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“It’s best not to think about it at all—like the new taxes”: Reality, Observer, and Complementarity in Bohr and Pauli

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Abstract. This article considers the concepts of reality, observer, and complementarity in Pauli and Bohr, and the similarities and, especially, differences in their understanding of these concepts, differences defined most essentially by their respective views of the role of the human observer in quantum measurement. These differences are significant even in the case of their respective interpretations of quantum phenomena and quantum mechanics, where the influence of Bohr’s ideas on Pauli’s understanding of quantum physics is particularly strong. They become especially strong and even radical in the case of their overall philosophical visions, where the impact of Jungean psychology, coupled to that of the earlier archetypal thinking of such figures as Kepler and Fludd, drives Pauli’s thinking ever further away from that of Bohr.

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1. INTRODUCTION

The title of this paper is the statement by P. Debye, cited by W. Pauli in his open letter to the Gauverein meeting in Tübingen. The letter announced Pauli's neutrino hypothesis, introduced by him in order to account for beta decay, which was described by means of quantum field theory by E. Fermi shortly thereafter. Pauli says:

> I admit that my remedy may perhaps appear unlikely from the start, since one probably would long ago have seen the neutrons [neutrinos] if they existed. But ’nothing venture, nothing win,’ and the seriousness of the situation with regard the continuous structure of the β-spectrum is illuminated by a remark of my respected predecessor in office, Herr Debye, who recently said to be in Brussels: “Oh, it’s best not to think about this at all—like the new taxes.” One ought therefore to discuss seriously every avenue to rescue.—So, dear radioactive folk, put it to the test and judge. [1, p. 198]

Debye’s advice notwithstanding, Pauli, or his fellow founding figures of twentieth-century physics, such as A. Einstein, N. Bohr, W. Heisenberg, and E. Schrödinger never stopped thinking about difficult things physics had to confront. Pauli’s neutrino hypothesis is one of the products of his continuous thinking concerning the nature of quantum processes in quantum mechanics and then in quantum field theory, and also a product of “plausible reasoning” in science, as G. Polya (incidentally, Pauli’s colleague in Zürich at the time) and his fellow Bayesians would say [2].[1] Pauli’s appeal to probability, in relation to both his hypothesis itself and observing neutrinos, is worth noting because it intriguingly mirrors his emphasis on the role of probability

[1] For Pauli’s account of the history of neutrino, see [1, pp. 193-218].

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in quantum physics [1, pp. 43-48]. For the moment, this thinking of the founders of quantum theory extends even to the point of arguing, as Bohr did, that the ultimate nature of quantum objects and processes cannot be thought of at all, is unthinkable. This conclusion took a lot of hard thinking and thus could hardly have been a product of the kind of resignation that Debye's statement conveys, although Schrödinger, who, like Einstein, never accepted this view or even quantum mechanics, which he co-invented, spoke of this view of nature as "a doctrine born of distress" [3, p. 154].

Schrödinger appears to have meant the distress of not being able to find a more classical-like (realist and causal) way of dealing with quantum phenomena. He was not wrong insofar as this approach emerged after a prolonged history of trying to find such a classical-like solution of the quantum dilemma, as Einstein sometimes called it, first, by means of the so-called old (pre-quantum-mechanical) quantum theory and then by trying to find a more classical-like interpretation of quantum mechanics. However, the feeling from the other side of the debate (which started the moment quantum mechanics was introduced by Heisenberg), that of Bohr, Born, Heisenberg, Dirac, and Pauli, was quite different. For one thing, abandoning the project of describing the behavior of quantum objects and settling instead only for predicting, moreover probabilistically, what is observed in measuring instruments enabled Heisenberg to discover quantum mechanics, and Bohr to offer the first consistent interpretation of quantum phenomena and quantum mechanics in terms of complementarity. For them, what the classically minded physicists saw as a problem became a path to a solution.[2]

Neither Einstein nor Schrödinger, however, nor indeed most other physicists and philosophers, ever accepted this type of solution of the quantum dilemma. In their view, quantum mechanics, in this type of interpretation, that is, insofar as it does not provide a realist (and preferably causal) mathematical description of individual quantum objects and their behavior (similarly to the way classical mechanics does for classical objects) was essentially incomplete. This is correct if one subscribes to this classical view of completeness, and assumes that nature should allow for a more complete theory in this sense in the case of quantum phenomena. On the other hand, as Bohr argued, one can see a given theory as complete insofar as it adequately *predicts* all known phenomena within its proper scope, which quantum mechanics essentially does. It is true that quantum-mechanical predictions are probabilistic even and in particular in the case of primitive individual quantum objects and processes, that is, objects ("elementary particles") and processes that permit no further subdivision. However, this is in accord with the observable quantum data, given that, as is well known, the identically *prepared* quantum experiments in the sense of the state of the measuring instruments involved (and this preparation is possible, because we can classically control these instruments), in general lead to different outcomes, which we, accordingly, cannot control. According to Bohr (and Pauli follows Bohr on this point), the epistemological situation of quantum physics is due to the irreducible role of measuring instruments in the constitution of all quantum phenomena, as opposed to classical physical phenomena, where this role can be disregarded or compensated for,

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[2] It is true that Schrödinger's discovery of his wave mechanics was rooted in classical-like epistemological thinking, and this difference is worthy of further discussion, which cannot, however, be undertaken here. I have discussed the subject in ([4], pp. 137-178).

at least ideally or in principle.[3] This fact as such does not exclude the existence of the underlying causal dynamics that may, hopefully, be eventually accessed by our theories.[4] The question, then, becomes whether nature will one day allow us to do better in terms of our experiments or theories, again, in the case of primitive individual quantum processes and events. Einstein and Schrödinger, again, thought it should, while Bohr, Heisenberg, and Pauli thought it *might not*, which is not the same as it *will not*. Bohr, Heisenberg, and Pauli are often misunderstood on this point, although Bohr and, especially, Pauli sometimes come close to making this stronger claim.

As I shall argue here, Pauli's thinking concerning quantum theory (both quantum mechanics and quantum field theory) and his philosophical thinking were, *in part*, grounded in the epistemological situation just outlined, and hence, *up to a point*, they follow Bohr's interpretation of quantum phenomena and quantum mechanics—*but only in part and only up to a point*. Ultimately, under the impact of his engagement with C. G. Jung's psychoanalytic theory, Pauli's understanding of quantum phenomena and quantum theory depart and his philosophy in general depart, in some respects radically, from Bohr's views.

The remainder of this article will proceed as follows. First, in Section 2, I shall outline Bohr's quantum-theoretical concepts of reality, phenomena, observer, and complementarity, in juxtaposition to Einstein's ideal of fundamental physics, based, in Pauli's view of this ideal, on the concept of "the detached observer." Section 3 addresses the same concepts, most especially that of the observer, in Pauli. Pauli both grounds his definition of these concepts in the irreducible role of measuring instruments in the constitution of quantum phenomena, in accordance with Bohr's understanding, and yet also, beginning with his concept of the observer, departs from this understanding, thus parting ways not only with Einstein but also with Bohr. Section 4 address Pauli's intriguing "conjecture" that "the observer in the present-day [1957] physics is still too completely detached, and that physics will depart still further from the classical example" ([1], p. 141). While it may be natural to assume that Pauli's conjecture refers to the observer's detachment from quantum objects, Pauli's statement itself does not expressly say what the observer in the present-day physics is actually detached from. I shall suggest that this may not have been coincidental, if not deliberate (it might have been unconscious), and that this statement may be read as saying that the observer in the present day physics it is still too detached *both* from quantum objects *and* from the mind of the *human* observer, specifically the unconscious. (Pauli's concept of the observer combines the human observer and the measuring apparatus in a single entity.) This is a radical claim on Pauli's part, and Pauli offers an equally radical potential resolution of this problem of

[3] By "quantum phenomena," I mean those phenomena in considering which Planck's constant, *h*, must be taken into account.

[4] Bohmian, hidden-variables theories (there are several) see or idealize the behavior of quantum objects in this way, but this idealization is achieved at the expense of nonlocality (in the sense of the existence of instantaneous physical connections between spatially separated events, which is in conflict with relativity), while standard quantum mechanics may be seen as local. For the sake of full disclosure, there is some debate concerning this point in view of Bell's theorem and related findings. It may be added, even in the case of Bohmian theories, we cannot know the value of all the variables pertaining to quantum objects (the uncertainty relations still apply) and are limited to the statistical predictions of the outcomes of experiments, predictions that coincide with those of quantum mechanics.

the double detachment of the observer in the present-day physics, a resolution in which his departure from Bohr becomes especially pronounced and significant.

2. PARTING WAYS WITH EINSTEIN: REALITY, OBSERVER, AND COMPLEMENTARITY IN BOHR

In characterizing Einstein's main philosophical requirements for a proper, "complete," physical theory in his article, "Phenomenon and Physical Reality," Pauli correctly notes the primary significance of the realist, rather than only causal or, in his terms, deterministic, character of a physical theory for Einstein ([1], p. 131).[5] Einstein would prefer causality as well, in accordance with the epistemological structure of both classical physics (classical mechanics and classical electrodynamics) and relativity (special and general). Pauli cites one of Einstein's many statements describing this ideal: "'There is such a thing as a real state of a physical system, which exists objectively, independently of any observation or measurement, *and can in principle be described by the methods of expression of physics*'" ([1], p. 131; emphasis added).

