Could Kant Shed Light on the Ontological Indeterminacy in Quantum Theory?[1]

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Abstract: Quantum theory, particularly with its concepts of indeterminacy and superposition, demands of philosophers of science a profound review and a complete redefinition of the foundation of the notion of representation. This review has significant implications for assessing the Kantian heritage, especially for those among us who recognize the advances of the transcendental approach over realist and empiricist perspectives in epistemology. Kant endeavored to establish a foundation for the notion of representation consistent with the physics of his time. Today, as inheritors of Kant's legacy in the philosophy of science, we face the challenge of establishing a new foundation for the idea of representation that aligns with the principles of contemporary science. In his *Progress of Metaphysics*, as well as in *Religion Within the Boundaries of Mere Reason*, Kant distinguishes between analogical (symbolic) schematism and real (transcendental) schematism. My aim in this work is to explore the notion of analogical schematism for evaluating the content of extra-empirical concepts in contemporary physical theories, where intuition proves to be intrinsically indeterminate.

Keywords: Kant; quantum theory; analogical schematism; extra-empirical concepts

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¿Podría Kant arrojar luz sobre la indeterminación ontológica en la teoría cuántica?

Resumen: La teoría cuántica, en particular sus conceptos de indeterminación y superposición, exige a los filósofos de la ciencia una revisión profunda y una redefinición completa de los fundamentos de la noción de representación. Esta revisión tiene implicaciones significativas para evaluar la herencia kantiana, especialmente para aquellos de nosotros que reconocemos los avances del enfoque trascendental sobre las perspectivas realistas y empiristas en epistemología. Kant se esforzó por establecer un fundamento para la noción de representación coherente con la física de su tiempo. Hoy, como herederos del legado de Kant en la filosofía de la ciencia, enfrentamos el desafío de establecer un nuevo fundamento para la idea de representación que se alinee con los principios de la ciencia contemporánea. En *Los progresos de metafísica*, así como en *La religión dentro de los límites de la mera razón*, Kant distingue entre esquematismo analógico (simbólico) y esquematismo real (trascendental). Mi objetivo en este trabajo es explorar la noción de esquematismo analógico para evaluar el contenido de conceptos extraempíricos en las teorías físicas contemporáneas, donde la intuición demuestra ser intrínsecamente indeterminada.

Palabras clave: Kant; teoría cuántica; esquematismo analógico; conceptos extraempíricos

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1. Introduction

This work seeks to evaluate the Kantian legacy through an analysis of the limitations of schematism, as outlined in the first chapter of the Analytic of Principles in the *Critique of Pure Reason* (KrV, A/B)[2] , considering

[2] All translations of Kant's works are cited from *The Cambridge Edition of the Works of Immanuel Kant*, following the guidelines established by the *Kant-Forschungstelle* in Mainz. Citations from the *Kritik der reinen Vernunft* (KrV) refer to the pagination in the first «A» edition and the second «B» edition. All other citations from Kant's works refer to

the epistemological challenges introduced by quantum physics. This theory compels us, as philosophers of science, to undertake a profound reassessment and redefinition of the foundational concept of representation. Such a reassessment significantly impacts the evaluation of Kantian heritage, particularly for those who acknowledge the transcendental approach's advancements over realist and empiricist perspectives in epistemology. Kant made significant efforts to ground the notion of representation in a way that aligned with the physics of his time. Today, as philosophers of science inheriting Kant's legacy, we face the immense challenge of either establishing a new foundation for this notion or abandoning it altogether, in accordance with the framework of contemporary science.

Quantum theory, with its counterintuitive principles and abstract constructs, challenges traditional notions of representation in philosophy. Classical physics, grounded in determinism and the clear distinction between subject and object, offered a relatively straightforward framework for understanding the role of representation. However, as we delve into the quantum realm, where particles do not follow predictable paths and where phenomena like wave-particle duality and superposition arise, we encounter a radical shift in how reality is conceptualized. This shift necessitates a reconsideration of how representation functions, particularly regarding concepts that resist empirical intuition, such as those found in quantum mechanics.

