PERSPECTIVAS
REVISTA DO PROGRAMA DE PÓS-GRADUAÇÃO EM FILOSOFIA
DA UNIVERSIDADE FEDERAL DO TOCANTINS

VOL. 8, Nº 1, 2023, P. 263-281
ISSN: 2448-2390

“When language goes on holiday” Reflection on the problems of language in QM through Wittgenstein's philosophy

"Quando a linguagem sai de férias." Reflexão sobre problemas linguísticos em QM através da filosofia de Wittgenstein

DOI: 10.20873/rpv8n1-67

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Abstract
The new discoveries of QM led to re-assessing, broadening the meanings of many physical concepts, and formulating a new logic that was no longer based on the classical principles of non-contradiction, identity, and causality. Heisenberg considered the classical logic and the conception of language expressed in the *Tractatus Logico-Philosophicus* inadequate for the understanding of the problems of language with which the physicists of the Copenhagen school had had to deal in order to define the foundations of Quantum Mechanics. On the contrary, he saw in Wittgenstein’s posthumous *Philosophical Investigations* the key to solving those problems. One may formulate a proposition and state that the use of language described in the *Tractatus* fits the use of language in Classical Mechanics, as the use of language described in *PI* fits the use of language in QM. In this article, I interpret the reflections of the physicists of the Copenhagen school on the limits of language relative to QM by highlighting how the epistemological revolution of quantum physics shares a conception of language similar to that expressed by late Wittgenstein in *PI*. By doing so, I also aim to explain why Heisenberg considered it inappropriate to subsume the propositions and concepts of QM under the rules of the propositional logic of *Tractatus*. Furthermore, I explain why the philosophy of language expounded in *PI*, which is based on language games and resemblance families, sheds a light on how and why QM has contributed to renewing existing concepts (such as space, trajectory, observer, etc.) and to formulate a new logic, namely quantum logic.

Keywords
Quantum mechanics e Language; Werner Heisenberg; Ludwig Wittgenstein; *Tractatus logoco-Philosophicus*; *Philosophical Investigations.*

Resumo

As novas descobertas da Mecânica Quântica levaram a reavaliar e ampliar os significados de muitos conceitos físicos e a formular uma nova lógica que não fosse mais baseada sobre os princípios clássicos da não-contradição, identidade e causalidade. Heisenberg considerava a lógica clássica e a concepção da linguagem expressas no *Tractatus Logico-Philosophicus* inadequadas para compreender os problemas da linguagem com as quais os físicos da Escola de Copenhague haviam precisado se confrontar para definir os fundamentos da Mecânica Quântica. Ao contrário, via nas postumamente publicadas *Investigações filosóficas* de Wittgenstein a chave para resolver esses problemas. Poder-se-ia afirmar que o uso da linguagem descrito nas *Investigações* se adapta ao uso da linguagem na Mecânica Quântica. Neste artigo, interpreto as reflexões dos físicos da Escola de Copenhague sobre os limites da linguagem ligados à Mecânica Quântica, evidenciando como a revolução epistemológica da física quântica partilha de uma concepção de linguagem semelhante àquela expressa pelo segundo Wittgenstein nas *Investigações*. De tal modo, proponho-me também a explicar o porquê de Heisenberg ter considerado inapropriado subsumir as proposições e os conceitos da Mecânica Quântica às regras da lógica proposicional do *Tractatus*. Além disso, explico porque a filosofia da linguagem exposta nas *Investigações*, baseada sobre os jogos de linguagem e semelhanças de família, joga luz sobre como e por que a Mecânica Quântica contribuiu para renovar conceitos existentes (como espaço, trajetória, observador etc.) e a formular uma nova lógica, a lógica quântica.

Palavras-chave
Mecânica Quântica e Linguagem; Werner Heisenberg; Ludwig Wittgenstein; *Tractatus logoco-Philosophicus*; *Investigações filosóficas.*

Introduction

In an interview dated 1970, conducted by David Peat and Paul Buckley, Heisenberg asserts:

> I should first state my own opinion about Wittgenstein's philosophy. I never could do too much with early Wittgenstein and the philosophy of the *Tractatus Logico-Philosophicus*, but I like very much the later ideas of Wittgenstein and his philosophy about language. In the *Tractatus*, which I thought too narrow, he always thought that words have a well-defined meaning, but I think that is an illusion. Words have no well-defined meaning. We can sometimes by axioms give a precise meaning to words, but still we never know how these precise words correspond to reality, whether they fit reality or not. We cannot help the fundamental situation – that words are meant as a connection between reality and ourselves – but we can never know how well these words or concepts fit reality. This can be seen in Wittgenstein's later work. I always found it strange, when discussing such matters with Bertrand Russell, that he held the opposite view; he liked the early work of Wittgenstein and could do nothing whatsoever with the late work. On these matters we always disagreed, Russell and I. I would say that Wittgenstein, in view of his later works, would have realized that when we use such words as *position* or *velocity*, for atoms, for example, we cannot know how to far these terms take us, to what extent they are applicable. By using these words, we learn their limitations (PEAT, 2016).