The last part of Einstein's statement is crucial, although the concept of the real state of a physical system, if conceived, as it appears to be by Einstein, on the model of classical physics, already implies a particular, and specifically mathematical (although not only mathematical), form of expression in physics. The role of this expression is important for Einstein, first, because this expression can only be achieved by means of a "free conceptual construction," rather than by means of observable facts themselves, which Einstein sees as the empiricist or positivist "philosophical prejudice." "Such a misconception," he adds, "is possible because one does not easily become aware of the free choice of such concepts, which, through success and long usage, appear to be immediately connected with the empirical material" ([6], p. 47). Thus, Einstein is a realist, and not an empiricist or positivist, and moreover not a naïve realist, given the role of "free conception construction" in creating our theories.

For Einstein, it is this kind of expression that quantum mechanics fails to deliver, which makes it incomplete.[6] As noted from the outset, although Einstein is factually correct, the question is whether nature allows us this kind of expression in the case of quantum phenomena or not. Einstein thought it should. Bohr's view was that it *might not* (which is, again, not the same as it never will), which allows Bohr to see quantum mechanics as complete within its proper scope: as complete as, within this scope, nature allows a theory of quantum phenomena to be, as things stand now.[7] Pauli, in the article just citer, somewhat more strongly saw the kind of theory Einstein wanted as

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[5] Arguing that this is more consistent with the terminology used in modern physics, Pauli prefers "deterministic" to "causal" in characterizing a physical theory in which the state of the physical systems considered by this theory at a given point is assumed to define its states at all points. In my view, "causal" is historically more precise even in physics, and it was used by both Einstein and Bohr, as well as Pauli. I have discussed causality in physics in [5].

[6] For more specific aspects of Einstein's definition of this "expression" see [7].

[7] The question of locality becomes important in this context, but I shall put it aside here. See ([4], pp. 237-278).

"logically possible" but "physically unrealistic" ([1], p.131; translation modified).[8] Einstein, incidentally, often used the locution "logically possible" in describing quantum mechanics (especially in the type of interpretation that Bohr or Pauli adopted), "logically possible" but to him unacceptable or in any event incomplete. Pauli, while agreeing with Bohr that quantum mechanics is unlikely to be completed on Einstein's lines of thinking, takes a somewhat different view of the situation and sees quantum mechanics as, in a certain sense, incomplete. This, however, is not because quantum mechanics is incomplete as a *physical* theory but because he sees physics itself as incomplete, incomplete "within the totality of life." I shall discuss this subject in Section 4. For the moment, it is the requirement that a theory should physically (and specifically mathematically) express the actual physical state of the system considered as such, independently of observation and without the observer's constitutive impact on the observed events, that Pauli "designat[es] as 'realist' in the narrow sense" ([1], p. 131; translation modified).

This sense is "narrow" because a theory can assume, as quantum mechanics (even in Bohr's interpretation) in effect does, the independent existence of "reality" without being able to offer, or assume the possibility of, expressing this reality by means of this theory, or by any means available to us (e.g., [1], p. 128). Pauli sees Einstein's "requirement" as an expression of "a special ideal which is satisfied in classical particle mechanics and [classical] electrodynamics, and also in the theory of relativity, but not in the equally objective description of nature given by quantum mechanics. Einstein always emphasized anew that on this account he regards quantum mechanics as *incomplete*, and is unwilling to abandon the hope of a completion of quantum mechanics which would again restore his narrow reality requirement" ([1], pp. 131-132). By contrast, in agreement with Heisenberg, Born, and Bohr, Pauli "do[es] not share these misgivings, and regard[s] as definitive just this step, which was made in quantum mechanics, of including the observer and the conditions of experiment in a more fundamental way in the physical explanation of nature" ([1], p. 132). Pauli's invocation of "the equally objective" nature of this alternative understanding of nature is important, and I shall return to this point presently. Pauli's statement itself appears to especially refer to Bohr's argument concerning the irreducible role of measuring instruments and his concept of phenomenon, which Pauli expressly brings up earlier in the same article and which he incorporates, with some inflections, into his own concept of the observer ([1], p. 132). I shall now explain Bohr's interpretation of quantum phenomena and quantum mechanics, based on this concept, defined by the effects, manifest classically, of the (quantum) interactions between quantum objects and measuring instruments.[9] Bohr was eventually (sometime around 1938) compelled to introduce this concept, under the impact of his, by then a decade long, debate with Einstein. Bohr writes:

> I advocated the application of the word phenomenon exclusively to refer to the observations obtained under specified circumstances, including an account of the whole experimental

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[8] I modify the English translation of [1], which incorrectly uses "realist" (describing reality) instead of "realistic" (feasible) and vice versa.

[9] I can only offer here a summary of Bohr's interpretation, and moreover only of the ultimate version of this interpretation, which is by and large followed by Pauli in his works considered here. For a full-fledged treatment of Bohr's interpretation (his several interpretations!) by the present author, see [9].

> arrangement. In such terminology, the observational problem is free of any special intricacy since, in actual experiments, all observations are expressed by unambiguous statements referring, for instance, to the registration of the point at which an electron arrives at a photographic plate. Moreover, speaking in such a way is just suited to emphasize that the appropriate physical interpretation of the symbolic quantum-mechanical formalism amounts only to predictions, of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physical concepts [describing measuring instruments]. ([8], v. 2, p. 64)

Bohr sees quantum-mechanical formalism as *symbolic* because, while it uses mathematical symbols analogous to those used in classical mechanics, beginning with Heisenberg (who, accordingly, spoke of the "new kinematics" of quantum mechanics), it does not refer these symbols to and, hence, does not describe the actual behavior of, quantum objects. Instead, the formalism only predicts, in general probabilistically, what is observed in measuring instruments under the impact of quantum objects. Bohr's concept includes a rigorous specification of each arrangement, determined by the type of measurement or prediction we want to make, which specification also reflects the irreducibly individual, unique character of each phenomenon. It is crucial that the term refers "to the observations [already] *obtained* under specified circumstances" and hence to already *registered* phenomena, rather than to what can be predicted. For one thing, such predictions are always probabilistic and, hence, what will happen can never assured, unlike, at least ideally or in principle, in classical mechanics. We always have a free choice as concerns what kind of experiment we want to perform, in accordance with the very idea of experiment, which defines classical physics as well ([10], p. 699). Contrary to the case of classical physics, however, implementing our decision concerning what we want to do will allow us to make only a certain type of prediction (for example, that concerning a future position measurement) and will unavoidably exclude the possibility of certain other, complementary, types of prediction (in this case, that concerning a future momentum measurement). Bohr's concept of complementarity, which I shall explain more formally below, reflects this kind of mutual exclusivity of certain situations of measurement or phenomena.

By the same token, experimental decisions that we make actually shape what will and will not happen, even though only with a certain degree of probability, as opposed to, in generally, merely tracking, as in classical physics, what is bound to happen in any event. Thus, given that, in classical mechanics, both the position and the momentum of a given object are always determined at any given point (thus also ensuring the causal nature of the evolution of this object), which we measure at any given point does not affect the value of the other. But in quantum physics this is not the case. This is why quantum phenomena are subject to the uncertainty relations (which are independent of quantum mechanics, although they can be derived from it). Indeed, in Bohr's interpretation, the uncertainty relations mean that one cannot even define, rather than only measure, both variables simultaneously. Probability, to which the uncertainty relations are, in turn, correlative, is the cost of our active, shaping role in *defining* physical events in quantum physics, rather than merely tracking or encountering them, as we do in classical physics.

Importantly, our freedom of choosing the experimental setup only allows us to select and control the initial setting up of a given experiment but not its outcome, which, again, can only be probabilistically estimated. This fact further reflects the "objectivity" of the situation, defined by the verifiability and, thus, the possibility of the unambiguous communication of the data involved in our experiments (both that of their setup and their outcome), and hence, the objective character of quantum mechanics in this interpretation. The "objectivity" in this sense becomes an important emphasis in Bohr's later writings and is correlative to his concept of "detached observer," which is different from that of Einstein but which troubled Pauli nevertheless (though the objective character of quantum measurements did not). Bohr summarizes the argument just outlined, in terms of complementarity, in his 1955 "Unity of Knowledge:"

> A most conspicuous characteristic of atomic physics is the novel relationship between phenomena observed under experimental conditions demanding different elementary concepts for their description. Indeed, however contrasting such experiences might appear when attempting to picture a course of atomic processes on classical lines, they have to be considered as complementary in the sense that they represent equally essential knowledge about atomic systems and together exhaust this knowledge. The notion of complementarity does in no way involve a departure from our position as *detached observers* of nature, but must be regarded as the logical expression of our situation as regards objective description in this field of experience. The recognition that the interaction between the measuring tools and the physical systems under investigation constitutes an integral part of quantum phenomena has … forced us … to pay proper attention to the conditions of observation. ([8], v. 2, p. 74; also p. 73; emphasis added)

In appealing to "detached observers" Bohr might have had in mind Einstein and Pauli, as representing two contrasting views of the situation. For Einstein, as explained above, the quantum-mechanical observer is not sufficiently *detached* and, hence, not sufficiently objective. For Pauli is it still too detached, or even "too completely detached," which, as will be seen below, compels him to take issue with Bohr, specifically a propos this article. Their conceptions of the quantum observer and, correlatively, of phenomena are, however, different in the first place, and Pauli should not have been as surprised as he appears to have been by Bohr's invocation of the detached observer, which, while not used by Bohr earlier, is consistent with Bohr's earlier views. In Bohr's understanding of quantum phenomena, the observers are as detached *vis-à-vis measuring instruments* as they are in classical physics *vis-à-vis classical objects*, thus ensuring the objectivity of Bohr's scheme. On the other hand, the measuring instruments used in quantum measurement can, in an act of observation or measurement, never be "detached" from quantum objects because the latter cannot be "extracted from" the *closed* observed phenomena (in Bohr's sense) containing them ([8], v. 2, p. 73). Phenomena *cannot be opened* so as to reach quantum objects by disregarding the role of measuring instruments in the way it is possible in classical physics or relativity, and thus are in conflict with Einstein's ideal of objectivity. Hence, although quantum objects do exist independently of us and of our measuring instruments, they can never be observed independently (nobody has ever seen, at least not thus far, a moving electron or photon as such). In *Bohr's interpretation*, quantum phenomena strictly preclude any description or even conception of quantum objects themselves and their behavior, which behavior is, nevertheless, responsible for the emergence of these phenomena.[10]

