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THE CONCEPT OF REALITY IN QUANTUM PHYSICS BETWEEN RATIONAL AND REALISTIC INTERPRETATION

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Abstract:
The objective of this article is to elucidate the philosophical implications of quantum mechanics, a theory capable of describing the infinitesimal and facilitating the emergence of various conceptions of "physical reality." Additionally, the article addresses the interpretative challenges regarding reality that compel epistemologists in physics to interrogate the ontological dimensions of the physical world, which remain concealed beneath an abstract mathematical formalism. In light of this plurality of interpretations, quantum physicists confront a dichotomy between Einstein's realism and Bohr's positivism. The fruitful philosophical discourse between these two eminent physicists reaches a conclusion in the 1980s with Alain Aspect's experiments, which oblige both physicists and philosophers to abandon the notion of realism in favor of Bohr's contextualist approach.

Keywords: Interpretation; Metaphysic; Ontology, Rationalism, Realism.

Introduction :

Quantum theory, or quantum mechanics, is regarded within the scientific community as one of the most complex and paradoxical frameworks in physics. It notably challenges established axioms and common intuitions, presenting profound contradictions to formal logic. Formal logic is constructed upon immutable laws of thought that are characterized by independence from external determinations of existence. These laws, articulated by Aristotle, include the law of identity, the law of non-contradiction, and the law of the excluded middle, each considered self-evident within the cognitive framework. Additionally, formal logic adheres to a methodological principle involving binary values (truth and falsehood). In the terminology of Gaston Bachelard, this principle poses an epistemological obstacle that contemporary physics must surmount, particularly in relation to quantum theory, which delves into the realm of atoms and subatomic particles. This minuscule domain, defined by its inherent uncertainties, necessitates the formulation of a new conceptual framework predicated on a ternary value principle. This new system accommodates significant scientific advancements, including Heisenberg's indeterminacy principle, probabilistic calculations, and Erwin Schrödinger's wave function, all of which stand in stark contrast to the tenets of formal logic.

It may not be an exaggeration to assert that throughout the history of science, no theory has engendered as much scientific and philosophical controversy as quantum theory since its emergence at the beginning of the twentieth century to the present day. Scientists have exhibited unprecedented division in their interpretation of a scientific theory, particularly regarding the concepts and foundations of this peculiar and remarkable theory. Quantum theory and Einstein's theory of relativity are regarded as the two most significant achievements of the twentieth century, and the endeavor of physicists to integrate them into a unified model represents one of the most profound scientific challenges, with the objective of developing a comprehensive theory that elucidates the universe at both macroscopic and microscopic levels. The distinctiveness of quantum theory resides in its transcendence of the concepts and foundations underpinning classical physics, such as the principles of determinism and causality, as well as its treatment of space and time as absolute and independent entities. Furthermore, quantum theory has surpassed the assertions of relativity theory in its conceptualization of the dimensions of space and time and the nature of light particles, or photons. Einstein, adhering to Newtonian principles, maintained a commitment to the determinism of physical phenomena and harbored a steadfast belief in the principle of causality within nature. As will be discussed in the following sections of this article, it is evident that he was astounded by the inevitability of quantum events, which ultimately lead to an extraordinary realm characterized by chaos, despite his profound conviction that "God does not play dice."

Quantum theory signifies a profound transformation in the understanding of matter and the material world, compelling physicists to consider human consciousness as a critical

