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Kant, Quantum Physics and Transcendental Judgments

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ABSTRACT

Kant's philosophy of science has been applied to quantum physics since the time when Niels Bohr formulated his interpretation of quantum physics. In recent years various Kantian interpretations of quantum physics have been put forward. One aspect that still needs further exploration is what a Kantian approach to the epistemic status of quantum entities would entail. In this paper a new kind of judgment consistent with Kant's system, called a transcendental judgment, able to account for the real existence of quantum entities in the pre-measurement phase is discussed. The advantage of this kind of judgment is that it allows for a fine-tuning of the Kantian system to account for the discovery of quantum entities that are known to exist but whose existence can epistemologically not be accounted for in traditional Kantian philosophy. With this new kind of judgment, a wider range of possible judgments becomes available which can determine the epistemological status of concepts/ideas/theories quite carefully, discriminating between different kinds of knowledge claims.

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The philosophy of Immanuel Kant made a significant contribution to the natural sciences. It is generally acknowledged that Kant's philosophy did not only lay the philosophical foundations for mathematical science, of Newtonian science as well as classical science more generally including Einstein's theories (Friedman, 2001), Niels Bohr also made use of it in his effort to formulate an adequate response to the new kind of observations found in quantum physics (Pringe, 2007).

1. Kant's Philosophy of Science

In his *Critique of Pure Reason* (First *Critique*; edition A 1781, edition B 1789), Kant is concerned with the question: How is mathematical science (and mathematics) possible for humans with their discursive form of cognition, i.e., that needs both sensibility (intuitions) and concepts of the understanding for the cognition of objects (Friedman, 2001, 10)? In it he develops an epistemology in accordance with the conditions for and limitations of human knowledge. He establishes the limits of pure reason.

Kant then uses the conceptual framework developed in the First *Critique* as the basis for the formulation of his philosophy of science in *Metaphysical Foundations of Natural Science* (1786). In more recent times, modified versions of Kantian scientific epistemology have been developed in which his a priori constitutive principles have been reworked into dynamic and relativized principles consistent with contemporary scientific theory (see Friedman, 2001, 31, 47; Dorato, 2002; Ryckman, 2010; Kauark-Leite, 2010; Bitbol, 2007, 240-241, 2008, 62; etc.).

This, however, is not the full extent of Kant's philosophy of science. In his *Critique of the Power of Judgment* (Third *Critique*; KdU 1790), and more specifically in the Introductions (both the published and unpublished versions) as well as the second part called the Critique of the Teleological Power of Judgment, Kant is concerned with more general questions in science (again building on the foundations laid in the First *Critique*, especially the Transcendental Dialectic). In this regard, interpreters emphasize concept formulation and hypothesis development in empirical research (McLaughlin, 1990, 128) as well as the problem concerning underdetermination in scientific theories (Allison, 2012, 210). The Third *Critique* has also been understood as having special application to the life sciences (although Kant's main concern there is with biology), and it holds the possibility that both physical and life sciences can be comprehended in a common meta-framework (Friedman, 2001, 126).

What is moreover quite significant is that various authors have followed in Bohr's footsteps in developing Kantian approaches to quantum physics, epistemically grounding both quantum mechanics and quantum field theory (McLoud. 2018; Palmquist, 2015; Pringe, 2007; Bitbol, 2007; Auyang, 1995; etc.). In addition to the other well-known interpretations of quantum physics, namely the Copenhagen interpretation, David Bohm's interpretation, John von

Neumann's observer interpretation and the many-worlds interpretation, various Kantian interpretations of quantum physics have been developed in recent years (McLoud, 2018, 2024; Bitbol, 2007; Pringe, 2007; Auyang, 1995). In this paper the focus falls on this aspect and the application of Kant's philosophy of science to quantum physics.

2. The Challenge Quantum Physics holds for Epistemology

With contemporary quantum physics, the Kantian approach to epistemology faces significant challenges. These challenges include the epistemological status of quantum entities in the pre-measurement phase as well as that of their appearances in spatial configurations. The problem with quantum entities in the pre-measurement phase is that they exist beyond the possibility of empirical access; they can never be empirically detected while they are in the quantum mode described as a superposition of states. Once the quantum entities are measured, they exhibit a different kind of behaviour and their appearances are empirically accessible.

