

ON A FUTURE TRANSCENDENTAL ACCOUNT OF PROBABILITY  
IN QUANTUM MECHANICS

*Acerca de una futura explicación transcendental de la probabilidad  
en mecánica cuántica*

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**Abstract**

In this paper I put forward some ideas for a future transcendental account of probability in quantum mechanics. Such account will be based on the determination of the epistemological function that probabilistic laws play in quantum mechanics. By means of this determination I expect to take some steps toward a metaphysical foundation of quantum mechanics along Kantian lines, as well as to shed some new light on the current philosophical debate on the notion of probability in quantum mechanics.

**Key words:** Kant, probability, quantum mechanics.

**Resumen**

En este trabajo propongo algunas ideas para una futura explicación transcendental de la probabilidad en mecánica cuántica. Tal explicación se basará en la determinación de la función epistemológica que desempeñan las leyes probabilísticas en mecánica cuántica. Mediante esta determinación espero avanzar hacia una fundamentación metafísica (en sentido kantiano) de la mecánica cuántica, e iluminar el debate actual acerca de la noción de probabilidad en mecánica cuántica.

**Palabras clave:** Kant, mecánica cuántica, probabilidad.

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## On the Necessity of a Transcendental Account of Quantum Probabilities

In recent years, a growing trend in Anglo-American philosophy has claimed the necessity of providing a metaphysical account of nature, reacting to the analytical identification of saying what 'P' means and saying what being P is.<sup>1</sup> In doing this, a field called *metaphysics of science*<sup>2</sup> has been demarcated, in which questions concerning natural laws, probability, dispositions, properties and modal determinations have found their place. According to this philosophical position, a metaphysical knowledge of nature is needed, in contradistinction to the anti-metaphysical attitude of the investigations broadly pertaining to the logical-positivist tradition. In particular, against influential trends in philosophy of science, it is contended that philosophical arguments should have more in their favour than just being scientifically informed.<sup>3</sup> However, in their search for "what ultimately exists",<sup>4</sup> these metaphysicians of science explicitly ignore the conditions under which we may have cognitive access to that ultimate reality. In their view, such conditions are not part of metaphysics, but belong to epistemology.<sup>5</sup> Unfortunately, this leaves a wide front open to a sceptical counterattack which may rightly cast doubt on the justification of claims of knowledge of this sort. Thus, even though this new philosophical current asks for metaphysical foundations of science, trying to go beyond the mere analysis of phenomena, the old dispute between scepticism and dogmatism seems to hang over this enterprise as the sword of Damocles.

As a matter of fact, this dispute has already adopted a very concrete form in the philosophical debate on the *subjective/objective* character of probability statements in quantum mechanics. On the one hand, some maintain that quantum probabilities represent agent's degrees of belief, rather than corresponding to objective properties of physical systems.<sup>6</sup> But this seems too weak a position if we were to ask how it is then possible that these mere subjective probability rules may in fact be successfully applied to nature. In this situation, on the other hand, the recourse to some kind of objective chance grounding quantum probability appears to be quite natural.<sup>7</sup> However, the ontological commitments of this objectivism seem to be too heavy. In fact, these various kinds of objective chances (propensities and dispositions included) come near to *qualitates occultae* we dogmatically assign to nature, by which no satisfactory answer is achieved.<sup>8</sup>

A way out of this situation may nevertheless be found if the problem is investigated from an alternative perspective which, in accordance with the philosophical tradition inaugurated by Kant, may be called *transcendental*.<sup>9</sup> Along this line of thought, important developments have been made by von Weizsäcker, and more recently, by Petitot and

<sup>1</sup> See Molnar (2003), pp. 22f.

<sup>2</sup> See: Molnar (2003); Mumford (2004); Bird (2007).

<sup>3</sup> Mumford (2004), p. xiv.

<sup>4</sup> Mumford (2004), p. 6.

<sup>5</sup> See, e.g., Mumford criticism to Cartwright in Mumford (2004), pp. 14f.

<sup>6</sup> See, e.g., the Bayesian approach of Caves et al. (2007) and Appleby (2005).

<sup>7</sup> See, e.g., Loewer (2001) (2004).