Kant's framework, which emphasizes the limits of human knowledge and the role of a priori categories in shaping our experience of the world, offers a valuable lens through which to assess the epistemological challenges posed by quantum theory. Yet, as we encounter quantum phenomena that defy ordinary categorization and intuitive grasp, it becomes evident that Kant's notions of representation, particularly the role of schematism, must be reexamined and adapted to address these new scientific insights.

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the volume and page number in the *Akademie Ausgabe* of his *Gesammelte Schriften* (Berlin: Georg Reimer, 1900–; Berlin/Leipzig: De Gruyter, 1968–), cited as AA.

Quantum physics, in particular, requires a thorough redefinition of the nature and scope of critical metaphysics, along with its foundational semantics and epistemology. It distinguishes itself from realist perspectives, which entail an ontological commitment to unobservable entities or a deeper microphysical or structural reality, and from empiricist or naturalist approaches, which reject metaphysical inquiry, confining themselves to empirical concepts and denying any commitment to extra-empirical entities. I believe this redefinition can be conceived from a Kantian perspective, which, unlike empiricism, does not reject metaphysical inquiry but requalifies it. Instead of seeking knowledge of ultimate reality, as realists do, it treats metaphysical inquiry as an investigation into the limits and conditions of human cognition, emphasizing the boundaries within which knowledge is possible, rather than attempting to access a transcendent reality.

By seeking to establish a connection between Kantian epistemology and the epistemic justification of quantum theory, we are led to recognize a radical extension of the limits of human cognition, surpassing mere conformity to the objects of sensible intuition. In my view, this redefinition can be framed within a contemporary Kantian approach, which Michel Bitbol (2010) terms «reflective metaphysics». A Kantian reflective metaphysics, as proposed by Bitbol, seeks to examine the conditions for the possibility of knowledge in contemporary physics. This approach helps correct the naturally antinomic illusion that arises when extra-empirical concepts—fundamentally regulative and heuristic—are mistakenly treated as constitutive principles governing the existence of space-time objects given in empirical intuition. Such «reflective metaphysics» emphasizes the role of the reflecting power of judgment and the critical function of imagination in its free play with understanding.

Kant introduced the reflecting power of judgment in his third *Critique* (KU, AA 05), distinguishing it from the determining power of judgment presented in the Analytic of Principles of the *Critique of Pure Reason*. The determining power of judgment plays a crucial role, especially in the

transcendental schematism, where it bridges pure concepts of the understanding with sensible intuition. In turn, the reflecting power of judgment plays a distinct but equally essential role in the context of analogical schematism.

This work thus aims to delve into the cognitive dimension of this analogical process, which Kant himself refers to in the third *Critique* as *symbolic hypotyposis*. Despite its significance, Kant himself acknowledged that this subject had been underexplored (KU, AA 05: 250), and few interpreters have engaged with it in depth. Joãosinho Beckenkamp's recent book, *Analogy and Symbolization in Kant* (2023), is a notable exception. It provides a valuable contribution and positions itself within the interpretative lineage established by Gérard Lebrun (1970) and Zeljko Loparic (2000).

Building on the perspective of these authors, this work aims to explore how analogical schematism can address the challenges posed by the indeterminacy of intuition in the context of quantum mechanics. The discussion will be divided into three interconnected parts. The first part, *Quantum Indeterminacy*, addresses the fundamental issues of indeterminacy in quantum mechanics, focusing particularly on its implications for Kantian epistemology. The second part, *The Problem of Intuitive Indeterminacy in the Quantum Context*, examines how quantum indeterminacy disrupts the traditional role of empirical intuition, which, in Kantian terms, bridges abstract concepts and sensory experience. In the quantum realm, phenomena resist being fully captured by sensible intuition, posing a challenge to Kant's framework for structuring knowledge. Finally, the third part, *Analogical Schematism as a Possible Solution to the Problem of Intuition Indeterminacy*, argues that analogical schematism, as developed in Kant's third *Critique*, offers a promising cognitive strategy for addressing these gaps. In the absence of direct intuition, analogical reasoning, through symbolic hypotheses, may provide a way to conceptually engage with quantum phenomena. Drawing on Kantian heuristic, this section suggests that analogical schematism can supply the symbolic structures

needed to navigate the complexities of quantum mechanics, thus compensating for the limitations of empirical intuition and offering a more nuanced epistemological framework for understanding indeterminacy.