2.1 Quantum Entities are not Observable in Experiment

Let us take a closer look at quantum entities in their pre-measurement phase. The fundamental difference between objects with classical properties and entities having quantum properties follows from their mathematical formalization (Cartwright, 1999, 217). Despite the fact that the quantum properties of the system are called "observables" and they (in the relevant cases) assign a discrete spectrum of possible eigenvalues to the superimposed states in reference to probable outcomes, neither the superpositions of states nor their properties are actually observable in experiment. As a consequence, Bas van Fraassen says that quantum properties are merely a "theoretically described" reality that can never be given in experiment (Van Fraassen, 2008, 299).

Quantum systems as such have no eigenvalues; they only have amplitudes. To realize some eigenvalue, another condition is required, namely classical realization (Auyang, 1995, 79) when the reduction of the wave packet produces a reduced state associated with an eigenvalue (taken on the individual level).

The reason why quantum properties cannot be given in experiment is that the amplitudes associated with them are complex quantities while our instruments can only measure real numbers. Whereas some complex quantities can be decomposed into real and imaginary parts, which could be separately represented by real numbers, this is not the case with these quantum values. They are "irreducibly complex", that is, they have no real parts (Auyang, 1995, 73).

Sunny Auyang (1995), who discusses this aspect of quantum physics in some detail, regards such irreducible complex values as outside the possibility of human perception. She formulates a criterion which serves to decide what falls within the bounds of our form of perception, namely that we must be able to map object structures into a real number system or its direct products (which is possible, for example, when a complex number is decomposable into real and imaginary parts). Her argument is that perception involves the ability to visualize which is not possible with regard to irreducible complex numbers.

This irreducible complexity of the quantum states (superposition of states) and their amplitudes, as well as the amplitudes of the quantum properties, implies that they are beyond our ability of representation in perception. They can therefore never be empirically given in experiment (which is always representable in perception). Auyang writes in this regard:

> In stipulating that quantities admissible as measured results [i.e., eigenvalues] must be real numbers, quantum theories make explicit a general limit to human empirical capabilities. The general form of our sensible capacity is representability by real numbers... Eigenvalues are numerical and fall within the bounds of our form of perception, whereas quantum amplitudes do not (Auyang, 1995, 72, 81).

The reduction of the wave packet takes the system from such irreducible complex amplitudes to eigenstates which are associated with measurable real eigenvalues.

2.2 Quantum Entities are not in Proper Space-Time

Another important feature of quantum physics is that the space-time manifold associated with quantum states is distinctly different from proper space-time. In quantum physics, abstract mathematical space-time (in quantum field theory) or abstract space (in quantum mechanics) replaces proper space-time. In contrast with the classical picture where particles can be described in terms of both time and space, in quantum mechanics, the entities (in superpositions of states) can be described in time but not in proper space. They are described as mathematical objects (represented by state vectors or wave functions) in a mathematical space, called a Hilbert space.

The main problem is that in quantum physics the Hilbert spaces are complex vector spaces (Cartwright, 1999, 217). Although there have been efforts to describe quantum mechanics in a real Hilbert space (as was done independently by Mackey and Stueckelberg), these formulations merely make the complex nature of Hilbert space implicit, it does not remove it (Auyang 1995, 74). The complex nature of Hilbert spaces expresses in mathematical terms the fact that quantum states with their complex amplitudes cannot be represented in proper space (McLoud 2018, 63-4). When entities cannot be represented in space, they are not visualizable since this involves our ability to spatialize. In the Kantian approach, the representability of objects in space is closely associated with human perception which involves the ability to visualize objects in space. For Kant, this presents the limits of both human sensibility and understanding.

What we discover is that quantum entities exist but outside the possibility of direct empirical detection. As Auyang (1995, 75) says, they are "kickable" and thus have empirical ramifications. The quantum state (and its properties) is "a genuine feature of reality" (Cartwright, 1999, 232) despite the fact that this can only be established through indirect empirical considerations.

What about quantum appearances? Quantum entities can produce outcomes in space-time, appearances that are distinctly different from those known from the classical world. The representations (appearances) that result from the transitions from quantum to reduced modes are distinctly different from those where no transition is involved (i.e., mere changes within the classical mode). The first kind "appears" in space-time. They include microscopic particles that become manifest by impacts, bubble chamber tracks and clicks on counters. The second kind is always in space-time.