element in comprehending any quantum state of the universe. This notion will be further explored through the rational interpretation offered by the Copenhagen School.
The theory is characterized by its complex mathematical formulations and ambiguous epistemological interpretations. It does not fit neatly into the categories of speculative theory, ordinary scientific theory, or purely philosophical constructs; instead, it represents a confluence of all these elements.
Much like the theory of relativity instigated a paradigm shift in describing the nature of phenomena at macroscopic scales, particularly with general relativity and its engagement with extraordinarily high velocities, quantum theory emerged to elucidate the nature of entities at atomic and subatomic levels. A group of physicists developed this theory to facilitate the exploration of particles with infinitesimal masses, governed by principles distinct from those of classical mechanics or the special and general theories of relativity. Quantum mechanics can be characterized as a mathematical framework that scrutinizes the behavior of atomic particles and employs complex equations designed to measure and investigate the phenomena of the subatomic realm. It emerged as a response to the profound physical and philosophical (metaphysical) controversies concerning the nature of physical reality and how the objective reality observed manifests from its foundational structure. Concurrently, it sought to address the challenges regarding the connection or separation of energy. The dominant perspective at the conclusion of the nineteenth century posited that energy, in its various representations, is a continuum devoid of gaps, and that light possesses a wave-like nature. Nevertheless, classical physics proved insufficient in elucidating certain phenomena associated with atomic and molecular behavior. Quantum mechanics effectively addressed these inadequacies by elucidating the nature of atomic particles and articulating its discoveries through mathematical formulations, thereby resolving these dilemmas, transforming our conventional understanding of the world and its governing laws, and engendering a "Copernican revolution" that established an innovative and unprecedented paradigm in physics. This article examines the two primary schools that constituted the epistemological framework accompanying the quantitative theory in its interpretation of the concept of reality: the rationalist school and the realist school. Through the lens of these two schools, we endeavor to provide a philosophical analysis that approaches the metaphysical structure inherent in the concepts of this theory.
Our goal in this article is to affirm the presence of metaphysics in contemporary epistemological discourse, and to trace the relationship and cognitive link between this discourse and quantum theory.
We can define the fundamental issue in our article as follows: Can we speak of an objective reality independent of any observation process in quantum mechanics, according to both schools of thought?
To address the central research problem, we relied on the historical-analytical method, as it is the most suitable approach for our study. Firstly, the historical method was employed when we discussed the prominent interpretations that were put forward to approach the concept of physical reality, as well as when mentioning the notable scientists who contributed to the formation and development of quantum theory in the twentieth century.
Secondly, the analytical method served as a tool to elucidate the ideas, perceptions, and philosophical and metaphysical implications embedded in quantum mechanics in its

engagement with the concept of physical reality as envisioned by both schools. This particular method helped us uncover the metaphysical aspect lying at the heart of quantum theory on one hand, while also highlighting the degree to which physics intertwines with philosophy at the level of the concepts used to describe the nature of reality.

1- Quantum Mechanics and the Ontological Revolution:

Quantum mechanics has revived a profound philosophical conflict regarding the theory of knowledge and has introduced contemporary physics into a wide-ranging metaphysical debate. This significant division is evident in the stances of physicists and philosophers of physics concerning the interpretation and understanding of quantum mechanics, which is rightly regarded as a radical revolution in our perceptions and ideas about the world and reality. The latter is treated by quantum theory as a multifaceted and ever-renewing reality in its representations. It resembles the ever-flowing river of Heraclitus, which never ceases to flow. This compels both the scientific and philosophical mind to engage with this concept through a perspective that allows for continuous revision and adjustment. It is not immediately given nor ready for empirical observation, but rather it is an intellectual creation that works to complete the picture of the relationship between the language of science and nature (the world). This is what Gaston Bachelard proposes in his rational epistemological project, where he believes that reality does not present itself as such; instead, we attempt to simplify it and demonstrate it through our cognitive tools.

The significance of physical interpretation lies in its ability to provide a clearer pathway for understanding experimental results more precisely. The process of interpretation involves contemplating the meanings of the mathematical formulations in physics and their philosophical implications. Interpretation directs the mind to perceive the various images of the world suggested by physical theories, including the things that physics reveals in nature that shape reality, even if they are not directly perceived. Thus, interpreting a physical theory means: "stripping reality of the appearances that cloak it as if they were veils, in order to see this reality in its bare form, face to face." (Duhem, 2016, p.6)

The world is always eager to understand the various arrangements of the reality in which it lives, and the interpretation of physical theories, in particular, offers that desired scientific image. It even defines the conceptual framework that explains the realistic nature of our world and the various relationships that characterize the things that scientific minds strive to classify.

Approaching quantum mechanics without the aid of specialist interpretation is a near impossibility, for several reasons summarized by physicist Roland Omnis in three points: "First and foremost, because the theoretical representation has reached the peak of ambiguity and obscurity. Secondly, because the essence of the observer's conception is no longer clear at all, and those who have utilized it have ended up incorporating the observer's consciousness, which contradicts the objective nature of science. Finally, because the probabilistic aspects of the theory must ultimately align with the certain existence of facts and realities. Thus, interpretation ceases to be merely a translation and becomes a theory in its own right."(Omnès, 1999, p72)

Both Niels Bohr, Werner Heisenberg, and Max Born proposed an interpretation of quantum mechanics known as the Copenhagen interpretation, named after the physics institute that Bohr managed in the city of Copenhagen. This is a positivist school that presented its interpretation between 1927 and 1932. What distinguishes this interpretation is its philosophical approach, which suggests the disappearance of boundaries between the subject and its object. This is illustrated by Bohr's statement, referenced by Heisenberg in his work, where Bohr said: "It is wrong to think that the task of physics is to find out how nature is; physics concerns what we can say about nature."(D'Espagnat, 2017, p.81).