<sup>8</sup> See the criticism to this objectivism in Stekeler-Weithofer (2007).

<sup>9</sup> In B25 Kant states: "I entitle *transcendental* all knowledge which is occupied not so much with objects as with the mode of our knowledge of objects in so far as this mode of knowledge is to be possible *a priori*." More specifically, this knowledge explains that and how certain representations (intuitions of concepts) can be employed or are possible purely *a priori*. (B80). On the concept 'transcendental' see: Höffe (1994), pp. 47ff.

Bitbol. From their point of view, probabilistic laws are in different ways connected with the *a priori conditions of possibility* of a certain moment of objective cognition. In this manner, one may maintain the *objective validity* of probability laws and likewise avoid any claim concerning a mysterious adequacy of these laws to any element of a transcendent reality. Specifically, von Weizsäcker searches for a kind of transcendental foundation of probability in quantum mechanics by means of his theory of “zeitüberbrückenden Alternativen.”<sup>10</sup> In turn, Petitot proposes a transcendental aesthetics of the Hilbert space of probability amplitudes.<sup>11</sup> Finally, from a pragmatic-transcendental point of view, Bitbol understands quantum mechanics as a generalized predictive scheme, the role of probability being thus *a priori* grounded in the conditions of possibility of our predictive activity.<sup>12</sup>

But, however promising these investigations may be, they have problems too. The main difficulty associated with von Weizsäcker’s approach is that he seeks for a *completely a priori* justification of the probabilistic structure of quantum mechanics. This seems to go beyond the limits that a transcendental foundation should respect, for the aim of a transcendental investigation on physics is not to eliminate the empirical elements from scientific knowledge, but rather to show how this knowledge is as *empirical* possible.<sup>13</sup> In turn, Petitot’s proposal has the paradoxical character of maintaining a theory of sensibility which completely dispenses with sensations. No object is given to us in the Hilbert space of quantum probability amplitudes. Therefore, Petitot’s analysis can only account for the theoretical formalism of the theory as a pure mathematical structure and not as a formalism which can be physically applied. The core of the problem of quantum probability laws, i.e., the issue of their justified *application* to *nature* remains untouched.<sup>14</sup> Finally, in the case of Bitbol, his extremely rich analysis of quantum probability loses much of its philosophical potential because he assumes the possibility of a *certain predictive practice* and not the possibility of *experience* as the touchstone of truth in his investigation. Against this pragmatic-transcendental approach, one should rather stress that scientific theories and experiments have “practical” character, not because they are necessarily aiming at an outer purpose (e.g., prediction), but merely in the sense that it is the *unity of thought* which stands before us as an ultimate goal, directing our cognition.<sup>15</sup>

The relationship between quantum probabilistic laws and transcendental philosophy has also been considered by Kantian scholars.<sup>16</sup> In the recent literature, some pointed out that quantum probabilistic laws do not render the Kantian principle of causality obsolete, because this principle concerns not the predictability of events but their explainability. The principle of causality has a mere regulative character, leaving undetermined the sort of laws according to which causal connections are to be grasped.<sup>17</sup> The crucial point is therefore to articulate in the quantum case both this regulative character of the principle of

<sup>10</sup> von Weizsäcker (1971), p. 425ff; von Weizsäcker (1979).

<sup>11</sup> Petitot (1994).

<sup>12</sup> Bitbol (1996), chapter 2.

<sup>13</sup> See Pringe (2007). In the same sense, Falkenburg stresses that the conceptual richness of a transcendental approach results precisely from the fact that for an *a priori* foundation of a *physical* theory *empirical* elements are indispensable. See: Falkenburg (2000).

<sup>14</sup> See Pringe (2007).

<sup>15</sup> Cf.: Cassirer (1910), pp. 422ff.

<sup>16</sup> For an historical analysis on Kant’s view on probability, see: Funaki (2002).