2. Quantum indeterminacy

I refer to quantum indeterminacy as the notion that captures the fact that the physical facts of the universe appear to be indeterminate at the subatomic level. This notion suggests that, unlike the macroscopic world, where objects exhibit definite properties and behaviors, the subatomic realm operates within a framework of probabilities and uncertainties. In this context, particles lack fixed positions or velocities until they are observed, underscoring the inherently probabilistic nature of quantum theory.

The origins of quantum indeterminacy can be traced back to several foundational principles and experiments in quantum theory. One of the key principles is Heisenberg's Uncertainty Principle (Heisenberg, 1927). This principle asserts that it is fundamentally impossible to determine both the position and momentum of a particle with absolute precision; the more accurately one property is measured, the less precisely the other can be known. This encapsulates the intrinsic limitations of measurement at the quantum level, demonstrating that fundamental uncertainties are inherent to the very nature of quantum systems.

Another manifestation of quantum indeterminacy is wave-particle duality, proposed by Louis de Broglie (1924), and later confirmed by various experiments. This duality posits that particles, such as electrons, exhibit both wave-like and particle-like properties. One of the most illustrative experiments demonstrating this duality is the Double-Slit Experiment (Cf. Feynman, Leighton and Sands, 1965: 1.1–1.8), which reveals the principle of superposition and the wave-like behavior of particles. When electrons or photons pass through two slits without being «observed» — meaning it is unknown through which slit they passed — an interference pattern is created on a screen, suggesting that these particles pass through

both slits simultaneously, as if they were waves. However, when they are «observed» — meaning their path through a particular slit is measured— they behave like particles, passing through one slit or the other, which eliminates the interference pattern. This duality suggests that the behavior of quantum particles cannot be fully captured by classical concepts of waves and particles. Instead, it points to either an intrinsic ontological indeterminacy in defining the inherent properties of quantum particles, or an epistemic indeterminacy regarding the extent to which theory can reveal information about these quantum objects.

The so-called Copenhagen Interpretation, developed by Niels Bohr, Werner Heisenberg, Paul Dirac, John von Neumann, Max Born, and Erwin Schrödinger, and others, suggests that a quantum system remains in a superposition of states until it is observed. Upon observation, the system collapses into one of the possible states. This collapse is inherently probabilistic, meaning that the exact outcome cannot be predicted with certainty; it is only the probabilities of different outcomes that can be predicted (Cf. Dirac 1958: 46-50; Heisenberg, 1958: 54-58; von Neumann, 1955: 211-229).

Another manifestation of quantum indeterminacy is quantum entanglement, a phenomenon famously referred to by Albert Einstein as «spooky action at a distance». In a 1947 letter to Max Born, Einstein wrote: «I cannot seriously believe in [quantum theory] because the theory cannot be reconciled with the idea that physics should represent a reality in time and space, free from spooky actions at a distance» (Born and Einstein, 1971: 170-173). This phenomenon occurs when particles become entangled, meaning the state of one particle instantaneously influences the state of another, regardless of the distance separating them. Such entanglement creates correlations between the particles' properties that defy explanation through classical physics, further highlighting the fundamentally non-deterministic nature of quantum mechanics.

Together, these principles and experiments constitute a robust framework that illustrates quantum indeterminacy. They reveal how the behav-

ior of subatomic particles defies classical expectations, requiring a fundamentally new approach to describing physical reality. This profound reevaluation of existence and observation at the smallest scales continues to challenge and inspire both physicists and philosophers, pushing the boundaries of our understanding.

3. The Problem of Intuitive Indeterminacy in the Quantum Context

Quantum theory's fundamental concepts—such as uncertainty, indeterminacy, and superposition—present a direct challenge to the traditional Kantian idea of representations grounded in sensory experience. For Kant, representation is always linked to intuition; it is through the synthesis of the manifold presented in intuition that we form concepts. However, in quantum mechanics, many of the phenomena described by the theory cannot be directly visualized or empirically represented. Particles do not have well-defined locations or velocities until measured, and their behavior is often better understood in terms of probabilities rather than certainties.