From this passage, one learns that Heisenberg considered the conception of language expressed in the *Tractatus Logico-Philosophicus* (from now on referred to as Tractatus) and in propositional logic inadequate for the understanding of the problems of language with which the physicists of the Copenhagen school had had to deal in order to define the foundations of Quantum Mechanics (from now on QM). On the contrary, he saw in Wittgenstein's posthumous *Philosophical Investigations* (from now on *PI*) of 1953 a way of overcoming those problems. The new discoveries of QM led to re-assessing, broadening the meanings of many physical concepts, and formulating a new logic that was no longer based on the classical principles of non-contradiction, identity, and causality. One may formulate a proposition and state that the use of language described in the *Tractatus* fits the use of language in Classical Mechanics (from now on CM), as the use of language described in *PI* fits the use of language in QM. Heisenberg recognised in the late philosophy of Wittgenstein an adequate conception of language capable of dissolving the epistemological paradox of QM. Nevertheless, if one looks at the literature about Wittgenstein and QM, one would note the tendency to focus on the link between quantum physics and *Tractatus* (ISHIKAWA, 2020; LUGG, 2019; BERISLAV, 2015; and GRELLAND, 2010), rather than *PI* (DALE, 1999).

In this article, however, I interpret the reflections of the physicists of the Copenhagen school on the limits of language relative to QM by highlighting how the epistemological revolution of quantum physics shares a conception of language similar to that expressed by late Wittgenstein in *PI*. By doing so, I also aim to explain why Heisenberg considered it inappropriate to subsume the propositions and concepts of QM under the rules of the propositional logic of *Tractatus*. Furthermore, I explain why the philosophy of language expounded in *PI*, which is based on language games and resemblance families, sheds a light on how and why QM has contributed to renewing existing concepts (such as space, trajectory, observer, etc.) and to formulate a new logic, namely quantum logic.

The limits of language

At least once in our lives, in the attempt to explain a feeling, a sensation or some extraordinary event, we have all happened to not find the right words and propositions. In fact, our language is not always adequate and sufficient to communicate feelings or extraordinary experiences and events. This limitation appears not only in some contexts of daily life, but sometimes occurs also in science, which instead requires clear and exhaustive propositions. This happens because phenomena in physics, both classical and quantum, must be described not only in mathematical terms but also linguistically through propositions which have the same grammatical structures and are formed by the same words as the propositions that we use in any other context of everyday life. One of the emblematic cases in which these limitations occur in science dates back to the origin of quantum discoveries during the first decades of the twentieth century. At that time, Heisenberg and Bohr immediately realised that the words used to describe physical phenomena in CM were not suitable to describe those of QM. These limitations involved two kinds of problems: the first is epistemological since it concerns the difficulty of clearly defining a phenomenon that is not directly observable and that can only be described through the effects produced by an experiment; the second is instead logical, since the scientific argument, to be clear, univocal and coherent, must satisfy the principles of individuation, non-contradiction, locality, and cause-effect. However, in QM, these principles cannot be applied in the same way as in CM, nor can concepts have the same meaning that have in CM. In other words, the linguistic definition of quantum phenomena was characterised by a paradox, that is, the necessity to use the classical concepts of physics even if "we know that the concepts of this language [the everyday language] are inaccurate, that they have a limited area of application, but we have no other language" (HEISENBERG, 1971, p. 130). These concepts are the same that we use in our usual life (time, space, speed, weight, etc.) given that "the concepts of classical physics are just a refinement of the concepts of daily life and are an essential part of the language which forms the basis of all natural science" (HEISENBERG, 1958, p. 55). One possible solution to solve the paradox was to "depart from the classical concepts altogether and that a radical change in the concepts used for describing the experiments might possibly lead back to

a nonstatical, completely objective description of nature" (HEISENBERG, 1958, p. 55). But this solution was not feasible for, according to Bohr,

> it would be a misconception to believe that the difficulties of the atomic theory may be evaded by eventually replacing the concepts of classical physics by new conceptual forms [because] the recognition of the limitation of our forms of perception by no means implies that we can dispense with our customary ideas or their direct verbal expressions when reducing our sense impressions to order (BOHR, 1972–2008, p. 294).