3. Kant's Epistemology and Quantum Entities

The goal that Kant set out in constructing his epistemology was to establish "objective" cognition through which the necessary and universally valid principles for mathematics and the natural sciences could be established (A93/B125). In his view, our discursive intellect necessitates that the appearances given in perception be brought under the principles of the understanding for us to make truth judgments. In Kant's epistemology two possible kinds of judgments can be made according to the context of the situation. These are determinate/objective and the reflective judgments. Let us first consider determinate judgments, judgments that establish whether objective knowledge of something can be obtained.

3.1 Determinate Judgments

The distinct feature of Kant's epistemology is that he establishes the necessary a priori (i.e., before experience) conditions for achieving actual empirical cognition (i.e., empirical truth) when objects are given in empirical intuition (i.e., perception). Objective cognition is obtained when the various epistemic conditions which are necessary, and presumably together sufficient for that, are adhered to (Allison, 2004, 12).

These conditions include the human abilities which make cognition possible in the first place (Gardner, 1999, 83), namely the pure (a priori) forms of sensibility, namely space and time, the pure "form of sensibly intuiting" (i.e., the manner/form in which intuitions are given for synthesis with concepts; Allison, 2004, 15, 114) as well as the pure forms (concepts) of the understanding, all of which relate to objects completely a priori (A86/B118; A88-89/B120-122). The formal conditions which make our experience of objects possible at the same time make them into possible objects of experience.

In formulating these conditions Kant complements the discussion of the *possibility* (a priori conditions) of experience (that follows from his transcendental idealism) with that of the *actuality* of experience and the *necessary* and objective world of experience (that follows from his empirical realism). For Kant the term "empirical" refers to the givenness of objects; that outer objects are given from outside us in the senses (B166; Allais, 2004) whereas the term "real" refers to their independent existence, which is not inferred, but directly perceived as "matter" in appearances:

> [T]he transcendental idealist is an empirical realist, and grants to matter, as appearance, a reality which is not inferred, but is immediately perceived (A372).

Whereas the conception of objects, which precede perceptions, signify mere (though real) possibility, perceptions provide the material for these conceptions, and as such "is the sole characteristic of actuality" (B273). For experience to be actual, it must involve not merely establishing something about objects a priori *before* they (as real objects) are given to us (Bxvii), but also about the real objects of the senses. Objects must not only conform to our cognition; cognition must also incorporate that which is real in objects. A priori cognition does not mean that no a posteriori data is involved (Bird, 2010, 127). On the contrary, the determinate judgment that a cognition is true or false must involve both a priori (transcendental) rules (only general rules can have necessary and strict universal application) as well as particulars (when pure apprehension is particularized in experience) which are brought under those rules.

Determinate judgments can only be made in the context of the classical world with regard to objects that can be perceived by humans when they are given in the senses. It should be noted that Kant's epistemology is not restricted by the crudeness of our human sensibility. Kant allowed that our conceptual formulations can in the progress of experience (and experiment) be applied to "possible" perceptions "in accordance with the laws of the empirical progression", i.e., "in the footsteps of cause and effect" (A493/B521; A495/B523). Kant has no problem with the idea that we can "observe" very small objects; he even mentions the existence of the magnetic field force ("magnetic matter") in this regard (A226/B273). As long as a detailed causal structure can be established, scientists can apply some conceptual structure to appearances given in experiment.

The question is whether a determinate judgment can be made about quantum appearances which are in fact observable in human perception (or at least located in proper space-time). This challenge has been taken up by Michel Bitbol and Hernán Pringe.

Bitbol (2007) discusses the distinct differences between material entities that are extended in space-time and those that merely "appear" or manifest in space-time. To establish the latter as objective phenomena, Bitbol proposes that the Kantian rules of the understanding be replaced by other theoretical structures, especially symmetries. He argues that the collective behaviour of the different classes of particles, which are embedded in universally valid symmetries, are law-like. Although it is not clear that single instances of phenomena ascribed to one isolated quantum entity can be ordered like this, he thinks that in the context of quantized fields the individual manifestations in space-time can be combined with global law-like ordering as is manifest in global field equations. In the final instance, he argues that the quantum entities that appear in space-time can indeed be regarded as matter:

> Manifestations in space-time, plus law-likeness (objectivity) applied to probabilistic predictors of classes of phenomena, is enough to characterize matter (Bitbol, 2007, 255).