<sup>17</sup> Höffe (1994), pp. 103ff.

causality in regard to *intuition* and the regulative character of the principle of systematicity of nature in regard to *experience*.<sup>18</sup> In this connection, it has been argued that in quantum mechanics this purposiveness of nature for our cognitive capacity has given up its character of “lawfulness of the contingent as such”<sup>19</sup> in favour of a statistical account of events non-deterministically explainable.<sup>20</sup> But then the precise relationship between these two levels of regulative principles must be reassessed in the quantum case.<sup>21</sup>

Thus, the current debate on quantum probability demands a metaphysical investigation which clarifies the problem of the objective validity of probabilistic laws and statements in quantum mechanics. But this investigation cannot be carried out dogmatically, i.e., in ignorance of the conditions under which it is first possible. However, as the transcendental attempts just considered suggest, a metaphysical account of quantum probability may be accomplished if one shows that and how quantum probabilistic laws are grounded in the conditions of the possibility of experience. A future transcendental account of quantum probabilities should inscribe itself in this Kantian tradition, trying to overcome the shortcomings of the proposals already put forward. Thus, it should provide a metaphysical account of quantum probability in a critically justified sense. But it will not thereby seek for a completely a priori justification of the probabilistic structure of quantum mechanics (as von Weizsäcker tries), or for a new transcendental theory of sensibility (as Petitot proposes) or for a pragmatic-transcendental approach (à la Bitbol). Moreover, such transcendental account should differ from current analytic appropriations of Kantian philosophy, because no identification of transcendental arguments allegedly independent from the thesis of transcendental idealism is to be sought.<sup>22</sup> Neither should it adopt an analytic (or regressive) method,<sup>23</sup> which seems to be the method most of these arguments presuppose.<sup>24</sup> A transcendental account of quantum probabilities should rather be a consistent progressive development of the Kantian approach, firmly founded on Kant’s own results. In the following I shall show how this could be done.

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<sup>18</sup> On the relationship between the regulative character of the principle of causality in regard to intuition and its constitutive in regard to experience, see: Bayne (2004), pp. 158ff. and Watkins (2005), pp. 230ff.

<sup>19</sup> AA XX, 217.

<sup>20</sup> Düsing (1985), p. 206.

<sup>21</sup> On the necessary role of Kantian regulative principles for scientific practice, see: Buchdahl (1969).

<sup>22</sup> A compact review of this tradition, broadly relying on Strawson (1959) (1966) and Bennett (1966) (1974), can be found in Walker (2006). See also Cassam (2007), Sacks (2005), Stern (2004) (1999); Vahid (2002), Schaper and Vossenkuhl (1984); Bieri, Horstmann and Krüger (1979).

<sup>23</sup> “Analytische Methode, sofern sie der synthetischen entgegengesetzt ist, ist ganz was anderes als ein Inbegriff analytischer Sätze: sie bedeutet nur, daß man von dem, was gesucht wird, als ob es gegeben sei, ausgeht und zu den Bedingungen aufsteigt, unter denen es allein möglich.” AA IV, 276n. Kant maintains that in the *Prolegomena* he follows this method: AA IV, 276.

<sup>24</sup> For, should we apply such a method for the study of probability in quantum mechanics, we would face the danger of turning a transcendental investigation into the mere ‘owl of Minerva’ of an empirical science (i.e., physics) in its historical development. See: Baum (1979). In this connection, Baum maintains: “The weaknesses of transcendental arguments are the weaknesses of the analytic method.” Ibid., p.7. See also Baum (1986), pp 173ff. This position is criticized by Bittner (1979). See also Cramer (1979).

## Transcendental Approaches to Quantum Mechanics

I have already put forward a transcendental perspective on quantum mechanics by means of an interpretation of Bohr's thought along Kantian lines.<sup>25</sup> In particular, I have argued how transcendental philosophy may perform its critical task regarding 'dogmatic' metaphysical readings of quantum mechanics and, moreover, how metaphysical knowledge of the quantum realm is possible under these critical restrictions.<sup>26</sup> Let me here recall my main claim. Transcendental philosophy conceptually distinguishes two different moments in the enterprise of knowledge.<sup>27</sup> Briefly, in the first place, perceptions are to be brought under concepts in order to acquire *objective* validity. Secondly, these objectively valid cognitions must be combined into a *systematic* experience. The first moment may be called *constitutive* and the second *regulative*. I claim that the specific transcendental task of the concepts of *quantum* objects is *regulative*, in sharp contradistinction to the *constitutive* task of the concepts of *classical* objects.<sup>28</sup> The concepts of quantum objects bring about *systematic unity* among contextual phenomena constituted by classical concepts.<sup>29</sup> In particular, this distinction led to the following principle: the conditions of possibility of *systematic unity* of *contextual experience* are likewise conditions of possibility of *quantum* objects. I have argued that this Copernican turn in our understanding of quantum objectivity offers a way out of the dispute between instrumentalism and realism in the current epistemological debate on quantum mechanics.<sup>30</sup>

