the urgent need to combine both the creativity of researchers and the testing of any theory in practice (Baer, 2024).

4.3.6 Lambda Cold Dark Matter (ΛCDM) Cosmological Model

The term "dark matter" was coined in 1933 by Fritz Zwicky of the California Institute of Technology. He found that the mass of all the stars in the Coma cluster of galaxies was only about 1 percent of the mass required to keep the galaxies in the cluster. In the 1970s, Vera

Rubin of the Carnegie Institution found evidence for dark matter in her study of galaxy rotation. In 1982, James Peebles first proposed the idea of a cold dark matter theory.

The ΛCDM model can now be said to be in good agreement between theoretical assumptions, predictions, and experimental observations. Its key elements are the cosmological constant (Λ) (Evans and Bryant, 2008), representing dark energy, and cold dark matter (CDM), which affects the formation and evolution of galaxies and galaxy clusters (Riess et al., 1998). The readings of the COBE, WMAP and Planck satellites confirmed the predictions of the ΛCDM model (Persic, Salucci & Stel, 1996; Smoot et al., 1992), revealing anisotropy in the cosmic microwave background. In addition, the calculations according to ΛCDM are in good agreement with the results of the Sloan Digital Sky Survey (SDSS) and the Baryon Oscillation Spectroscopic Survey (BOSS) in mapping the distribution of galaxies at huge cosmic distances (Ade et al., 2016; Tegmark et al., 2004; Alam et al., 2017).

At the same time, some questions and problems remain open that require solutions:

1, ΛCDM is based on the idea of the existence of dark energy, represented by the cosmological constant. Dark energy makes up approximately 70% of the energy density of the Universe, but its exact nature is not clear and requires experimental evidence. In addition, there is still no explanation for the corpuscular nature of cold dark matter.

2. Experiments conducted at the Large Hadron Collider have not revealed the presence of dark matter particles. This situation requires an explanation and continuation of experiments (Frieman, Turner & Huterer, 2008).

3. The predictions of ΛCDM contradict observations of the accelerated formation of galaxy clusters, which leads to the conclusion that ΛCDM is inaccurate.

4. ΛCDM does not provide alternative explanations for dark matter and dark energy, which cannot yet be experimentally verified (Bertone, Hooper & Silk, 2005; Danzmann et al., 2017).

Although ΛCDM successfully explains many observations and can predict various cosmological processes, new ideas and models may replace it in the near future.

4.3.7 Condensed Matter Physics: BCS Theory of Superconductivity

The Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity, proposed in 1957, took the model selection process to a new level, moving away from phenomenological descriptions and offering a completely new understanding of the quantum mechanical nature of superconductors at very low temperatures. In BCS, scientists managed to combine the principles of quantum mechanics and statistical mechanics. This unique model not only explains the results of experiments, but also provides a clear interpretation of the zero resistance property of superconductors. In addition, the achievement of BCS theory should be considered the explanation of the Meissner effect, in which, upon transition to the superconducting state, a material displaces magnetic fields from its interior, and the confirmation of the existence of a critical temperature below which the material becomes superconducting (Meissner & Ochsenfeld, 1933).

Along with the obvious successes of BCS, this model, like any other, has its limitations in application and the possibilities of theoretical predictions. For example, in the 1980s, high-temperature superconductors were discovered with critical temperatures much higher than those predicted by the BCS model (Tinkham, 1996; Bednorz & Müller, 1986). However, most modern research is based on the BCS model, using artificial intelligence to predict superconducting properties in new materials (Kivelson et al., 2003; Timm, 2020).

4.3.8 Quantum Computing: The Quantum Circuit Model

The quantum circuit model, based on the principles of quantum mechanics, exploits the properties of quantum bits. The property of a qubit called "superposition" in its ability to represent both 0 and 1 simultaneously is realized in quantum computers, which are capable of processing vast amounts of information in parallel. "Entanglement" refers to the situation where the state of one qubit becomes dependent on the state of another, regardless of the distance separating them. Entanglement explains the superiority of quantum algorithms in computing speed compared to classical algorithms (Gastiasoro & Andersen, 2018; Nielsen & Chuang, 2010).

One of the most significant quantum algorithms, with profound implications for cryptography and an exponential speedup compared to known classical algorithms for factoring large numbers, is Shor's algorithm for integer factorization (Ladd et al., 2010). This algorithm uses the quantum Fourier transform, which is efficiently implemented using quantum circuits.

Of equal importance for the implementation of the quantum circuit is the Grover search algorithm, which provides quadratic speedup for unstructured search problems in many promising applications (Shor, 1997; Grover, 1996; Montanaro, 2016).

IBM, Google, and Rigetti Computing are leaders in the creation of quantum computers. In 2019, Google announced that its 53-qubit quantum processor Sycamore achieved quantum supremacy, completing a certain task much faster than the most powerful supercomputers in the world (Kjaergaard et al., 2020).

Real breakthroughs in improving the quantum circuit model occur and are made public almost every week. This model allows for the creation of codes designed to detect quantum errors, and quantum computers can be developed based on it (Arute et al., 2019).

The practical value of the quantum circuit model can be assessed by the results of using the Qiskit (IBM) and Cirq (Google) languages. These languages have greatly expanded and deepened the possibilities of designing, modeling, and manufacturing quantum circuits in real quantum processors and simulators (Terhal, 2015; Kanazawa et al., 2023).

Thus, the quantum circuit model, continuously improving, will have a huge impact on the speed of computation and the achievements of scientific research in the future.

5. CONCLUSIONS: THE PROCESS OF CHOOSING A MODEL IN PHYSICS

The comments presented in the previous chapters were aimed at detailing the process of choosing a model, which is, on the one hand, inextricably linked with the consciousness of the thinker, his subjective philosophical views, and on the other hand, with physical reality, which objectively exists independently of the desires, intentions and actions of the thinker.

An ineradicable amazing feature of choosing models is the use of variables from one or another system of units, in particular, the International System of Units (SI), built by the joint intellectual efforts of scientists and engineers. The SI has the structure of an Abelian group, which is a speculative mathematical construction. The question of how it happened that an abstract structure became the basis for building a universal instrument, namely the SI, for the objective study of physical reality without individual preferences, remains beyond the scope of discussion. At the same time, SI allows for a situation where the measurement process, which is necessarily preceded by the construction of a model of a physical phenomenon, is objective and makes it possible to carefully compare and evaluate different models.

The method based on the application of the concept of "a variable containing a finite amount of information (FIQ)" can be considered as an innovative application of SI in constructing the structure of a model. Combining SI, the properties of an Abelian group and the concept of complexity, the FIQ method offers comparative uncertainty as a universal criterion for choosing the most plausible model of the object under study. This method, applied in various fields of science and technology, has proven its practical value.

The given examples of constructing models in physics demonstrate both the complexity of the process of formulating a model and the role of the subjective views of the thinker, as well as the importance of maintaining a balance between theoretical predictions and their experimental verification. Only if all these conditions are met is it possible to make predictions, expand and deepen knowledge about the world around us. In conclusion, it should be noted that the ability of a thinker to choose one or another model requires not only creative initiative from him, but also "forces" him to follow certain, pre-established principles.

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