The notion of representation in quantum theory, therefore, must be expanded to include not just empirical intuitions but also abstract conceptual frameworks that help us make sense of phenomena that lie beyond our sensory experience. This is where Kant's notion of schematism becomes particularly relevant. Schematism allows for the connection between pure concepts of the understanding and the empirical intuitions they govern. While Kant envisioned schematism as operating primarily within the realm of sensory experience, the contemporary challenge lies in extending this framework to include extra-empirical concepts such as those found in quantum theory.

In Kantian terms, quantum objects cannot be assimilated to the objects of empirical intuition, such as the cup of coffee before me as I write this. Nor can they be assimilated to the objects of pure intuition, such as geometric entities—points, lines, circles, and triangles—whose concepts are

formally defined a priori and can be constructed and represented both a priori and *in concreto* through the faculty of imagination.

Moreover, quantum mechanical objects should not be confused with metaphysical real objects. In classical atomistic ontology—now incompatible with contemporary quantum theory—such real objects are conceived as «things in themselves», that is, entities independent of the mind in the Kantian sense of positive noumena. Consequently, quantum microphysical objects cannot be assimilated to a «transcendental object», whose independent existence could only be intuited through some form of intellectual intuition. Quantum theory, therefore, necessitates a conception of objectivity for microphysical entities that departs from empirical objectivity, mathematical objectivity, and the classical notions of noumenal or transcendental objectivity.

In this context, the transcendental semantic problem concerning the validity of judgments about unobservable or microphysical entities — whose contents cannot be immediately given to intuition — remains unresolved. Kant's theory of the determinability of the predicates of judgments, as outlined in the *Critique of Pure Reason*, does not provide a transcendentally coherent solution. Contemporary physical theories, therefore, necessitate a different approach to addressing the semantic problem of the relationship between concepts and intuitions, one that reflects the specific characteristics of these objects.

Therefore, within the framework of a reflective metaphysics that aligns with quantum theory, we must confront the definitive loss of univocal and intuitive representations of microphysical processes. Quantum theory's conceptual framework diverges from the intuitive, three-dimensional space of Euclidean geometry, instead addressing a multidimensional conceptual space that defies both visual imagery and intuitive representation — be it through mathematical construction or the Kantian notion of schematism.

This creates a paradoxical situation: while intuitive representations are indispensable, they remain inadequate for explaining quantum phenomena. As the Neo-Kantian philosopher Grete Hermann aptly notes in her analysis of the philosophical foundations of quantum theory:

> [t]he effort of classical research to obtain an adequate account of natural processes through intuitive constructions has failed: in place of an intuitive description of natural events comes the formal assignment of a wave function, which already makes any intuitive interpretation difficult if not impossible by developing not in the usual three-dimensional space but rather in a higher-dimensional phase space. (Hermann, 2016: 265)

Thus, Hermann recognizes the impossibility of describing the conceptual content of quantum mechanics through space-time intuitive images. However, she also paradoxically acknowledges the impossibility of entirely eliminating intuitive representations. Bohr's principle of complementarity aims to clarify the role of intuitive images in atomic phenomena, connecting perceptual data with the conceptual framework of the theory through intuitive and classical representations. These representations are strictly confined to what is empirically observed.

The necessary use of intuitive images in our understanding of quantum phenomena is not intended to describe the formal content of the theory. Instead, it serves to describe the experimental laboratory situations faced by physicists. The complementary and mutually exclusive use of intuitive representations, governed by Bohr's principle, is necessitated by our inability to directly observe atomic phenomena.

While some interpreters of quantum mechanics entirely dismiss the role of intuition in the microphysical domain, Hermann, in agreement with Bohr and Heisenberg, affirms the essential role of intuitive representations. She thereby assigns a necessary function to the transcendental imagination. In her words:

> Despite this unintuitive character, the quantum mechanical formalism ultimately signifies no detachment from intuition; as the correspondence principles shows, in each interpretation of a sensation, in each passage from one observational context into another, it [the quantum mechanical formalism] seamlessly retains the connection to the

> intuitive space-time constructions of classical physics. To wish to eliminate these constructions thus means to obstruct the access to intuition and thus to a meaningful association between the data of sensation and the posits of a physical theory. (Hermann, 2016: 268).