But, in addition to this, the identification of the conditions of possibility of quantum objects with those of the systematic unity of contextual experience opens a new field of metaphysical knowledge in the critical sense. For, in view of this identification, we may determine those features of quantum objects by means of which they carry out their transcendental function *independently of their being given in experience*. In other words, those properties of a quantum object that enable its regulative task may be *synthetically* but nevertheless *a priori* connected to the concept of the object. These properties would not be merely empirical, mathematical or formal-logical determinations of quantum objects, but they would express what makes quantum objects, *qua* objects,<sup>31</sup> first possible.<sup>32</sup>

<sup>25</sup> See: Pringe (2007) (2008) (2009) (2012). Transcendental approaches to quantum mechanics have been adopted in the seminal works of Cassirer, Hermann and von Weizsäcker as well as on recent studies by Auyang, Bitbol, Falkenburg, Mittelstaedt and Petitot. See: Auyang (1995); Bitbol (1996) (1998) (1998b) (2000); Cassirer (1936); Falkenburg (2000) (2007); Hermann (1935); Mittelstaedt (1995) (2004); Petitot (1994) (1997); von Weizsäcker (1943) (1971) (1985).

<sup>26</sup> Pringe (2013).

<sup>27</sup> "Die Grundlegung der kritischen Philosophie schließt nicht nur eine veränderte Bestimmung des Verhältnisses des Wissens zum Gegenstand in sich, sondern sie enthält hierin zugleich eine neue Begriffsbestimmung des Wissens selbst. Die beiden wesentlichen Momente des Wissens lassen sich in die Forderung seiner Objektivität und in der Forderung seiner durchgängigen Einheit zusammenfassen". Cassirer (1923), p. 236.

<sup>28</sup> In other words, the concepts of *classical* objects are rules for the *determining* power of judgment, whereas the concepts of *quantum* objects are rules for the *reflecting* power of judgment.

<sup>29</sup> For example, in Bohrian terms, the epistemological function of the concept of a photon is to bring about *systematic unity* among complementary wave- and particle-phenomena of light, the *objectivity* of which relies upon the use of classical concepts for their description. The *contextual* character of these phenomena is based on the fact that they appear *only* under certain experimental conditions, i.e., experimental contexts.

<sup>30</sup> Pringe (2007).

<sup>31</sup> The objectivity at issue here is a mere *regulative* one, which just amounts to the necessity of a given concept for the systematic unity of experience under certain conditions.

<sup>32</sup> Thus, the proposed investigation does not belong to physics, proto-science or methodology of science. On the relation between a transcendental critique and the aforementioned disciplines, see: Höffe (1994), p. 49.

In this sense, we may call the *synthetic a priori* judgments thereby obtained *metaphysical* judgments and their system *quantum metaphysics*.<sup>33</sup> Therefore, these results have *propaedeutic* significance in regard to quantum metaphysics. They establish the *possibility* of quantum metaphysics in the critical sense, as *a priori* knowledge of quantum objects.