Accordingly, the physical quantities obtained in quantum measurements can no longer be assumed to represent the corresponding properties of quantum objects, even any single such property, rather than only certain joint properties, in accordance with the uncertainty relations. In Bohr's view, an attribution *even of a single property* to any quantum object as such is *never possible—before, during, or after measurement*. The conditions that experimentally obtain in quantum experiments only allow us to rigorously specify measurable quantities that can, in principle, physically pertain to measuring instruments and never to quantum objects. Even when we do not want to know the momentum or energy of a given quantum object and thus need not worry about the uncertainty relations, neither the exact *position* of this object itself nor the actual time at which this "position" is established is ever available and hence in any way verifiable. These properties, assuming they could be defined (as they can be in some interpretations of quantum mechanics or in Bohmian theories), are lost in "the finite [quantum] and uncontrollable interaction" between quantum objects and measuring instruments ([10], p. 697). However, this interaction leaves a mark in measuring instruments, a mark that can be treated as a part of a permanent, objective record, which can be discussed, communicated, and so forth. The uncertainty relations remain valid, of course, but they now apply strictly to the corresponding (classical) variables of suitably prepared measuring instruments, impacted by quantum objects. We can either prepare our instruments so as to measure a change of momentum of certain parts of those instruments or so as to locate a spot impacted by a quantum object, but never do both together, which makes the uncertainty relations correlative to the complementary nature of these arrangements or phenomena.

The wholeness or indivisibility of phenomena in Bohr's sense is defined by the features just outlined, and thus also reflects the irreducible distinction between the classically describable effects of the interactions between quantum objects and measuring instruments and quantum objects, which are indescribable by quantum theory or any means available to us, and in Bohr's interpretation are ultimately inconceivable. Claiming this distinction is not inconsistent with the wholeness of phenomena, quite the contrary: this wholeness results from the fact that quantum objects cannot be observed independently and, hence, cannot be seen as identical with objects as in classical mechanics. Technically, phenomena and objects are also different in classical mechanics, but there this difference can be disregarded for the purposes of the idealized physical description, since there we can, at least in principle, isolate objects from their interactions with measuring instruments and treat observed phenomena as objects. In the case of quantum phenomena, at least in Bohr's interpretation, it is not possible to do so, which prevents the use of idealized descriptive models of the classical type.

Bohr's epistemology, as just outlined, entails an understanding of randomness or chance (or quantum correlations, which are an important part of quantum phenomena) and probability that is different from that found in classical physics, including in

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[10] I would like to stress that, at least in my view, this remains an interpretation of quantum phenomena, rather than "the truth of nature," although, as I mentioned, at certain junctures, Bohr and even more often (and less guardedly) Pauli take a stronger position on this point.

classical statistical physics. This understanding is defined by the suspension of the applicability of the idea of causality even to individual quantum processes and events, and thus fundamentally departs from the view adopted in classical statistical physics, where the behavior of the individual entities comprising the multiplicities considered statistically is assumed to be causal, at least ideally. Our predictions themselves only concern the effects of such processes manifest in the measuring instruments involved. The probabilistic character of our predictions concerning quantum phenomena is unavoidable, because, in Bohr's words, "one and the same experimental arrangement may yield different recordings" ([8], v. 2, p. 73). As I explained earlier, it is possible to speak of "one and the same experimental arrangement," because, unlike the outcomes of experiments, we can control the measuring instruments involved, given that the parts of these instruments relevant for setting up our experiments can be described classically. Under these conditions, the probabilistic character of such predictions will also concern primitive individual quantum events. For, unlike in the case of certain classical individual events, such as a coin toss, in the case of quantum phenomena it does not appear possible—and in Bohr's interpretation, it is in principle impossible—to subdivide these phenomena into entities of different kinds, concerning which our predictions could be exact, even ideally or in principle. Any attempt to do so will require the use of an experimental setup that leads to a phenomenon or set of phenomena of the epistemologically same type (they could be different physically), concerning which we could again only make probabilistic predictions. "Touching" quantum objects, unavoidably, given the nature of quantum phenomena, rather than being detached from them, makes probability unavoidable not only in practice but also in principle. Indeed, this would be the case even under the assumption of the underlying causality of quantum processes, a fact reflected in Bohmian theories, which, for that reason (of displacing quantum objects by touching them) retain the uncertainty relations.

Accordingly, as noted from the outset, rather than whether quantum phenomena entail a probabilistic theory predicting them (since they manifestly do), the question is whether there is or not an underlying classical-like causal dynamics ultimately responsible for such events. If this kind of underlying causal dynamics exists, it would imply that a classical-like account of such events could in principle eventually be developed. Bohr argued, however, that quantum phenomena may disable, and in his interpretation they do, the underlying assumptions of classical statistical physics (or accounts of individual classical phenomena that we cannot sufficiently track), based on the causality of the primitive individual processes involved. Indeed, in Bohr's interpretation, the lack of causality in these processes in quantum physics is automatic because quantum objects and processes are beyond any description and even conception. Causality would be a feature of such a description and hence is disallowed automatically, as Schrödinger noted, by way of a very different assessment of this argumentation, which, as noted earlier, he saw as "a doctrine born of distress": "if a classical [physical] state does not exist at any moment, it can hardly change causally" ([3], p. 154).

Before I turn to Pauli's view of quantum phenomena and quantum mechanics, I would like to comment on Bohr's *concept* of complementarity, given its importance for Pauli, although his use of this concept departs from Bohr's use of it as well. I emphasize "concept" because eventually Bohr came to call "complementarity" his overall interpretation, based on this concept, of quantum phenomena and quantum mechanics. Complementarity is defined by

(a) a mutual exclusivity of certain phenomena, entities, or conceptions; and yet

(b) the possibility of applying each one of them separately at any given point; and

(c) the necessity of using all of them at different moments for a comprehensive account of the totality of phenomena that we must consider.

Parts *(b)* and *(c)* of this definition are just as important as part *(a)*, and to miss them, as is often done, is to miss much of the import of Bohr's concept. This definition is very general and allows for different instantiations of the concept in the case of quantum phenomena and for the application of the concept beyond physics.

In particular, in Bohr's interpretation outlined above, one only deals with complementary phenomena, manifest with measuring instruments under the impact of quantum objects. One never deals with complementary properties of quantum objects themselves or their independent behavior, given that, in Bohr's view, no attribution of any such properties, single, joint, or complementary, is ever possible. Indeed, no such complementary arrangement or phenomena can even be associated with a single quantum object either. One would always require two quantum objects in order to enact, in two separated experiments, two complementary arrangements, say, those associated with the position and the momentum measurement, respectively, with, in each case, the measurement itself physically pertaining strictly to the measuring instruments. Accordingly, as explained above, in this view the uncertainty relations apply to the variables physically pertaining to measuring instruments and not quantum objects themselves.

3. PARTING WAYS WITH EINSTEIN, AND WITH BOHR: PAULI'S CONCEPT OF THE OBSERVER

Pauli adopts most of the key epistemological features of Bohr's interpretation of quantum phenomena and quantum mechanics, as just outlined, and, as I said, he even appears to see most of the features of this interpretation as those of nature itself (arguably more so than Bohr, who appears to have been more cautious in this regard). However, using Bohr's concepts as his starting point, Pauli develops different concepts of the quantum observer and of complementarity, or more accurately, of the corresponding *instantiations* of complementarity, defined by his concept of the observer. As a result, Pauli not only parts ways with Einstein, with Bohr's help, but also parts ways with Bohr.

Most significantly, Bohr, as explained above, essentially separates, *detaches*, the human observer, or subject, from the measuring instruments, interacting with and, as a result, inseparable, undetachable, from quantum objects within phenomena, which, in each case of measurement, form a closed whole independent from the observing human subject. In this sense, human observers are as detached from what they observe in quantum physics as they would be in classical physics, or relativity, from classical or relativistic physical objects, but now, and this is of course a crucial difference, with measuring instruments, rather than quantum objects, taking the position of classical or relativistic objects. Only measuring instruments themselves, but not human observers, "observe" (interact with or "touch") quantum objects. For Bohr, quantum phenomena are classical physical objects observed by human observers, even though it is our interference (as in our choice of one or the other complementary setup) that establishes what we can observe or predict, what will happen, albeit only within the limits of probabilistic estimates. At the same time, however, and in a way because of this unavoidable interference with, this "touching" of, quantum objects, classical physics cannot make correct predictions of the data found in and defining quantum phenomena. Bohr, thus, retains a classical-like detachment of the observer from the observed, although, in a radical departure from the classical view, what is actually observed by the human observer only pertains to measuring instruments and not to quantum objects, placed, as independent entities, beyond any observation and, ultimately, beyond any description or even conception. By the same token, Bohr's view is in accord with Einstein's classical ideal of the detached observer, but only of quantum phenomena manifested in measuring instruments and not of quantum objects. Their debate is about a possible applicability of this ideal to quantum objects, desired by Einstein but "in principle excluded" by Bohr's concept of phenomena ([8], v. 2, p. 62).