According to Hermann's analysis, there is a precise meaning that can be attributed to empirical images and intuitions in quantum theory: they are circumscribed to macroscopic processes. In this view, the semantic relationship between conceptual content and the object of intuition can only be defined contextually, i.e., in reference to a specific experimental situation. It no longer makes sense to attribute any ontological or independent reality to microphysical objects or to apply any semantic description to microscopic entities as if they were unobservable phenomena.

As Bohr pointed out, the term «phenomenon» should be reserved solely for what can be observed in three-dimensional space or, in Kantian terms, for what can be empirically perceived. Therefore, the expression «unobservable phenomenon» contains a contradiction in terms. The answer to the problem of quantum objectivity does not lie in a referential semantics for unobservable objects. Instead, the transcendental analysis of the principle of complementarity reveals that the only acceptable use of intuitive images is analogical. Furthermore, this use is intrinsically tied to the conditions for the possibility of unequivocal communication.

The «Kantian turn» I identify in Bohr's interpretation of quantum mechanics signals a more radical renunciation of the concept of objectivity than what is required in classical physics (Cf. Kauark-Leite, 2012: 335-340). In this new framework, objectivity cannot be explained through transcendental realism or within the bounds of a restricted transcendental semantics, such as the one presented in Kant's first Critique. What is at stake here is an even deeper transformation of the «Copernican Revolution» that Kant proposed for traditional epistemology and metaphysics.

In Bohr's «Kantian turn» or «post-Kantian revolution», the concept of the object in quantum mechanics cannot be understood without reference, on one hand, to the a priori formal theoretical conditions of objective

representation, and, on the other hand, to the context-dependent experimental conditions in which the observer and the object interact. The theory of experience as outlined in Kant's first *Critique* does not account for this second type of limitation, especially in its semantic analysis of determining judgments.

Translating Bohr's interpretation into Kantian terms, I suggest that the intuitive representations required by quantum mechanics no longer align with pure concepts according to the rules of transcendental schematism, as outlined in the *Critique of Pure Reason*. Bohr's principle of complementarity ultimately exposes the limitations of Kant's doctrine of schematism, which subordinates the object of empirical intuition to the conceptual representations produced by the faculty of understanding. This shows the impossibility of making intuitive representations homogeneous with conceptual representations.

By explaining the necessity of using two mutually exclusive classical images – such as the wave and particle images – Bohr challenges, and even denies, the possibility of replacing these conflicting images with a new, unified intuitive representation of the microphysical object that would be consistent and harmonious with the concept (Bohr, 1958: 30). The complementary use of intuitive representations, tied to mutually exclusive experimental contexts, reveals the limitation of our faculty of sensibility when faced with the unobservable. In this way, the principle of complementarity uncovers the inherent limitations of these representations, as they cannot provide a fully cohesive or intuitive understanding of quantum phenomena.

In light of this situation, we cannot transcendently understand the activity of imagination in the context of quantum mechanics as reducible to the synthetic procedure of subordinating sensible intuitions to concepts, where it has no freedom to create new cognitive objects. The function of imagination, as presented in the first part of the transcendental doctrine of determining judgment or the «Analytic of Principles» of the first *Critique*, was restricted to the synthesis of schematism that unifies, through

schemata, the multiplicity of intuition under the pure concepts of understanding through the temporal determination of internal sense (KrV, A145/B185). Along with the other transcendental functions of the mind, imagination forms the transcendental basis for explaining how a posteriori and empirical assertions are logically dependent on a priori and transcendental principles. Consequently, the creative function of imagination is highly restricted in the *Critique of Pure Reason*. For this reason, we must explore the role of creative imagination in the *Critique of the Power of Judgment* to better grasp, from a transcendental point of view, the complex epistemic nature of quantum mechanics.

