Quanta, Rationality and Archaic Images

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Кванти, рационалност и архаични образи

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Резюме: *В центъра на анализа са парадоксите на квантовата механика. Атомите и субатомните частици разкриват такива свойства, които са неприсъщи на телата и силите в макросвета: корпоскуларно-вълнов дуализъм, отсъствие на континуитет в пространството и времето, непроследимост на трансформациите между състоянията на частиците. Единствените закони, които се оказват еднакво валидни в макро- и микросвета, са законите за запазване на енергията, момента (momentum) и заряда (charge). Валидните в макросвета категории (причинност, прекъснатост и непрекъснатост, процесуалност, пространство и време) загубват валидността си в света на микрочастиците. В такъв контекст се разглежда въпросът за кризата на класическата рационалност и за езика, който би бил адекватен за описание на квантовите явления. Аргументира се твърдението, че математическият език, който се справя успешно с парадоксите на квантовата физика, не е и не може да бъде самодостатъчен и че той неизбежно е в диалог с други, много по конкретни и близки до обикновения човешки опит. Нещо повече, именно поради парадоксалността на квантовата механика, дори нейните създатели намират за удобно да прибягват до образи, характерни за магико-митологичното съзнание и поезията. Дисконтинуитетът на квантовите явления намира аналог в магическото преобразяване на персонажи от митологията и приказките. Така науката, която, в стремежа си към абсолютна обективност, прогресивно се е освобождавала от антропоморфните представи, открива в глъбините на материята (както и в singularities на космическата еволюция) аналози на образите на архаичното съзнание и техните метаморфози.*

Ключови думи: *квантова физика, микрочастици, причинност, рационалност, митология, поезия, метаморфози.*

Abstract: *The analysis in this article is focused on the paradoxes of quantum mechanics. Atoms and subatomic particles display properties unlike those of bodies and forces in the macro-world; these new properties include particle-wave dualism, absence of continuity in space and time, the impossibility of tracing the transformations occurring across the states of the particles. The only laws that prove equally valid both for the macro and the micro worlds are those of conservation of energy, momentum and charge. The categories valid in the macro-world (causality, discontinuity and continuity, processuality, space and time) lose their validity in the world of micro-particles. This is the framework in which we examine the crisis of classical rationality and the language that would be adequate to describe quantum phenomena. We argue that the mathematical language which successfully deals with the paradoxes of quantum physics is not, and cannot be, sufficient in itself, and that it inevitably engages in dialogue with other languages that are more concrete and closer to common human experience. Moreover, due precisely to the paradoxical nature of quantum mechanics, even its creators found it convenient to resort to images typical of magical-mythical mentality and poetry. The discontinuity of quantum phenomena is similar to the magical transformations of characters in mythology and fairy tales. Thus, science, which in its pursuit of absolute objectivity has progressively freed itself of anthropomorphic representations, has found within the depths of matter (as well as in the singularities of cosmic evolution) certain images analogous to the images and metamorphoses proper to archaic mentality.*

Keywords: quantum physics, microparticles, causality, rationality, mythologies, poetry, metamorphoses

1. The cosmic marginalization of man

The anthropomorphic view of the world was predominant until the beginning of the modern age. In empirical phenomena, or somewhere beyond them, people discerned a variety of beings: idols, spirits, gods and demigods. As much as they differed in their qualities and activity, these imaginary beings had at least one common feature: they were created in the image of man. They had certain needs and demanded sacrifices, respect and reverence from people. They were endowed with consciousness, will and power: they could punish and reward. They could be good or evil, and the relationships they entertained between themselves were modeled after those between people. Humans perceived themselves as part of that mythical world, without which their lives would have lost meaning.

Although the anthropomorphic view of the world prevailed until the start of the modern age, for many centuries prior to that, some critical minds had questioned this view; they had tried to explain the world in terms of some immanent law – a law that, while not completely excluding the validity of religious-mythological ideas, at least restricted it. Philosophers took the lead in this respect: they conceived of various models of the world and man's place in the world based not on myths but on rational explanations. It was in the womb of philosophy that sciences, in the narrow sense of the term, were born. For them, rational explanation was an even stricter imperative.