Not unlike Bohr, Heisenberg stated that "our actual situation in science is such that we do use the classical concepts for the description of the experiments, and it was the problem of quantum theory to find a theoretical interpretation of the experiments on this basis. There is no use in discussing what could be done if we were other beings than we are" (HEISENBERG, 1958, p. 55). Since QM "starts from the fact that we describe our experiments in the terms of classical physics and at the same time from the knowledge that these concepts do not fit nature accurately" (HEISENBERG, 1958, p. 55), its paradox had to be dissolved through reasoning and arguments consisting of the same concepts that made such arguments logically senseless, even if, interpreting the discoveries of the subatomic world according to the principles of logic and explaining them using the traditional concepts of CM inevitably led to falling into contradictions and formulating sentences that according to logic were meaningless. Nonetheless, an experimental observation confirmed precisely the fact that elementary particles had an extravagant behaviour in that they sometimes acted like particles and sometimes like waves, which depends on the variation of the type of observation and experiment. Elementary particles, therefore, lack determination unlike all other objects: they are called objects because, in fact, they possess stable qualities independent of the influence of external factors. This finding led Niels Bohr to formulate the principle of complementarity[1] and Werner Heisenberg that of uncertainty, according to which we cannot determine with certainty the position or the speed of a particle but we can only predict the probability with which, at the moment of the verification of the experiment, the particle will be within a limited area. This discovery originally appeared so absurd with

[1] According to the principle, the corpuscular and wave aspects of an object, which are never observed simultaneously, are complementary as they are both indispensable to provide a physical description of the phenomenon.

respect to the epistemological system of CM that even Einstein rejected it, stating that denying the principles of locality and causality would contradict the special theory of relativity, which proved, according to him, that the QM was true but incomplete (EINSTEIN, 1935).

The greatest difficulty, therefore, lay in convincing that the discoveries had to be interpreted according to new principles, extraneous to classical logic. This difficulty stemmed from the fact that for the time being one of the most influential conceptions of language was precisely that one presented in of Wittgenstein's *Tractatus*, according to which it would be possible to build an objective and exhaustive system of rules capable of establishing the conditions for the formulation of meaningful propositions in an unambiguous way.

From logical principles to language games

Heisenberg discussed more than once with his colleagues the inadequacy of classical logic. One of the most debated problems by the physicists of the Copenhagen school concerned precisely the rigid view of the propositional logic determined in Wittgenstein's *Tractatus*. In his intellectual biography Physics and Beyond, Heisenberg often remembers that together with his colleagues and friends like Bohr, Pauli, and Dirac often criticized the approach to language proposed in the *Tractatus* and by the logic of the time. During a discussion with Carl Friedrich, Heisenberg stated:

> If you hear a positivist or a logician speak about language […] you get the impression that the forms and expressive power of language can be treated and analyzed quite regardless of evolution and biological precedent. Yet if one compares intellect and instinct, as you have just done, it is possible to imagine that different forms of intellect and language could have appeared in different parts of the world. And, in fact, the grammars of different languages are quite distinct, and perhaps differences in grammar may produce differences in logic (HEISENBERG, 1971, p. 138).

Like Russell and Frege,[2] who aspired to create an axiomatic system that should include all the truths that one can talk about, Wittgenstein sought to elaborate a notational system

[2] Wittgenstein's approach to logic is semantic, considered as opposed to that of Frege and Russell, which is instead axiomatic. However, this difference does not make the two theories opposed but, as Emil Leon Post will demonstrate later, complementary, since, although the axiomatic system allows us to prove the theorems while the

suitable for logical analysis, which would ultimately indicate WHICH are the elementary propositions. Such claims of certainty and objectivity were criticized by Heisenberg, who considered them an illusion: "In classical physics science started from the belief – or should one say from the illusion? – That we could describe the world or at least part of the world without any reference to ourselves" (HEISENBERG, 1958, p. 54). Heisenberg understood that this was a problem for the physicist, who "must be able to talk about his experiments and therefore he is forced to employ the concepts of classical physics, although he realizes full well that they provide an inadequate description of nature. This is his fundamental dilemma, and one cannot simply dismiss" (HEISENBERG, 1971, p. 209). Also, Wolfgang Pauli was sceptical of the positivists' approach because, although they sought clarity, – which is good against ignorance and superstition – they nevertheless had too narrow a view of language and refused to consider those problems that remained beyond their conception of language. In Physics and Beyond Heisenberg recalls that Pauli addressed this problem by replying to Bohr, who had just told an anecdote: during a conference of logicians he had explained the fundamentals of quantum physics, but since no one had asked questions he had believed he had expressed himself badly. Hearing this story, Pauli replied:

> The fault need not necessarily have been yours. It is part and parcel of the positivist creed that fact must be taken for granted, sight unseen, so to speak. As far as I remember, Wittgenstein says: "the world is everything that is the case". "The world is the totally of facts, not of things" [...] the positivists have gathered that QM describes atomic phenomena correctly, and so they have no cause for complaint [...] what else we have had to add – complementary, interference of probabilities, uncertainty relations, separation of subject and object, etc. – strikes them as just so many embellishments, mere relapses into prescientific thought, bits of idle chatter that do not have to be taken seriously (Heisenberg, 1971, p. 206).

This observation of Pauli touches on a fundamental aspect of the logic of the *Tractatus*, namely that any proposition that is not a representation of states of fact should not be taken into consideration. From this point of view, all the propositions of religion, ethics, and aesthetics would be essentially nonsensical (*unsinnig*). And by extension, as Pauli noted, the

semantic system allows us to understand if a formula is a tautology, the theorems and formulas they are both tautologies (POST, 1921).

propositions concerning the epistemological problems of QM would also be meaningless: the logicians could not consider them false, but since those propositions did not represent any state of affairs, they must necessarily be nonsense to be ignored as metaphysical chit-chat. In *Physics and Beyond* Heisenberg complains again about the narrow-mindedness of the positivistic logicians, who would admit in language only "unambiguous logical representation." Heisenberg found it absurd to abandon a problem just because it cannot be expressed in the way logicians prescribe. On the contrary, the German physicist was convinced that even expressive forms extraneous to science can help to understand the world, as long as we try and grasp their meaning beyond logical schemata:

> I have no principled objections to re-examination of old questions, much as I have no objections to using the language of any of the old religions. We know that religions speak in images and parables and that these can never fully correspond to the meaning they are trying to express […] the positivists may be right in thinking that it is difficult nowadays to assign a meaning to such parables. Nevertheless, we ought to make every effort to grasp their meaning, since it quite obviously refers to a crucial aspect of reality (Heisenberg, 1971, p. 211-12).

Heisenberg, therefore, was aware that the problem of the limits of language in QM was connected with the limits imposed by the positivistic logic on language and writes that

> the positivists have a simple solution: the world must be divided into that which we can say clearly and the rest, which we had better pass over in silence. But can anyone conceive of a more pointless philosophy, seeing that what we can say clearly amounts to next to nothing? If we omitted all that is unclear, we would probably be left with completely uninteresting and trivial tautologies (Heisenberg, 1971, p.213).

In this passage, Heisenberg refers exactly to the last proposition of the *Tractatus* "what we cannot speak about we must pass over in silence" (WITTGENSTEIN, 2013, prop. 7, p. 577), by which Wittgenstein decreed that all propositions that are not representations of states of affairs should be considered senseless and should not be taken as conveying any descriptive content. And since these propositions represent the vast majority of everyday language, and for Wittgenstein "just as they stand, are in perfect logical order" (WITTGENSTEIN, 2013, prop. 5.5563, p. 533), there was a split between them and a "super language" that satisfies the logical conditions determined in the *Tractatus*. Together with these two types of propositions there

are also those that Heisenberg defines as "trivial tautologies". In the *Tractatus*, in fact, among the propositions that might be either true or false, there are two remarkable cases: either all truth-possibilities of propositions are conditions of truth; or truth-possibilities are conditions of falsehood (WITTGENSTEIN, 2013, prop. 4,461, p. 302). The former case constitutes a tautology, which is a proposition that is always true no matter what its truth conditions are; the latter case represents a contradiction, which is always false. These two particular types of propositions need no empirical proof because their verifiability or nullification are self-evident in the sense that they manifest themselves in their logical form. Their validity, therefore, does not depend on their content. Moreover, tautology and contradiction being the limits of language – since they do not possess the possibility of being true or false – and self-evident in their logical structure, they do not represent any state of affairs and are thus different from other propositions, which are images of reality. They "are without sense" (*sinnlos*) (WITTGENSTEIN, 2013, prop. 4,461, p. 302), even if they "are, however, non-senseless" (*nicht unsinnig*) (WITTGENSTEIN, 2013, prop. 4,4611, p. 302). This distinction is very important because in German *unsinnig* indicate a 'trifle' or a silly proposition, while the adjective *sinnlos* indicates a meaningless proposition; consequently, a tautology is without sense because it does not affirm anything about reality. The fundamental aim of *Tractatus* was to eliminate nonsense (*unsinnig*), which were considered mistakes, by establishing the rules of syntax which prevent nonsense in a logically perfect language and "single symbols which always have a definite and unique meaning" (RUSSELL, 2013, p. 7). From the perspective of the *Tractatus*, the errors of common language derive essentially from the polysemic character of the names. A word is a sign that stands for a symbol but not in a unique way. As, on the contrary, many signs can refer to a single symbol, "in the language of everyday life it very often happens that the same word signifies in two different ways – and therefore belongs to two different symbols – or that two words, which signify in different ways, are apparently applied in the same way in the proposition" (WITTGENSTEIN, 2013, prop. 3,323, p. 257). Wittgenstein saw in the equivocal use of words the cause of "the most fundamental confusions (of which the whole of philosophy is full)" (WITTGENSTEIN, 2013, prop. 3,32, p. 258). From the point of view of QM, on the other hand, the philosophy that