In contrast with Bitbol, Pringe (2007) uses classical Kantian philosophy to argue that measurable phenomena in quantum physics observe systematic unity and objectivity. He distinguishes between two kinds of causality, namely classical and quantum causality. Quantum causality signifies that quantum objects are the ground of quantum phenomena, which is why such objects bring meta-contextual systematic unity among contextual phenomena.

Such a non-sensible (supersensible) ground can be problematically assumed, and the interactions of quantum objects which constitute this ground are discontinuous and uncontrollable (i.e., spontaneous); they may be conceived of as a series with an absolute beginning. Classical causality, on the other hand, operates in contextual situations as an element of a series of causes and effects. As such it grounds the epistemic objectivity of quantum phenomena (Pringe, 2007, 156; Pringe, 2023, 252).

The systematic unity between complementary quantum phenomena, which are constituted by classical concepts, then serve as symbols of the quantum object which falls beyond the possibility of experience. Moreover, this systematic unity of contextual experience makes the formulation of the principles of quantum metaphysics possible (in accordance with Kant's regulative principles of reason), placing quantum physics on a secure epistemological basis. Pringe writes:

> [Q]uantum metaphysics is possible as a specification of the regulative principles belonging to general metaphysics of nature…. The metaphysical principles of quantum theory contain the a priori determinations of the objectivity of those regulative objects that must be assumed for the possibility of the systematic unity of contextual experience. Such principles are therefore the *constitutive* principles of metacontextual regulative objects, and they are in this sense objectively valid (Pringe, 2023, 260-5).

As the noumenal realm, described as the supersensible substratum of nature, forms a crucial part of Kant's philosophy of science in the Third *Critique*, especially in the part called Critique of the Teleological Power of Judgment, we can safely assume that Kant regarded this concept as consistent with science. We cannot eliminate it from Kant's philosophy of science without seriously damaging his arguments for teleology, which he applies to organisms through reflective judgment (McLoud, 2018, 50).

3.2 Reflective Judgments

In his Third *Critique* Kant introduces reflective judgments. He suggests that it sometimes happens that a problem occurs for the faculty of the power of judgment which subsumes particulars under universals, namely how to judge particulars when the universals are not given. In this instance a contingency exists between the particular and the universal and the possibility arises that our understanding would not necessarily grasp the universal (Allison, 2012, 171). This possibility arises in the case where we assume that nature could have a supersensible ground. When such a supersensible ground is assumed, the universal could even be "beyond the sphere of the insights into nature that are possible for us" (see *EEKU* 20, 218 and *KdU* 5, 170).

Reflective judgment is the ability then to subsume a given particular under a rule that is not given, i.e., the rule under which the particulars may be subsumed must be sought for. In this case an a priori principle is required for the power of judgment according to which such universals can be found (Allison, 2010, 240). Kant identifies the transcendental principle which guides the reflective power of judgment (both in aesthetic and teleological judgment) as the purposiveness of nature which he describes as "the lawfulness of the contingency as such" (*EEKU* 20, 217). This principle basically says that we have to take nature heuristically *as if* it is designed for purposes of the scientific study of nature (i.e., for us), even though we recognize that the objectivity of such a cognizable order is contingent (*KdU,* 5, 185). Kant moreover introduces two regulative principles according to which natural products could be considered in reflective judgment in accordance with its own rule (i.e., the transcendental principle of purposiveness), namely mechanism and teleology.

In teleological judgments, two different kinds of judgments are moreover possible, namely when relative (extrinsic) or internal (intrinsic) purposiveness is considered. In the case of relative purposiveness, which explores the existence of one thing for the sake of another (or the existence of one part for another within the framework of a product of nature), things are explained according to mechanical laws (McLaughlin, 1990, 43). In the case of intrinsic purposiveness, something's internal possibility for the production of its outer form is considered (in analogy to production by the causality of a concept, called a "final causality"). The internal possibility that the products of nature have to produce their outer forms may lie in the supersensible substratum of nature; it can be judged in terms of teleological (instead of mechanistic) laws (with both serving as regulative principles, i.e., mere hypotheses; *KdU* 5, 415) as Kant mentions:

> The power of judgment, through its a priori principle of judging nature in accordance with possible particular laws for it, provides for its supersensible substratum (in us as well as outside us) determinability [i.e., that it can determine outcomes as phenomena] through the intellectual faculty [i.e., we can think it] (*KdU* 5, 196).