Science, above all mathematics and physics, were the intellectual force that ultimately demythologized the world, turning it into an external sphere of objects, something entirely independent of, and even hostile to, man. The pioneers of modern science viewed the Christian God as the creator of the world and man. God continued to look after His "supreme creation", but the physical world no longer required His intervention and continued its movement according to the law posited in it – a law that science had to unravel. The world was reduced to bodies and to forces acting upon bodies. Moreover, man was pushed out of the center of being. Man's home, the Earth, was no longer the immobile center of the universe, as Aristotle and Ptolemy had believed, but was in fact situated at the margin of the Solar System. And this was only the start of the cosmic marginalization of man. "The Sun happens to be just an average star among a collection of a hundred billion stars which make up our galaxy called the Milky Way. (…) At still larger scales, we find that the universe is strewn with galaxies of various shapes and sizes, with the observable part of the universe containing more than several billion galaxies." (Padmanabhan 2016: 187-188)

But there was still more to come. The visible part of the universe comprises only about 5% of all matter. Another 25% consist of so-called "dark matter", whose existence physicists can detect only by its gravitational effect on the visible segments of matter. The remaining 70% of the mass-energy balance of the universe consists of the even more enigmatic "dark energy", which is referred to in explaining the accelerated dispersion of the galaxies (Bahcall 2015: 3175; Spergel 2015). We find that "the matter we are made of, known as baryonic matter, constitutes less than 5% of the total of matter in the universe. This implies another unexpected turn in the Copernican principle: Not only are we not the center of the universe, we are not even made of the kind of matter that is most abundant matter in the universe. (Gaumé 2008: 248)

And so, modern science reveals an enormous universe, in which man appears minute and insignificant. Humans are no longer seen as an essential and necessary element of the universe. The natural sciences testify not to man's grandeur but to his insignificance. The cause of man is entrusted to religion, philosophy and the human sciences, the status of which in the last 100-150 years has undergone a dramatic reduction even as the authority of the natural sciences has grown.

This trend of marginalization of man, however, is not absolute. In the 20th century, a contrary tendency emerged in – moreover – one of the vanguard fields of natural science, i.e., quantum mechanics. Physics has once again come up against the necessary presence of the human being within the picture of the micro-world.

2. The "wonders" of quantum mechanics

From the viewpoint of "common sense", the picture of the micro-world seems profoundly paradoxical. It would be hard to find anything more alien and contrary to the rationalized human experience (free of magical and animistic notions) and to the picture of the world drawn by classical science. "Quantum mechanics may be among the strangest and most abstruse subject matters in science. Its fundamental ideas are fussy, counterintuitive, and difficult to explain to the uninitiated." (Ornes 2018: 1667; see also: Arndt, Juffmann & Vedral 2009: 387) After conducting long discussions on quantum physics with Niels Bohr, Werner Heisenberg would often ask himself the question, "Can nature possibly be as absurd…?" Another eminent physicists, Richard Feynman, specifically uttered the famous phrase, "I think I can safely say that nobody understands quantum mechanics." And he advised his hearers to "just relax and enjoy." (The Long Road to Understand Quantum Physics, 2020) In one of the chapters (entitled "On the borderline between physics and philosophy") of his textbook, a teacher addressed an equally characteristic warning to his students : "Do not read this chapter, especially if you will be holding an examination on quantum mechanics. If you, nevertheless, decide to read it, the author refuses all responsibility for your mental health, and also for the grade you will receive. But if, contrary to this advice, you are interested in the interpretations of quantum mechanics, at least avoid discussing what you have read with the examiner during the examination on theoretical physics" (Ivanov 2012: 259).

In the macro-world, bodies and material systems are constantly evolving; they have a limited lifespan, even if, as in the case of the stars, it is measured in billions of years. Some microparticles (electrons, photons, some neutrinos and their anti-particles), however, never decay, or at least their lifespan is thought to be much longer than that of the present universe to date (which is 13.7 billion years) [1]. Other particles (protons, many atomic nuclei, etc.) are virtually "immortal": they have existed since the moment of the Big Bang and until now.

In a free state, the neutron lasts about 15 minutes, but once included in the atomic nucleus, it acquires their stability. Other particles are preserved only for minute fractions of a second (some last a trillionth of a trillionth of a second or less) before decaying (Most Particles Decay – But Why? 2020). The speed of microparticles is of the same category as that of light (299,792,458 m/s in a vacuum). Some (photons) are constantly traveling through the universe (Domínguez, Primack and Bell 2015: 40). Others (neutrinos) can penetrate all matter due to their small mass and lack of electrical charge: there are hardly any physical barriers to them (for instance, stellar or planetary masses) (Hall, 2015: 25). Finally, some particles (quarks and gluons), although traveling at the speed of light, remain perpetually enclosed within the space of the proton and neutron (Arkani-Hamed, 2012: 55).