4. Analogical Schematism as a Possible Solution to the Problem of Intuition Indeterminacy

I argue that quantum theory employs what Kant refers to in the *Critique of the Power of Judgment* as ideas of reason. In §49 of this book, Kant defines an idea of reason as «a concept to which no intuition (representation of the imagination) can be adequate» (KU AA 05: 314). This type of idea serves as the counterpart to the aesthetic idea, which is a representation of the imagination (intuition) that no determinate thought or concept can fully capture.

The notion of the idea of *reason* aligns perfectly with quantum concepts, for which, unlike classical physics concepts, no single intuition is adequate. In the quantum context, divergent intuitive images (such as particle and wave) are employed, each complementarily related to the same presumed quantum object (e.g., an electron). The use of these images to describe wave or particle behavior is confined to distinct and mutually exclusive experimental contexts.

In section §59, titled «On Beauty as a Symbol of Morality», Kant further elaborates on the concept by introducing the idea of symbolic representation. He expands his theory of meaning, providing a foundation capable of conferring cognitive legitimacy to ideas of reason. Addressing the

question of the foundation for the relation between a universal representation (or type) and the particular that accompanies it, Kant acknowledges that *hypotyposis* — i.e., the process of sensitizing concepts that allows us to give particular intuitive content to a specific conceptual representation — admits two distinct forms: schematic and symbolic. The process that helps us understand possible relations between the particular and the concept-type is not exhausted in schematism. In this text, Kant points out the incorrectness of opposing the symbolic to the intuitive, emphasizing that *symbolic hypotyposis* is one form of intuitive representation. He argues that «(the intuitive) can be divided into the **schematic** and the **symbolic** kinds of representation» (KU AA 05: 351). The difference is that in schematic representation, the determining power of judgment subjects the concept thought by the understanding to a corresponding intuition, while in symbolic representation, no sensible intuition can be adequate to the concept thought by reason. Instead, the reflective power of judgment proceeds analogically to schematism, offering an intuitive but symbolic representation of the concept. In this case, it is the form of reflection—the rule of procedure—and not the content of the intuition that corresponds to the concept. In this sense, we can speak of an indeterminate intuition, as the symbol, even if intuitive, never determines the concept. What occurs in *symbolic hypotyposis*, as Kant explains, is a «transportation of the reflection on one object of intuition to another, quite different concept, to which perhaps no intuition can ever directly correspond» (KU, AA 05: 353).

It is important to recognize that Kant introduces the notion of *symbolic hypotyposis* within the context of moral ideas, without intending to ground it epistemically. The distinction between symbol and schema was primarily made to clarify the process of sensitizing ideas or concepts of reason that transcend the scope of possible experience. In this context, the goal was to present beauty, regarded as a symbol of morality, as a paradigmatic example of this form of exposition. Kant was not seeking to es-

tablish a cognitive claim but rather to demonstrate that the symbol provides intuitive content analogous to our supersensible representations through the reflective operation of the power of judgment.

In the work published three years later, *Religion Within the Boundaries of Mere Reason* (1793), Kant blurs the distinction between schematism and symbolization, opting to use the term «schematism» to also characterize the process of symbolization. He does this by naming symbolic *hypotyposis as schematism of analogy (Schematism der Analogie)*, in contrast to the *schematism of object-determination (Schematism der Objektbestimmung)* (RGV, AA 06: 65). However, he warns against transforming the *schematism of analogy*, which is a process of reflection for explanatory purposes, into *schematism of object-determination*. Such a misunderstanding has harmful consequences in the moral domain, as it inevitably leads to anthropomorphism. Moreover, I believe it also affects the theoretical domain by attributing reality to explanatory concepts. In this sense, there is no possible analogy between the relationship of the schema to its concept and the relationship of the schema to an existing thing.

Also in the same year, 1793, when Kant began drafting the essay On the Progress of Metaphysics, later published posthumously, he acknowledges that the «schematism of analogy» is not confined solely to the moral realm but is also present in the process of knowledge. As he states: «For experience, however, knowledge contains schematism, either the real schematism (transcendental), or the schematism by analogy (symbolic)» (FM, AA 20: 332). This possibility, presented in this text, undoubtedly expands the transcendental research program concerning the foundations of natural science beyond the schematism of the categories.