### A Future Transcendental Account of Probability in Quantum Mechanics

While the possibility of quantum metaphysics has already been argued for, such a metaphysics is nevertheless still to be developed. Now that the critical job concerning our knowledge of the quantum realm has been done, the positive metaphysical determination of quantum objects needs to be accomplished. But, what should be the first step toward this goal? The transcendental investigation on quantum mechanics has hitherto established that the conditions of the possibility of the *systematic unity of contextual experience* are likewise conditions of possibility of quantum objects. However, this result leaves indeterminate what these conditions are. In other words, one should now consider how this systematic unity of contextual experience is in fact accomplished. Otherwise, no determinate knowledge of quantum objects could be gained in view of this principle. At this point, the most general but nevertheless determinate feature of the systematic unity of contextual experience must be investigated. The natural candidate is precisely the probabilistic character of this unity: different contextual phenomena are systematically connected to each other by such laws that, a contextual phenomenon being given, they ascribe to the other phenomena their corresponding *probability*. Thus, an articulation of the *probabilistic* character of the laws of quantum mechanics and the *regulative* function of the concepts of quantum objects is required. Specifically, in order to determine *how* the systematic unity of contextual experience is brought about it would suffice to show that the regulative function of the concepts of quantum objects is carried out *by means of* the subsumption of these objects under the probabilistic laws of quantum mechanics. Accordingly, a first step beyond the results already established can be taken by considering the connection between the transcendental function of the concepts of quantum objects and the transcendental function of quantum probabilistic laws. In a second step, once it has been proved that the *systematic unity of contextual experience* provided by the concepts of quantum objects is no other than that obtained by the subsumption of these objects under the *probabilistic* laws of quantum mechanics, one may *a priori* ascribe to quantum objects those features by means of which they fall under these *probabilistic* laws of mere *regulative* character. This will provide us with metaphysical knowledge of quantum objects in the critical sense.

On this basis, a transcendental account of quantum probabilities may achieve the following results. Firstly, the reduction of the ontological commitments of quantum probability to the mere requirements of *systematic unity of contextual experience* may allow us to overcome the subjectivism/objectivism dispute concerning quantum probability. Whereas this critical reduction should enable us to reject any kind of dogmatic objectivism, it will not entail the relapse into a subjectivism which dispenses with the objective validity of

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<sup>33</sup> More precisely, these judgments would be *non-pure* synthetic *a priori* judgments, because they would depend on the *empirical* assumption of the quantum postulate. Quantum metaphysics would be an *applied*, i.e., empirically conditioned, metaphysics. On the problem of non-pure synthetic *a priori* judgments, see: Cramer (1985).

these laws, because the latter play a necessary (albeit regulative) role for the possibility of experience.<sup>34</sup> More specifically, the systematic unity of contextual experience provided by the concepts of quantum objects will only be gained by the subsumption of these objects under the probabilistic laws of quantum mechanics.

Secondly, a transcendental account of quantum probabilities would enable us to advance toward a critically justified metaphysical determination of quantum objects, for it should identify those features that are to be ascribed to quantum objects *a priori*, if these objects are to be ruled by probabilistic laws of mere regulative character. Substantial research to achieve this goal has already been accomplished by Bitbol's account of quantum mechanics as a contextual predictive scheme. Bitbol 'transcendentally' deduces a number of features of quantum objects (e.g., their contextual reality, their non-separability, the non-Boolean character of their properties and moreover, regarding their states, the formalism of vectors in Hilbert space associated with Born's rule) by showing how they correspond to conditions of possibility of a general predictive frame.<sup>35</sup> But these transcendental-pragmatic conditions should be now reinterpreted in transcendental-logical terms. In this way, those features corresponding to conditions of a certain predictive *praxis* will rather be shown to be grounded in conditions of systematic unity of our scientific *knowledge*. In this way, metaphysical knowledge of quantum objects will be gained under critical restrictions.

Along these lines, I have already argued that the use of a non-distributive logic in quantum mechanics may receive a transcendental justification.<sup>36</sup> In a recent work, Holik, Plastino and Sáenz study the origin of quantum probabilities as arising from non-Boolean propositional-operational structures.<sup>37</sup> Their approach may thus open a road to connect the axioms of quantum probabilities with the metaphysical principles of quantum mechanics by means of the consideration of quantum logic.

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<sup>34</sup> Stekeler-Weithofer also argues for an alternative to the subjectivism/objectivism dispute on probability. In his view on probability statements as *generic* statements, probabilistic laws acquire a status very similar to the mere *regulative* I believe they have. See: Stekeler-Weithofer (2007).

<sup>35</sup> Bitbol (1996), pp. 141 ff.; Bitbol (1998).

<sup>36</sup> Pringe (2013).

<sup>37</sup> Holik et al (2012).



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