Microparticles have some even stranger properties, seemingly impossible in the perspective of classical physics.

At the beginning of the 20th century, physicists distinguished between two fundamental things to which all phenomena are reducible: matter and force (field) (Rosenfeld [2] 1979: 247). Werner Heisenberg says the same regarding the pre-quantum age: “The permanent in the flux of phenomena was taken to be matter unchangeable in mass and capable of being moved by forces (…) it seemed plausible to consider the atoms, in the sense of classical natural philosophy, as the truly real, as the unchangeable building stones of matter (…) the all-too-simple world view of nineteenth century materialism was formed: the atoms, as intrinsically unchangeable beings, move in space and time and, through their mutual arrangement and motion, call forth the colorful phenomena of our sense world” (Heisenberg 1958: 97-98).

Quantum mechanics sublated this dualism but only in order to shift it to each of its two sides: particles and the field each have both a particle aspect and a wave aspect. Particles are the source of waves (energy) and waves (energy) have a particle structure (Rosenfeld 1979: 260-262).

The foundation of quantum mechanics was laid by Max Planck in 1900, when he discovered the universal constant of action (Plank’s constant). He himself strove to belittle his discovery, trying to interpret it in the spirit of classical conceptions (Rosenfeld 1979: 257-258). The idea of the quantum nature of microparticles was further developed significantly by Einstein [3] in 1905 in the context of his theory of the photoelectric effect; Bohr incorporated Planck’s constant in his own model of the hydrogen atom. The idea that portions of energy are specific to a given atom and cannot fall below a definite value calculated according to Planck’s constant, serves to explain in particular the fact that electrons are not annihilated under the impact of the nucleus's positive charge, and the atom remains stable, does not self-destruct (Einstein 1940: 490; Rosenfeld 1979: 258-259).

The forces of electromagnetism were the first to be explained in terms of quantum mechanics. In addition to them, modern physics assumes there are three other fundamental forces in nature: strong force, weak force and gravitational force. The first of these ensures the integrity and stability of protons and neutrons within the nucleus of the atom; it also keeps the protons within the nucleus by countervailing their strong mutual repulsion. Weak interaction is characteristic of radioactive nuclear decay, while gravitational force explains phenomena related to gravitation. All these, as well as electromagnetic force, possess the quantum feature of simultaneously having the properties of particles and of waves. Photons are the carriers of electromagnetic forces; gluons are carriers of strong force within the nucleus; W- and Z-bosons, of weak force; and gravitons (still hypothetical particles), of gravitational force (Bernstein 2012: 154; Ent, Ullrich and Venugopalan 2015: 45-48).

One of the greatest challenges to quantum mechanics is the interpretation of the causality principle. Classical physics grounds a strictly deterministic understanding of causality – largely typical of classical science in general. Classical causality has two aspects: the principle of conservation (of energy, momentum and electrical charge) [4] and the spatial-temporal aspect. In classical mechanics, these two aspects go together smoothly. In an isolated system, momentum is conserved and the trajectory of movement is a function of time; to every point in time, there corresponds a point on the trajectory; the latter, in turn is an indicator of the continuity of the energy states of a body. The following assertions are valid with regard to these energy states: "1. if there are causal relations, they must be identical with the relations between states; 2. if two states are causally related, then one can be predicted uniquely on the basis of the other in accordance with non-statistical laws; 3. the kind of predictability referred to above requires precise (non-statistical) specification of the states." (Prasad 1978: 47)

The quantum nature of the interaction in the micro-world brings a radical change to this picture. The first aspect of causality is preserved: "In quantum physics, the classical principles of conservation remain valid." (Ibid., 51). However, the spatial-temporal aspect becomes problematic. For instance, if an electron absorbs or emits a photon, this amounts to a leap-like change in the electron's energy state: there is nothing to connect the two successive energy states in question. The continuity of time and space that characterizes mechanical movement is disrupted, and it becomes possible that the connection between the states will be more or less accidental. This is also the case as regards various interactions in the sphere of quantum mechanics. For instance, “an atom in a high state of excitation can effect transitions to anyone of the lower excited states; but there is nothing in the conditions of the phenomenon to tell us which of these possibilities will be realized in a definite case. Therefore, all we can do is to try to find the relative probabilities of their occurrence; it is just to cope with such situations that the concept of probability has been invented.” (Rosenfeld 1979: 508).