In contrast with determinate judgments, there is no objectivity nor can any be claimed for this kind of judgment. Reflective judgments, which are neither theoretical nor practical, "do not determine anything about the constitution of the object nor the way in which to produce it" (*EEKU* 20, 201). There is an explicit acknowledgment of the subjective, reflective (self-referential) character of this principle of judgment which does not prescribe rules to nature but merely to itself. Kant calls this the "heautonomy" of the power of judgment (*EEKU* 20, 225 and *KdU* 5, 185). The reason why we must take purposiveness as a (subjective) universal and necessary (i.e., transcendental) principle guiding empirical research, is that without it no "thorough interconnection of empirical cognition into a whole of [i.e., unified] experience" is possible (*KdU* 5, 184).

The claim is not that nature is purposive, i.e., that we have some sort of *a priori* guarantee that it is ordered in a manner commensurate with our cognitive capacities; nor is it even that we must believe it to be purposive in this sense (which is basically Hume's position). The claim is rather that we are rationally constrained to approach nature as if it were so ordered (Allison, 2010, 186). Butts describes this approach as follows:

> Determinate judgments are either true or false of objects of possible experience. Reflective judgments, based as they are on subjective maxims, are neither true nor false, not even probable or improbable; they are rather rational *estimates* of the way nature operates (Butts, 1990, 4).

This brings us to the epistemological status of quantum entities. As these entities are not empirically accessible to our measurement devices, no determinate judgment about them is possible. In Kantian epistemology it is therefore not possible to obtain any objective knowledge about quantum entities despite the fact that we know that they do in fact exist.

4. Introducing Transcendental Judgments

What we find is that quantum entities exist but Kantian epistemology cannot show how such knowledge is possible. On the one hand it is clear that a determinate judgment is too strong a requirement whereas a reflective judgment, on the other hand, is too weak. So, the question is whether the knowledge obtained from quantum physics with regard to quantum entities existing in the supersensible quantum realm can in fact be recognized as such in the Kantian system. Can the Kantian system be fine-tuned so to say?

Let us take a closer look at Kant's transcendental idealism. By "transcendental" Kant means that his idealism is concerned with the possibility of and conditions for (objective) experience, and as such with a priori cognition. More generally it can be stated that transcendental idealism is concerned with "the possibility of and conditions for" certain epistemic conclusions to be arrived at. In this case the Kantian system can be generalized to make provision for other kinds of epistemic conclusions, namely those that fall somewhere between the two extremes of determinate and reflective judgments, namely to arrive at a transcendental judgment (also called a "regulative judgment"; McLoud, 2018) when the necessary and sufficient epistemic conditions for something are satisfied.

In a transcendental judgment the particulars (observations) do not only agree with the rule (mathematical descriptions like quantum theory), the conditions for its possibility are also satisfied. A transcendental judgment would decide whether the conditions for the possibility of something have been satisfied even though such conditions may involve aspects that fall outside direct empirical observation, for example, when they are derived from mathematics and experimentation in physics. Different kinds of transcendental judgments can be distinguished, namely epistemic transcendental judgments which take epistemic conditions into consideration and ontological transcendental judgments which take ontological conditions into consideration.

4.1 Extending the Kantian System

An important way in which the Kantian system can be extended in accordance with its original formulation is to move to an epistemology based on the conditions for the possibility of arriving at certain epistemological conclusions for situations that go beyond the possibility of human sensibility and in which case the concepts of the understanding are replaced by ideas of reason. Examples are the concepts of space/time and causality, with causality now referring not to that of the Second Analogy of Experience, which applies when objects are presentable in space/time intuitions (Kauark-Leite, 2010, 248).

In such cases the empirical use of reason can be logically extended to the anti-thesis position of Kant's third antinomy ("conflict of laws") to conceptualize the sensible world as systemic "nature", which is comprised of the totality of causal relations called "mechanism". In this case, space-time and causality become *conceptual constructs* that belong to nature, outside the reach of human perception. Abstract mathematical theories like general relativity, which can never be brought under sensible conditions, are such descriptions of aspects of nature. Mauro Dorato

(2002) has shown how time and causality as conditions of experience can be related to concepts thereof in the framework of space-time theories.