In Bohr's interpretation, then, while quantum phenomena or measurement processes, defined by the quantum interactions between quantum objects and measuring instruments that give rise to these phenomena, can never be detached from quantum objects, they are essentially detached from the human observer or subject, from the conscious and the unconscious of the human observer. Consciousness does play a certain but not essential role in Bohr's understanding of the situation, in particular, that of observing quantum phenomena. Consciousness and even the unconscious also play a role in Bohr's scheme in deciding which experiments, for example, which of the two possible complimentary experiments we decide to perform, and in this sense, as noted above, radically depart from classical physics in defining, rather than merely following, what would have happened independently of our interference with nature. In quantum physics, this interference plays a shaping, creative role. On this point, Bohr is closer to Pauli's views of the observer, just as, on certain other points, Pauli's views come closer to those of Bohr, thus making the difference between their respective physical and philosophical positions stratified and nuanced, but important nonetheless.[11]

Now, in contrast to Bohr's concept of the observer, Pauli's concept of the observer combines, *unites*, the human subject and the measuring apparatus, and makes them indissociable, *undetachable*, from each other, *up to a point*, because this unity is only in place during a certain time and becomes broken once the actual measurement is taken place. It follows that, because quantum objects are already united with the measuring instruments in Bohr's view of measurement (Pauli follows Bohr on this point), Pauli's concept of the observer combines, unites all three—quantum objects, measuring instruments, and human observers—within a single entity, again, *up to a*

[11] While the irreducible and active (even creative) role of human participation in measurement in quantum, as against classical, physics was clearly realized by Bohr and Pauli, the mental processes involved were not really examined by either, although, as will be seen, Pauli makes some steps in this direction on Jungian lines. The nature of these processes remains a difficult and, thus far, largely unexplored subject.

point. For, in each case of measurement, when an actual observation has taken place and has been registered in the measuring instruments, and thus made objective, the split between the apparatus (or the registered phenomenon in Bohr's sense) is reinstated within Pauli's scheme. Thus, as concerns *registered* phenomena (and there are no other phenomena in Bohr's definition), the difference between Pauli and Bohr is not essential, if present at all. In other words, once the measurement is finished and its outcome is established, fixed, this outcome is detached from the observer, or in any event can be treated as so detached, which also ensures the objectivity of the outcome and the possibility of its unambiguous communication, again, in accordance with or sufficiently close to Bohr's view of the situation.

These circumstances might have compelled Bohr to say in their exchange on the subject that he and Pauli agree on essential points, although, as I argue here, their points of disagreement are equally essential, as Bohr appears to have been aware as well, but which he, perhaps diplomatically, did not really bring up in their exchange (Bohr to Pauli, 2 March 1955, [11], IV/3, 3025, cited in [12], p. 132). In particular, the difference between Bohr's and Pauli's concept of the observer comes into play and becomes decisive in the interval between when a given measurement situation is established and the actual measurement has taken place.[12] In either view, the *actual physical* process of observation or measurement is defined by the interaction between the apparatus and the object involved, either after the decision concerning what kind of measurement to perform is made or sometimes even before. For, one can always change one's decision as to what kind of measurement one will perform, and thus change what *type* of phenomenon, say, which of the two complementary phenomena (such as either one associated with the position measurement or with the momentum measurement) will be observed.[13] (I speak of the "type" of phenomenon because the actual (numerical) outcome can only be estimated probabilistically.) According to Bohr's understanding of the situation, the human observer is always detached from the apparatus, and hence such an observer would still be equally detached from it, and thus from the quantum objects under investigation, during this time-interval as well. By contrast, according to Pauli's view of the observer, as a unity of the human observer and the apparatus, the human observer would not be detached from the apparatus and hence from the quantum object under investigation during this time, indeed in particular or even only during this time. For, as just explained, after the measurement is finished and its outcome is fixed, the human observer is separated from the apparatus in Pauli's view of the situation as well. Prior to this point, however, the apparatus and the human observer, including, importantly for Pauli, the unconscious, are united, and both are united, or at least are united, are "in touch," with the quantum object under investigation.

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[12] Schrödinger's famous cat paradox, introduced in 1935 ([3, p. 157]) and under debate ever since, could be considered from this perspective as well, but the subject cannot be pursued here.

[13] The fact that in any situation of quantum measurement there is always an interval during which we can change our decision, or, to begin with, make one or another decision, concerning what kind of measurement we want to perform was expressly noted by Bohr ([8], v. 2, p. 57). This fact is also central to the so-called delayed-choice experiment introduced by J. A. Wheeler, whose concept of the participatory universe, in part brought about by this experiment, is close to Pauli's concept of the observer, although this concept can also be seen along Bohr's lines [13].

Pauli explains his understanding of the situation, as just outlined, in his letter to Bohr responding, and even taking exception, to Bohr's invocation, cited earlier, of the detached observer in "The Unity of Knowledge" ([8], v. 2, p. 74). First, Pauli comments, essentially in accordance with Bohr's view, on the quantum-mechanical observation, as different from the classical one, which conforms to Einstein's ideal and defines Pauli's concept of the detached observer. Taking as his point of departures Bohr's observation, made a few times, to the effect that quantum physics makes us both actors and spectators (e.g., [8], v. 1, p. 119), Pauli says, citing his conversation with Einstein:

> The observer has according to this ideal to disappear entirely in a discrete manner as a hidden spectator, never as actor, nature being left alone in a predetermined course of events, independent of the way in which the phenomena [thus, exactly corresponding to the objects] are observed. "Like the moon has a definitive position," Einstein said to me last winter, "whether or not we look at the moon, the same must also hold for the atomic objects, as there is no sharp distinction possible between these and macroscopic objects. Observation cannot *create* an element of reality like a position, there must be something contained in the complete description of physical reality, which corresponds to the *possibility* of observing a position, already before the observation has been actually made." I hope, (sic) that I quoted Einstein correctly; it is always difficult to quote somebody from memory with whom one does not agree. It is precisely this kind of postulate that I call the ideal of the detached observer. (Pauli to Bohr, 15 February 1955, [11], IV/3, 2015, cited in [12], p. 131)[14]

Pauli then expounds the quantum-mechanical situation in its contrast with this idea, first, pretty much following Bohr, albeit it not entirely, since Pauli appears to suggest that the mathematical laws of quantum mechanics actually describe the physical behavior of independent quantum systems, which is then changed, here and now, or "hic et nunc," as Pauli says, in way not contained in these laws. By contrast, as explained above, in Bohr's view, at least in his ultimate view, the mathematical laws of quantum mechanics offer no such description either, but only probabilistically predict the outcome of experiments.[15] Hence, Bohr does not (it appears, ever) speak, as Pauli does below, of the reduction of the wave packet. This is an important point to which I shall return in Section 4. For the moment, Pauli says: "In quantum mechanics, on the contrary, an observation hic et nunc changes in general the 'state' of the observed system in a way not contained in the mathematically formulated *laws*, which only apply to the automatic time dependence of the state of a *closed* system. I think here on the passage to a new phenomenon by observation which is technically taken into account by the so-called 'reduction of the wave packet'"(Pauli to Bohr, 15 February, 1955, [11], IV/3, 2035; cited in [12], p. 132).

So far, there is no major departure from Bohr's view, apart, again, from the point, just noted, concerning what the mathematical formalist of quantum mechanics actually does or does not describe. This point is, again, important, but it is not clear that Pauli is fully aware of this difference or, in any event, he does not reflect on it on this

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[14] Cf., S. Gieser's discussion in ([12, pp. 131-134]), which cites Pauli's letter and Bohr reply, and offers a cogent discussion of the difference between Bohr's and Pauli's positions. This discussion, however, and Gieser's book as a whole (informative as it is, especially as concerns Pauli's thinking) appear to me to miss some of the more radical implications of this difference, in part, I would argue, by considering both positions primarily from a psychological, rather than, as here, philosophical perspective.

[15] Bohr might have briefly held a position similar to that of Pauli's around the time of his introduction of complementarity in 1927. Cf., ([4], pp. 179-218) and ([9], pp. 51-58).

occasion. Pauli's next sentence, however, expressly breaks with Bohr as concerns their respective concepts of the observer. Pauli says: "As it is allowed to consider the instruments of observation as a kind of prolongation of the sense organs of the observer, I consider that un-predictable change of the state by a single observation—in spite the objective character of the result of every observation and notwithstanding the statistical laws for the frequencies of repeated observations under equal conditions—to be *an abandonment of the idea of the isolation (detachment) of the observer from the course of physical events outside himself*" (Pauli to Bohr, 11 March 1955, [11], IV/3, 2031, cited in [12], p. 132).