The latter conclusion is valid for all fields of quantum mechanics. For instance, the behavior of the photon falls under the concept of probability: “When a particle of light strikes a half-silvered mirror, it either reflects off it or passes through; the outcome is open until the moment it occurs.” (Musser 2015: 90). The situation is similar in the case of radioactive decay: “When a radioactive nucleus decays, it does so spontaneously; no rule will tell you when or why.” (Ibid., 88). In a free state, outside the nucleus, the neutron also decays probabilistically: “We cannot predict exactly when a particular neutron will decay because the process is a fundamentally random quantum phenomenon – we can say only how long neutrons live on average. Thus, we must measure the average neutron lifetime by studying the decay of many neutrons” (Greene and Geltenbort: 2016: 38). In some cases, a particle may decay in different ways: “Just as a vending machine might return the same amount of change using different combinations of coins, a particle can decay into different combinations of other particles. These sets of secondary particles represent different decay channels. (…) The Higgs particle, for example, is unstable and has many decay channels, each having a certain probability to occur called the branching ratio or branching fraction.” (The Higgs Boson Glossary 2012: 1558).

Based on such facts, a Russian scientist has reached the logical conclusion: “In quantum mechanics, albeit with different amplitudes of probability, anything that does not contradict the laws of conservation may happen.” (Ivanov 2012: 63).

True, statistical correlations are well known to classical physics as well, but there they pertain to macro-processes involving enormous numbers of particles (atoms, molecules), whose movement cannot be traced individually but only in average. By contrast, quantum physics reveals the probable behavior of separate particles, and here lies its revolutionary significance (Bohr 1950: 51; Rosenfeld 1979: 457; Prasad 1978: 47-48).

I believe we may refer to quantum mechanics processes in the strict sense when the interaction encompasses a large number of microparticles – for instance, in the case of radioactive decay of a certain quantity of uranium or some other element. In such cases, as in classical physics, the law of large numbers is valid. The larger the number of particles, the more precisely predictable is their behavior; and for a certain value of that number, the behavior becomes fully predictable.

The main thesis of the creators of quantum mechanics was that classical causality (determinism) is not valid in quantum mechanics with regard to individual particles; the nature of phenomena at this level is probable, statistical. Based on this, it has been stated at times that the idea of causality is entirely incompatible with quantum phenomena (Heisenberg) or that a weaker, statistical, form of causality is valid there (Rosenfeld). According to Bohr, “we meet in atomic processes regularities of quite a new kind, regularities that defy the deterministic pictorial description” (Bohr, 1956: 87). Heisenberg states that the classical “formulations of the causal law no longer have any real meaning, when the latest development in physics is taken into consideration” (Heisenberg 1931: 172). Rosenfeld, for his part, traces the historical development of the idea of causality and argues that the content of the term changes, assuming various historical forms. The non-deterministic concept of causality in quantum mechanics on the one hand negates the classical concept, but on the other, further develops and enriches it (Rosenfeld 1979: 447-448, 454-455, 476-477).

Einstein, the most prominent critic of quantum mechanics, had a very telling view in this respect. He firmly asserted that “[s]ome physicists, among them myself, cannot believe that we must abandon, actually and forever, the idea of direct representation of physical reality in space and time; or that we must accept the view that events in nature are analogous to a game of chance” (Einstein 1940: 492). But this does not mean that Einstein, who made a fundamental contribution to quantum mechanics, rejected the validity of its principles; however, he held that this theory was incomplete and was yet to be theoretically resolved (Einstein 1934: 169; Rosenfeld 1979: 517, 520; Albert Einstein 2010: 36).

The category of causality holds such a central place in human thought and conduct that it would entail changes in a whole series of other basic categories, including those of necessity and chance, continuity and discontinuity, matter and energy. The basic parameters of the picture of the world must change.

3. Quantum poetry

The classical models of explanation are inapplicable to the micro-world, but the intuitions of everyday experience are even less reliable there. Higher mathematics is a universal language that succeeds in describing consistently the counterintuitive phenomena of the micro-world (Salmon 2010: 764). Georges Steiner has even cautioned that the description of phenomena pertaining to quantum physics and the theory of relativity in a language other than mathematical is “arrogant, if not irresponsible“ (Matlack 2017: 65).