eliminates propositions that contain blurred concepts is nonsensical. Beyond all the empirical propositions that can be true or false, respectively if they refer or do not refer to a state of affairs, only tautologies would remain, which add nothing to knowledge.

Only many years later, Wittgenstein renounced his attempt to define the essence of language and to discover the form that unites simple propositions. In *PI*, rather than looking for the common form among objects of the same class, Wittgenstein focuses on observing language in its practical use and formulates the expression 'language games' to represent the different parts of language and their practical functions. Language games are not theoretical elements used to prepare analytics: "The language-games are rather set up as objects of comparison which are meant to throw light on the facts of our language by way not only of similarities, but also of dissimilarities" (WITTGENSTEIN, 1986, § 130, p. 50) and "a clue to the understanding of logic." By identifying in the foundations of language no longer the logical principles but the network of connections, Wittgenstein denies the value of universality and the claim of completeness of both Russell's and Frege's logic:

> When Frege tried to develop mathematics from logic he thought the calculus of logic was *the* calculus, so that what followed from it would be correct mathematics. Another idea on a par with this is that all mathematics could be derived from cardinal arithmetic. Mathematics and logic were one building, with logic the foundation. This I deny; Russell's calculus is one calculus among others. It is a bit of mathematics (WITTGENSTEIN, 2001, §11, p. 13).

Thus, Russell's calculus, like the principles of logic, is nothing more than games among the multitude of games, which are no longer established a priori. From this new perspective, the meaningfulness of propositions is no longer determined by logical correctness, but by their adequacy with respect to the practical context in which they are formulated.

Already in the *Lectures of 1932-33*,[3] Wittgenstein had pondered some practical problems linked to the idea of creating an exhaustive logical system. In these lectures, Wittgenstein began to rethink the mistakes of his *Tractatus*, in which he started from the assumption that "the method of formulating [the problems of philosophy] rests on the misunderstanding of the logic

[3] The lectures are not a real text by Wittgenstein but the transcription of the notes taken by Alice Ambrose and Margaret Macdonald during his lessons in Cambridge (WITTGENSTEIN, 2001).

of our language" and proposed to "draw a limit to thinking, or rather – not to thinking, but to the expression of thought" (WITTGENSTEIN, 2013, p. 226), by which he formerly believed to have solved the philosophical problems "in essentials" (WITTGENSTEIN, 2013, p. 257). Wittgenstein was interested in understanding the truthfulness of atomic propositions, even if he thought that one could not anticipate what an elementary proposition looks like that is for this would only be achieved by carrying out the process of logical analysis to the end. Wittgenstein clearly expounded this problem in the 1930s, when he wrote:

> Russell and I both expected to find the first elements, or "individuals", and thus the possible atomic propositions, by logical analysis. Russell thought that subject-predicate propositions, and 2-term relations, for example, would be the result of a final analysis. This exhibits a wrong idea of logical analysis: logical analysis is taken as being like chemical analysis. And we were at fault for giving no examples of atomic propositions or of individuals. We both in different ways pushed the question of examples aside. We should not have said "We can't give them because analysis has not gone far enough, but we'll get there in time". Atomic propositions are not the result of an analysis which has yet to be made. We can talk of atomic propositions if we mean those which on their face do not contain "and", "or", etc., or those which in accordance with methods of analysis laid down do not contain these. There are no hidden atomic propositions (WITTGENSTEIN, 2001, §10, p. 11).