As Loparic (2000) points out in his analysis of transcendental semantics, the Kantian doctrine requires considering two canons to ground problem-solving activity: a doctrinal semantic canon, which deals with transcendental schematism and the a priori principles of pure understanding, and a heuristic canon, which addresses symbolic schematism and the a priori ideas of reason. However, this does not mean replacing one canon

with the other, nor one schematism with another. The semantic canon plays a fundamental role in the transcendental theory of truth and objectual problems within the realm of phenomena. On the other hand, the heuristic canon is conceived as a set of fictions and heuristic maxims of thought aimed at solving problems related to the systemic unity of theoretical constructions.

Thus, Loparic draws attention to the fact that the types of problems addressed by Kant's theoretical philosophy can be subdivided into two classes: one related to objects and another related to systems. The first class can be further divided into empirical and mathematical, both strictly related to understanding. The second class, in turn, originates from reason itself and its cognitive function, aiming to expand knowledge not only in the determination of empirical objects per se but in the systematic cognition of these objects.

In this context, the problems presented by reason, in its systematic cognitive function, differ from objectual problems related to the interaction between understanding as the faculty of concepts and sensibility as the faculty of intuition. Reason, in its problem-solving function, inevitably resorts to certain extra-empirical conditions. Even in scientific research, when addressing empirical problems, reason must introduce ideas and ideal objects from the noumenal domain, which have a primarily explanatory function. Such metaphysical concepts of reason, such as the idea of absolute space and the idea of fundamental forces presented by Kant in the *Metaphysical Foundations of Natural Science* (MAN, AA 04), transcend phenomenal experience and originate from the very nature of human reason.

However, according to the doctrinal semantic canon, these ideas cannot be considered objectively valid assertions and, consequently, lack truth value. They are fictitious representations that surpass the limits of phenomenal experience but reflect fundamental aspects of the nature of human reason. One such aspect is related to the task that reason imposes on itself, as expressed in the following logical maxim: «to find the unconditioned for conditioned cognitions of the understanding, with its unity

will be completed» (KrV, A307/B364). Faced with this demand, non-critical or dogmatic reason falls into the error of attributing objective validity or truth value to non-empirical propositions that fundamentally serve a heuristic function. The dogmatic interpretation of this logical maxim transforms the supersensible objects of ideas, such as the idea of simple substance, the idea of cosmological totality, the idea of supreme intelligence, and also the metascientific ideas of absolute space and fundamental forces, into objectively real entities, as if they were given in the world. In doing so, dogmatic reason produces antinomies and an endless series of philosophical problems that are *a priori* unsolvable.

On the other hand, critical reason interprets the supreme principle of reason in its search for the unconditioned in a non-realist manner, thereby dispelling the semantic misunderstanding. Despite its non-realist nature, the postulate of reason drives the advancement of knowledge by fostering the development of theoretical systems of empirical laws. Critical reason resolves the semantic paradox by making a non-dogmatic yet positive use of metaphysical ideas from the numen domain. The heuristic canon regards these ideas not as constitutive principles of knowledge but as regulative principles or heuristic maxims that have an eminently fictitious nature. In this sense, as Loparic (2000: 273) states, «our variable x (x transcendental) is not an object, but the unified system of empirical explanations of given objects in a possible experience.» The unity produced by reason in empirical sciences is not a unity of empirical data but a systemic unity aimed at an ordered whole that integrates laws and mathematical constructions, empirical causal laws, and also hypothetical metaphysical propositions.

Thus, the distinction between the doctrinal and heuristic canons lies in the fact that the former is grounded in the constitutive rules of understanding, while the latter relies on the regulative maxims of reason. The rules of understanding are objectively valid principles that precisely determine empirical objects, axioms, and laws through cognitive operations given by exemplification or intuitive construction. In contrast, the max-

ims of reason do not conclusively specify these kinds of operations (Loparic, 2000: 115). As Kant explains in the «Appendix to the Transcendental Dialectic», these maxims of reason are «subjective principles that are taken not from the constitution of the object but from the interest of reason in regard to a certain possible perfection of cognition of this object» (KrV, A666/B694).