Such a statement seems understandable considering that in the last three or four centuries, physics has tended to abandon natural language and use the language of mathematics instead. “It is easier to translate between Chinese and English - both express human experience, the vast majority of which is shared - than it is to translate advanced mathematics into a spoken language, because the world that mathematics expresses is theoretical and for the most part not available to our lived experience.” (Ibid, 57-58)

Still, the definiteness of Steiner’s view seems strange in a man of words (a literary critic, philosopher, essayist, novelist). An indicative observation is that some eminent physicists are concerned by the contemporary “alienation between the world of science and the world of public discourse” (Robert Oppenheimer). Even scientists working in separate disciplines are becoming mutually alienated and unable to understand one another (Ibid., 58-59).

It is important to point out here that the classical authors of quantum mechanics (both those belonging to the Copenhagen current and their opponents) are not inclined to withdraw into the domain of pure mathematics. Although they were generally brilliant mathematicians, they did not abandon natural language, because they understood the latter was organically inherent to human beings. For instance, Heisenberg points out, “We can of course finally succeed in understanding this world by representing its formal structures in mathematical formulae; but when we wish to talk about it we must make use of images and parables, almost as in religious language” (Heisenberg 1975: 472). In this connection, we must mention Bohr’s famous statement: “We must be clear that, when it comes to atoms, language can be used only as in poetry." (quoted in: Matlack 2017: 61). And Rosenfeld presents the dual particle–wave characteristics of microparticles through the following comparison: “I am a bird, see my wings ... I am a mouse, long live the rats! Never in the memory of physicists had there been such a dilemma.” (Rosenfeld 1979: 456) In his dispute with Bohr, Einstein tried to demonstrate the absurdity of his opponent’s thesis by arguing that Bohr assumed “spooky action at a distance” (“spukhafte fernwirkung”) (see, for instance, Castelvecchi 2020: 461). A vivid example of the use of figurative language is to be found in the “Schrödinger’s cat” thought experiment; whether the cat lives or dies will depend on the behavior of the subatomic particle (Ivanov 2012: 361-265).

Such figurative language is far from specific to the classics of modern physics. For instance, more recent authors have quite often likened the world of quantum mechanics to

Alice's Wonderland (see, for instance, Salmon 2010: 764; Most Particles Decay – But Why? 2020). Popular literature is full of anthropomorphic imagery, which also occurs in serious publications: we come across expressions like "electrons in love", "love, quantum physics and entanglement" (Sinhababu 2017: 89; Daniel and Thomson 2017). There are pseudo-theories, such as those referring to a "quantum conspiracy" of the particles. There is an abundance of all sorts of "comparisons between modern physics and various forms of mysticism, esoterics, theosophy, astrology. Even academics have published books with titles like 'Quantum Magic'" (Ivanov 2012: 269-270, 291).

When they are part of the muddy stream of mass culture, such anthropomorphisms can easily be disregarded. We may view them as nothing more than an extra ingredient needed to make a product marketable. And yet, why is this ingredient so important? Why do the products of which it is the "active substance" attract interest as much as, or more than, a high-society scandal? I believe at least part of the answer is that the fabulous tales about the micro-world – tales taken to be statements of cutting-edge "science" – provide in fact an alternative to a disenchanted "objective" world that is devoid of meaning. They satisfy the thirst for meaning; one seems to discern in them the mysterious outlines of a new beyond, a new haven of hope for salvation and eternal life.

But we should also have in mind that not all can be accounted for by the mass social need for primitive narratives and a new beyond. As mentioned, anthropomorphic symbolism has been part of the way of expression of the first-class minds that created quantum physics and fervently discussed its principles and scientific status. How is this to be explained?

The path of classical science is marked by the progressive emancipation from anthropomorphic representations and from the "vagueness" of everyday speech. By contrast, quantum physics, in rejecting classical rationality and the rational intuitions of common experience, is forced to return in a specific way to mythological imagery and poetry. Classical science rejects the magical-mythological aura of human experience and limits itself to the purely rational core of experience. The physics of the 20th and 21st centuries, on the contrary, reveals the limitations of this core, its ineffectiveness in explaining the phenomena of the micro-world and certain processes pertaining to the macro-world (for instance, the so-called singularities [5]). The principles of rationalized human experience fail in this respect. Hence, the mind comes up against the fateful question: what is the adequate language to use in describing the new truths about the world?