Pauli, thus, agrees with Bohr on the objective nature of our experimental findings in quantum mechanics, but not on the concept of the observer. As explained above, Pauli's concept of the observer only allows for the split of the human observer and the apparatus after, in a given experiment, the observation or measurement has take place and the corresponding registered phenomenon in Bohr's sense is established. Hence, he refers here to "the objective character of *the result* of every observation and notwithstanding the statistical laws for the frequencies of repeated observations under equal conditions" (emphasis added). Prior to that moment, however, once the measurement situation is established (even if still allowing one to change one's decision concerning what kind of measurement one will perform, as explained), the measuring apparatus and the human observer are united. It is at this stage when quantum physics breaks with the classical, such as Einstein's, ideal of the detached observer decisively insofar as "*an explicit reference to the action or the knowledge of the observer*" becomes essential, because, unlike in the case of the classical ideal, this action defines what can or cannot happen (within the limits of probability). This, as explained above, is also true in Bohr's views of the situation, but still under the condition of the separation of the apparatus and the human observer, and opposed to their unity, which thus indeed implies two different interpretation of the situation of quantum measurement and thus of quantum phenomena (now in general, rather than Bohr's sense). This unity is especially in place during "the *passage* to a new phenomenon by observation" (emphasis added), invoked by Pauli, when the observer in his sense of combining the apparatus and the human observer are also in touch with the quantum object under investigation.

It is Pauli's view of "the instruments of observation as a kind of prolongation of the sense organs of the observer," never found in Bohr (whom Pauli has perhaps misread on this point before he read "The Unity of Knowledge"), that reflects the difference between their respective concepts of the observer in quantum physics most pointedly and even defines it. Pauli's phrasing "as it is allowed" indicates that one need not take this view and that he now realizes that Bohr does not. Bohr might well have agree that Pauli's view might be allowed, and he is certainly aware that every observations involves and even is ultimately reduced to our sense perception (e.g. , [8], v. 1, pp. 53-54, [10], p. 701). As explained above, he also stresses that our decision as to what kind of measurement we want to perform constitutively shapes what will happen, rather than merely reflecting what would happen in any event, as in classical physics. However, for Bohr, as explained earlier, especially in his view at the time shaped by his concept of phenomena (introduced around 1937-1938), the measuring instruments, and hence phenomena remains separated, detached from the sense perception and thus the human subject in a classical like way, at all points. By contrast, quantum objects are, again, entirely beyond our reach, either on their own accord or, in the case of a given measurement, absorbed, inaccessibly to us, within a closed envelop of the corresponding phenomena. This defines the quantum character of the measuring situation, as opposed to the classical character, desired by Einstein, which would allow us to dispense, at least ideally and in principle, with the role of measuring instruments and reach the behavior of quantum objects themselves. The observer stands outside this independent technological configuration, which thus also makes possible the objectivity of our recorded findings by different human observers and their unambiguous communication between different human subjects.

This objectivity and, correlatively, the unambiguous communications of our experimental findings (once, the measurement has taken place, but, again, not before) are, as I said, also possible within Pauli's scheme, which may be seen as "translating" both concepts into his scheme, as defined by his concept of the observer. Correlatively, as defined by Pauli, the observer (this is in part what makes this translation possible) should not be identified with "the individually distinguished observer." Pauli (in the same letter to Bohr), defines "a reference to experimental conditions [as] an 'information on the observer' (though an impersonal one), and the establishment of an experimental arrangement fulfilling specified conditions [as] 'an action of the observer'—of course not an individually distinguished observer but of 'the observer' in general. In physics I speak of a detached observer in a general conceptual description or explanation only then, *if it does not contain an explicit reference to the action or the knowledge of the observer*" (Pauli to Bohr, 11 March 1955, [11], IV/3, 2031, cited in [12], p. 132). Quantum measurement always contains such a reference, and, again, what is measured or predicted is defined by the action, the creative action, of the observer, in either Bohr's or Pauli's sense of the terms.

Nevertheless, the difference between Bohr's and Pauli's concepts of the observer and, it follows, their concept of complementarity or quantum instantiations of complementarity is important. My analysis, thus far, only explored one, arguably less crucial, facet of this difference, found at one pole of the quantum-mechanical situation, that where observer connects, via the measuring instruments, to quantum objects. As noted from the outset, however, there is the other pole of this situation, at which the observer connects to the unconscious of the human observer, either as separated from the measuring apparatus, as in Bohr, or, in Pauli, united with the apparatus. It is at this pole that the difference between Bohr's and Pauli's thinking concerning the quantum-mechanical situation becomes especially profound and implicative. Beyond two different interpretations of quantum phenomena and quantum mechanics that emerge as a result, at stake are two very different philosophical visions of the world and our interaction with the world.

4. QUANTUM THEORY AND THE UNCONSCIOUS: PHYSIS AND PSYCHE AS COMPLEMENTARY ASPECTS OF THE SAME REALITY

It should be noted first that Pauli's interpretation of quantum phenomena and quantum mechanics retains conscious and (they are not quite the same) rational aspects of the human observer within his scheme, in part, just as in Bohr, in connection with the objective nature of quantum observations and measurements and the possibility of the unambiguous communications of our experimental findings.[16] As explained in Section 3, one can maintain these features compatibly with Pauli's concept of the observer, especially keeping in mind that this concept refers not to "an individually distinguished observer but [to] 'the observer' in general" (Pauli to Bohr, 11 March 1955, [11], IV/3, 2031, cited in [12], p. 132). Indeed, as also explained in Section 3, in this juncture, defined by the role of already registered observation or phenomena (when the measurement process has run its course), *but only in this juncture*, the unity of the human observer and the measuring instruments, defining Pauli's concept of the observer, is broken, and Pauli's and Bohr's scheme become essentially equivalent.

Pauli departs from Bohr more radically, both in his interpretation of quantum mechanics and in his overall philosophy, in view of his emphasis on the unconscious, both in the architecture of his concept of the observer and in his philosophical views in general. As noted from the outset, Pauli's statement that "the observer in present-day physics is still too completely detached, and that physics will depart still further from the classical example" ([1], p. 132) does not specify what the observer is detached from. While it may be seen as more immediately referring to the observer's detachment from quantum objects, the present article offers an alternative reading of this statement, specifically, as saying that the quantum observer is still too detached from both quantum objects and the unconscious. However, bringing the unconscious into play and making it the decisive part of the observer also serves Pauli's goal of making the observer less detached from quantum objects as well. Pauli's view of the observer as "the observer in general," rather than only a particular observer, allows for the integration of the unconscious, given the role of "the collective ('objective') psyche," defined by the collective, universal role of symbolic imagery as "raw material" in the processes of this collective psyche, on Jungian lines ([1], p. 259). In sum, it is, Pauli argues or at least conjectures, the unconscious that should enable the observer to be less detached from quantum objects, as well. This argument becomes a crucial juncture of Pauli's *philosophical* thinking, and, I contend, it makes this thinking fundamentally different from Bohr's *philosophical* thinking.

It is a more complex question whether Pauli's bringing in the unconscious of the observer is germane for the actual practice of physics, and I shall by and large put this question aside here, even though Pauli himself thought that it might affect and even be germane to this practice.[17] Thus far, it does not appear to have had such an effect,

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[16] More would need to be said on the role of consciousness and the interactions between consciousness and the unconscious in Pauli's quantum-theoretical and philosophical thinking, but my limits here do not permit me to do so. For a discussion of some aspects of these interactions in Pauli see ([12], pp. 231-246).

[17] Pauli's conjecture must have been with quantum field theory in mind. In his, "Phenomenon and Physical Reality," Pauli sees quantum field theory as related to "some fundamental problems" still hidden in the relationships "between observer or instrument of observation and the system observed" ([1], p. 133). Pauli was actively involved in its developments for decades by then, and was in particular, engaged in intense and sometimes heated exchanges with J. Schwinger concerning the renormalization of quantum electrodynamics, successfully accomplished by Schwinger and independently by S.-I. Tomonaga and R. Feynman. The new physical and epistemological complexities, which were introduced by quantum electrodynamics and then quantum field theory, and specifically the necessity of renormalization, appear to be connected to measurement. As a result, the question of the detachment of

including in Pauli's own work, which as theoretical physics, appeared to have remained conventional until the end of his life. This is not to say of course that his thinking concerning a possible role of the unconscious, including as conceived along Jungian lines, did not have any effect on his thinking in theoretical physics. It might have had such an effect.

As we have seen, the departure of quantum physics from the ideal of detached observer is essentially connected to the circumstance, which is at the center of Einstein's criticism of quantum theory and of the Bohr-Einstein debate, that quantum mechanics does not provide, even in principle or by way of idealization, an exact description of individual quantum processes, but only offers probabilistic predictions concerning outcomes of quantum experiments. "Touching" quantum objects removes the possibility of a complete description (by Einstein's criteria) and makes probability an unavoidable, essential part of the theory, the circumstance correlative to the uncertainty relations.[18] Unlike Bohr, who sees quantum mechanics as complete (as complete as nature allows a theory to be, at least now, but possibly ever), Pauli accepts that quantum mechanics is incomplete, although Bohr and Pauli agree that it is unlikely to be completed in the way Einstein wanted. In speaking of the incompleteness of quantum mechanics, Pauli has something else in mind. In commenting on this "incompleteness," as "certainly an existing fact somehow-somewhere," Pauli says: "However, this [incompleteness] does not indicate an incompleteness of quantum theory within physics, but an incompleteness of physics within the totality of life" (Pauli to Fierz, 10 August 1954, cited in [14], p. 133). All of physics, at least as physics, from classical mechanics to quantum field theory, is currently already constituted! If this qualification applies, as, I think, it does, it may well be that, for Pauli, the reason for this incompleteness is that physics, thus far, is not sufficiently connected to the unconscious of the observer. In Pauli's psychoanalytically informed view (especially, again, along Jungian lines), the unconscious is a crucial part of our life, and this statement does appear to refer to human life, to the life of thought, which is largely and most essentially unconscious. As he says in the same letter to Fierz:

> It might be that matter, for instance considered from the perspective of life, is not treated "properly" if it is observed as in quantum mechanics, *namely totally neglecting the inner state of the "observer"* … The well known "incompleteness" of quantum mechanics (Einstein) is certainly an existing fact somehow-somewhere, but of course it cannot be removed by reverting to classical field physics (that is only a "neurotic misunderstanding" of Einstein), it has much more do with *holistic relationships between "inside" and "outside" which contemporary science does not contain*. (Pauli to Fierz, 10 August 1954, cited in [14], p. 133)

The appeal to Einstein's "*neurotic* misunderstanding," even in quotation marks, and its psychoanalytic inflection are worth noting here. It is important that, as H.