The same can also be done for the thesis position in the said antinomy. Whereas the anti-thesis position *thinks* the unconditioned in the framework of sensible conditions (as systemic "nature"), the thesis position does not merely think the unconditional, it also thinks it outside sensible conditions in an intelligible (noumenal or supersensible) realm. Instead of creating a conflict of reason, this represents a real (logical) possibility.

In contrast with the mechanism of "nature", an absolute spontaneity (in accordance with the idea of transcendental freedom) serving as the cause of phenomena, can without any contradiction be ascribed to this supersensible realm, a spontaneity that can be viewed as beginning "a series of occurrences *entirely from itself*" (A534/B562, italics in the original). This spontaneity can without contradiction produce outcomes that interact with the causal chains of the phenomenal world (see also A532/B560). Kant says:

> Accordingly, a causality must be assumed through which something happens without its cause being further determined by another previous cause, i.e., an absolute causal spontaneity beginning from itself. (A446/B474, boldfacing in the original)

In the Third *Critique*, Kant reworks this idea into that of a spontaneous potentiality that underlies his concept of "final causality".

4.2 Application to Quantum Physics

These concepts can be applied to quantum physics. McLoud (2018) shows that all the Kantian conditions for the possibility of the supersensible realm as described in the First and Third *Critiques* (which he argues are consistent in this regard) are being satisfied in the quantum realm. This entails an ontological transcendental judgment. In his application the Kantian conception of "nature" (to be distinguished from our usual concept of nature) refers to the "classical world" (where the space-time theories of relativity apply), his supersensible substratum of nature refers to the pre-measurement "quantum world" and the reduction of the wave packet is understood in terms of the spontaneous causality (potentiality) that Kant ascribes to that realm.

Pringe also takes the non-sensible realm from which quantum phenomena are produced as Kant's noumenal realm (Pringe, 2007, 157, n. 31). He moreover takes quantum entities (in a methodological sense) as noumenal "objects" belonging to the noumenal/quantum realm from which quantum phenomena are produced. What is more is that the idea of an absolute spontaneous cause belonging to the supersensible realm that produce outcomes in nature forms the basis of Pringe's concept of quantum causality.

The reason why we can gain indirect empirical access to the quantum realm despite the fact that it is a supersensible realm, is that in quantum mechanics proper time is combined with an abstract concept of space, namely Hilbert space (see the previous discussion; McLoud, 2018). In our experiments we thus have control over these entities in time despite the fact that they are not located in proper space and as a consequence they can be manipulated in different experimental settings.

At this point the idea of a transcendental judgment becomes relevant. When quantum entities are distinguished from the objects of possible experience and instead viewed as "noumenal objects", as an idea of reason, that is, not as a constitutive concept, but a "regulative" concept (as Pringe emphasizes), this conceptualization allows us to relate such phenomena consistently with noumenal objects. In this way indirect empirical confirmation for the existence of quantum entities can be obtained despite the fact that Kant did not think that possible.

In this case Pringe takes the conditions of the possibility of the systematic unity of contextual experience as the conditions for the possibility of quantum objects. He calls this principle the highest principle of quantum objectivity (Pringe, 2023, 261). Since these conditions are satisfied, an epistemic transcendental judgment can be made that such entities do in fact exist. This is a weaker claim than that based on a determinate judgment but is nonetheless a very substantial claim that goes far beyond that of a mere reflective judgment.

In turn McLoud (2018) argues that the Kantian idea of "transcendental" freedom can in its wording actually already include a reference to *the possibility of and conditions for* absolute spontaneity. In Kant's critical metaphysics such spontaneity becomes conceivable as something that can really exist if certain basic *conditions for the possibility of freedom* (both as an effective spontaneous causality and practical freedom) are introduced. Although Kant does not formally mention "conditions" in this regard, this is in keeping with Kant's manner of thinking and transcendental philosophy in general. These necessary conditions are 1) an ontologically distinct noumenal realm (problematically assumed) governed by absolute spontaneity instead of determinism (A255) and 2) the ability of noumena to produce outcomes in nature.