As we saw, some believe this can only be the language of mathematical symbols. If, however, a vow of mathematical silence were kept, we would be left with an essentially esoteric science. But since we are talking about symbols, albeit mathematical ones, and not simply about a structured series of graphic images, mathematical silence proves illusory: the symbol offers a meaning that goes beyond the graphic object to which it refers. That meaning predetermines and ensures the embeddedness of the symbol. In physics, mathematical symbolism should serve to represent the real world that is given prior to purely mathematical language. Consequently, the latter is inevitably linked to other languages, whose symbolism is not mathematical; behind the mathematical silence there is always a continuing dialogue with other, not so abstract and universal, languages.

The alternative to mathematical exclusiveness is to openly acknowledge and accept that a pure and exclusively mathematical language is impossible, and that it is necessary to combine the latter with some form of natural language. Reason is obliged to accept this compromise, whether a concrete scientist is willing to make it or not. Of course, the use of a natural language does not entail an uncritical acceptance of the assertions that have already been made in it.

But what happens when the principles of classical rationality have lost their validity in the new scientific field of quantum mechanics? Then, along with those principles, the language of classical science and, even more so, the language of rationalized everyday life, also come to nothing or at least become insufficient. As paradoxical as it may seem, the new science feels the need to use some of the expressive means of archaic imagery, though remaining aware of their limitations and of the risk of abuse they may involve.

And how could it be otherwise, given that the behavior of each separate microparticle (in contrast with their behavior as a “mass”) is not of the processual kind typical of the macro-world? The state of each particle changes instantaneously, at a leap, and changes cannot be traced: it is not a processual state. Moreover, the time of occurrence of the leap cannot be strictly determined. As Ivanov aptly points out (2012: 68-70), “quantum mechanics is a theory of transformations”, where only the laws of conservation remain valid.

But instantaneous and untraceable transformation (metamorphosis) is likewise typical of the characters of mythology and folk tales. For instance, metamorphoses are typical of the gods in Ancient Greek and Roman mythology: “The boundaries between gods, humans, monsters, and animals, and occasionally plants and inanimate objects as well, are transgressed with ease in the service of seduction, punishment, escape, and reward.” (Sonik 2012: 385-386). Zeus turns into a bull in order to seduce Europe; into a swan to possess Leda; into a shower of gold to impregnate Danae. When Actaeon accidentally sees the naked Artemis bathing, the goddess punishes him by turning him into a stag. Jealous Athena turns the charming Medusa into the petrifying Gorgon (Ibid., 385-386). Countless examples are to be found in the Greek pantheon. Such metamorphoses are much rarer in other mythologies, such as the Mesopotamian, but they can be found in all of them (Ibid, 386).

Magical metamorphoses typically occur in folk tales as well: a princess turns into a servant girl or a frog, and vice versa; an evil magician or a witch possess the ability of transforming themselves instantaneously.

The archaic mind distinguished between the sacred (magic, myths) and the profane (daily life). At a later stage, a similar contradistinction was made between poetical language and the languages of purposeful rational action and utilitarian behavior. There is a similar split between paradoxical imagery in the language of quantum mechanics and the rigorous formality of classical science. After all that has been said above, I cannot but agree with the following conclusion: "Homo sapiens began his quest for knowledge in the realm of poetry. And in the end it seems that in basic respect we are destined to remain close to this starting point." (Matlack 2017: 61-62)

4. Conclusion

Our discussion closes a kind of circle. The development of astronomy pushed man out of the center of the universe, relegating people to an insignificant, marginal status. The other sciences, including classical physics, rejected the specifically anthropomorphic representations of the world. Classical physics, emancipated from the human perspective, strove to make reason assume an absolute and universal perspective on things as they are in themselves, free of any irrational element.

Quantum mechanics, however, reveals the limitations of classical rationality. The latter's basic categories (body and force, space and time, causality, continuity and discontinuity) prove inapplicable to the phenomena of the micro-world. On the other hand, modern astronomy has found that the universe had a start (the Big Bang). And this start is a singularity, meaning that the laws of physics do not apply to it; it represents the beginning of space, time and matter. In other, local, kinds of singularities (black holes), the reverse process occurs: matter, time and space are consumed.