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the observer (in Pauli's sense) from quantum objects takes on a new significance as well, and this question enters already at the level of the interactions between quantum objects and measuring instruments. Hence, the difference between Bohr's and Pauli's views of the observer is less germane in this context, albeit not entirely discountable. The subject is beyond the scope of this paper. See, however, the other contribution by the present author to this volume.

[18] As explained earlier, this circumstance as such does not eliminate the possibility, in principle, of developing a causal or, in the first place, realist interpretation of quantum mechanics or of developing alternative causal and realist theories of quantum phenomena, but poses further difficulties for both types of approach.

Atmanspacher notes, "Pauli's made it explicitly clear that his suggestion was not to mix physics up with the psyche of human observers" ([14], p. 133).[19] In fact, the relationships Pauli has in mind are not so much holistic as complementary, and hence are mutually exclusive; in other words, you can pursues either domain of investigation, say, the psychological domain of (for Pauli, the same) reality or the other, physical, but never both together. Pauli, however, appears to suggest that, the complementary nature of these relationships notwithstanding, we might be do better by *consciously*, deliberately building up on, rather than merely unconsciously using the structures, such as the archetypal structures, of the unconscious in quantum physics as well. In this respect, he, *in a certain sense*, extends J. Kepler's approach, which was "a remarkable intermediary stage between the earlier, magical-symbolic [archetypally grounded] and modern, quantitative-mathematical description of nature" ([1], p. 222). I qualify because Pauli argues that one needs a kind of new synthesis, defined by the complementary relationships of the two descriptions, with the description of nature now inevitably involving very complex mathematics, both formally and quantitatively (i.e., in terms of experimentally handling and mathematically predicting the data in question). It is not inconceivable, however, and Pauli appears to have thought so, that the symbolic-archetypal description of reality (of which physical and psychical nature form a complementary side) would be quite complex as well, more complex than found in Kepler and his contemporary alchemists, although the fundamental symbols at work may be the same as in Jung's psychoanalytic theory.

I shall now sketch Pauli's argument, as it is outlined in his article on Kepler, just cited, an argument clearly grounded in his concept of the observer, as considered in Section 3.[20] Pauli begins by observing that, while Kepler did discover, "on the basis of the heliocentric conception, … [his] three famous laws of planetary motion, … these laws … are not what he was originally seeking" ([1], pp. 222-223). Kepler sought the harmony of the world, in which physis and psyche would be united, with this harmony itself grounded in the Pythagorean idea of proportion and, via proportion, the music of the spheres. Historically, the way in which this unity was worked out (to the degree it was actually worked out) by Kepler encountered considerable difficulties on both sides, that of psyche and that of nature, physis, because of the conflict between the approaches to each side used by Kepler. On the side of psyche, "the contrast between [Kepler's] scientific method of approach and the magical-symbolic attitude of alchemy [the leading "science" of soul then] was … [far too] strong" for this method to be acceptable to the alchemists. "[Robert] Fludd, in his day a famous alchemist and Rosicrucian, composed a violent polemics against Kepler's chief work, *Harmonices Mundi*" ([1], p. 223), the polemic that Pauli examines in detail in his article, an examination that is not unsympathetic to Fludd either, arguably, in the account of Fludd's insistence on the greater necessary harmony between physis and psyche. In

[19] See this article and Atmanspacher's contribution to this volume for analyses of Pauli's philosophy and the role of the idea of complementarity there, and useful further references.

[20] For an extended discussion of Pauli's views, see, again, [12] and [14], and Atmanspacher's contribution to this volume, although these works have a different take on Pauli's argument in question, especially as concerns the differences between Pauli's and Bohr's philosophical views that are under discussion here.

particular, in the internal conflict with his argument for the unity of soul and nature, "the de-animation of the physical world has already begun to operate in Kepler's thought." At the same time, considered from the other, modern—quantitative-mathematical—side, this de-animation did not progress far enough in Kepler. As Pauli explains:

> [Kepler's Pythagorean] axiom ["geometry is the archetype of beauty in the world"] was at once even his strength and his limitation: his [particular] ideas on regular bodies and harmonious proportions did, after all, not work out in the planetary system, and a trend of research, like that of his contemporary Galileo, which directed attention to the constant acceleration of freely falling bodies, was quite foreign to Kepler's attitude, since for such a trend the de-animation of the physical world, which was to be completed only with Newton's *Principia*, has not yet progressed far enough. In Kepler's view, planets are still living entities endowed with individual souls. ([1], p. 223)[21]

Kepler's axiom "geometry is the archetype of beauty in the world" may apply to de-animated nature, and this axiom is operative (differently than in Kepler) in Galileo's and Newton's thinking, or later in Einstein's thinking concerning general relativity. While, however, this subject is relevant to Pauli's broader argument under discussion, I shall put it aside. The main point at the moment is the de-animation of nature resulting in the split between the mathematical-quantitative approach of modern physics that, unlike that of Aristotle, brackets the soul, the psyche, and physis, a move sometimes also known as the Galilean reduction.[22] The role of psyche is now limited to the invention of concepts through which physis can be understood—to the degree possible.

This philosophy extends throughout the development of classical physics and then relativity, and in most cases, including that of Bohr in quantum physics, but not that of Pauli himself, because Pauli, unlike Bohr, makes the human observer, including the unconscious, part of his concept of the observer. While, as explained earlier, important on other grounds as well, this difference acquires its greatest significance and even *raison d'etre* in the present context. Bohr's thinking belongs to the modern mathematical-quantitative paradigm, just as Einstein's thinking does, crucial epistemological differences between their views notwithstanding. For Pauli, on the other hand, "modern quantum physics," coupled to a parallel development of modern psychology suggests a possibility of bringing physis and psyche together, rather than separating them, as in modern science, beginning, again, even with Kepler, but especially with Galileo. In this bringing together both physis and psyche, and hence physics and psychology, would remain separate and even mutually exclusive, complementary, but they will be brought together as the complementary sides and, in the case of physics and psychology, modes of investigations of the same reality, the same *unus mundus*. Unlike the parallels themselves between psychology and quantum theory, this coupling, I would argue, is not found in Bohr and is indeed in conflict with his views. For the moment, for Pauli, this coupling allows us to bring physis and psyche together objectively through the concept of the observer in general (which incorporates the unconscious, via the symbolic, collective unconscious) and, at the

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[21] Although Pauli is correct to see Newton as a kind of completion of "the de-animation of the physical world," Newton's own extensive alchemical interests would complicate even his case.

[22] Aristotle is an important figure in this history, and certainly a key figure for Kepler and for the medieval philosophical tradition to which Kepler's thinking belongs.

same time, without sacrificing the mathematical-qualitative way of approaching physics, as it was by Fludd or differently Goethe ([1], p. 258). Pauli sees Jung's "employability of old alchemical ideas," as part of his concept of the symbolic psyche, conducive to such a different coupling between psychology and quantum theory ([1], pp. 256-259). This coupling, Pauli argues, allows for "the point of view [the only one acceptable to modern man] that he recognizes *both* sides of reality—the quantitative and the qualitative, the physical and the psychical—as compatible with each other, and can embrace them simultaneously" ([1], p. 259). Once again, however, in Pauli's version of this view, these two sides are *complementary* to each other, rather than joined in a single form of understanding the world, but remain "the complementary aspects of the same reality" ([1], p. 260).

It is not surprising that this ambitious philosophical vision, which is, I argue, quite different from that of Bohr, entails a concept of the observer in quantum physics that is different from that of Bohr. Indeed, this concept becomes necessary given Pauli's vision. It would be difficult to see these two sides of reality, even if conceived as complementary, as two sides of the *same* reality without making the human subject and specifically the unconscious part of the concept of observer or phenomena, and moreover making the observer no longer detached from quantum objects at one pole and the unconscious at the other. As discussed in Section 3, by uniting the measuring apparatus and the human observer, Pauli's concept of the observer allows him to bring the human observer and quantum objects closer to, or in "touch" with, each other. Now, however, my main concern is the second pole of the observer, defined by, as things stand now, the observer's *detachment* and, as Pauli wants to change it, the observer's connection to the unconscious, and by the same token, perhaps even bringing the observer yet closer in "touch" with quantum objects. This would be possible already in quantum mechanics, although changing quantum field theory may bring us even closer to the ultimate reality of the world.[23] Be it as it may on this score, Pauli's conjecture clearly requires a concept of the observer that includes the human observer and thus is essentially different from Bohr's concept of the observer.

Perhaps less obviously but equally significantly, Pauli's scheme also entails a concept of complementarity different from that of Bohr. I now refer not only the particular complementarity of physis and psyche, although the latter is not found in Bohr either and this fact is important, but also and primarily to the difference between Bohr's and Pauli's *concepts* of complementarity, or rather between their respective quantum-theoretical instantiations of Bohr's general concept. While subtle and rarely, if ever, addressed, this difference is as crucial, and indeed correlative to, that between Bohr's and Pauli's concepts of the observer. First of all, Pauli notes that "the general problem of the relation between psyche and physis, between the inner and the outer, can, however, hardly be said to have been solved by the concept of 'psychophysical parallelism' which was advanced in the last century" ([1], p. 260). We are, however, "brought to a more satisfying conception of this relationships by setting up, *within the field of physics*, the concept of *complementarity*" ([1], p. 260, emphasis added). Pauli, now, proposes to extend this conception to the relationship itself in question between psyche and physis. In his view, as indicated above, "it would be most satisfactory of

[23] See note 16 above.

all if physis and psyche could be seen as complementary aspects of the *same* reality" ([1], p. 260; emphasis added).