Even though Kant did not foresee that these conditions could ever be satisfied (since this lie beyond sensible reach and he thinks that we cannot even *prove* the real possibility of freedom—see A558/B586), the progress of science has made it possible to engage with these conditions in a way Kant had never foreseen. McLoud (2018) has shown that the necessary and presumably sufficient conditions for absolute spontaneity are indeed satisfied in quantum physics in the framework of quantum causality that produce quantum phenomena (in contrast with efforts to describe it in mere stochastic (deterministic) terms as in the Ghiradi-Rimini-Weber (G-R-W) theory; Allori et al. 2008; Bitbol and Osnaghi, 2013, 153; McLoud, 2024). As these conditions are primarily concerned with ontological conditions this also entails an ontological transcendental judgment.

The G-R-W theory turns the Schrodinger equation into a scholastic dynamical law in which the instantaneous (often called "spontaneous") collapses of the system happen in accordance with the causal determinism that belongs to the classical world (Allori, 2008, 357). Recently the Majorana Demonstrator experiment performed at the Sanford Underground Research Facility has effectively shown the G-R-W theory to be wrong (Donadi et al. 2020).

The ascription of spontaneity to the quantum realm is based on McLoud's view that Kant's regulative use of reason (in his critical metaphysics) implies that the classical and quantum worlds belong to different modes of existence, with determinism (mechanism) ruling the classical mode of existence (systemic "nature") and spontaneity the quantum mode of existence (the supersensible substratum of "nature"). This view is based on the fact that the two dynamical principles underlying the third and fourth antinomies are concerned with the modes (third antinomy) and ground (fourth antinomy) of existence.

To conclude, Bohr's view as formulated in the quantum postulate concerning quantum indeterminism (absolute spontaneity) is thus born out to be correct according to a transcendental judgment. This aligns with what was shown by Michael Redhead (1987, 89), namely that the Aspect experiment not only confirmed the violation of the Bell inequality which assumes determinism, but also that the Bell inequality can be reformulated in such a manner that this violation even negates what might be called "stochastic" determinism, that is, that in this experiment the probabilities for possible values to occur are also not determined—at least in the framework of the Lorentzian space-time manifold (Redhead 1987, 83, 102-103). All forms of determinism break down in quantum physics.

5. Other Applications to Contemporary Physics

A few remarks can also be made about cosmology and the origins of the cosmos. In Kant's view, the question about the ultimate origins of the universe and that of the purposiveness or laws that we as humans ascribe to nature cannot be answered in any objective way because of the subjective nature of our human institution. No more than a reflective judgment can be made in this regard.

5.1 The Big Bang Theory

In contemporary physics the dominant theoretical model for the origins of the cosmos is the Big Bang theory. In this theory the origin of the cosmos is mathematically described as a singularity (in several measurable quantities like the energy density and the curvature of space-time), which is not really satisfactory since it is generally assumed that this merely means that the theory breaks down at this point and that we do not know what happened. What is concluded from this description is that the cosmos started out as an infinite dense point of energy from which space, time and the universe were born.

What makes the Big Bang theory widely acceptable is that certain empirical evidence has been interpreted in support thereof, especially the redshift of light (implying an expanding universe) and the cosmic microwave background radiation with its temperature fluctuations in accordance with star and galaxy formation. Images obtained from the James Webb space telescope have led to some speculations that the Big Bang theory is "broken" but careful analysis have shown that this is not the case. The observations simply show that some smaller galaxies (with 10^8 solar masses) formed at a very young age in the history of the universe (Keller et al. 2023).

The question then follows as to what the epistemological status of the Big Bang theory is. In the Big Bang theory, the "rule" that has been discovered is a solution of Albert Einstein's general relativity equations that conforms to the aforementioned empirical data (serving as particulars). As the Big Bang itself was not situated in space-time (instead space-time evolved from it), it falls outside the possibility of direct empirical confirmation. Even though this reminds of quantum entities that also fall outside proper space–time in the quantum fields description, the situation is not the same.