Although they serve different functions, both canons are equally essential to science. While the doctrinal canon establishes that noumenal concepts are empty – that is, they do not refer to anything – they still possess meaning and should not be excluded from scientific activity. From the perspective of the heuristic canon, these concepts, rather than being problematic, take on a positive role in advancing reason's supreme interest: the pursuit of the highest perfection of knowledge.

How, then, can one respond to the dilemma proposed by Lebrun (2002 [1970]: 286), who raises the issue of how to discern between a valid hypothesis and a mere chimera? Lebrun contends that even the most absurd fictions can, according to him, satisfy the criterion of schematism by analogy, making it difficult to differentiate between the two. The answer to this question, which Kant does not explicitly address, must arise from the interplay between the two types of schematism or the two canons outlined by Loparic. Thus, in offering a partial and preliminary response to Lebrun's challenge, one can assert that these fictions cannot be dismissed outright as chimeras or absurdities. Instead, their validity is determined by their integration with and relation to the products of real schematism and the doctrinal canon.

5. Conclusion

Kant's distinction between real (or transcendental) and analogical (or symbolic) schematism proves particularly useful for interpreting quantum phenomena marked by intrinsic indeterminacy. While real schematism connects concepts to intuitions through concrete links, analogical sche-

matism employs analogies to bridge the gap between empirical observations and transcendental ideas. Building on Kant's ideas, analogical schematism provides a framework for addressing the epistemological challenges of quantum theory, accommodating its abstract concepts while fostering theoretical insight.

As elaborated in the *Critique of the Power of Judgment* and *Religion Within the Boundaries of Mere Reason*, the concept of analogical schematism, originally developed by Kant in the context of practical reason, can serve—as we expand its scope—as an interpretive tool for engaging with the abstract and non-empirical aspects of quantum mechanics. Through symbolic representation, quantum phenomena—such as wave-particle duality and superposition—can be grasped as meaningful analogies rather than direct empirical intuitions. For instance, the wave-particle duality, though not a literal representation, functions as a predictive schema that allows for anticipating outcomes, making accurate predictions, and effectively interacting with the physical world. This approach allows for a more nuanced engagement with microphysical entities, balancing the constraints of intuitive comprehension with the theoretical and practical challenges posed by quantum theory. The theory emerges not as an intuitive depiction of reality but as a practical framework for engaging with physical phenomena. This highlights the ongoing relevance of Kantian epistemology for contemporary science, particularly where empirical representation encounters its limits.

Grete Hermann and Niels Bohr both emphasized that quantum concepts derive their meaning primarily through analogical use. Hermann highlighted the epistemological distinctiveness of quantum theory, arguing that its concepts cannot be reduced to classical representations but function instead as analogies that connect abstract mathematical structures to empirical observations. Similarly, Bohr advocated for the contextual nature of quantum concepts, framing them as tools for understanding rather than as direct depictions of physical reality. These perspectives

align closely with Kant's notion of symbolic schematism, which underscores the necessity of analogical reasoning when empirical representation falls short.

The reflections of Hermann and Bohr further illustrate how quantum theory compels us to reconsider the boundaries of representation and cognition. Analogical schematism, as a bridge between empirical intuition and theoretical abstraction, becomes indispensable for navigating the indeterminacy inherent in quantum mechanics. This approach not only deepens our understanding of the limits of quantum theory but also reaffirms the relevance of Kantian philosophy in addressing the epistemological challenges presented by contemporary science.

In sum, the symbolic tools provided by analogical schematism suggest a possible pathway for interpreting quantum phenomena, aiming to engage with their intrinsic indeterminacy while tentatively offering conceptual insights. By integrating Kant's ideas with the reflections of Hermann and Bohr, we can begin to outline a framework for exploring the interplay between empirical intuition, theoretical abstraction, practical demands, and the complex challenges of contemporary science. However, this integration raises further questions about the adequacy and limits of such approaches, inviting continued dialogue between philosophy and physics to explore the epistemological and representational boundaries inherent in quantum mechanics.

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