In the *Lectures* the terms are thus overturned: atomic propositions are not determined by applying logic because the abstract definition of rules and grammar derives from the accumulation of words that have a practical function and through that he acknowledged the limits and the "serious mistakes" (WITTGENSTEIN, 1986, p. VIII) of his first book. Also in this period, when Wittgenstein "began his second major work, *Philosophical Investigations*" (WITTGENSTEIN, 2001, p. I), he proposed to no longer apply the rules of logical systems to understand the complexity of the language, but to use the concept of language-game to understand the role of logic itself within language.

Metaphors in QM: blurred concepts are still concepts

Let us, therefore, return to the paradox of the language of QM and see why classical logic could no longer be applied, and then why, in the new epistemology of quantum logic, the

concepts of classical physics could only be used by modifying their definition and redefining all classical quantities.

To understand the inadequacy of classical logic, let us examine the distributive law of logic. According to it, if *P* designates the proposition "the glass is broken", *Q* "John broke the glass" and *R* "the cat broke the glass", therefore logically from *P* and (*Q* or *R*) one can infer that (*P* and *Q*) or (*P* and *R*): this inference is always valid, independently from the content of the proposition *Q* and *R*. Now, there are other distributive formulae in which "and" and "or" are interchanged, which "resemble the distributive law of arithmetic, which states, for instance, that the expression 2 X (3 + 4) is equal to (2 X 3) + (2 X 4)" (HUGHES, 1981, p. 202). Classical logic, therefore, is perfectly consistent with mathematical logic and the Boolean algebra used to describe the phenomena of CM. The inconsistency is born instead with the QM because in the

> description of electron spin, however, the logical step from the first line of the distributive law to the second line is disallowed [and] hence the suggestion that QM may demand the revision of a law of logic amounts to the proposal that the roles of the connectives *and* and *or* must be altered so that statements about QM no longer combine logically to satisfy the distributive law (HUGHES, 1981, p. 203).

From a mathematical point of view, this impasse was solved in 1936 by Garrett Birkhoff and by John Von Neumann in the paper *The Logic of QM* (BIRKHOFF, 1936), in which they "showed that the lattice structure of a physical theory can be regarded as a mathematical model of the system of logic appropriate to the theory" (HUGHES, 1981, p. 205). Thus, they founded QM on a new logic, which is based on the principles of uncertainty and probability, complementarity, and non-locality.

As for the modification of concepts and physical quantities in QM, from the point of view of the *Tractatus* the paradox remains unsolved. Here it is established that just as an area that is not clearly delimited cannot be called an area, a concept that is not perfectly delimited is not a concept. In science, according to Bohr, this point cannot be ignored because every scientist cannot neglect the problem of objective "description of experience, by which we mean unambiguous communication" (BOHR, 1958, p. 6) by which he means exactly the "unambiguous logical representation of relations between experiences" (BOHR, 1958, p. 67). Hence, for Bohr, the

findings of QM also had to be formulated and communicated unambiguously. In CM this means that: 1) all the values of the qualities of an object can be known; 2) the behaviour of an object can be known objectively without any external factor, such as the presence of the observer and the means used for experiments, may influence the observation result.[4] In QM this is not possible because the observed system of 'objects' suffer from disturbances caused by the measurement performed on the system. The concepts of certainty and objectivity as used in CM are not therefore applicable in QM. In the quantum world, one can only know what possibility one has of finding, for example, the particle in a spatial range at the moment in which the measurement is taken. Not only, therefore, by changing the parameters of the experiment, the elementary particle behaves in two different ways, like a wave or like a particle, but the more precise data one has regarding the spatial determination, the less one has on the temporal one and vice versa: in other words, the probability is not an evaluation factor, as in thermodynamics, but intrinsic to the behaviour of the particle. How can classical concepts, which are unambiguous and certain, be used to describe phenomena which possess a quid of ambiguity and uncertainty and which can only be known in terms of probability? The most appropriate way is to use the concepts in a blurred way, accepted in *PI* as particular games useful for communicating in different practical contexts. Here, Wittgenstein states with a metaphorical comparison that just as a fence remains as such even if it has a hole in it, so a sentence can be employed in a given language game even if the predicate that is part of it is not perfectly delimited. The concept of game itself has no certain boundaries because the variety of qualities that can characterize different types of games is very wide, so the concept cannot be defined exhaustively and exactly. In other words, it is a blurred concept.