Whereas in quantum physics the conditions for the possibility of the systematic unity of contextual experience serve as the conditions for the possibility of quantum objects, the Big Bang can never be brought within such an experimental setting. This implies that in contrast with quantum entities that can be shown to exist through indirect empirical means, the existence of the Big Bang cannot be confirmed through similar means. As a consequence, we can at most make a reflective judgment that the empirical cosmological data is consistent with a Big Bang. The problematic nature of the Big Bang has led to many different theories as to how the cosmos supposedly came into being. Among these theories count Eternal Inflation (the Big Bang resulted from a quantum fluctuation in a region of the Multiverse towards the end of a period of space expansion or inflation), the Big Bounce (the Big Bang was preceded by an infinite sequence of universes), the Cyclic Universe (the universe undergoes endless cycles of expansion and cooling, each beginning with a Big Bang) and the No Boundary Proposal (the Big Bang was preceded by a four-dimensional space with one dimension of space turning into time during that event).

What these theories have in common is that they posit something instead of nothing before the Big Bang, something that is not God. The problem with all of them is that there is no substantial empirical evidence to support them and to the extent that they are concerned with what happened before the Big Bang (described as a singularity, which is an absolute discontinuity), they are also untestable and thus unfalsifiable. This means that their epistemic status is below that of the Big Bang theory since not even a reflective judgment is possible in these instances.

5.2 God as the Creator

Another question that Kant engages in is whether the real cause of the purposiviness of nature and even nature itself (i.e., the cosmos) can be established. In Kant's view the restricted nature of our human constitution makes it impossible to establish objectively what such a cause might be; only a reflective judgment is possible. He discusses two possible causes, namely the mere mechanism of nature and a cause that acts intentionally, which would be God (*Kdu* 5, 434). Like the Big Bang, God would exist outside the possibility of empirical confirmation, with the idea of God as Creator or the God-hypothesis serving as the rule and the observed design in the cosmos as the particulars. In Kant's opinion God provides a good explanation and this second option also allows for a purpose to existence. But even though an intentional cause or God may exist there is no possible way for us to establish that in objective terms:

> Hence, we can make no objective judgment whatever, whether affirmative or negative, about the proposition as to whether there is a being who acts according to intentions and who, as cause (and hence author) of the world, is the basis of the beings we rightly call natural purposes (*KdU* 5, 401).

What is interesting about the Big Bang theory is that it is neutral to the question about ultimate origins. In recent years the design argument for the existence of God has been complimented by evidence of many fine-tuning constants in the cosmos strengthening the case for intentionality in creation. The counterargument that the Multiverse makes that non-significant fails because no evidence exists for the Multiverse; we only have evidence for this phenomenon in our universe, the only one that we know exists.

Interestingly, the fine-tuning argument has made some inroads among non-Christians, for example with Philip Goff proposing some kind of cosmic purpose (see Goff, 2023). But in his view, it can be explained by a conscious universe.

Conclusions

In this paper the idea of a transcendental judgment is introduced. This kind of judgment which is concerned with the conditions for the possibility of something is clearly at home in Kant's transcendental idealism. The advantage of this kind of judgment is that it allows for a fine-tuning of the Kantian system to account for the discovery of quantum entities that we know exist but whose existence can epistemologically not be accounted for in traditional Kantian philosophy.

What is discovered is that a range of possible judgments now becomes available which can determine the epistemological status of concepts/ideas/theories quite carefully, discriminating between different kinds of knowledge claims. Whereas determinate judgments pertain to objects that are empirically accessible to our instruments, transcendental judgments pertain to quantum entities that are only indirectly so accessible and reflective judgments merely serve as an estimate as to whether something might be true.

This paper not only presents a new kind of Kantian judgment in generalized terms, it also shows how the different Kantian judgments can fruitfully be used to establish the epistemological status of the different physics theories about the universe currently in circulation. The multiplicity of current mathematical theories about the origins of the cosmos reminds of the multiplicity of ontological views based on pure reason demolished by Kant in his First *Critique*. As had happened in Kant's own time when those "ontologies" abounded, we experience very much the same with regard to all the many theories about the universe that nowadays abound in the physics community. Pure mathematical considerations and subjective opinions are however not enough to give theories credibility. As already mentioned, certain popular theories about the origin of the cosmos do not even reach the lowest epistemic threshold associated with a reflective judgment.

Adaptations of Kant's philosophy of science to quantum physics should follow in the First *Critique*'s footsteps in providing epistemic guidelines in evaluating the real significance of mathematical theories. It is time that Kantian philosophers of science again enter and engage in this important conversation.

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