The interpretation of this school is characterized by its denial of the objective reality of the components of the microscopic world and the assertion that the term "reality" has no inherent meaning. The proponents of the Copenhagen interpretation distanced themselves from discussing the concept of reality as an objective truth. For them, quantum mechanics is effective theoretically and, to a large extent, experimentally. The wave function, for example, is merely a predictive tool that allows us to calculate various measurement probabilities, rather than an objective entity that exists in nature.

The conceptual framework of classical physics cannot penetrate the realm of the microscopic or express it, as classical physics assumes an objective separation between the measured entity and the measuring instrument. This is something the Copenhagen school rejects. Heisenberg stated in this regard: "The Copenhagen interpretation of quantum theory arose from a paradox; classical physics concepts form the language through which we describe the conditions under which our experiments occur and communicate with each other about the results of those experiments. It is impossible for us to replace those concepts with others, and we should not attempt to do so. However, the application of these concepts is limited by relationships of uncertainty. When we use these classical concepts, we must recognize their limitations."(Lurçat, 2001, p.180)

According to the Copenhagen interpretation, one cannot separate the measurement process from the physical event in the realm of microphysics, as the phenomena studied at this atomic level do not possess an independent reality. The subject and the object together constitute external things, as phenomena "only exist in relation to a subject that observes and experiences them. Thus, scientific statements do not refer to objective reality, but rather to our procedures and experimental methods; they are merely mental constructs of sensations."

According to the Copenhagen interpretation, the existence of any object, say an electron, does not have real existence unless we perceive it through measurement. "Therefore, the object is a mixture of subjectivity and objectivity, and thus the external world has collaborated with the subject in its creation."(D'Espagnat, 1989, p.117). In this interpretation, quantum physics describes the interaction of the subject with the physical world and does not describe reality as it is in itself; hence, the representation of any phenomenon at the quantum level is entirely dependent on the measuring instruments.

Albert Einstein is considered the greatest opponent of the Copenhagen school led by Bohr. One of the most notable features of Einstein's philosophy is his complete separation between the world of the subject and the world of the object, that is, between the perceiver and the perceived. The subject of physics is a real, independent world that has its actual existence even if we do not observe it. This is strongly contested by the Copenhagen school, as it views the subject and object as intertwined in an interactive relationship. The independence of the self-observing world is a cornerstone of Einstein's position, and we will relatively elaborate on the changing nature of the object with quantum mechanics through the two interpretations that have been presented in the scientific and philosophical arenas.

2. Quantum Mechanics: Between Rational and Realistic Interpretation:

The concept of interpretation places the physical theory in a close relationship with the philosophy of physics, as it refers us to the metaphysical implications arising from the conceptual apparatus used by physics in its attempt to understand the external world. This is evident in the relationship that quantum theory has established with physical reality by reshaping the meanings of physical concepts in a way that is entirely different from what classical physics and even Einstein's relativistic physics provided.

2-1 Rational Interpretation: Niels Bohr and the Copenhagen School:

The quantum theory cannot be separated from mathematics, as the precision that characterizes quantum mechanics is a direct result of the exact nature of the language of mathematics. This connection between the two is what imparts a rational significance to the concepts of quantum mechanics. It is a theory deeply rooted in abstraction and possesses a high degree of mathematical formalism. Therefore, we cannot talk about "any possible representation of the minuscule real world," but only about "dry mathematical formulations based on important probabilistic calculations."(Gavet, 2012, p.51) This means that physical phenomena at the atomic level do not possess an independent reality. This is the stance of the famous Copenhagen School, which argues that one cannot separate the knowing subject from the physical event in the micro-world. Phenomena "only exist in relation to a subject that tests and experiments upon them." Thus, scientific propositions do not refer to objective reality but to our procedures and experimental methods; they are merely mental constructs. According to the Copenhagen interpretation, the existence of an entity, such as an electron, does not possess real existence unless we perceive it through measurement. This perspective is based on describing the interaction of the subject with the physical world, rather than describing reality as it is in itself. "The entity, therefore, is a mixture of subjectivity and objectivity; thus, the external world is co-created with the subject." (D'Espagnat, 2017, p.115).The task of quantum mechanics for Bohr's group is to provide a mathematical description of the phenomena studied that aligns with experimental data, regardless of what happens in reality. This implies that the school denies realism because it separates the meanings of mathematical description from the described reality. Moreover, the measurement process is intertwined with the time taken during the experiment. As Bohr put it: "There is no quantum world; there is only an abstract quantum description. Reality is created and emerges from observation."(Herbert, 1987, p.17)