It is possible that each of these aspects could be considered in analogous epistemological terms, those of quantum epistemology as discussed here, and hence each would involve the concept of complementarity within itself. In this respect, there may be a degree of psychophysical parallelism here, albeit quite different from that of the nineteenth-century form of it. For, in this view, both quantum theory and psychology would be *symbolic* theories. As explained earlier, Bohr sees quantum theory, in the sense that, while it uses the mathematical symbols analogous to those of classical physics, these symbols only highly indirectly relate to the reality of quantum objects by way of probabilistic predictions of what is observed in measuring instruments under the impact of quantum objects. Pauli follows this view, at least up to a point, and I shall comment on the point of his possible divergence from this view presently.

For the moment, while this epistemology, at least in Pauli's view, is already in place in the quantum-mechanical view of nature, physis, when it comes to psychical processes, this assumption remains conjectural. As Pauli says: "We do not yet know, however, whether or not we are here confronted—as surmised by Bohr and other scientists—with a true complementary relation, involving mutual exclusion, in the sense that an exact observation of the physiological processes would result in such an interference with psychical processes that the latter would become downright inaccessible to observation," just as quantum objects are in physics ([1], p. 260). Would, then, probability unavoidably appear in psychology as well? This and the role of probability in psychology in general is an intriguing question, which I cannot address here. It may, however, be suggested that, even apart from how one views Pauli's unifying scheme, it is just as fundamental is our psychological or even neurological functioning as it is in quantum physics, although it remains an open question whether the psychological or neurological processes involved are causal or not.[24]

Even though the question of a true complementary relation and the corresponding epistemology in psychology remains open, Pauli now argues, quantum physics, again, in combination with modern psychology, sufficiently changed the situation with respect to the relationships between "the apprehending subject and the apprehended objects." He says: "[This] modern point of view is more liberal in this respect: microphysics shows that the means of observation can also consist of apparatuses that register automatically; modern psychology proves that there is on the side of that which is observed introspectively an unconscious psyche of considerable objective reality. Thereby the presumed objective order of nature is, on the one hand, relativized

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[24] As Gieser notes, Jung considered this subject, apparently under the impact of his exchanges with Pauli, but arguably with an overall causal and ultimately realist "symbolic" scheme, rather than the kind of symbolic scheme Bohr uses in quantum mechanics ([12], p. 158). The role of probability and, specifically, Bayesian probability has been a subject of recent neurological investigations (e.g., [15]). This subject and the overall Paulian problematic addressed here also has important connections to Bayesian approaches to quantum mechanics, via quantum information theory. See C. A. Fuchs's contribution to this volume, which also links this problematic to William James's philosophy, which is, as Gieser argues, important for Jung ([12, pp. 113-119), and, in part via Jung, Pauli, and possibly Bohr (although the influence of James on Bohr appears to be indirect and it degree is uncertain).

with respect to the no less indispensible means of observation outside of the observed system; and, on the other, placed beyond the distinction of 'physical' and 'psychical'" ([1], p. 260).

This position is, I would argue, deeply alien to that of Bohr, beginning with speaking of "the complementary aspects of the *same* reality," even in the case of quantum physics, let alone in considering our conceptions of physical and psychological processes as complementary aspects of the *same* reality ([1], p. 260; emphasis added]. The expression, "the same reality" does not ever occur anywhere in Bohr even in considering complementary situations in quantum physics. As explained in Section 2, according to Bohr, in quantum physics complementarity pertains to mutually exclusive phenomena, such as, those related to certain, at any given moment, mutually exclusive (and yet each possible separately at any given moment) situations of observation and measurement, situations defined by the state of classically observed and classically described measuring instrument. It does not pertain to complementary aspects of quantum objects and behavior, which are, in Bohr's epistemology, beyond our knowledge or even conception, and hence cannot be assigned complementary features any more than other features. All assignable features belong strictly to the measuring instruments involved. Quantum theory, only predicts, in general probabilistically, the outcomes of quantum experiments without describing quantum objects and their behavior, or for that matter, measuring instruments, which (i.e., those parts of the instruments where the outcomes of experiments are registered) are described by classical physics, although the behavior of the instruments under the impact of quantum objects is not. Each complementarity situation establishes its own "reality," incompatible with the reality of the other complementary opposite situation, even though this "reality" is unknowable and even unthinkable in each case. One might be able speak of the "reality," still ultimately unthinkable, of overall underlying quantum constitution of nature, but, in Bohr's view, our experiments dealing with individual phenomena or quantum mechanics, while impacted by this unthinkable "reality," do not in general relate to it, but only to effects of individual or collective quantum objects on particular, localized experimental setups.[25]

I am not saying that Pauli was entirely unaware of these aspects of Bohr's view. However, he might not have been entirely aware of them either or entirely follow Bohr in this regard, given that on several occasions he appears to think in terms of complementary aspects of the *same* quantum reality. Arguably even more significant is that Pauli, as discussed earlier, assumes that "the mathematically formulated *laws* [of quantum mechanics], only apply to the automatic time dependence of the state of a *closed* system," while "an observation hic et nunc changes in general the 'state' of the observed system," thus leading to "the passage to a new phenomenon by observation which is technically taken into account by the so-called 'reduction of the wave packet'" (Pauli to Bohr, 15 February 1955, [11], IV/3, 2035; cited in [12], p. 132). The recourse to probability would be, then, the result of this hic et nunc passage. Does

[25] This point has important connections to the question of quantum correlations, at stake in Einstein's critique of quantum mechanics and the Bohr-Einstein debate, especially their exchange concerning the so-called Einstein-Podolsky-Rosen (EPR) experiments, and then Bell's theorem, Kochen-Specker theorem, and related theoretical and experimental developments, from the 1960s on. The subject is, however, beyond my scope here.

Pauli then assume that a closed quantum system itself, apart from measurement, evolves causally? Although this assumption is not uncommon, and commonly accompanies this kind of picture of the quantum situation, Pauli's position concerning the causality of the evolution of closed quantum systems so changed by observation is not certain. Indeed, it appears that he does not see this independent evolution as causal, and most of his statements, such as those cited in this article, suggest that he would not. In any event, either way, this is, as I argue, not the way Bohr see the situation, at least not in his ultimate interpretation, at the time of Pauli's letter to Bohr. He did hold, briefly, a similar view (indeed, presuming the evolution of an independent quantum system to be causal) at an earlier point, around 1927, and perhaps Pauli assumed that Bohr, in 1955, still subscribed at this type of view, the type of view that is quite common.[26] I would strongly argue, however, that this was not Bohr's position at the time. Instead, as noted earlier, in Bohr's view by then was that the mathematical laws of quantum mechanics offer no such description, but only probabilistically predict the outcome of experiments.

This is a crucial difference. For, in Pauli's view, one could speak of the same underlying reality (at the moment the same *physical* reality) at each point. Its complementary aspects arise due to one or the other possible hic at nunc change of the state of the system, leading to the passage to the corresponding complementary phenomenon, each of which, thus, reflects the complementary aspect of the same reality. By contrast, this type of claim concerning reality as the same, single reality is not possible in Bohr's scheme, because with each such measurement we deal with a separate "reality," and thus the complementarity of two "realities," and in order to enact these two complementary situations we, generally, need two separate experiments on two different quantum objects. This "reality" is, again, inaccessible and even unthinkable each time, even as "reality" in any given sense we can give to this term (hence, my quotation marks), but is still different each time.

Pauli goes further along these lines in his overall argument under discussion. In his 1946 letter to R. König, he says: "I should like to say that it seems there must be very deep connections between soul and matter, and, hence, between the physics and the psychology of the future, which are not yet conceptually expressed in modern science. … Such deep connections must surely exist, because otherwise the human mind would not be able to discover concepts which fit nature at all" (Pauli to R. König, 10 March, 1946, cited in [12], p. 7).[27] One might argue, however, this is not necessarily so, and Bohr did not appear to think that this is necessarily the case either. Indeed, Pauli's statement comes perilously close to Einstein's view that physical reality can be grasped by our concepts that fit this reality, even though Pauli reject Einstein's concept of the detached observer as untenable, and this difference is of course

[26] On this subject see, again, ([4], pp. 179-218) and ([9], pp. 51-58).