Thus, in the borderline zones of being, in the world of microparticules, as well as at the initial point of cosmic evolution, classical rationality and the language related to it lose their validity. Images derived from mythology and religious consciousness find a natural place there. As we saw, mythological and poetic imagery were not alien even to the greatest minds of non-classical physics, albeit scientists were well aware this imagery was archaic and untenable. Thus, when penetrating into the depths of matter and the beginning of cosmic evolution, scientists encounter paradoxes that would seem “natural” only for the archaic mind (seeped in myth and magic) and its creations (folk tales, poetry).

Under the circumstances, the question of the epistemological status of quantum mechanics naturally arises. How can its scientific results be interpreted? I mentioned Einstein’s doubts: he believed the theory was incomplete. But disputes as to its epistemological status are going on more or less obviously among the adherents of the Copenhagen current as well. The problem is so fundamental that it ultimately touches on how we understand nature and the meaning of human knowledge in general. Within the limited size of this article, we cannot analyze this set of questions.

Notes

[1] For several decades now, the prevailing cosmological theory has been that our world appeared approximately 13.7 billion years ago as a result of the so-called Big Bang. The word “bang” – explosion – seems misleading: it was not an expansion in space, as a bomb explosion would involve, but an expansion of space itself, an “explosion of space” (Lineweaver and Davis. 2005: 38-39). According to Joseph Silk, “the big bang is the modern version of the creation myth” (Silk 1999: 258). Stephen Hawking comments that, despite its serious scientific justification, many people do not like the idea that time had a beginning, “probably because it smacks of divine intervention”. The Catholic Church “siezed on the big-bang model and in 1951 officially pronounced it to be in accordance with the Bible” (Theckedath 2003: 66). In 1963, the Soviet scientists Evgenii Lifshitz and Isaac Khalatnikov tried to refute the theory, but according to Penrose and Hawking, even their model assumes the existence of singularities (Ibid, 66-67).

[2] In this text, I have referred very often to Niels Bohr, Werner Heisenberg and Leon Rosenfeld. They are part of a wide group of scientists who maintained close professional and personal contacts between themselves and of which Bohr was the central figure. This group was associated with the so-called Copenhagen interpretation of quantum physics (Jacobsen 2007: 3, 5).

[3] It would be inexact and erroneous to say that Einstein rejected quantum mechanics. In fact, he was one of its founders, who grounded the wave-particle duality of light. Einstein did not put in question the basic facts and principles of this theory, but did not accept the Copenhagen thesis that the theory was self-sufficient; he believed a more fundamental theory was possible, which would resolve those paradoxes of quantum mechanics that testified to its

incompleteness. His intensive efforts on this problem were not successful; nor, for that matter, were the related efforts of other theorists (Musser 2015: 90).

[4] Conservation of energy means that energy does not come into being or disappear but only passes from one form into another (kinetic and potential, mechanical, heat, chemical, etc.). All these forms have a mechanical equivalent. Momentum is the product of the body's mass multiplied by its velocity.

[5] Singularity is a place in relation to which the solution of a given equation is undefined and the familiar laws of physics do not operate. It is believed that the beginning of the world, the Big Bang, was a singularity, an initial moment in which the entire universe was concentrated into a single, infinitely dense point, which served as the beginning of space, time and matter. Singularity is also assumed to be a property of "black holes" (Afshordi, Mann and Pourhasan 2014: 40; Psaltis and Doeleman 2015: 77)

Cited literature

Afshordi, Niayesh, Robert B. Mann and Razieh Pourhasan. 2014. The Black Hole at the Beginning of Time. // *Scientific American*, 311(2), 36-43.

Arkani-Hamed, Nima. 2012. The Future of Fundamental Physics. // *Daedalus*, 141(3), 53-66.

Arndt, Markus, Thomas Juffmann and Vlatko Vedral. 2009. Quantum physics

meets biology. //*HFSP Journal*, 3(6), 386-400.

Bahcall, Neta A. 2015. Hubble's Law and the expanding universe. // *Proceedings of the National Academy of Sciences of the United States of America* , 112, 3173-3175.

Bernstein, Jeremy. 2012. Palette of Particles. // *American Scientist* , 100(2), 146-155.

Bohr, Niels. 1950. On the Notions of Causality and Complementarity. // *Science*, New Series, 111 (2873), 51-54.

Bohr, Niels. 1956. Mathematics and Natural Philosophy. // *The Scientific Monthly*, 82(2), 85-88.

Castelvecchi, Davide. 2020. The 'Spookiness' of Quantum Physics Could Be Incalculable. // *Nature*, 577, 461-462.