Thus, the denial of realism in the quantum world outside the framework of observation is the cornerstone for Bohr and his followers. The direct realism of our sensory-perceived world masks, at the atomic level, a world that does not possess that realism at all; rather, it is an ideal world to a large extent. For this school, physics is not objective; through measurement and observation, the physicist interacts with events, and the results of measurement cannot be considered direct realities. Quantitative facts "only emerge when they are first recorded in the consciousness of aware beings, as the pinnacle of measuring tools."(Rovelli, 2018, p.74).

Gaston Bachelard calls for transcending realism, asserting that science derives from the internal structure of its concepts, not from the given phenomena as raw material. He

illustrated how contemporary physical science shifts from rationality to experience, indicating that it is a mental construct, based on the idea that "the sources of contemporary scientific thought belong to the field of mathematics."(D'Espagnat, 1989, p.143) The latter forms the solid foundation upon which the conceptual constructions of modern physics stand. Bachelard concluded that physics is no longer a science dealing with facts; rather, scientific activity has become governed by mathematical rationality, which is entirely different from traditional rationality. In his words, "Completing a program of experiments, an organized program rationally, defines an experimental reality free of any irrational elements."
Science studies reality through its process and development within a network of relationships; in other words, it is a constructed or artificial reality.
The quantum theory has given rise to a rational conception that is fundamentally related to the nature of contemporary epistemological thinking. This specificity has accompanied the structure of the concepts related to this theory, which has linked its understanding of physical reality to a rational aspect that distances itself from naive sensory reality.

2-2 Realistic Interpretation: Einstein and Physical Realism
Albert Einstein is considered the foremost advocate of the realist position in physics, which posits the possibility of describing reality as it truly is. He was also a significant opponent of the Copenhagen School led by Niels Bohr. One of the most distinguishing features of Einstein's philosophy is his complete separation between the subjective world and the objective world, that is, between the perceiver and the perceived. The subject of physics is an independent reality that exists even if we do not observe it. This is strongly contested by the Copenhagen School, which does not accept the validity of this position because, as we have seen in their view, the subject and object interact in a relational manner. The independence of the self-observing world is a cornerstone of Einstein's stance. Thus, the proponent of the theories of relativity believes that the objective world is entirely subjected to causal and deterministic relationships. His famous phrase, "God does not play dice," encapsulates much of his position, expressing his opposition to Bohr's group, which posited a non-deterministic and non-causal world. For Einstein, the Copenhagen interpretation is incomplete because his philosophical thought, which organizes all his analyses, is based on the premise that the world is real and rational, meaning that thought has the ability to penetrate this world and provide a true representation, even if it is temporary.
Einstein believes that reason can comprehend the truth of objective reality and grasp the precise order governing it. He started from the premise that reality in the microscopic world is no less organized than it is in the infinitely large world in which we live and interact. He emphasized his belief that we can demonstrate things in reality that the Copenhagen School has not accounted for. The latter does not inform us about what can be known about reality, which is why Einstein described its interpretation as incomplete, writing: "The sole aim of established science is to ascertain what exists."(Klein, 2014, p.52).
Einstein's phrase "what exists" serves as a criterion for physical reality, meaning that his starting point is not the hypothetically constructed components but rather "the general properties of naturally occurring phenomena from which formulated mathematical

standards arise."(Einstein, 2014, p.71), Therefore, one cannot discuss any component of this reality, such as the speed of a particle, without it corresponding to a specific quantity in the mathematical formulation of the theory, regardless of whether we can measure that quantity or not. In this mentioned sense, Einstein considers that physical theory objectively describes reality. In his words, "Every element of physical reality must have a counterpart in physical theory (Klein, 1991, p.99), and this is the meaning of a theory being complete and whole."

Einstein did not accept the results of the Copenhagen School's interpretations of quantum mechanics and spent a long time trying to prove that quantum theory is incomplete and self-contradictory. He sought to demonstrate, through a number of thought experiments -of which he was a master- the reality of the atomic world and the determinism of the laws governing it. The characteristics of physical theory, according to Einstein, must fundamentally possess four attributes: realism, completeness, locality, and determinism. His stance led to significant debate and discussion with Niels Bohr, the pioneer of the Copenhagen interpretation, which became known as the "Einstein–Bohr dialogues." These discussions hold great importance for the philosophy of science due to the philosophical nature raised between the two great physicists.