[27] Gieser opens her book with this quotation ([12], p. vii), which fact corroborates, as does Gieser's book overall, the present argument concerning Pauli's views. See, especially, the chapter on "Complementarity, Symmetry, and the Cosmic Order" and the subsequent chapters on Pauli and Kepler ([12], pp. 170-216). On the other hand, the difference, in question here, between Bohr's and Pauli's philosophical views, is, as I said, missed by Gieser, who indeed appears to see complementarity, in physics and beyond, in Bohr's and Pauli's cases alike, following Pauli's concept of it, as referring to the complementary aspects of the same reality. This, as follows from the present analysis, works in Pauli's case but not in that of Bohr.

important. In Bohr's view, our quantum-theoretical concepts are not seen as fitting nature at the quantum level or for that matter at any other level, given that quantum mechanics does not describe, but only predicts, what is observed in measuring instruments or their macro-world equivalents, which (i.e., their observable parts) are described by means of classical physics. The connections (again, strictly probabilistically predictive and never descriptive in character) to nature at the quantum level are enabled by our technologies of observation. Our quantum-mechanical mathematical concepts, which, unlike those of classical physics or relativity, have no descriptive physical content, fit these technologies and only them. This appears to be yet another reason why Bohr prefers to separate the human observer from the measuring instruments, while, given his views under discussion, Pauli would clearly prefer to unite them. This fit of the mathematical concepts defining the quantum-mechanical formalism to what is observed in measuring instrument may be enigmatic or even mysterious (without being mystical), but it is, I would argue, not about a fit between our concepts and nature at the quantum level.[28] Or at least, if Pauli sees this fit more along the lines of Bohr's epistemology (although I doubt that he does, even though, as we have seen, he speaks of the "downright inaccessible" nature of quantum, as well as, possible psychical processes ([1], p. 260), it is not about connections, however deep or hidden, between matter and soul that Pauli has in mind here.[29]

By the same token, Bohr, I would argue, would have also been unlikely to agree with Pauli's views that physis and psyche should or even could be seen as two complementary aspects of the same reality, even assuming that Pauli believed that Bohr's epistemology applies from each side, although, as I just explained, their epistemological views may ultimately diverge as well. There is no mentioning of this type of complementary relationship anywhere in Bohr. He would agree and has suggested that parallel epistemology and complementarity may apply in both domains and that, as a result, both theories would be *symbolic*, rather than descriptive of the ultimate nature of things in each domain. That, however, need not mean that these domains form complementary aspects of the same reality, to which our theories in each domain may relate.[30] Reality may be quite different in each such domain, even though unknowable and even inconceivable in each, without representing two sides of the same reality. Bohr never considers our psychological and physical theories as complementarily describing the same reality and he would, I would argue, be

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[28] Bohr strongly objects to any association of quantum mechanics or his interpretation with mysticism (e.g., [8], v. 2, p. 63). He stressed this point in his correspondence with Pauli, whose views appear to be more open to certain *ideas* found in religious mysticism, without, however, accepting mysticism as such. On the question of mysticism in Pauli and Pauli's exchanges with Bohr concerning this subject, see Gieser's discussion ([14], pp. 250-258).

[29] One of the reasons for my doubt is the fact, noted earlier (note 24), that Jung appears to see the symbolic, such as archetypal, structures associated with the unconscious in more representational terms, that is, as mapping, rather than only indirectly related to the (unconscious) psychic reality.

[30] It appears that for Pauli, as well as for Jung, the ultimate nature of this reality is material. Cf., Jung's revealing comments on this point: "The deeper layers of the psyche lose their individual uniqueness as they retreat farther and farther into darkness. Lower down, that is to say as they approach the autonomous functional systems, they become increasingly collective until they are universalized and extinguished in the body's materiality, i.e., in chemical substances. The body's carbon is simply carbon. Hence 'at bottom' the psyche is simply 'world'" ([16], p. 173).

extremely reluctant to accept that they are likely to ever do so. This may well be yet one more reason why he saw the human observer as detached from the observed phenomena even in quantum physics, while, again, the measuring apparatus and the quantum object under investigation could never be separated, detached, with the wholeness of each observed quantum phenomena.

We can now see even more clearly that the difference between Bohr's and Pauli's views of the quantum mechanical situation is much more substantive and significant than it might appear. Indeed, this difference is fundamental. It is true that, as noted earlier, Bohr, in their letter exchange on the subject, said that they agree on essential things (Bohr to Pauli, 2 March 1955, [11], IV/3, 3025, cited in [12], p. 132). Well, they might agree on some among the essential things! Thus, they agree that quantum objects can never be observed or considered apart from their interaction with measuring instrument and that, as a result, our predictions can only pertain to what is observed in measuring instruments under the impact of quantum objects and can—this is especially crucial for Bohr and Pauli alike—only be probabilistic ([1], pp. 45-48). As just explained, however, even on this point there are differences between them, insofar as Pauli sees the quantum-mechanical formalism as describing the behavior of closed (independent) quantum systems, while Bohr rejects this view. Pauli, as explained in Section 3, also appears to agree that Bohr's argumentation applies to already registered quantum phenomena, once an actual measurement has already been performed, and to this degree, Pauli retains Bohr's concept of phenomenon, as referring to always registered, fixed phenomena. However, Pauli's inclusion of the human observer or, again, the human subject and specifically the unconscious makes his concept of the observer, or, again, complementarity, in quantum physics a radical departure not only (with Bohr) from Einstein but also from Bohr.

First of all, this difference leads to two different interpretations, two different *Copenhagen* interpretations, of quantum phenomena and quantum mechanics, even though these interpretations share certain epistemological features, stemming from Bohr's understanding or, again, interpretation of quantum phenomena (which is why one might see both as "Copenhagen interpretations"). This is hardly a small matter, both in its own right and in view of still common and persistent misconceptions surrounding the rubric of "Copenhagen interpretation," which tend to disregard the difference, sometimes considerable, between the interpretations offered by different figures associates with this rubric.[31] Furthermore, one encounters here two very different and arguably irreconcilable visions of the world and our interactions with the world, whether these visions have led to these two different views of quantum physics, or have arisen from these views. Most likely, however, these two philosophical visions and two views or interpretations of quantum phenomena and quantum mechanics, have emerged reciprocally over the years, even decades. Certainly, Pauli's encounter with Jung's psychoanalytic theory, which coincided with the development of his views played a key role here, and one should not forget that Bohr's views and his interpretation of quantum mechanics evolved as well. As I explained, his concept of phenomenon, crucial here, and his overall interpretation, as here considered, only emerged around 1937-1938 ([9], pp.137-166].

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[31] In fairness, this has changed somewhat more recently, and these differences are now considered.

It is, accordingly, not surprising that Pauli was so resistant to Bohr's use of the expression and (it follows from the preceding argument, that it is hardly a matter of expression alone) concept "detached observer," in his correspondence and thought that the issue had never been really resolved.[32] Pauli was right on this point, perhaps more right than he knew, and Bohr in the exchange of the subject might have been more diplomatic than straightforward and in fact knew better, or should have known better. As indicated earlier, the only surprise here is that, although they did not appeal to the idea "detached observer," Bohr's earlier arguments, well familiar to Pauli, were not really different, although this appeal may have helped Pauli realize this fact and thus the differences between their respective views or see them more sharply ([9], pp. 167-170). The issue cannot be resolved insofar as these two positions can only be brought to, at most, limited accord with each other, but not fundamentally. Fundamentally, these positions are far apart, and, again, even irreconcilable with each other, just as each is fundamentally irreconcilable with Einstein's position.

One might argue, however, that the scope Pauli's vision ultimately extends beyond that of Bohr and Einstein. Of course, Bohr and Einstein, too, had deeply held philosophical positions. This philosophy, however, was, in either case, still most essentially a philosophy of physics, although both, especially Bohr, sometime extended their philosophical views elsewhere, usually in partial and preliminary ways, as in Bohr's attempts to extend his concept of complementarity and his epistemological ideas to psychology or biology. Pauli, on the other hand, taking Bohr's interpretation of quantum mechanics, via complementarity, and Jung's psychology as his joint point departure, offers a grand, unified philosophical vision of nature and mind, and their relationships, their complementary relationships. This vision is not unlike and perhaps inspired by that of Kepler, arguably more so than by that of Bohr, even though Pauli's vision encompasses the mathematical understanding of nature developed by modern physics and uses some of the aspects of Bohr's epistemology. The germs of this mathematical approach to nature are found already in Kepler, where, however, this approach is in conflict rather than in harmony with Kepler's understanding of the soul, a harmony that is perhaps impossible (Pauli, again, thinks that it is impossible) apart from the complementary relationships between physis and psyche, a modern form of *harmonices mundi*.

Whether one is sympathetic to it or critical of it, this is a bold and adventuresome vision. That Pauli ventured to offer it may appear surprising because Pauli is often seen as cautions and even risk-averse in his work on physics, sometimes in juxtaposition to his friend Heisenberg. This is, I think, a misconception, in part perhaps helped by Pauli's own comment on his temperament in physics. Remarkable achievements in physics, and those of Pauli were remarkable, are hardly possible without boldness and the sense of adventure and taking major risks, even though they may also, and simultaneously, require great caution, as indeed do our philosophical arguments. It may well be, however, that Pauli reserved more caution for physics, which is not unwise, while Bohr extended his customary caution to philosophy, and was perhaps too cautious in his philosophical ventures, which, however, might not have been unwise either. Pauli's boldness and his taking a chance on the existence of

[32] Cf., ([12], p. 134).

the neutrino, with which I started here, shows this perhaps most dramatically, but his other major discoveries would easily demonstrate this as well. “Almost improbable,” he, we recall, said about his prediction of the neutrino, and yet it came through. His philosophical bet on bringing together “physis and psyche as complementary aspects of the same reality” may well be “almost improbable” as well, arguably even more improbable than his bet on the neutrino, and it is certainly not lacking in boldness, regardless how much chance one gives it. It is also difficult, much more difficult than in physics, to assess which bet came or did not come through in philosophy, for one thing, because what comes through for some does not for others. But then, this happens in physics, too, and Einstein’s, Bohr’s, and Pauli’s different and, even in the case of Bohr and Pauli, diverging views or, I am certain, my readers’ possible assessments of their views testify to this complexity in physics and philosophy alike.

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