Daniel, Ari and Peter Thomson. 2017. // Love, Quantum physics and 'entanglement'. // *The World*, July 25.

Domínguez, Alberto, Joel R. Primack and Trudy E. Bell. 2015. All the Light There Ever Was. // Scientific American , 312(6), 38-43.

Einstein, Albert. 1934. On the Method of Theoretical Physics. // *Philosophy of Science*, 1(2), 163-169.

Einstein, Albert. 1940. Considerations Concerning the Fundaments of Theoretical Physics. // *Science*, New Series, 91(2369), 487-492.

Albert Einstein. 2010. // *Science News*, 178(11), 36.

Ent, Rolf, Thomas Ullrich and Raju Venugopalan. 2015. The Glue That Binds Us. // *Scientific American*, Vol. 312(5), 42-49.

Gaumé, Luis Álvarez. 2008. Riddles in Fundamental Physics. // *Leonardo*, 41(3), 244-251.

Greene, Geoffrey L. and Peter Geltenbort. 2016. The neutron enigma. // *Scientific American,* 314(4), 36-41.

Hall, Shannon. 2015. The Big Bang's Particle Glow. // *Scientific American*, 313(6), 25.

Heisenberg, Werner. 1931. Kausalgesetz und Quantenmechanik. // *Erkenntnis,* 2, 172-182.

Heisenberg, Werner. 1958. The Representation of Nature in Contemporary Physics. // *Daedalus*, 87(3), 95-108.

Heisenberg, Werner. 1975. Scientific truth and religious truth. // *CrossCurrents*, 24(4), 463-473.

Ivanov, M. G. 2012. *Kak ponimat kvantovuyu mehaniku?* Moskva- Izhevsk: NIZ "Regularnaya i haoticheskaya dinamika".

Jacobsen, Anja Skaar. 2007. Léon Rosenfeld's Marxist defense of complementarity. // *Historical Studies in the Physical and Biological Sciences*, 37,, 3-34

Lineweaver, Charles H. and Tamara M. Davis. 2005. Misconceptions About the Big Bang. // *Scientific American*, 292(3), 36-45.

Matlack, Samuel. 2017. Quantum Poetics. // *The New Atlantis*, 53, 46-67.

Most Particles Decay — But Why? 2020. *Updated 10 December 2021. Avalable at: https://profmattstrassler.com/.*

Musser, George. 2015. Is the Cosmos Random? // *Scientific American*, 313(3), 88-93.

Ornes, Stephen. 2018. Quantum games aim to demystify heady science. // *Proceedings of the National Academy of Sciences of the United States of America*, 115(8), 1667-1669.

Padmanabhan, T. 2016. Cosmic Odyssey: Past, Present and Future. // *India International Centre Quarterly*, 43(1), 182-194.

Prasad, Rajendra. 1978. Causality and Quantum Mechanics. // *Social Scientist*, 6(9), 37-54.

Psaltis, Dimitrios and Sheperd S. Doeleman. 2015. The Black Hole Test. // *Scientific American*, Vol. 313(3), 74-79.

Rosenfeld, Léon. 1979. *Selected Papers*. Dordrecht / Boston / London, D. Reidel Publishing Company.

Salmon, James F. 2010. Evolution of Information. // *Revista Portuguesa de Filosofia*, 66(4) 759-768.

Silk, Joseph. 1999. The Fundamental Parameters of Cosmology. // *Publications of the Astronomical Society of the Pacific*, 111(757), 258-263.

Sinhababu, Neil. 2017. Divine Fine-Tunning vs. Electrons in love. // *American Philosophical Quarterly*, 54(1), 89-98.

Sonik, Karen. 2012. Breaching the Boundaries of Being: Metamorphoses in the Mesopotamian Literary Texts. // *Journal of the American Oriental Society*, 132(3), 385-393.

Spergel, David N. 2015. The dark side of cosmology: Dark matter and dark energy. // *Science*, New Series, 347(6226), 1100-1102.

Theckedath, K. K. 2003. Dialectics and Cosmology: The Big Bang and the Steady State Theories. // *Social Scientist*, 31(1/2), 57-84.

The Higgs Boson Glossary. 2012. // *Science*, New Series, 338(6114), 1558-1559.

The Long Road to Understand Quantum Physics. 2020. Updated 10 December 2021. Available at: https://www.bbvaopenmind.com/en/science/physics/understand-quantum-physics/.