Through this paradox, Einstein aimed to highlight the reality of the quantum world itself and that it lacks certain elements he considered hidden, which experimental means have not allowed us to discover. For Einstein, quantum theory is incomplete and provisional. He spent the rest of his life searching for a more fundamental theory that could unify with general relativity to provide an accurate description of physical reality. This reality must objectively include elements of physical reality. The paradox provided a definition of this criterion that determines the meaning of the concept of "an element of reality," which states: "If we can predict with certainty the value of a physical quantity without affecting the system, then there exists an element of physical reality corresponding to that physical quantity." (D'Espagnat, 2017, p.79), In other words, Einstein wanted to define the realistic element by relating it to observable physical quantities. However, Niels Bohr did not take long to respond to this paradox, and his reply essentially consisted of rejecting the third hypothesis, asserting that the locality he described is not applicable: "Quantum mechanics is not local."(Omnès, 1999, p73.)

Bohr objected to the conclusion reached by the proponents of the paradox by arguing that quantum mechanics is incomplete, specifically challenging the criterion for defining physical reality. He stated, "The criterion of physical reality proposed by Einstein, Podolsky, and Rosen involves ambiguity related to the phrase 'without affecting the system.' Clearly, the issue in such a case is not about the mechanical influence of the studied system during the final phase of measurement. However, even at this stage, the fundamental question relates to the impact on the conditions that define the possible types of predictions concerning the future behavior of the system" (Boyer, 2015, p.98). This stems from "his conviction that we cannot complete the quantitative formulation without undermining its internal logic" (Aspect, 2016, p.23).

As previously mentioned, Bohr believed that quantum mechanics is based on a holistic experiment that has its own logic, where the subjective and objective intertwine contextually in the measurement process. However, the proponents of the paradox reject the hypothesis of contextuality and assert that physical reality relates to systems as they exist independently of the observer. "What must be demonstrated is the unobserved objective reality, not the observed reality, which quantum mechanics has not fully described" (Bachtold, 2005, p.402).

The core of the disagreement between Einstein and Bohr revolved around the principle of quantum entanglement and its physical and philosophical implications, a term first introduced by the Austrian physicist Erwin Schrödinger. An entangled system possesses characteristics that cannot be understood as individual properties of its components. "The measurement results applied to one component of the system are linked to the measurement results conducted simultaneously on the other parts of the system" (Coudreau, 2007, p.38). This "instantaneous effect, which Einstein described as 'spooky action at a distance'" (Kaku, 2005, p. 75), denies all the tenets of physics as envisioned by the advocates of local realism, led by Einstein. How can two separate bodies influence each other without any intermediaries? This led Einstein to propose the existence of hidden variables that would make this effect reasonable, which is why he and his colleagues Rosen and Podolsky described quantum mechanics as incomplete. However, experimental evidence confirmed the non-locality principle predicted by quantum mechanics in a remarkably mathematical manner, thereby undermining the locality principle that Einstein believed in.

A significant shift in the quantum world occurred in 1964 when John Bell (1928-1990), an Irish physicist, presented mathematical proposals to detect the existence of hidden variables. If such variables were confirmed within the theoretical framework of quantum mechanics, it would necessitate a statement about the local realistic nature based on the principle of causality in the quantum realm. In the words of Alain Aspect (1947-), "Bell's work shifted the dialogue between Einstein and Bohr from the realm of epistemology to that of experimental physics" (Aspect, 2016, p.23). The issue was no longer confined to a philosophical stance oscillating between Einstein's realism and Bohr's positivism; it could now be resolved experimentally.

In the world of physics, Bell's proposition is known as Bell's inequalities. According to this theorem, "Quantum mechanics and the hypothesis of local separability of interacting physical systems stand at opposite ends" (Paty, 2003, p.44). Bell concluded that if his inequalities were found to be false, it would validate the non-locality principle and the existence of hidden variables that causally connect quantum particles. This was the first announcement affirming what the Copenhagen interpretation led by Bohr posited.