Considering blurred concepts useful from a practical point of view and therefore sensible in certain contexts is fundamental because this means that the meaning of the concepts and propositions is not determined through a logical evaluation that determines their truthfulness

[4] It should be noted that the problem of objectivity and completeness of scientific knowledge was already debated in CM, especially in the 19th century when some opponents of Laplace's devil emerged (Ulanowicz 1986). Moreover, in CM there were also insoluble problems, like the algebraic problems regarding the values associated with the motion of objects, for which physicists developed answers based on approximations to "real" equations, i.e. Poincaré's solution to the three-body problem (Barrow-Green 1996).

or falsity, but by the connections which these have with other concepts based on a relationship of similarity. From this perspective, therefore, the contradiction that would arise if one wanted to understand the use of the concepts of CM in QM through logic, vanishes and the "super concepts", including those of exactness, certitude, and purity, lose their metaphysical aura and become concepts among other concepts which make sense depending on how they are used within a given context.

For this reason, according to Bohr, the best way to describe quantum phenomena is to use metaphorical propositions: "we are forced to speak in images and parables which do not express precisely what we mean. Nor can we avoid occasional contradictions; nevertheless, the images help us to draw nearer to the real facts" (HEISENBERG, 1971, p. 210). Bohr says that we tend to perceive a clear distinction between the aseptic language of science and that of religion, which are made of parables and metaphors, insofar as the former is intended to give us information on objective facts while the latter, such as poetry and ethics, concerns moral values, feelings, and aesthetics. However, as Heisenberg recalls in *Physics and Beyond*, Bohr claimed that "the fact that religions through the ages have spoken in images, parables and paradoxes means simply that there are no other ways of grasping the reality to which they refer. But that does not mean that it is not a genuine reality. And splitting this reality into an objective and a subjective side won't get us very far" (HEISENBERG, 1971, p. 88). Therefore, in another chapter of *Physics and Beyond*, Heisenberg remembers Bohr claiming that "when it comes to atoms, language can be used only as in poetry. The poet, too, is not nearly so concerned with describing facts as with creating images and establishing mental connections" (HEISENBERG, 1971, p. 40). The solution to the paradox, therefore, seems to suggest that when we fail to adequately define and communicate a new phenomenon through classical concepts and logic, it is more appropriate to use blurred concepts and metaphorical propositions.[5]

[5] To date there are many studies on the use of metaphors in scientific discourse (BLACK, 1962; BOYD, 1979; HESSE, 1966; and GHIAZZA, 2005) and on the role that metaphors have in introducing new scientific concepts far from the human capacity for direct experience (FAUCONNIER, 2002).

Two examples: the metaphors of *walking* and *jumping*

Not all metaphorical propositions are, however, adequate to represent the phenomena of QM. Let's consider the case of the metaphor of the path. In CM, the movement of any object of the physical world on a human scale can be expressed with the phrase "the object walks on the trajectory" or "the planet walks on the orbit", where walking essentially means the movement of an object from one point to another or, if we were in an inertial system, of a uniform movement at a constant speed. In CM, the use of the verb to walk is therefore metaphorical and derives from our physical experience of the act of walking: in this case, the metaphorical use of the word allows an expansion of the range of meanings of the word itself so that the verb "to walk" shifts from indicating the physical act of the human being to any displacement in space of an object. In CM the metaphor of the journey makes sense because its action shares many connections and similarities with that of the human being: in both reference systems (of CM and the human being), there is information that allows us to establish with certainty that: 1) there is an object that we can observe in its entirety; 2) there is a path and a travel time during which an object goes from a starting point to an endpoint; 3) there is a trajectory that we can know and even predict. Based on this information, the following propositions can be formulated: "Mario walked from home to the beach according to this trajectory, in a uniform way, thus taking 10 minutes" and then I can say "the object walked from point A to point B according to this trajectory employing time x". The two propositions have the same form but this in no way justifies that the two events share the same characteristics: this is why it makes sense to ask if Mario was happy on the way, but it makes no sense to ask if the object was. This does not mean, as the point of view of logic would suggest, that the second proposition is meaningless as far as it is metaphorical, but simply that, as it happens to all other propositions, its meaning is determined by the use one makes of it in a context. Already in his Lectures, Wittgenstein was doubtful about the fact that two propositions with the same logical form are identical:

> "There are men on the island" and […] "There is a circle in the square". Now in the case of human beings, where we use names, the question "Which men?" has meaning. But to say there is a circle in the square may not allow the question "Which?" since we have no names "*a*", "*b*" , etc. for circles. In

> *some* cases it is senseless to ask "Which circle?", Though "What sort of circle is in the square — a red one ?, a large one?" may make sense. The questions "which?" and "What sort?" are muddled together [so that we think both always make sense] (WITTGENSTEIN, 2001, §6, p. 6).

The two propositions *there are men on the island* and *there is a circle in the square* have the same form as one object is included in another. The fact that the two propositions are formally the same does not mean that everything that concerns one also concerns the other: this principle may be valid from the logic-metaphysical point of view, but from the practical point of view it does not work because the two metaphors are used for two different purposes.