The second experimental fact confirming Bohr's interpretation was the experiment conducted by French physicist Alain Aspect in 1982 at the Institute of Optics. Aspect's experiment demonstrated the validity of quantum entanglement and the principle of non-locality, providing the strongest scientific response to the Einstein -Podolsky- Rosen (EPR) paradox. This experiment showed that quantum mechanics calculations are accurate, that Bell's inequalities are violated, and that the concept of entanglement is real. Particles can be correlated and entangled across space, and the measurement of one particle can affect its entangled partner, as if the distance between them were nonexistent. This revelation deeply troubled Einstein, who struggled to accept such a bizarre possibility. Aspect's experiment and those preceding it "undoubtedly present a different image of the world than what we instinctively know in our daily lives, indicating that particles which were once connected in interference remain, in some way, parts of a single system, responding together in other interferences" (Gribbin, 1984, p. 249).

The debate between Bohr and Einstein did not come to a definitive end with their deaths, as it is fundamentally a philosophical discussion infused with metaphysics seeking to understand the meanings of things and the concepts they express. Issues concerning the nature of physical theories, the ultimate goal of science, and whether quantum mechanics is complete reflect how we understand the world around us and whether it is even comprehensible. The difference in perspectives stems from Einstein's deep-rooted realism in contrast to Bohr's anti-realism, which views quantum entities as not existing in themselves. Bohr believed that classical world concepts cannot be reconciled with the quantum realm, asserting that all quantum paradoxes arise from using classical physics language to describe the quantum world.
Such questions are unlikely to yield a final answer, as human consciousness's role in shaping our perceptions of the world complicates the matter more than we might imagine.

Conclusion:

The quantum theory has significantly contributed to the advancement of human understanding of the concept of truth from a physical perspective on one hand, and from an epistemological practice on the other. Both approaches have played their part in drawing closer to the physical truth of our perceived world. Rationality has manifested itself through the free creativity of contemporary physical theories, while realism has emerged in the expression of the objectivity of the physical world.
Einstein's general theory of relativity, which provided the theoretical framework for understanding the external world at large scales, and quantum mechanics, which seeks to comprehend the world at smaller scales, together "form the foundation of the tremendous progress in physics over the past century -progress that has explained the expansion of the heavens on one hand, and the fundamental structure of matter on the other- yet they are fundamentally incompatible" (Green, 2000, p. 47). This has prompted physicists to search for a theory that unifies Einstein's relativity with quantum mechanics, hoping to reveal the hidden aspects of the physical world.
However, claiming an absolute truth regarding the physical realm, whether through a rational or realistic approach, remains elusive. This has been affirmed by the contemporary philosophical framework of quantum theory as it engages with physical phenomena and events, fundamentally revisiting the epistemological dialectic between thought and reality, as well as between science and philosophy.

References :

In english :

D'Espagnat, B. (1989). Reality and the physicist, Cambridge : cambridge university press.
D'Espagnat, B. Zwirn, H. (2017). The quantum World : philosophical debates on quantum physics, Springer International Publishing.
Green, B.(2000). The Elegant Universe, New York : Random House Inc.
Gribbin, J. (1984). In Search of Schrodinger's Cat, USA : Bantam Books.
Herbert, N. (1985). Quantum Reality : Beyond the new physics, Anchor Books.

Kaku, M. (2005). Parallel Worlds, USA : Doubleday.
Omnès, R. (1999).Understanding quantm mechanics, Princeton University Press.
Rovelli, C. (2018). Reality is not what is seems, UK : Penguin Books.
In french :
Books :
Albert Einstein, A. (2014). Comment je vois le monde, Paris, Flammarion.
Aspect, A. (2016). « Le débat Einstein-Bohr est complètement clos », Revue Dossier pour la science, n°93, octobre-décembre.
Bachtold, M. « Le possible, l'actuel et l'événement en mécanique quantique », thèse de doctorat en philosophie, sous la direction de Michel Bitbol, Paris 1, 2005, p.402. En ligne http://tel.archives-ouvertes.fr,consulté le 06-07-2015.
Boyer Kassem, T. (2015). Qu'est-ce que la mécanique quantique, Paris, Vrin.
Coudreau, T. « Domestiquer l'intrication quantique », revue Pour la science, n°361, novembre 2007.
Duhem, P. La théorie physique : son objet, sa structure, texte en ligne, disponible sur www.ac-nanacy-metz/enseign/philo.fr
Klein, E. (1991). Conversations avec le sphinx : les paradoxes en physique, Paris, Albin Michel.
Klein, E. (2014). Le monde selon Etienne Klein, Paris, éditions des Equateurs
Lurçat, F. (2001). Niels Bohr et la physique quantique, Paris, Le Seuil.
Louis-Gavet, G.(2009). Comprendre Einstein, Paris, Eyrolles.
Paty, M.(2003). la physique du 20 siècle, France, EDP sciences.