In the case of Mario and a physical object, however, both Mario and the object cannot be in two different places at the same time, and according to the principle of causality, there is a relationship between walking and reaching the final point.

When, on the other hand, the metaphor of path is used to represent the "movement" of the photon, things change. In the case of the photon, there is no precise information but only a plausible evaluation of the possibility that the photon is within a predicted probability range. The path of the photon is therefore unknown: the photon is "anywhere" until by an experiment we measure the probability of finding the proton signal in a certain position. For simplicity, we call the photon the object of observation, although actually, it is not an object in the classical sense as it lacks determination. The photon, it can be said, is an entity (in so far as it exists, ergo it is real) which manifests itself when it is observed. Thus, Heisenberg writes that "we cannot hope to speak of the path of the electron in the cloud chamber without inner contradictions" (HEISENBERG, 1971, p. 66) and therefore proposes to no longer consider the metaphor the path of electrons because this expression is deviant and confusing as it represents a false image. Since it is not possible to observe an atom and consequently not even the movement of electrons inside it, Heisenberg proposed to consider only the frequencies of different radiation emitted by the atom which correspond to the "amplitudes of its electrons" (HEISENBERG, 1971, p. 63). This made it possible to discover that electrons do not "walk" in the atom but move from one state to another. To express this action a new metaphor has been formulated: electrons "jump". Also, in this case, the metaphor comes from physical experience, and better than that of the path it represents how the electrons "move". To better explain how this movement should

be represented pictorially, Heisenberg uses a further comparison, by which he compares the passage of an electron from an upper to a lower energy state with the fade-out and fade-in of switching scenes in a movie:

> One must imagine the transitions from one stationary state to the next as so many fade-outs in a film. The change is not sudden – one picture gradually fades while the next comes onto focus so that, for a time, both pictures become confused and one does not know which is which. Similarly, there may well be an intermediate state in which we cannot tell whether an atom is in the upper or the lower state (HEISENBERG, 1971, p. 68).

Both "representations" include a moment in which the image is blurred, that is, the frame in which one scene fades out and the other fades in. Both scenes exist and are real, neither is it possible to say which of the two is clearly to be seen. Likewise, at the moment before the measurement, the electron is in two superimposed states, neither fully here nor completely there, and its path cannot be known: essentially, it can be said that before the measurement the electron can be widely found in one place, which makes it impossible for it to travel in any direction. For this reason, speaking of "walking" is not adequate, while it is better to speak of a "jump": the act of jumping involves a rapid action during which a body leaves the contact with the earth and then falls back on the same spot or in a different position.

Conclusions

In conclusion, the members of the school of Copenhagen were aware that the findings of their quantum experiments appeared absurd, contradictory, and aporetic if interpreted by applying the principles, models, and philosophical premises of classical logic.

The fact that we always tend to use concepts in the same way and to believe in logical principles as if they were universal and objective, if not a priori with respect to language itself, is nothing more than a part of our way of thinking and organizing knowledge. In other words, in all our activities we tend to learn the rule and then apply it almost automatically without questioning it anymore. So we can think that the logician of the *Tractatus* tends to behave a bit like Galileo's contemporary Cesare Cremonini who, invoking the Aristotelian *ipse dixit*, refuses

to look into the telescope to verify with his senses the astronomical discoveries that Galileo had announced in *Sidereus nuncius*; or like Simplicius of Galileo's *Dialogo sopra i due massimi sistemi del mondo*, who keeps on supporting the Ptolemaic geocentric model based on Aristotle's *auctoritas*.

Also in the case of *Tractatus*, a theory is applied rather than observing how language is used in practice. To believe that this theory is exhaustive and a priori is a superstition that produces grammatical illusions. Just as Galileo, who, to destroy the prejudices and errors deriving from the belief in a fallacious theory invited Aristotelian metaphysicians to look into his telescope, so the late Wittgenstein urges us not to "think, but look!" (WITTGENSTEIN, 1986, 66, p. 33), that is, not to apply the rules established by logic but to observe how language is used in different contexts. In this case, if we looked closely at how we use language, we would notice that the tendency to think that "language (or thought) is something unique 'is none other than' a superstition (not a mistake!), itself produced by grammatical illusions" (WITTGENSTEIN, 1986, § 110, p. 47). And so did the members of the Copenhagen school who, starting from the observation of data, highlighted the inadequacy of classical logic.

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Recebido em: 24/05/2022
Aprovado em: 24/01/2023

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